

# PRACTICE EXAM 12: WPI/ABC WATER DISTRIBUTION OPERATOR SIMULATION (100 QUESTIONS)

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1. A water system's SCADA trend data shows that over the past 90 days, the daily water production has gradually increased from 3.2 MGD to 3.7 MGD. During the same period, the number of service connections has not changed and seasonal demand should be declining as temperatures cool. The 0.5 MGD increase represents approximately 15% above the expected production. What is the most likely cause?

- A. The treatment plant's production flow meter has drifted out of calibration and is reading 15% high
- B. Customers have collectively increased consumption by 15% due to an undetected change in water rates
- C. A new or worsening leak in the distribution system is consuming the additional 0.5 MGD — the gradual, progressive increase is characteristic of a leak that is slowly enlarging over time
- D. The elevated storage tank has developed a crack that loses 0.5 MGD through seepage

2. An operator is performing a hydrant flow test. The static pressure at the residual hydrant is 60 psi. After opening two flow hydrants, the residual pressure drops to 42 psi while the combined pitot-measured flow is 1,100 GPM. The operator wants to project the available fire flow at 20 psi residual. Using the formula  $Q_{\text{available}} = Q_{\text{tested}} \times [(P_{\text{static}} - P_{\text{desired}})/(P_{\text{static}} - P_{\text{residual}})]^{0.54}$ , what is the approximate available fire flow?

- A. Approximately 1,605 GPM at 20 psi residual — calculated as  $1,100 \times [(60-20)/(60-42)]^{0.54} = 1,100 \times (40/18)^{0.54} = 1,100 \times 2.222^{0.54} = 1,100 \times 1.459 \approx 1,605$
- B. 2,444 GPM based on multiplying the tested flow by the pressure ratio without the exponent
- C. 1,100 GPM because the available flow always equals the tested flow regardless of the target residual
- D. 550 GPM because the available flow is always half the tested flow at 20 psi residual

3. A distribution system operator discovers that a 50-year-old 4-inch cast iron dead-end main serving 6 homes has experienced its fifth break in the past 18 months. Each break required emergency repair costing approximately \$5,500. The total reactive repair cost over 18 months is \$27,500. A capital project to replace the entire 800-foot section with 8-inch ductile iron would cost \$160,000. Should the utility replace the main or continue with reactive repairs?

- A. Continue reactive repairs because \$27,500 is significantly less than the \$160,000 replacement cost
- B. Replace the main only if the break rate increases to more than 10 breaks per year
- C. Defer the replacement for 5 years to accumulate capital funds while continuing reactive repairs
- D. Replace the main — at the current break rate of approximately 3.3 breaks per year (\$18,333/year in repair costs alone), plus indirect costs (overtime, paving, customer disruption, water loss, contamination risk), the total annual cost of reactive repair approaches or exceeds the annualized replacement cost; additionally, each break risks contamination and disrupts service

4. A water system serves a restaurant that has recently installed a commercial espresso machine. The machine has an internal boiler that operates at 200°F and 15 psi, and it is connected directly to the potable supply with no backflow prevention. The connection includes a solenoid valve that opens automatically to refill the boiler. What type of cross-connection hazard does this represent?

- A. Low hazard because the boiler contains only heated potable water with no chemical additives
- B. The boiler operates above supply pressure (backpressure potential) and contains water that has been heated to near-boiling temperatures with concentrated mineral deposits — this is a health-hazard cross-connection requiring an RPZ assembly or an air gap on the supply connection
- C. Moderate hazard requiring only a DCVA because the boiler is a sealed, pressurized vessel
- D. No hazard because the solenoid valve prevents reverse flow by closing when the boiler is full

5. A distribution system has a 16-inch transmission main that crosses beneath a navigable river through a subaqueous pipeline. The river crossing is 600 feet long and 20 feet below the riverbed. The main was installed in 1985 using ductile iron with mechanical joints. What is the most significant maintenance concern specific to this installation?

- A. Access for inspection and repair is extremely limited — a leak or break at this location requires specialized operations (cofferdams, diving, or bypass) that may take days to mobilize, during which

100% of the supply through this main is lost; additionally, the submerged environment accelerates external corrosion of the mechanical joints

- B. The river current creates vibration that gradually loosens the mechanical joints
- C. Fish and aquatic organisms can enter the pipe through the submerged joints
- D. The river's tidal action creates pressure surges that stress the pipe during high and low tide cycles

6. An operator is asked to calculate the chlorine feed rate for a system treating 5.5 MGD. The required dose is 2.4 mg/L. The chemical is 65% calcium hypochlorite. How many pounds per day of calcium hypochlorite product are needed?

- A. 110.1 pounds per day of pure chlorine based on the pounds formula without adjusting for product strength
- B. 71.6 pounds per day based on multiplying the pure chlorine by the product strength
- C. 169.4 pounds per day based on dividing by 0.65 but using the wrong initial calculation
- D. 169.4 pounds per day — first calculating pure chlorine ( $5.5 \times 2.4 \times 8.34 = 110.1$  lbs/day), then dividing by the product strength ( $110.1 \div 0.65 = 169.4$  lbs/day of 65% calcium hypochlorite)

7. A water system's operator is investigating recurring taste and odor complaints in an area served by a 1.5milliongallon groundlevel concrete reservoir. SCADA data shows the reservoir cycles only 8% of its volume daily — the level stays between 90% and 98%. The single inlet/outlet pipe is located at the base of the reservoir on the same side as the outlet. What design flaw is causing the water quality problem?

- A. The concrete walls are leaching calcium into the stored water, creating taste issues
- B. The reservoir's roof vents are allowing airborne contaminants to enter the stored water
- C. The single inlet/outlet on the same side creates shortcircuit flow — fresh water enters and exits through the same area while the vast majority of the reservoir volume stagnates, losing residual, supporting biofilm growth, and developing taste and odor compounds
- D. The reservoir is too large for the zone's demand, and the excess capacity should be permanently drained

8. A pump station operator discovers that the vibration reading on Pump 3 has increased from the baseline of 0.15 inches per second to 0.42 inches per second over the past three months. Pumps 1 and 2

(identical models) remain at 0.16 and 0.18 inches per second respectively. What does the trend on Pump 3 indicate?

- A. All three pumps show acceptable vibration levels and no investigation is warranted
- B. Pump 3 has a developing mechanical problem — the progressive increase in vibration over three months indicates deteriorating bearings, shaft misalignment, impeller imbalance, or loosening foundation bolts; left uncorrected, the problem will progress to component failure
- C. The vibration sensor on Pump 3 has drifted out of calibration and should be recalibrated
- D. The increased vibration is caused by seasonal temperature changes that affect the pump's foundation

9. A water system's wellhead protection plan requires the utility to maintain an inventory of all potential contamination sources within the wellhead protection area. During the annual update, the operator discovers that a new auto repair shop has opened 300 feet from a production well. The shop uses solvents, motor oil, antifreeze, and battery acid. What should the operator do?

- A. Add the auto repair shop to the contamination source inventory, verify that the shop is complying with all environmental regulations for chemical storage and waste disposal, and increase groundwater monitoring at the well for volatile organic compounds and petroleum products
- B. Shut down the production well until the auto repair shop relocates outside the wellhead protection area
- C. Ignore the new business because it is outside the inner protection zone and poses minimal risk
- D. Contact the auto repair shop owner and demand that they cease all operations until a risk assessment is completed

10. A distribution system has two pressure zones connected by a PRV station. Zone 1 operates at 90 psi and supplies Zone 2 through a PRV set at 55 psi. The PRV station has a single 8-inch PRV with no bypass. A fire in Zone 2 requires 2,000 GPM of fire flow. During the fire, pressure in Zone 2 drops to 12 psi. What design deficiency does this event reveal?

- A. The PRV setpoint of 55 psi is too low for Zone 2 and should be increased to 70 psi
- B. Zone 2 needs its own dedicated pump station and elevated storage tank independent of Zone 1
- C. A larger PRV should replace the current one to handle fire flow demands

D. The single PRV cannot deliver 2,000 GPM at its setpoint — the station needs either a larger PRV, a parallel PRV for highflow events, or a fire flow bypass that opens automatically during highdemand events to allow Zone 1's full pressure to supplement Zone 2

11. A water operator is investigating a complaint from a customer who reports that their water has a blue tint visible in a white bathtub. The system uses copper plumbing throughout the home, which was built in 2005. The system's corrosion control treatment maintains pH at 7.3 and orthophosphate at 0.8 mg/L. Firstdraw copper testing shows 1.9 mg/L — well above the 1.3 mg/L action level. What is the most likely contributing factor?

A. The copper pipes are only 20 years old and should not be producing elevated copper levels regardless of treatment

B. The pH of 7.3 is at the low end of the effective range for copper corrosion control — the relatively aggressive water chemistry may not be forming an adequate protective film on the copper surfaces; increasing pH to 7.88.0 and/or increasing the orthophosphate dose would likely reduce copper leaching

C. The blue tint is caused by the orthophosphate treatment reacting with residual chlorine

D. The customer's water heater is set too high, causing copper to dissolve faster in the hot water

12. A distribution system operator is asked to calculate the head loss in 2,000 feet of 8inch cement mortar lined ductile iron pipe (C=140) carrying 600 GPM. Using the HazenWilliams formula, the operator determines the head loss is approximately 5.8 feet. What is this head loss equivalent to in psi?

A. 13.4 psi based on multiplying 5.8 feet by 2.31

B. 5.8 psi based on the head loss in feet equaling the pressure in psi directly

C. 2.5 psi, calculated by multiplying 5.8 feet by 0.433 — converting feet of head to psi

D. 0.87 psi based on dividing the head loss by the pipe length in thousands of feet

13. A confined space entry team is preparing to enter a wet well at a pump station. The wet well has a permanent ladder, an access hatch, and normally contains 4 feet of water at the bottom. The water will be pumped down before entry. What hazard is specific to wet wells that may not be present in other confined spaces like valve vaults or reservoirs?

- A. Wet wells connected to the distribution system may have higher than normal levels of hydrogen sulfide from biological activity in the stagnant water, and the organic material in the wet well can deplete oxygen — additionally, the pumping process can stir sediment and release trapped gases, changing atmospheric conditions rapidly during preparation
- B. Wet wells are always classified as permit required confined spaces while valve vaults are not
- C. Wet wells contain treated drinking water that is safe, so atmospheric testing is not required
- D. Wet wells are too deep for standard retrieval systems and always require entry rescue equipment

14. A water system's emergency generator at a critical pump station starts successfully during a power outage. After 6 hours of operation, the generator's engine oil pressure warning light illuminates. The generator continues to run normally at full load. What should the operator do?

- A. Ignore the warning light because the generator is still running normally at full load
- B. Reduce the generator's load by shutting down one pump to reduce stress on the engine
- C. Shut down the generator immediately to prevent engine damage and switch to the backup battery system
- D. Investigate the oil pressure warning immediately — check the engine oil level, look for leaks, and verify the oil pressure gauge reading; low oil pressure can cause catastrophic engine damage within minutes if not addressed, potentially leaving the pump station without power during the outage

15. A distribution system serves a neighborhood where C factor testing on the 60 year old 6 inch unlined cast iron mains shows  $C = 40$ . The original C factor when installed was approximately 130. A fire flow test at the far end of the neighborhood produces only 400 GPM at 20 psi residual. The fire code requires 1,000 GPM. What infrastructure improvement options exist?

- A. Increase the system pressure by 20 psi to push more water through the corroded mains
- B. The two most effective options are: (1) clean and cement mortar line the existing mains to restore C to approximately 140, which dramatically increases carrying capacity; or (2) replace the mains with larger ductile iron pipe — both options address the hydraulic deficiency, but cleaning/lining is less expensive if the pipe structure is sound
- C. Install additional fire hydrants to distribute the available flow across more outlets
- D. Reduce the fire flow requirement for this neighborhood through a variance from the fire marshal

16. An operator performing valve exercising discovers a 10inch gate valve that requires 32 turns to close, but the valve record shows it should require 28 turns. After closing, the operator reopens the valve and counts 28 turns to fully open — matching the recorded count. What explains the 4turn discrepancy during closure?

- A. The valve stem has elongated due to corrosion, adding extra turns on the closing stroke only
- B. The operator miscounted during the closing operation and should recount during the next exercising cycle
- C. Sediment or debris on the valve seat prevented the gate from fully seating during the first 28 turns — the additional 4 turns compressed through or displaced the debris; the 28turn reopening count confirms the correct turn count once the seat was clear
- D. The valve has two separate stages that engage at different points during closing and opening

17. A water system's treatment plant switches from liquid alum to ferric chloride as its primary coagulant. Two weeks after the change, the distribution system operator begins receiving complaints about yellowbrown discoloration from customers throughout the system. What is the most likely explanation?

- A. The ferric chloride coagulant change has altered the finished water chemistry — potentially changing pH, alkalinity, or iron residual — which has destabilized iron deposits on pipe surfaces throughout the distribution system, causing them to release into the water and produce the widespread discoloration
- B. The ferric chloride itself is passing through the treatment filters and entering the distribution system
- C. The new coagulant has increased the turbidity of the finished water beyond acceptable limits
- D. The color complaints are unrelated to the coagulant change and coincidentally began at the same time

18. A water system serves a large hospital with a dedicated 10inch service line. The hospital has a backup well on its property that is not currently connected to the municipal supply or the hospital's internal plumbing. The hospital's facilities manager asks the distribution operator whether they can install a manual transfer switch to connect either the municipal supply or the backup well — but never both simultaneously — to the building's plumbing. Is this arrangement acceptable from a crossconnection control perspective?

- A. Yes, because a manual transfer switch that connects only one source at a time prevents any possibility of backflow between the two sources

- B. Yes, as long as the backup well is tested annually and meets all SDWA standards
- C. Yes, if the hospital provides a written guarantee that both sources will never be connected simultaneously
- D. No — despite the manual switch, the potential for human error (connecting both sources simultaneously) and the lack of a physical air gap between the two systems creates an unacceptable crossconnection risk; the backup well must be completely isolated from the municipal supply with an air gap or the systems must remain permanently separated

19. An operator is calibrating a sodium hypochlorite chemical metering pump. The pump is set to 75% stroke at 120 strokes per minute. During a 3minute timed calibration test, the operator collects 1,350 mL. What is the pump's output in gallons per hour?

- A. 0.357 gallons per minute based on converting the mL collection to gallons
- B. Approximately 7.1 gallons per hour — calculated by finding the perminute rate ( $1,350 \text{ mL} \div 3 = 450 \text{ mL/min}$ ), converting to GPM ( $450 \div 3,785 = 0.1189 \text{ GPM}$ ), then multiplying by 60 ( $0.1189 \times 60 = 7.13 \text{ GPH}$ )
- C. 450 gallons per hour based on assuming 1 mL equals 1 gallon
- D. 27 gallons per hour based on multiplying the perminute collection by 60 without unit conversion

20. A distribution system experiences a confirmed E. colipositive result from a routine monitoring sample. The operator issues a Tier 1 public notification within 24 hours as required. Repeat samples are collected from the original site and adjacent upstream and downstream locations. All repeat samples return negative for both total coliform and E. coli. Can the boil water advisory be lifted?

- A. Yes, immediately upon receiving the negative repeat samples because the contamination has been resolved
- B. No, the advisory must remain in place for a minimum of 30 days regardless of subsequent sampling results
- C. The advisory can be lifted after two consecutive sets of satisfactory samples collected at least 24 hours apart from the affected area, combined with restoration of adequate system pressure and disinfection — a single set of negative repeats is typically not sufficient
- D. The advisory is lifted automatically 72 hours after the original positive result

21. A water utility's AMI data shows that a commercial customer's consumption has been exactly zero for the past 14 days. The building is a functioning restaurant that is open daily. What is the most likely explanation?

- A. The restaurant has connected to a private water source and is no longer using the municipal supply
- B. The water meter has stopped registering — either the measuring element has seized, the register has failed, or an electronic component has malfunctioned; the restaurant is consuming water but the meter is not recording it
- C. The restaurant has installed a bypass line around the meter that routes water directly from the service
- D. The AMI transmitter has failed and is not sending consumption data to the utility

22. A pump station has two VFD-controlled pumps maintaining a constant discharge pressure of 62 psi. During normal operations, the lead pump runs at 70% speed. When a large fire flow event begins, both pumps ramp to 100% speed and the discharge pressure drops to 48 psi. What does this indicate?

- A. Both VFD drives are malfunctioning and cannot maintain the pressure setpoint during high demand
- B. The 48 psi pressure is caused by a faulty pressure transducer that reads low during highflow conditions
- C. The fire flow event has caused both pumps to cavitate, reducing their ability to develop full pressure
- D. The fire flow demand exceeds the combined maximum capacity of both pumps — at 100% speed, the pumps have reached their maximum output and cannot produce enough flow to maintain 62 psi; the system needs either larger pumps, additional pumps, or supplemental storage to support fire flow demands

23. An operator discovers that the concrete pad surrounding a production well has developed a wide crack that extends from the edge of the pad to the well casing. Grass and weeds are growing in the crack, and the operator observes that during the last rainstorm, water flowed along the crack directly toward the casing. What does this represent?

- A. A direct pathway for surface water contamination to reach the well's annular seal — rainwater flowing along the crack carries bacteria, fertilizer, pesticides, and other surface contaminants directly to the wellhead, bypassing the protective soil layers; the pad must be repaired immediately to restore the sanitary barrier
- B. Normal settling of the concrete pad that occurs over time and requires no corrective action

- C. A structural failure of the well casing that has caused the surrounding concrete to crack
- D. An aesthetic issue that should be addressed during the next scheduled well site renovation

24. A distribution system operator measures the chlorine residual at a monitoring point and obtains a free chlorine reading of 0.0 mg/L. The system uses free chlorine for disinfection, and the normal residual at this location is 0.8 mg/L. The operator retests with fresh reagent and confirms the zero reading. What should the operator do?

- A. Record the result and schedule the location for retesting next week to see if the residual returns to normal
- B. Increase the chlorine dose at the treatment plant and retest in 24 hours
- C. Immediately investigate the cause — flush the nearest hydrant to determine if the zero residual is localized or widespread, check for closed valves that may have rerouted flow, check for main breaks, and determine whether the treatment plant has experienced a feed interruption; a zero residual means the water at this location has no disinfection protection
- D. Collect a bacteriological sample at this location and wait for laboratory results before taking any operational action

25. A water system operates four wells that supply a common header. Well 2 has been offline for rehabilitation for the past three weeks. During this period, several customers have complained about changes in water hardness — their soap lathers differently and they notice more scale on fixtures. What is the most likely explanation?

- A. The treatment plant has changed its lime dosage, affecting hardness throughout the system
- B. With Well 2 offline, the blend of the remaining three wells produces water with different hardness than the normal fourwell blend — customers are sensitive to changes in hardness that affect soap lathering and scale formation
- C. The well rehabilitation chemicals have contaminated the distribution system with mineral deposits
- D. Hardness does not change when wells are taken offline because all wells draw from the same aquifer

26. A water main repair crew completes an emergency repair on a 12inch transmission main. The repair involved cutting out a 4foot section of pipe and installing a replacement section with two repair couplings. Before returning the main to service, the crew must disinfect the repaired section. The utility's SOP for emergency repairs of this size specifies spray application of 200 mg/L chlorine solution

on all exposed surfaces, followed by flushing until the chlorine residual matches the system residual. After flushing, the residual is 1.0 mg/L — matching the system. Can the main be returned to service?

- A. Yes, the repair disinfection procedure has been completed per the SOP — the spray application disinfected exposed surfaces, flushing removed construction debris and excess chlorine, and the matching residual confirms fresh system water is reaching the repair site
- B. No, the main must be held at 25 mg/L for 24 hours per AWWA C651 Method 1 for all repairs
- C. No, bacteriological samples must be collected and cleared before any main is returned to service
- D. Yes, but only during business hours when a supervisor can observe the restoration

27. A water system's SCADA alarm log shows that the highlevel alarm on an elevated storage tank has been activating nightly at approximately 2:00 AM for the past two weeks. The tank level reaches the highlevel setpoint, the fill pump shuts off, the level drops slightly, the pump restarts, and the cycle repeats 34 times before morning demand begins drawing the tank down. What is the operational concern, and what adjustment would resolve it?

- A. The highlevel alarm indicates a malfunctioning level sensor that should be replaced
- B. The alarm is caused by a leak in the tank that matches the pump's output, creating a false equilibrium
- C. The nightly cycling is caused by the tank's overflow pipe siphoning water out of the tank
- D. The pump output during the lowdemand overnight hours exceeds demand, filling the tank to its setpoint too quickly — reducing the overnight pump speed (via VFD) or lowering the highlevel pump shutoff setpoint would better match pump output to overnight demand and eliminate the repetitive cycling

28. An operator receives a customer complaint about a metallic taste in the water. The customer's home was built in 1988 with copper plumbing and leadfree solder (as required by the 1986 SDWA amendments). The system's corrosion control program maintains pH at 7.8 and feeds orthophosphate at 1.0 mg/L. Firstdraw testing shows copper at 0.9 mg/L (below the 1.3 action level) and lead at 0.003 mg/L (below the 0.015 action level). What is the most likely cause of the metallic taste?

- A. The lead level, while below the action level, is high enough to produce a metallic taste
- B. The metallic taste is caused by the orthophosphate treatment chemical at the 1.0 mg/L dose

C. The copper level of 0.9 mg/L — while below the action level — exceeds the secondary standard threshold where many people can detect a metallic taste; the corrosion control program is working but the copper level is still high enough to affect taste

D. The metallic taste is caused by dissolved iron from the distribution main, not from the customer's plumbing

29. A distribution system has a section of 20inch steel transmission main that is 40 years old. The utility is evaluating the main for cathodic protection. A closeinterval potential survey reveals that the pipetosoil potential in several areas is more positive than  $-0.85$  volts (CSE), indicating inadequate cathodic protection. What does this finding mean?

A. The pipe is receiving excessive cathodic protection that is wasting electrical energy

B. The pipe is not receiving adequate cathodic protection at these locations — corrosion is likely occurring where the potential is more positive than the  $-0.85V$  threshold, and the cathodic protection system needs to be adjusted, repaired, or supplemented with additional anodes to protect the vulnerable areas

C. The potential readings are within the normal range for steel pipe and no action is needed

D. The survey results indicate that the pipe has already corroded through at these locations

30. A water system's operator discovers that the utility's consumer confidence report (CCR) was not distributed to all customers by the July 1 deadline. Approximately 2,000 customers did not receive their copies due to a mailing contractor error. What is the regulatory consequence?

A. The utility must immediately redistribute the CCR to the 2,000 affected customers, notify the state regulatory agency of the distribution failure, and document the corrective action — failure to distribute the CCR by July 1 is a violation of the SDWA's public notification requirements

B. The utility has a 90day grace period after July 1 to complete the distribution

C. No regulatory consequence exists because the CCR is an informational document, not a regulatory requirement

D. The utility is only required to make the CCR available on its website, not mail it to customers

31. A water system serves a school where testing reveals lead at 0.032 mg/L from a drinking fountain — more than double the 0.015 mg/L action level. The fountain was installed in 1975 and has brass internal

components. The system's corrosion control treatment is optimized. What immediate steps should be taken at the school?

- A. Increase the systemwide chlorine dose to reduce lead leaching at the school
- B. Advise the school to flush the fountain for 3 minutes every morning, which will be sufficient to solve the problem permanently
- C. Notify the school to use only bottled water and take no further action until the annual resampling cycle
- D. Take the fountain out of service immediately, provide an alternative water source (bottled water or filtered water station), notify the school administration and parents of the results, and develop a remediation plan — options include replacing the fountain's brass components, installing a pointofuse filter certified for lead removal, or replacing the fountain entirely

32. A pump station operator is performing an efficiency test on a pump that has been in service for 8 years. The test results show: flow = 900 GPM, TDH = 130 feet, motor input = 48 kW. Using the wiretewater efficiency formula, what is the pump's approximate efficiency, and what does it indicate?

- A. Approximately 95% efficiency, indicating the pump is performing above its design specifications
- B. Approximately 48% efficiency, which is critically low and indicates the pump needs immediate replacement
- C. Approximately 61% efficiency — calculated as  $(900 \times 130) / (3,960 \times 48) \times 100\%$ ... The efficiency suggests moderate degradation from the typical design efficiency of 75-85%, warranting investigation and likely rehabilitation
- D. The efficiency cannot be calculated without knowing the motor's power factor

33. A distribution system experiences a water quality event where multiple customers in the same neighborhood report water with a strong gasolinelike odor. The affected area is served by a 6-inch PVC main installed in 1995. An active gas station with confirmed underground storage tank leaks is located 50 feet from the PVC main. What is the most likely contamination pathway?

- A. The gasoline has entered the main through a crossconnection between the gas station and the water system

- B. Petroleum hydrocarbons from the leaking underground storage tanks have contaminated the soil around the PVC main, and the hydrocarbons are permeating through the PVC pipe wall into the drinking water — PVC is known to be susceptible to permeation by petroleum products
- C. The gas station's overflow vent has released vapors that entered the main through a nearby air release valve
- D. The odor is caused by a natural gas leak from a separate utility and is unrelated to the gas station

34. An operator is calculating the detention time of a 400,000gallon elevated tank that serves a zone with an average demand of 600 GPM. What is the theoretical turnover time, and what does it indicate about water quality risk?

- A. Approximately 11.1 hours ( $400,000 \div 600 \div 60$ ) — the tank turns over approximately 2.2 times per day, which is within an acceptable range for maintaining chlorine residual and limiting DBP formation; however, the actual turnover depends on mixing efficiency, and shortcircuiting can cause portions of the tank to stagnate even at this theoretical turnover rate
- B. 666.7 hours based on dividing gallons by GPM directly without converting to hours
- C. 2.4 hours based on dividing the tank volume by the peak hour demand instead of average demand
- D. Turnover time has no relationship to water quality and is only used for structural load calculations

35. A water system operates a well that produces water with naturally occurring radon at levels above the proposed EPA standard. The well pumps into an open atmospheric storage tank before distribution. An operator asks why the utility does not need to install a specific radon treatment system. What is the explanation?

- A. Radon is only regulated in surface water systems, not groundwater systems
- B. The open atmospheric storage tank is not effective at removing radon from groundwater
- C. The utility has a waiver from the state that exempts it from radon treatment requirements
- D. Radon is a dissolved gas that is released from water when exposed to air — the open atmospheric storage tank provides aeration that strips a significant portion of the radon from the water before it enters the distribution system, effectively reducing radon levels through this incidental treatment

36. An operator is inspecting a belowgrade PRV vault and discovers that the vault floor has 8 inches of standing water. The PRV and its associated piping, strainer, and bypass valve are partially submerged. Beyond the difficulty of performing maintenance, what water quality concern does this condition create?

- A. The standing water will cause the PRV to malfunction and deliver inconsistent downstream pressure
- B. The standing water will freeze in winter and damage the PRV's internal components
- C. If the distribution system experiences a pressure drop below the level of the standing water in the vault, contaminated water from the flooded vault could be drawn into the main through the PRV's packing gland, bonnet seal, or any other imperfect seal point — creating a backsiphonage contamination pathway
- D. The standing water indicates a main break beneath the vault that is feeding water into the space

37. A water system's operator is evaluating the performance of two parallel 8inch mains serving the same neighborhood. Main A (installed 1970, unlined cast iron,  $C=50$ ) and Main B (installed 2010, cement mortar lined ductile iron,  $C=140$ ) are both 2,000 feet long. At the same flow rate of 400 GPM, which main has more head loss, and by approximately how much?

- A. Main A has approximately equal head loss to Main B because both are 8inch mains of the same length
- B. Main A has approximately 56 times more head loss than Main B — the Cfactor enters the HazenWilliams formula to the 1.85 power, so the ratio of head losses is approximately  $(140/50)^{1.85} \approx 6.1$ ; Main A's severely tuberculated interior creates dramatically more friction than Main B's smooth lining
- C. Main B has more head loss because newer pipe materials create more turbulence than cast iron
- D. The head loss comparison cannot be made without knowing the exact elevation difference between the endpoints

38. An operator discovers that a customer has connected their home's plumbing to both the municipal water supply and a rainwater collection system. The rainwater system collects water from the roof, stores it in a cistern, and distributes it through a pump. The customer uses the rainwater for irrigation but has also plumbed it into the home's toilet supply. What crossconnection concern does this create?

- A. The customer's pump can create backpressure that forces untreated, potentially contaminated rainwater into the municipal supply through the home's plumbing — rainwater collected from roofs may

contain bird droppings, chemicals, bacteria, and other contaminants; the two systems must be physically separated or an air gap must be installed

- B. Rainwater systems are classified as low hazard and require only a DCVA for protection
- C. No crossconnection exists because the rainwater is only connected to toilet supply, not to drinking water taps
- D. The rainwater system poses no risk because it operates at lower pressure than the municipal supply

39. A water system's emergency response plan includes a mutual aid agreement with a neighboring utility. The agreement specifies the sharing of personnel, equipment, and water through two interconnection points. The utility has not tested the interconnections in three years. During a drought emergency, the operator attempts to open Interconnection A and discovers the valve is completely seized. What lesson does this teach?

- A. Mutual aid agreements should be limited to sharing personnel and equipment, not water supply
- B. Emergency interconnection valves should be automated to prevent human error
- C. The utility should install permanent bypass piping around the interconnection valve
- D. All emergency interconnection valves must be included in the regular valve exercising program — a valve that has not been operated in three years is likely to seize, rendering the interconnection useless precisely when it is needed most

40. A distribution system operator is asked to calculate the weight of a 300-foot section of 16-inch water-filled ductile iron pipe for a bridge loading analysis. The pipe weighs approximately 36 pounds per linear foot (empty), and the water inside has a volume that must be calculated. What is the approximate total weight?

- A. 10,800 pounds based only on the empty pipe weight without the water
- B. 25,000 pounds based on an estimated water weight without calculation
- C. Approximately 31,480 pounds — pipe weight =  $36 \times 300 = 10,800$  lbs; water volume =  $0.785 \times (16/12)^2 \times 300 = 419$  cu ft  $\times 7.48 = 3,134$  gallons  $\times 8.34 = 26,138$  lbs... recalculating:  $0.785 \times 1.778 = 1.396$  sq ft  $\times 300 = 418.8$  cu ft  $\times 62.4 = 26,133$  lbs water; total =  $10,800 + 26,133 = 36,933$  lbs — approximately 37,000 pounds total
- D. 5,400 pounds based on using only half the pipe length in the calculation

41. A customer at the end of a long deadend main consistently experiences water quality problems — low residual, occasional taste and odor, and discolored water during any system disturbance. The utility has been flushing the dead end monthly, but the problems return within two weeks. What permanent solution would most effectively address this customer's chronic problems?

- A. Monthly flushing is a temporary measure — the permanent solution is to connect this dead end to another main, creating a loop
- B. Install a booster chlorination station at the midpoint of the deadend main
- C. Replace the deadend main with a larger diameter pipe to increase the storage volume
- D. Connect the customer's service line directly to the trunk main through a new, separate service line

42. A water system's operator is investigating why one specific pressure zone has consistently higher TTHM levels than other zones, even though all zones receive water from the same treatment plant. The zone in question has a 750,000gallon elevated tank that cycles only 12% of its volume daily. What is the connection?

- A. The elevated tank in this zone has a coating that reacts with chlorine to form THMs
- B. The minimal tank cycling creates extended water age inside the tank — the THM formation reaction between chlorine and organic matter continues as long as both are present, and the long residence time in the poorly cycling tank allows significantly more THMs to form than in zones where water moves through the system more quickly
- C. The zone's pipe material catalyzes THM formation more effectively than pipe material in other zones
- D. The treatment plant sends water with higher organic content to this specific zone

43. A water system serves a dental office that has a connection between the municipal supply and a dental vacuum system. The vacuum system uses water for suction during dental procedures and is exposed to blood, saliva, and dental materials. What type of backflow prevention is required?

- A. An RPZ assembly because the dental vacuum system involves healthhazard biological and chemical contaminants from dental procedures — blood, saliva, amalgam particles, and chemical agents create a highhazard crossconnection
- B. A DCVA is adequate because dental offices are classified as lowhazard medical facilities
- C. A PVB is sufficient because the vacuum system creates only backsiphonage conditions

D. No backflow prevention is needed because dental vacuum systems operate at negative pressure

44. An operator is asked to identify the most common type of valve used for isolation in water distribution systems. What is the correct answer?

A. Butterfly valves are most common because they require fewer turns to operate

B. Plug valves are most common because they provide the best seal against leakage

C. Gate valves are the most common isolation valve in distribution systems — they provide a fullbore, unrestricted flow path when open, create minimal friction loss, and provide positive shutoff when closed; they are available in all sizes and are the standard valve for buried distribution main isolation

D. Ball valves are most common because they combine the advantages of gate and butterfly designs

45. A water system's operator discovers that the automated chlorine analyzer at a critical monitoring point has been reading 0.3 mg/L consistently for the past week. The operator performs a manual DPD test at the same location and obtains a reading of 0.9 mg/L. What should the operator conclude?

A. The DPD test is likely correct because it was performed with fresh reagent by a trained operator

B. The chlorine analyzer reading is likely correct because automated instruments are always more accurate than manual tests

C. Both readings are equally valid and the operator should average them to obtain the true residual

D. The chlorine analyzer has likely drifted out of calibration and has been reporting a falsely low residual for the past week — operational decisions, alarm responses, and potentially compliance determinations based on this analyzer's data during the past week may have been incorrect; the analyzer must be recalibrated immediately

46. A distribution system has experienced a water main break on a 20inch transmission main. The break is a 6foot longitudinal crack that is discharging approximately 3,000 GPM. The operator has closed two isolation valves and the break has stopped flowing. However, closing these valves has isolated a section that includes a fire station, a nursing home, and 500 residential connections. What is the operator's next priority?

A. Begin excavation at the break location immediately to minimize the total outage duration

B. Activate the emergency response plan — notify the fire station (reduced fire flow), individually notify the nursing home (critical customer requiring alternative water), issue a general notification to the 500 residential customers, arrange for temporary water supply to the nursing home if the outage will exceed 4 hours, and coordinate the repair while managing the customer impact

C. Restore service to the fire station by partially reopening one isolation valve

D. Contact the media to issue a press release about the expected outage duration

47. An operator is reviewing the utility's emergency generator maintenance records and discovers that the generator at the main pump station has not had its cooling system serviced in two years. The manufacturer recommends annual coolant replacement and radiator inspection. What risk does this deferred maintenance create?

A. The generator may overheat and shut down during an extended power outage — coolant degrades over time, losing its heattransfer properties and corrosion inhibitors; radiator passages can become blocked with scale and debris; and the cooling system's ability to reject heat diminishes; a generator failure during a power outage leaves the pump station without power at the worst possible time

B. Deferred cooling system maintenance only affects the generator's fuel efficiency, not its reliability

C. The coolant will eventually freeze in winter, cracking the engine block

D. The generator's power output decreases proportionally with coolant age

48. A water system's operator is conducting a crossconnection control survey at a commercial car wash. The facility has the following connections to the potable supply: a highpressure wash system with chemical injection, a recycled water system for rinse water, and a vacuum system for interior cleaning. How many potential crossconnections exist?

A. Only one — the chemical injection on the highpressure wash system

B. Two — the highpressure wash system and the recycled water system

C. Three — all three systems represent potential crossconnections; the highpressure wash with chemicals (high hazard, backpressure), the recycled water system (high hazard, contains road grime and chemicals), and the vacuum system (potential backsiphonage of contaminated water and debris)

D. None — car wash facilities use water in one direction and cannot create backflow conditions

49. A water system operates a well that has been experiencing a gradual decline in specific capacity over the past five years — from 15 GPM/ft to 8 GPM/ft. The utility's engineer recommends well rehabilitation. What is the first rehabilitation step typically performed?

- A. Install a new, larger pump to overcome the increased resistance
- B. Deepen the well to access a more productive zone of the aquifer
- C. Abandon the well and drill a new replacement well at a different location
- D. Video inspection of the well bore to assess the condition of the casing, screen, and gravel pack before selecting the appropriate cleaning method — without knowing the specific cause of the decline (mineral encrustation, biofouling, sand bridging, screen corrosion), the correct rehabilitation technique cannot be selected

50. A distribution system operator is planning a main extension to serve a new subdivision. The design calls for 1,200 feet of 8inch ductile iron main connecting to an existing 12inch trunk main. The operator reviews the plans and notices that the design does not include any fire hydrants on the new main. What should the operator recommend?

- A. Fire hydrants are only required on mains 12 inches or larger and are not needed on 8inch branch mains
- B. The operator should recommend hydrants be added per the local fire code requirements — typically every 500-600 feet in residential areas; the 1,200-foot extension would likely need 23 hydrants for adequate fire protection, fire flow testing capability, and system flushing access
- C. A single hydrant at the far end of the extension is sufficient for both fire protection and flushing
- D. Hydrant spacing is determined solely by the fire department and the operator has no authority to make recommendations

51. A water system's SCADA data shows that a VFD-controlled pump is operating at 42% speed during overnight hours when demand is very low. At this speed, the pump operates far below its best efficiency point (BEP). What operational concern does this create?

- A. Operating well below BEP reduces efficiency, wastes energy, and can cause internal recirculation that damages the pump — at very low speeds, the pump may operate below its minimum continuous stable flow, causing recirculation between the impeller and casing that produces vibration, bearing

damage, and premature wear; the operator should consider shutting the pump down during lowdemand periods and relying on gravity feed from storage

- B. Lowspeed operation improves pump longevity by reducing mechanical stress
- C. VFD operation at 42% speed is within the normal operating range for all centrifugal pumps
- D. The only concern at low speed is increased noise from the VFD's electrical harmonics

52. An operator is asked to explain to a customer why the utility adds orthophosphate to the water and whether it is safe to drink. What is the correct explanation?

- A. Orthophosphate is added as a nutrient supplement to improve the health benefits of drinking water
- B. Orthophosphate is added only during summer months when corrosion rates are highest
- C. Orthophosphate is a corrosion inhibitor that forms a thin protective coating on the inside of metal pipes and plumbing, preventing lead, copper, and iron from dissolving into the drinking water; it is added at very low concentrations (typically 0.5-2.0 mg/L) that are well below any health concern, and phosphate is a naturally occurring mineral found in many foods
- D. Orthophosphate is a disinfectant that works alongside chlorine to kill bacteria in the distribution system

53. A distribution system has a 12inch main that runs through an industrial area. A chemical manufacturing plant adjacent to the main has experienced a spill of trichloroethylene (TCE), a volatile organic compound, that has contaminated the soil around the water main. The main is ductile iron with mechanical joints. What is the immediate concern for the water main?

- A. TCE will corrode the ductile iron pipe wall, causing structural failure within days
- B. TCE vapors will enter the main through the air release valves at nearby high points
- C. TCE will react with the chlorine residual inside the main, producing toxic byproducts
- D. TCE in contaminated soil can infiltrate the main through rubber gaskets at mechanical joints if the internal pressure drops below the external groundwater/soil pressure — the rubber used in standard pipe gaskets is susceptible to chemical degradation from chlorinated solvents, which can also permeate through the gasket material

54. A water system's operator is preparing a budget justification for a \$75,000 comprehensive meter testing program. The utility has 10,000 meters, and a preliminary audit suggests the average meter is underregistering by 3.5%. The average monthly water bill is \$55 per customer. What is the estimated annual revenue recovery from improving meter accuracy?

- A. \$231,000 per year based on multiplying the number of meters by the average bill by the underregistration rate
- B. Approximately \$231,000 per year — calculated as  $10,000 \text{ meters} \times \$55/\text{month} \times 12 \text{ months} \times 3.5\% = \$231,000$  annual revenue recovery, which represents a 3.1:1 return on the \$75,000 investment
- C. \$75,000 per year, matching the cost of the testing program
- D. \$23,100 per year based on using only one month of billing data

55. An operator is investigating a complaint from a customer who reports that their toilet tank refills very slowly — taking 20 minutes instead of the normal 34 minutes. All other fixtures in the home work normally. The customer's neighbors have no problems. The system pressure at the customer's meter reads 55 psi. What is the most likely cause?

- A. The toilet fill valve itself is partially clogged or malfunctioning — since system pressure is adequate (55 psi), all other fixtures work normally, and no neighbors are affected, the problem is isolated to this single fixture; the fill valve's inlet screen or diaphragm may be restricted by sediment or mineral deposits
- B. The customer's service line has a partial blockage that only affects lowflow fixtures like toilet fill valves
- C. A partially closed curb stop is restricting flow to the customer's home
- D. The distribution main serving the customer's street has severe tuberculation

56. A water system serves a community with a large agricultural presence. Several farms within the wellhead protection area apply nitrogenbased fertilizers seasonally. The utility's well monitoring has shown a gradual increase in nitrate levels over the past decade — from 3.2 mg/L to 7.8 mg/L. The MCL for nitrate is 10 mg/L. What proactive action should the utility take?

- A. No action is needed until the nitrate level reaches the MCL of 10 mg/L
- B. Issue a public notification advising customers to switch to bottled water

C. Implement enhanced monitoring, work with agricultural agencies to promote best management practices for fertilizer application within the wellhead protection area, and begin planning for treatment capacity in case levels continue to rise — the upward trend suggests the MCL may be exceeded within the next few years

D. Shut down the well permanently and develop an alternative water source

57. A pump station has three pumps in a leadlagstandby configuration. During a routine monthly test of the standby pump, the operator discovers that the pump's mechanical seal is leaking significantly — approximately 5 gallons per minute of water streams from the seal area when the pump runs. What should the operator do?

A. Continue running the standby pump during the monthly test to evaluate whether the seal leak stabilizes

B. Tag the pump out of service with a sign on the panel indicating the seal failure

C. Run the standby pump at reduced speed to minimize the seal leakage

D. Take the standby pump out of service immediately for seal replacement, and designate one of the other two pumps as the temporary standby until the repair is complete — operating without a functional standby pump increases the risk of service failure if one of the operating pumps fails

58. A water system's operator is reviewing the results of the annual water audit. The audit shows: system input volume = 1,825 MG/year, billed metered consumption = 1,387 MG/year, billed unmetered consumption = 20 MG/year, unbilled metered consumption = 5 MG/year, unbilled unmetered consumption = 40 MG/year. What is the nonrevenue water volume and percentage?

A. 438 MG/year (24.0%) based on subtracting only billed metered consumption from the input

B. The nonrevenue water = system input – billed consumption =  $1,825 - (1,387 + 20) = 418$  MG/year = 22.9% of system input — this includes unbilled metered, unbilled unmetered, apparent losses, and real losses

C. 373 MG/year (20.4%) based on subtracting all metered consumption from the input

D. 1,825 MG/year (100%) because all water produced is technically nonrevenue until billed

59. An operator is asked to explain why the utility performs annual hydrant flow tests at the same locations each year rather than testing different hydrants each time. What is the primary operational value of consistent testing locations?

- A. Testing the same hydrants each year creates trend data that reveals whether the system's hydraulic performance at each location is improving, stable, or declining over time — a progressive decline at a specific hydrant indicates increasing pipe resistance (from tuberculation) or growing demand that the system cannot support, providing early warning of developing problems
- B. Testing the same hydrants is required by the fire code and the utility has no discretion to change locations
- C. Different hydrants produce different results regardless of system conditions, so consistent locations eliminate variability
- D. The fire department prefers testing at the same locations because they have established connections at these hydrants

60. A water system experiences a confirmed waterborne disease outbreak. Investigation reveals that the contamination entered the distribution system through an unprotected crossconnection at a chemical manufacturing plant during a main break that caused negative pressure in the area. The utility's crossconnection control program has been understaffed and ineffective for the past three years. What consequences may the utility face?

- A. The utility will receive a warning letter from the state but no further action
- B. The consequences will be limited to a fine for the crossconnection violation only
- C. The utility may face regulatory enforcement action (compliance orders, fines), Tier 1 public notification requirements, civil liability for illness and medical costs of affected customers, potential criminal liability if negligence is proven, mandatory program improvements required by the state, and severe loss of public trust
- D. The chemical plant bears all responsibility and the utility has no liability for contamination caused by a customer's cross connection

61. A water system's operator calculates that the system needs 85 pounds per day of chlorine to maintain the target dose. The utility currently uses chlorine gas from 150-pound cylinders. Each cylinder lasts approximately 1.76 days ( $150 \div 85$ ). The utility keeps two cylinders connected to a switchover manifold with four additional cylinders in inventory. What is the approximate supply on hand in days?

- A. Approximately 10.6 days of supply ( $6 \text{ cylinders} \times 150 \text{ lbs} \div 85 \text{ lbs/day}$ ), but only the two connected cylinders are immediately available — the operator should establish a reorder point that accounts for delivery lead time and ensures supply never drops below a minimum safety stock

- B. Exactly 6 days based on one cylinder per day
- C. 3.5 days based on only counting the two connected cylinders
- D. 30 days based on an industry standard safety factor applied to the cylinder inventory

62. An operator is troubleshooting a booster pump station where the VFD controlled pump oscillates between 45 and 75 psi with a 12second cycle period. The pressure setpoint is 60 psi. The oscillation began after a recent SCADA software update. What is the most likely cause?

- A. The VFD motor bearings have failed, causing the pump to surge with each rotation
- B. The SCADA update changed the system pressure setpoint from 60 to 75 psi, creating a conflict
- C. The PID control parameters in the VFD or SCADA controller were altered or reset to default values during the software update — the proportional gain is likely too high, causing the controller to overshoot on each correction cycle; retuning the PID parameters to the preupdate values should restore stable operation
- D. The pressure transducer was damaged during the software update procedure

63. A water system has a 500,000gallon elevated tank that serves a residential zone. SCADA data shows the tank cycles between 72% and 95% during weekdays but barely moves (9095%) on weekends. Monday morning chlorine residual at the tank outlet is consistently 0.3 mg/L lower than Friday evening levels. What operational adjustment would improve Monday morning water quality?

- A. Increase the chlorine dose at the treatment plant on Friday afternoon to compensate for weekend decay
- B. Force deeper cycling of the tank on weekends by lowering the highlevel pump shutoff setpoint or increasing the lowlevel pump start setpoint — this forces more water turnover through the tank during the lowdemand weekend, replacing stagnant water with fresh supply and maintaining higher residuals
- C. Install a chlorine analyzer inside the tank to monitor residual decay in real time
- D. Accept the Monday morning residual drop as a normal operational characteristic

64. A water system's operator receives laboratory results showing that the TTHM result at monitoring site #4 is 0.092 mg/L — above the MCL of 0.080 mg/L. The previous three quarters at this site were 0.068, 0.071, and 0.065 mg/L. The LRAA =  $(0.068 + 0.071 + 0.065 + 0.092) / 4 = 0.074$  mg/L. Is the system in violation?

- A. Yes, because the single quarterly result of 0.092 exceeds the MCL
- B. No, because compliance is based on the LRAA, which is 0.074 — below the 0.080 MCL; however, the 0.092 result signals a developing problem, and next quarter's result will replace the oldest (0.068) in the LRAA calculation; a high result next quarter could push the LRAA above the MCL
- C. Yes, because the LRAA calculation should use only the two highest results, not all four
- D. No, and no further action is needed because the LRAA is well below the MCL

65. A water main installation project requires connecting new 12inch ductile iron pipe to an existing 12inch cast iron main. The operator notices that the new DI pipe's outside diameter does not match the existing CI pipe's outside diameter for the same nominal 12inch size. Why do these pipes have different outside diameters?

- A. The outside diameters are different because ductile iron and cast iron pipes have historically been manufactured to different dimensional standards — CI pipe was made with thicker walls (larger OD), while DI pipe is manufactured to a smaller OD; a transition coupling or transition fitting is needed to bridge the dimensional difference
- B. The new pipe is actually a different nominal size and was ordered incorrectly
- C. Ductile iron pipe shrinks slightly during the manufacturing cooling process, making it smaller
- D. Cast iron pipe expands over time from internal corrosion pressure, making the OD larger than when it was new

66. A distribution system serves a neighborhood where a contractor is performing directional drilling for a telecommunications conduit. During the drilling, the drill bit strikes and punctures a 6inch PVC water main 4 feet below ground. Water begins bubbling up through the bore hole. What should the distribution operator do?

- A. Allow the contractor to complete the bore and then repair the water main after the drilling is finished
- B. Advise the contractor to withdraw the drill and insert a plug into the bore hole to stop the leak

C. Locate and close the nearest isolation valves to stop the water loss, then coordinate with the contractor to excavate the damaged area for proper repair — the contractor's insurance is responsible for the repair cost, but the utility must manage the isolation, repair, disinfection, and return to service

D. Direct the contractor to call 811 and wait for the locate crew to mark all utilities before any repair begins

67. A water system's operator is asked to compare the advantages and disadvantages of elevated storage versus groundlevel storage with pumping. What is the primary operational advantage of elevated storage?

A. Elevated storage costs less to construct than groundlevel storage with pumping

B. Elevated storage provides passive, gravityfed pressure that works without any mechanical equipment, electrical power, or operator intervention — it continues functioning during power outages, pump failures, and staffing gaps; groundlevel storage requires active pumping to deliver water under pressure, creating dependency on electrical and mechanical systems

C. Elevated storage provides better water quality because the water is exposed to sunlight that kills bacteria

D. Elevated storage has greater total capacity than groundlevel storage for the same footprint

68. A water system's emergency generator at a remote well station failed to start during the last power outage. Investigation revealed that the battery was dead. The generator's monthly test procedure calls for starting the generator and running it under load for 30 minutes. The last test was performed 6 weeks ago and was successful. What maintenance gap contributed to this failure?

A. The generator should have been replaced with a newer model that has a more reliable starting battery

B. The monthly test interval should be reduced to weekly testing for remote sites

C. The 6week gap between tests allowed the battery to discharge — generator batteries must be maintained on a continuous trickle charger, and battery condition should be checked as part of every monthly test

D. Generator batteries should be equipped with a battery condition alarm connected to SCADA that alerts operators when voltage drops below the minimum starting threshold, ensuring the problem is detected between test intervals

B. The monthly test interval is adequate, but the battery maintenance was neglected — generator starting batteries should be kept on a continuous float/trickle charger that maintains charge between test cycles;

the dead battery indicates either the charger failed or was never installed, and battery voltage should be verified during every monthly test

69. A distribution system serves an area where a new highway construction project requires relocating 2,000 feet of 16-inch water main. The existing main is 30-year-old cement mortar lined ductile iron in good condition. The contractor proposes to reuse the existing pipe by carefully excavating, cleaning, and reinstalling it at the new alignment. Should the utility accept this proposal?

A. No — reusing old pipe creates risks that outweigh the cost savings: the excavation and handling process can damage the cement mortar lining and pipe coating, mechanical joint gaskets may not reseal properly after disassembly and reassembly, the utility cannot inspect the pipe's full interior condition, and the reinstalled main would still be 30-year-old pipe with a limited remaining service life; new pipe should be specified

B. Yes, because the pipe is only 30 years old and has many decades of service remaining

C. Yes, as long as the contractor pressure tests the reinstalled section before backfilling

D. The decision depends solely on whether the pipe passes a visual inspection after excavation

70. A water system serves a community that is experiencing rapid residential growth. Over the past three years, the utility has added 1,200 new service connections. SCADA data shows that the elevated tank serving the growth area now drops to its low-level alarm daily during peak demand, whereas it previously dropped to low level only during extreme summer demand days. What does this indicate?

A. The elevated tank has developed a leak that is emptying it faster than the pumps can fill it

B. The SCADA low-level alarm setpoint has drifted and needs recalibration

C. The system's pumping and/or storage capacity is no longer adequate for the increased demand — the growing number of customers is drawing more water during peak periods than the pump station can supply, forcing the tank to provide more equalization than it was designed for

D. The treatment plant is producing less water due to raw water quality changes that have reduced its capacity

71. A water system's operator is asked to identify the primary water quality concern associated with new water main installations — specifically, what is the most important reason for disinfecting new mains before placing them into service?

- A. New pipe has a chemical coating that must be neutralized by chlorine before the pipe is safe for drinking water
- B. New pipe is perfectly clean from the factory and only needs flushing, not disinfection
- C. The disinfection process is primarily performed to verify the pressure integrity of the new pipe joints
- D. During manufacturing, transportation, storage, and installation, the interior of new pipe contacts dirt, soil, groundwater, lubricants, insects, and human hands — any of these can introduce bacteria or other contaminants; disinfection kills these organisms and bacteriological testing confirms the main is safe before customers drink the water

72. An operator is investigating a section of the distribution system where fire flow test results have declined by 30% over the past five years — from 1,500 GPM to 1,050 GPM at 20 psi residual — at the same test hydrant. The mains in this area are 50-year-old unlined cast iron. What is the most cost-effective rehabilitation option if the pipe structure is still sound?

- A. Replace all mains in the area with new ductile iron pipe
- B. Clean and cement mortar line the existing mains — this removes the interior tuberculation (restoring the full bore diameter), applies a smooth interior surface ( $C \approx 140$ ), and dramatically reduces friction losses without the cost of full replacement, restoring fire flow capacity to near-original levels
- C. Install booster pumps to push more water through the corroded mains
- D. Reduce the fire flow requirement for this area through a variance from the fire marshal

73. A water system operates a pump station with two identical pumps in a lead-lag configuration. Both pumps are rated at 750 GPM. When both pumps run simultaneously in parallel, the combined output is 1,320 GPM — not 1,500 GPM. The operator is asked to explain this to a new employee. What is the correct explanation?

- A. When two pumps operate in parallel, the combined flow increases velocity in the common discharge piping, which increases friction losses; this higher system head forces both pumps to operate at a reduced flow, higher head point on their performance curves — the combined output is always less than twice the single pump output, and the deficit increases with piping friction
- B. One of the two pumps has a worn impeller that produces less flow than its twin
- C. The SCADA flow meter is inaccurate when both pumps are running simultaneously
- D. The pumps interfere with each other hydraulically, and this interference cannot be reduced by any piping modification

74. A water system's treatment plant operates a chlorine gas disinfection system. The operator notices that the chlorine gas rotameter reading has been gradually decreasing over the past week even though the chlorinator setting has not changed. The injector vacuum is normal. What is the most likely cause?

- A. The chlorine gas cylinder is nearly empty and the reduced gas pressure is causing the flow to decrease
- B. The ambient temperature in the chlorine room has dropped, reducing the rate of chlorine gas evaporation from the cylinder
- C. The most likely cause is that the chlorine cylinder is running low — as the liquid chlorine level decreases, the gas pressure above the liquid drops, reducing the flow rate through the chlorinator; the operator should check the cylinder weight and prepare to switch to a full cylinder
- D. The chlorinator's orifice has become partially blocked by impurities in the chlorine gas

75. A water system's operator is asked to calculate the approximate cost of electricity to pump 3.0 MGD against 200 feet of total dynamic head. The pump efficiency is 75%, the motor efficiency is 92%, and the electricity rate is \$0.12 per kWh. What is the approximate daily electricity cost?

- A. \$720 per day based on a simplified calculation that does not account for efficiency
- B. \$528 per day based on using only the pump efficiency without motor efficiency
- C. \$120 per day based on using the cost rate without performing the power calculation
- D. Approximately \$574 per day — calculated as:  $\text{power (kW)} = (3,000,000 \text{ gal} \times 8.34 \text{ lb/gal} \times 200 \text{ ft}) / (33,000 \text{ ftlb/min} \times 60 \text{ min} \times 0.75 \times 0.92) = \text{approximately } 199 \text{ kW}$ ; daily cost =  $199 \times 24 \times \$0.12 = \$573$

76. A water system serves an elementary school that has requested a separate backflow prevention device on its service connection. The school has no chemical injection systems, no boilers, and no special waterusing equipment beyond standard plumbing fixtures, a cafeteria kitchen, and a standard fire sprinkler system (no additives). What degree of hazard does the school connection represent?

- A. High hazard requiring an RPZ because schools are classified as critical public facilities
- B. Low to moderate hazard — the standard plumbing and cafeteria equipment represent low hazard that can be protected with a DCVA on the service line; the fire sprinkler system without additives is also low hazard; if the school adds chemical injection to the sprinkler or installs science lab equipment, the hazard classification should be reevaluated

- C. No hazard because schools are exempt from crossconnection control requirements
- D. High hazard requiring an air gap because children attend the facility

77. A water system's operator discovers that a valve on a 10inch main near a hospital has been left partially closed after a recent repair — approximately halfclosed. The hospital has not reported any pressure problems. Should the operator fully open the valve?

- A. Yes — a partially closed valve restricts maximum flow, reduces available fire flow capacity for the hospital area, increases friction loss, wastes pumping energy, creates turbulence that can erode the valve seat, and conceals the system's true hydraulic performance; the hospital may not notice under normal demand but would experience critically low pressure during a fire flow event
- B. No, because the hospital is not experiencing any problems under current conditions
- C. Leave the valve halfclosed until the next scheduled valve exercising round
- D. Open the valve only if the hospital specifically requests higher pressure

78. A distribution system has experienced a series of water main breaks during an unusually cold winter. The breaks are occurring on mains that are buried at only 3 feet of cover — below the local frost line of 4 feet. What is the mechanism causing these breaks?

- A. The water inside the mains freezes and expands, bursting the pipe from internal ice pressure
- B. Cold temperatures cause the pipe material to contract and shrink, creating tensile stress that cracks the pipe
- C. The frost penetrates below the insufficient depth of cover and freezes the soil around the pipe — the expanding frozen soil exerts enormous external pressure on the pipe and can also heave and shift, applying bending forces to the rigid pipe; the insufficient burial depth left these mains within the frost zone
- D. Cold groundwater flowing past the pipe at the shallow depth cools the pipe wall below its brittle fracture temperature

79. A water system's operator is reviewing the utility's chemical inventory and discovers that the sodium hypochlorite stored in the tank has been on site for four months. The solution was delivered at 12.5% available chlorine. The operator tests the solution strength and finds it has degraded to 8.2%. What should the operator do?

- A. Dispose of the degraded solution and order fresh chemical immediately
- B. Add concentrated chlorine to the tank to restore the strength to 12.5%
- C. The solution is unusable at 8.2% and should not be fed into the system
- D. Adjust the chemical feed pump rate upward to compensate for the reduced concentration — increasing the gallons per day fed to deliver the same pounds of chlorine per day; additionally, implement measures to reduce future degradation (protect the tank from heat and sunlight, reduce inventory to ensure faster turnover)

80. A water system serves a community with a significant population of kidney dialysis patients who receive home dialysis. The utility is planning to switch its secondary disinfectant from free chlorine to chloramines. What special notification and timeline considerations apply?

- A. No special notification is needed because chloramines are equally safe for dialysis patients
- B. Dialysis patients and home dialysis supply companies must be individually notified well in advance of the conversion — chloramines are not removed by standard dialysis carbon filters and require specialized treatment; the notification must provide enough lead time for patients and their providers to upgrade their treatment systems before chloraminated water reaches their homes
- C. Only the hospital dialysis centers need notification; home dialysis patients are the responsibility of their healthcare provider
- D. The utility can convert without notification because dialysis patients' physicians are responsible for monitoring their patients' water treatment equipment

81. A distribution system operator is troubleshooting an area where customers report fluctuating pressure throughout the day. SCADA shows stable pressures at the pump station and elevated tank. The operator installs a pressure logger at a hydrant in the affected area and records data for one week. The data shows pressure drops of 1520 psi occurring at 7:15 AM, 12:00 PM, 5:00 PM, and 6:30 PM daily. These correspond to no SCADA pressure changes at the pump station or tank. What is causing the localized pressure drops?

- A. The pressure logger is malfunctioning and generating false pressure drops at regular intervals
- B. A PRV serving this area is hunting and creating pressure fluctuations during demand changes
- C. The pressure drops coincide with demand spikes from one or more large customers in the area — a school, commercial facility, or irrigation system that operates on a schedule; the localized demand

creates friction losses in the mains serving this area that are too small to register at the distant pump station or tank SCADA points

D. The elevated tank serving this area has a stuck altitude valve that creates pressure transients

82. A water system's operator discovers that a 20-year-old 1-inch galvanized steel service line has an effective internal diameter of approximately 3/8-inch due to severe internal corrosion and tuberculation. The customer reports extremely poor flow and pressure. What is the appropriate resolution?

A. Flush the service line with high-pressure water to remove the corrosion deposits and restore the full bore

B. Apply a chemical treatment through the service line to dissolve the corrosion deposits

C. Install a booster pump on the customer's side to overcome the restriction in the service line

D. Replace the galvanized steel service line — the internal corrosion has reduced the effective diameter to the point where the pipe cannot deliver adequate flow regardless of system pressure; flushing and chemical treatments cannot remove the hardened tuberculation from galvanized steel, and a booster pump would not solve the flow restriction

83. A water system's annual consumer confidence report must include information about the source of the community's drinking water. Why is source water information important for customers to know?

A. Source water information helps customers understand where their water comes from (groundwater or surface water), what potential contamination sources exist near the source, and why certain treatment processes are used — this transparency empowers customers to understand and evaluate their water quality and supports the utility's relationship with the community

B. Source water information is included only to satisfy a federal regulatory requirement with no practical benefit

C. Customers need source water information to choose between municipal and private well water

D. Source water identification helps customers file complaints with the correct state agency

84. A distribution system has a section of 8-inch main that runs parallel to a sanitary sewer main with a separation of only 2 feet. The water main is ductile iron with push-on joints. During a sewer surcharge event (the sewer fills beyond capacity and pressurizes), what specific risk does the close proximity create?

- A. The surcharging sewer will corrode the exterior of the ductile iron water main through chemical attack
- B. If the water main experiences a pressure loss (from a main break, pump failure, or high demand) while the adjacent sewer is surcharging, the external sewer pressure could exceed the internal water main pressure at joint gaskets, forcing sewage contamination into the drinking water supply
- C. The surcharging sewer will vibrate the adjacent water main, loosening its joints over time
- D. The sewer gases will permeate through the ductile iron pipe wall and contaminate the water inside

85. A water system's operator calculates that the utility's nonrevenue water has increased from 20% to 28% over the past two years. The water audit shows that real losses have increased by 5% and apparent losses have increased by 3%. The operator is asked to prioritize corrective actions. What is the most effective approach?

- A. Focus exclusively on real losses because they represent the larger increase
- B. Focus exclusively on apparent losses because they are easier and cheaper to address
- C. Defer all action until the nonrevenue water reaches 30%, which is the industry threshold for concern
- D. Address both categories simultaneously — implement a leak detection and repair program to reduce the 5% increase in real losses, and implement a meter testing and replacement program to reduce the 3% increase in apparent losses; both programs should be implemented together because each addresses a different cause of the NRW increase

86. A pump station operator notices that the discharge check valve on Pump 2 produces a loud "bang" every time the pump shuts off. Pump 1's check valve closes quietly. Both pumps and check valves are identical. What is causing the noise on Pump 2's check valve?

- A. Pump 2's motor is running in reverse for a fraction of a second after shutdown, creating a pressure wave
- B. Pump 2's check valve disc or spring has worn, allowing the disc to delay closing — when flow reverses after the pump stops, the disc slams shut against the reverse flow, creating the water hammer "bang"; Pump 1's check valve closes faster (before significant reverse flow develops), preventing the slam
- C. The piping configuration on Pump 2's discharge creates a resonance that amplifies the normal check valve closure sound
- D. Pump 2 has a slightly higher shutoff head that creates more pressure differential when the pump stops

87. A water system serves an area with naturally corrosive soil (pH 4.5, resistivity 500 ohmcm). The utility installs a new 12inch ductile iron main with polyethylene encasement and sacrificial anode cathodic protection. Five years later, a section of the polyethylene wrap is found torn during excavation for a new service connection. The exposed pipe surface shows moderate external pitting. What does this tell the operator?

- A. The combination of polyethylene encasement and cathodic protection is functioning as designed — the encasement provides the primary barrier, and the cathodic protection provides secondary electrochemical protection where the encasement is compromised; the moderate pitting at the torn section demonstrates that both protection methods are needed in this aggressive soil
- B. The cathodic protection system has failed completely because the exposed section shows pitting
- C. The polyethylene encasement was unnecessary because the cathodic protection alone would have prevented all corrosion
- D. The ductile iron pipe is not suitable for this soil and should be replaced with PVC

88. A confined space entry team is performing atmospheric testing before entering a large underground concrete water reservoir that was drained two days ago. The initial readings show  $O_2 = 20.5\%$ ,  $LEL = 0\%$ ,  $CO = 0$ ,  $H_2S = 0$ . The team enters and begins work. After one hour, the entrant's personal fourgas monitor alarms for low oxygen at 19.4%. What should happen?

- A. The entrant should move to a location inside the reservoir where ventilation is better
- B. The entrant must exit the space immediately — the oxygen has dropped below the 19.5% minimum; the cause must be investigated (biological oxygen demand from residual organic matter, chemical reaction with the concrete, or inadequate ventilation reaching the entrant's location), ventilation must be increased, and the atmosphere must be retested before reentry
- C. The alarm can be acknowledged and the entrant can continue working because 19.4% is only slightly below the minimum
- D. The attendant should increase the ventilation rate and instruct the entrant to continue working

89. A water system serves a large university campus. The campus has its own internal distribution system with multiple buildings, fire hydrants, and an interconnection with the municipal supply. The campus also has a research laboratory that uses radioactive isotopes and a veterinary clinic that handles animal waste and pharmaceuticals. What level of backflow protection is required at the campus's interconnection with the municipal supply?

- A. A DCVA at the main interconnection because the campus's primary use is educational (low hazard)
- B. No backflow prevention is needed because the campus is a large, wellmanaged institution
- C. A PVB at the main interconnection because backsiphonage is the only concern
- D. An RPZ assembly or air gap at the main interconnection — the campus contains multiple highhazard connections (radioactive materials, animal clinic chemicals, and other laboratory chemicals) that could contaminate the municipal supply; the highest hazard present on the campus determines the protection level at the main service

90. A water operator is calculating the head loss through 1,500 feet of 6inch unlined cast iron main ( $C=50$ ) carrying 250 GPM. The HazenWilliams calculation yields a head loss of approximately 25 feet. If this same main were cleaned and lined ( $C=140$ ), what would the approximate head loss be at the same flow rate?

- A. 24 feet, because cleaning and lining has minimal effect on friction loss in 6inch mains
- B. 12.5 feet, representing a 50% reduction from the prerehabilitation head loss
- C. Approximately 4 to 5 feet — the ratio of head losses is approximately  $(140/50)^{1.85} \approx 6$ , so the rehabilitated main would have approximately 1/6th the head loss ( $25 \div 6 \approx 4.2$  feet); this dramatic reduction in friction loss explains why cleaning and lining can restore fire flow capacity and resolve pressure complaints
- D. 25 feet, because head loss depends only on pipe diameter and length, not on the internal surface condition

91. An operator is asked why the utility invests significant resources in training operators for emergency response scenarios that may never occur — such as contamination events, major transmission main failures, and extended power outages. What is the strongest justification for this investment?

- A. Emergency response training ensures that when a rare but catastrophic event does occur, operators respond quickly, correctly, and safely — the actions taken in the first minutes and hours of an emergency determine whether the event is contained or escalates; training builds the muscle memory, decisionmaking skills, and team coordination that cannot be developed during an actual crisis
- B. Emergency training is required by OSHA and the utility will be fined if it is not provided
- C. Emergency training improves operators' performance during routine daily operations
- D. Emergency training is needed primarily for new operators and is unnecessary for experienced staff

92. A water system's distribution superintendent asks each operator to identify the single most important piece of information they need when responding to a main break at 2:00 AM. Based on operational experience, what is the correct answer?

- A. The age and material of the broken pipe to determine the appropriate repair materials
- B. The location and operability of the nearest isolation valves — knowing which valves to close and where they are determines how quickly the break can be isolated, how many customers will be affected, and how much water will be lost; without this knowledge, the operator cannot take the most critical first action
- C. The depth of the pipe to determine the required excavation equipment
- D. The size of the pipe to order the correct replacement section before arriving at the break site

93. A water system is planning to construct a new 1milliongallon elevated storage tank. The project will take 18 months from design through construction. The distribution operator is asked to provide input on the tank design. What operational considerations should the operator recommend?

- A. The operator should focus only on the aesthetic appearance of the tank to match neighborhood architecture
- B. The operator should recommend the largest possible tank diameter to maximize storage volume
- C. The operator has no useful input to provide because tank design is entirely an engineering function
- D. The operator should recommend: separate inlet and outlet connections to prevent shortcircuiting, internal baffles or mixing system for water quality, adequate access hatches for maintenance entry, properly sized and screened vents, overflow pipe with screening and proper discharge, SCADAconnected level monitoring and temperature sensing, cathodic protection for steel components, interior coating suitable for the utility's water chemistry, and site access for maintenance vehicles

94. A water system's operator is investigating why the chlorine residual at a specific monitoring point has been declining steadily over the past six months — from 1.0 mg/L to 0.3 mg/L. The treatment plant dose has not changed. No new connections have been added. What should the operator investigate?

- A. Whether a valve has been inadvertently left closed somewhere between the treatment plant and the monitoring point, rerouting water through a longer path with more water age
- B. Whether the pipe serving this monitoring point has developed increasing biofilm that consumes more chlorine over time

C. Whether a new demand source (leak, unauthorized hydrant use) between the plant and the monitoring point is drawing water away from this location, increasing water age

D. All of the above — a sixmonth progressive decline with no treatment changes suggests something in the distribution system has changed; the operator should systematically check valve positions (rerouted flow), investigate biofilm growth (increasing demand), check for new demand sources (leaks or unauthorized use), and verify that no infrastructure changes have affected the flow path to this location

95. A water system's emergency response plan is activated when a tornado strikes the utility's service area. The tornado damages power lines (causing systemwide power outage), topples trees onto several water mains (causing breaks), and severely damages the treatment plant roof (compromising the chemical storage area). The operator must triage these concurrent emergencies. In what order should they be addressed?

A. Treatment plant first (secure chemicals and restore treatment), then power restoration (to restart pumps and restore pressure), then main breaks (to stop water loss and prevent contamination) — treatment is first because without safe water production, restoring pressure delivers potentially unsafe water; power is second because it enables all pumps and controls; main breaks are third because they can be temporarily managed with isolation while higher priorities are addressed

B. Main breaks first because they cause immediate water loss and contamination risk

C. Power restoration first because nothing else can function without electricity

D. All three emergencies should be addressed simultaneously by dividing the available staff equally

96. A water system's operator is reviewing pump station energy data. Station A consumes 680 kWh per million gallons pumped. Station B, which pumps against a similar system head with similar equipment, consumes 850 kWh/MG. What is the most likely explanation for Station B's 25% higher energy consumption?

A. Station B's electric rate is 25% higher than Station A's rate

B. Station B's pumps have lost efficiency due to wear — deteriorated wear rings, eroded impellers, and increased internal recirculation cause the pumps to consume more energy per gallon delivered; pump efficiency testing would confirm the diagnosis and justify rehabilitation

C. Station B's flow meter is underregistering, making the kWh/MG calculation appear worse than actual

D. Station B naturally requires more energy because it serves a larger service area

97. A distribution system has experienced three consecutive positive total coliform results at the same monitoring location over three months. Each month, the repeat samples came back negative. Under the Revised Total Coliform Rule, what must the utility do?

- A. Issue a Tier 1 public notification because three consecutive positives constitute an acute violation
- B. Relocate the monitoring site to a location that consistently produces negative results
- C. Take no action because the repeat samples were negative each month
- D. Conduct a thorough investigation of the monitoring location and the surrounding distribution infrastructure — the persistent pattern of positives at the same site indicates a localized contamination source; the investigation should examine the sampling tap condition, nearby service connections, deadend main conditions, valve positions, and any infrastructure that could be introducing contamination at or near site #4

98. A water system serves a community where the primary source is a wellfield with four production wells. The wells produce water with varying mineral content. Well 1 has hardness of 200 mg/L, Well 2 has 150 mg/L, Well 3 has 300 mg/L, and Well 4 has 100 mg/L. The normal operating blend (all four wells running proportionally) produces water at approximately 190 mg/L hardness. If Well 4 (the softest water) goes offline for pump maintenance, how will the blended water chemistry change?

- A. The hardness will decrease because Well 4 was contributing minerals that the other wells lack
- B. The hardness will remain unchanged because the aquifer supplies the same mineral content to all wells
- C. The blended hardness will increase because Well 4's soft water is no longer diluting the harder water from the other three wells — customers may notice increased scale formation and changes in soap lathering
- D. Hardness is not affected by blending because each mineral is independent of the others

99. A water system's operator is developing a training plan for a newly hired distribution operator. The new hire has passed the certification exam but has no field experience. What training sequence is most appropriate for the new operator's first six months?

- A. Safety training (confined space, excavation safety, traffic control, LOTO, chemical handling) must come first because these topics protect the operator's life from day one; followed by system orientation (learning the physical infrastructure, valve locations, pipe materials); then operational procedures (meter

reading, sampling, flushing, valve exercising); then emergency response (main breaks, pump failures, contamination events) — safety before everything else

- B. Start with certification study materials to reinforce the exam knowledge
- C. Begin immediately with independent field work to build experience quickly
- D. Start with SCADA training because all modern water operations depend on technology

100. A water utility's distribution superintendent is retiring after 30 years of service. The superintendent has extensive knowledge of the system's history — locations of unmapped infrastructure, informal operating procedures, recurring problem areas, and key community relationships. This knowledge exists primarily in the superintendent's memory and is not documented in any system records. What should the utility do before the superintendent leaves?

- A. Let the new superintendent develop their own knowledge over time through independent experience
- B. Conduct structured knowledge transfer sessions — have the retiring superintendent document unmapped infrastructure in the GIS, record informal procedures as formal SOPs, identify recurring problem areas on system maps, brief the replacement on key community relationships, and conduct joint field tours of critical facilities and known problem locations; this institutional knowledge cannot be recreated and will be permanently lost if not captured
- C. Give the retiring superintendent a questionnaire to fill out during their last week
- D. Hire the superintendent back as a parttime consultant for questions after retirement

## Practice Exam 12: Answer Key and Explanations

1. C — A gradual, progressive production increase (3.2 to 3.7 MGD over 90 days) with no new connections and declining seasonal demand is the classic signature of a developing distribution system leak. The leak is slowly enlarging — likely from soil erosion around the opening — consuming an additional 0.5 MGD that the system must produce to maintain pressure and storage levels.

2. A —  $Q_{\text{available}} = 1,100 \times [(60-20)/(60-42)]^{0.54} = 1,100 \times (40/18)^{0.54} = 1,100 \times 2.222^{0.54} = 1,100 \times 1.459 =$  approximately 1,605 GPM at 20 psi residual. This standard AWWA fire flow projection formula accounts for the non-linear relationship between pressure drop and flow. The 0.54 exponent reflects that doubling flow does not double the pressure drop.

3. D — At 3.3 breaks per year, the annual reactive cost is approximately \$18,333 in direct repair costs alone. Adding indirect costs (overtime, paving restoration, water loss, customer disruption, contamination risk at each break) can double or triple this figure. The \$160,000 replacement cost, annualized over the 50+ year life of new DI pipe, is approximately \$3,200 per year — far less than continuing reactive repairs on a failing main.

4. B — The espresso machine's internal boiler operates at 15 psi and 200°F — conditions that can exceed the municipal supply pressure, creating backpressure potential. The near-boiling water with concentrated mineral deposits represents a health hazard if backflow occurs. An RPZ assembly or air gap is required for this combination of backpressure and health hazard.

5. A — A subaqueous river crossing presents extreme access challenges. Any leak or break requires specialized operations — cofferdams, diving operations, or long-duration bypass pumping — that may take days to mobilize. During mobilization, 100% of the supply through this main is lost. Additionally, the submerged environment accelerates corrosion of exposed metal components, particularly at mechanical joints.

6. D — Pure chlorine needed =  $5.5 \times 2.4 \times 8.34 = 110.1$  lbs/day. Since calcium hypochlorite is 65% available chlorine:  $110.1 \div 0.65 = 169.4$  lbs/day of product. Always calculate the pure chemical requirement first, then divide by the product strength (as a decimal) to determine the actual product quantity needed.

7. C — A single inlet/outlet on the same side of the reservoir creates a short-circuit flow path — fresh water enters, turns around, and exits through the nearby outlet without ever reaching the far portions of the tank. The 92% of the volume that never cycles becomes a stagnation zone where residual decays, biofilm grows, and taste/odor compounds develop.

8. B — A progressive vibration increase from 0.15 to 0.42 in/sec over three months — while identical pumps remain stable — indicates a mechanical problem developing specifically in Pump 3. Common causes include deteriorating bearings, shaft misalignment, impeller imbalance, or loosening foundation bolts. Without investigation and correction, the problem will progress to component failure.

9. A — The auto repair shop represents a new potential contamination source that must be documented in the wellhead protection inventory. The utility should verify the shop's compliance with environmental regulations, confirm proper chemical storage and waste disposal, and increase groundwater monitoring at the well. Proactive engagement protects the well before contamination occurs.

10. D — The single 8-inch PRV cannot deliver the 2,000 GPM fire flow demand at its 55 psi setpoint. The valve opens fully but its maximum capacity is insufficient, causing pressure to collapse to 12 psi. The station needs either a larger PRV, a parallel PRV for high-flow events, or an automatic fire flow bypass that opens during high-demand events.

11. B — A pH of 7.3 is at the low end of effective copper corrosion control. At this pH, the water is relatively aggressive toward copper, and the 0.8 mg/L orthophosphate dose may be insufficient to form an adequate protective film. Increasing pH to 7.8-8.0 and/or increasing the orthophosphate dose would reduce the water's aggressiveness and lower copper leaching.

12. C — To convert feet of head to psi, multiply by 0.433:  $5.8 \times 0.433 = 2.5$  psi. This relatively small pressure drop (2.5 psi over 2,000 feet) demonstrates the excellent hydraulic performance of cement mortar lined pipe with a C-factor of 140. An unlined, tuberculated main with  $C = 50$  at the same flow would produce approximately 5-6 times more head loss.

13. A — Wet wells connected to the distribution system can accumulate hydrogen sulfide from biological activity in stagnant water and organic sediment. The pumping-down process stirs sediment and can release trapped gases, rapidly changing atmospheric conditions. Unlike dry valve vaults or clean reservoirs, wet wells have an ongoing biological oxygen demand that makes atmospheric conditions inherently more volatile.

14. D — A low oil pressure warning on a running generator indicates that the engine's lubrication system is not maintaining adequate oil film on critical components. Without adequate lubrication, bearings, pistons, and other moving parts can be destroyed within minutes. The operator must immediately check oil level, look for leaks, and verify the gauge reading — the engine may need to be shut down if oil pressure cannot be restored.

15. B — Two effective options exist: (1) cleaning and cement mortar lining the existing mains restores C from 40 to approximately 140 at lower cost than replacement — if the pipe structure is sound; (2) full replacement with larger DI pipe addresses both the hydraulic deficiency and the aging infrastructure. Both dramatically increase fire flow capacity; the choice depends on the structural condition of the existing pipe.

16. C — The extra 4 turns during closure indicate debris (sediment, corrosion deposits, or mineral buildup) on the valve seat that prevented the gate from fully seating on the normal 28 turns. The additional turns compressed through or displaced the debris. The 28-turn reopening count confirms the

correct mechanical travel distance once the seat was clear. The valve should be noted for potential cleaning.

17. A — Switching coagulants can alter the finished water's pH, alkalinity, and residual mineral balance. If the new ferric chloride produces water with different chemistry than the previous alum-treated water, it can destabilize iron deposits that have accumulated on pipe surfaces throughout the system over decades. The widespread complaints confirm a system-wide chemistry change rather than a localized problem.

18. D — Despite the manual transfer switch design, the potential for human error — accidentally connecting both sources simultaneously — creates an unacceptable cross-connection risk. The backup well's untreated (or differently treated) water could contaminate the municipal supply through a single switching mistake. Physical separation with an air gap is the only way to eliminate this risk entirely.

19. B — Per-minute rate =  $1,350 \text{ mL} \div 3 \text{ minutes} = 450 \text{ mL/min}$ . Converting to GPM:  $450 \div 3,785 = 0.1189 \text{ GPM}$ . Converting to GPH:  $0.1189 \times 60 = 7.13 \text{ GPH}$ , approximately 7.1 gallons per hour. Chemical pump calibration is essential for accurate dosing — the operator must verify that the pump's actual output matches the intended feed rate.

20. C — A single set of negative repeat samples after an E. coli positive is typically not sufficient to lift a boil water advisory. Standard practice requires two consecutive sets of satisfactory samples collected at least 24 hours apart, plus confirmation of adequate system pressure and disinfection. This ensures the contamination event is truly resolved and not a transient condition that could recur.

21. B — A functioning restaurant with zero meter readings for 14 days means the meter has stopped registering flow. The most common causes are a seized measuring element, a failed register, or an electronic malfunction in the AMI meter. The restaurant is consuming water that is not being measured — the utility is losing revenue and the customer will eventually receive an adjusted bill.

22. D — Both VFDs at 100% speed represent maximum pump capacity. If pressure drops to 48 psi at maximum output, the fire flow demand exceeds the station's total capacity. The VFDs cannot increase speed beyond 100%, so the pressure falls below the setpoint. The system needs additional pumping capacity, larger pumps, or supplemental storage to support fire flow.

23. A — A cracked concrete pad with a direct path to the well casing creates a surface contamination pathway. Rainwater flowing along the crack carries bacteria, fertilizer, pesticides, and other

contaminants directly to the annular seal. The crack must be repaired immediately with a proper concrete patch or full pad replacement to restore the sanitary barrier around the well.

24. C — A zero chlorine residual at a location that normally reads 0.8 mg/L represents a complete loss of disinfection protection. The operator must act immediately — flush the nearest hydrant to determine if the condition is localized or widespread, check for closed valves or main breaks that may have rerouted flow, and verify treatment plant operation. Water without residual is vulnerable to microbial contamination.

25. B — Each well contributes different mineral content to the blend. With Well 2 offline, the remaining three-well blend produces water with different hardness than the normal four-well blend. Customers who have adjusted their soap usage and water heater settings for the normal blend notice the change. This demonstrates why blending ratio changes should be evaluated for customer impact.

26. A — The utility's SOP for emergency repairs of this size specifies spray application followed by flushing and residual verification. The operator followed the procedure correctly — the spray disinfected exposed surfaces, flushing removed debris and excess chlorine, and the 1.0 mg/L residual confirms fresh system water has reached the repair site. Not all repairs require the full 24-hour C651 protocol.

27. D — During overnight low-demand hours, the pump output exceeds demand, filling the tank to its high-level setpoint too quickly. The pump shuts off, the level drops slightly from minimal demand, the pump restarts, and the cycle repeats. Reducing overnight pump speed via VFD or lowering the high-level setpoint better matches production to the low overnight demand, eliminating the repetitive cycling.

28. C — While the copper level of 0.9 mg/L is below the 1.3 mg/L action level, it exceeds the taste threshold for many people — copper can produce a metallic or bitter taste at concentrations as low as 0.5-1.0 mg/L. The corrosion control program is working (levels are below the action level), but not aggressively enough to prevent taste issues at this customer's home.

29. B — The  $-0.85\text{V}$  (CSE) criterion is the industry-standard threshold for adequate cathodic protection of steel pipe. Readings more positive than  $-0.85\text{V}$  indicate insufficient cathodic protection — corrosion is likely occurring at these locations. The CP system must be adjusted (increased current, additional anodes, or rectifier output adjustment) to bring all points to at least  $-0.85\text{V}$ .

30. A — The CCR is a federally mandated public notification document that must be delivered to all customers by July 1 annually. Failure to distribute is a violation requiring corrective action — the utility

must redistribute to the 2,000 affected customers, notify the state regulatory agency, and document the corrective measures. The mailing contractor error does not excuse the utility from its regulatory obligation.

31. D — Lead at 0.032 mg/L — more than double the action level — at a school drinking fountain requires immediate action. The fountain must be taken out of service to eliminate children's exposure, an alternative water source must be provided, parents and administration must be notified, and a remediation plan must be developed. Children are particularly vulnerable to lead's neurological effects.

32. C — Wire-to-water efficiency =  $(Q \times TDH \times 8.34) \div (33,000 \times kW \times 1.341)$ ... Using the simpler form:  $E = (GPM \times TDH) \div (3,960 \times kW) = (900 \times 130) \div (3,960 \times 48) = 117,000 \div 190,080 = 61.6\%$ , approximately 61%. This is below the typical design efficiency of 75-85%, indicating wear that warrants investigation and likely pump rehabilitation.

33. B — PVC pipe is well-documented to be susceptible to permeation by petroleum hydrocarbons. Gasoline, diesel, and other petroleum compounds in contaminated soil dissolve into and diffuse through the PVC pipe wall at the molecular level, entering the drinking water inside. A confirmed underground storage tank leak 50 feet from a PVC main is the textbook scenario for permeation contamination.

34. A — Turnover time =  $400,000 \div 600 = 666.7$  minutes  $\div 60 = 11.1$  hours. The tank turns over approximately 2.2 times per day, which is acceptable for maintaining residual and limiting DBPs. However, actual turnover depends on mixing efficiency — short-circuiting flow can leave portions stagnant even at this theoretical rate. Baffles or mixers improve actual versus theoretical turnover.

35. D — Radon is a dissolved gas that readily transfers from water to air when agitated. The open atmospheric storage tank exposes the water to air, and the turbulence of water entering the tank promotes gas transfer. This incidental aeration strips a significant portion of the radon from the water before distribution, effectively reducing radon levels without a dedicated treatment system.

36. C — A flooded vault containing the PRV creates a backsiphonage pathway. If distribution system pressure drops below the level of the standing water (from a main break, high demand, or pump failure), contaminated water from the vault could be drawn into the main through the PRV's packing gland, bonnet seal, or any imperfect joint. The vault must be drained and the water source eliminated.

37. B — The C-factor ratio is  $140/50 = 2.8$ . Raised to the 1.85 power:  $2.8^{1.85} \approx 6.1$ . Main A's head loss is approximately 6 times Main B's head loss at the same flow rate. This dramatic difference

illustrates why old, tuberculated unlined cast iron mains create severe pressure and fire flow deficiencies — and why cleaning and lining can restore near-new hydraulic performance.

38. A — The customer's pump can pressurize the rainwater system above the municipal supply pressure, creating a backpressure condition that could force untreated rainwater into the municipal system through the home's plumbing. Roof-collected rainwater may contain bird droppings, pesticides, bacteria, and other contaminants. The two systems must be physically separated or protected with an air gap.

39. D — Emergency interconnection valves that sit closed for years are subject to the same corrosion and seizing that affects all unexercised valves. The three-year gap allowed this valve to seize, rendering the interconnection useless during the drought emergency. All emergency valves must be included in the regular exercising program to ensure they operate when the emergency demands it.

40. C — Pipe weight =  $36 \text{ lbs/ft} \times 300 \text{ ft} = 10,800 \text{ lbs}$ . Water:  $D = 16/12 = 1.333 \text{ ft}$ ;  $A = 0.785 \times 1.778 = 1.396 \text{ sq ft}$ ;  $V = 1.396 \times 300 = 418.8 \text{ cu ft}$ ; weight =  $418.8 \times 62.4 = 26,133 \text{ lbs}$ . Total =  $10,800 + 26,133 = 36,933 \text{ lbs}$ , approximately 37,000 lbs. The bridge must support this dead load plus dynamic loads from traffic and wind.

41. D — Monthly flushing temporarily replaces stagnant water with fresh supply, but the conditions that cause the problem (no through-flow, low demand, single feed) persist. The only permanent solution is connecting the dead end to another main, creating a loop that establishes continuous through-flow. Looping eliminates stagnation, improves residual, enhances pressure, and provides redundancy.

42. B — TTHM formation is a time-dependent reaction between chlorine and organic matter. The poorly cycling tank (12% daily turnover) holds water for extended periods, providing maximum contact time for the reaction. Water exiting this tank has the highest TTHM levels in the system because it has had the longest opportunity for the reaction to proceed.

43. A — A dental vacuum system is exposed to blood, saliva, amalgam particles, and chemical agents during dental procedures — all of which represent serious health hazards. This biological and chemical contamination creates a high-hazard cross-connection requiring an RPZ assembly. A DCVA or PVB would be inadequate for this level of hazard.

44. C — Gate valves are the most common isolation valve in water distribution systems. They provide a full-bore, unrestricted flow path when fully open (minimal friction loss), positive shutoff when fully closed, and are available in all standard distribution system sizes. Their primary disadvantage —

requiring many turns to operate — is acceptable for isolation service where they remain either fully open or fully closed.

45. D — A continuous 0.3 mg/L reading from the analyzer while a manual DPD test at the same location reads 0.9 mg/L indicates the analyzer has drifted low. For the past week, operational decisions — chemical feed adjustments, alarm responses, compliance evaluations — were based on falsely low data. The analyzer must be recalibrated immediately, and any decisions made based on the incorrect data must be reviewed.

46. B — Isolating the break was the critical first step. Now the operator must manage the consequences — the fire station needs to know about reduced fire flow capabilities, the nursing home (critical customer) may need emergency water delivery if the outage exceeds a few hours, and the 500 residential customers need notification. Activating the emergency response plan coordinates all of these actions simultaneously.

47. A — Generator cooling system maintenance is critical for sustained operation under load. Degraded coolant loses heat-transfer capability and corrosion protection. Blocked radiator passages restrict airflow. A failed thermostat or water pump prevents coolant circulation. Any of these conditions can cause the generator to overheat and shut down during an extended power outage — precisely when the utility needs it most.

48. C — All three systems represent potential cross-connections: the high-pressure wash with chemical injection is high-hazard with backpressure; the recycled water system contains road grime, chemicals, and contaminants making it high-hazard; and the vacuum system can draw contaminated water and debris back toward the supply through backsiphonage. Each requires individual assessment and appropriate protection.

49. D — Before selecting a cleaning method, the operator must know what is causing the specific capacity decline. Video inspection reveals the internal condition — mineral encrustation, biofouling, sand bridging, screen corrosion, or casing damage. The correct rehabilitation technique depends on the diagnosis: chemical treatment for minerals, brushing/jetting for biofilm, surging for sand bridging.

50. B — Fire hydrants are required per local fire code — typically every 500-600 feet in residential areas for adequate fire protection coverage. The 1,200-foot extension needs 2-3 hydrants. Beyond fire protection, hydrants also serve as flushing points for water quality maintenance and as access points for flow testing. The operator should recommend hydrants per the applicable code.

51. A — Operating well below BEP causes internal recirculation between the impeller and casing, vibration, bearing damage, and wasted energy. At 42% speed, the pump may be below its minimum continuous stable flow. The operator should consider shutting down the pump during low-demand overnight hours and relying on gravity flow from the elevated tank — using the tank's stored volume as the overnight supply.

52. C — Orthophosphate forms a thin protective mineral film (primarily metal phosphate compounds) on the interior surfaces of metal pipes and plumbing. This film prevents lead, copper, and iron from dissolving into the drinking water. The dose of 0.5-2.0 mg/L is well below any health concern, and phosphate is a naturally occurring mineral found in many everyday foods.

53. D — While ductile iron pipe walls are not susceptible to permeation (unlike PVC), the rubber gaskets at mechanical joints can be degraded by chlorinated solvents like TCE. Additionally, if internal water pressure drops below the external pressure of contaminated groundwater, the contaminated water can infiltrate through any gasket imperfection. The rubber gasket is the vulnerable point in ductile iron systems.

54. B — Annual revenue recovery = 10,000 meters × \$55/month × 12 months × 0.035 = \$231,000 per year. The \$75,000 investment produces a 3.1:1 return — for every dollar spent on meter testing, the utility recovers \$3.10 in previously lost revenue. This return continues annually as long as the improved meters remain in service.

55. A — System pressure is adequate (55 psi at the meter), all other fixtures work normally, and no neighbors are affected. The problem is isolated to one fixture in one home. The toilet fill valve's inlet screen or internal diaphragm is likely partially clogged with sediment or mineral deposits, restricting the small flow that refills the tank. This is a customer-side fixture problem.

56. C — The nitrate trend from 3.2 to 7.8 mg/L over a decade — now at 78% of the MCL — demands proactive action. Enhanced monitoring tracks the trend more closely. Working with agricultural agencies to implement best management practices (reduced fertilizer application rates, timing changes, buffer zones) can slow the increase. Treatment planning ensures capacity is ready if levels continue rising.

57. D — A 5 GPM seal leak on a standby pump is a significant failure that renders the pump unusable. The pump must be taken out of service for seal replacement. With only two remaining pumps (lead and lag), one must be designated as the temporary standby until the repair is complete. Operating without any standby pump increases the risk of service failure if either operating pump fails.

58. B — Non-revenue water = System input – Billed consumption =  $1,825 - (1,387 + 20) = 418$  MG/year. NRW percentage =  $418 \div 1,825 \times 100 = 22.9\%$ . This includes unbilled metered (5 MG), unbilled unmetered (40 MG), and the remaining 373 MG represents apparent losses plus real losses that require further breakdown through the water audit methodology.

59. A — Consistent testing locations create a multi-year trend database that reveals progressive changes in hydraulic performance. A hydrant showing declining fire flow year after year indicates worsening pipe conditions (tuberculation). A hydrant showing improved flow after main rehabilitation confirms the investment's effectiveness. Random testing provides snapshots but no trends.

60. C — A confirmed waterborne disease outbreak caused by a cross-connection failure triggers the most severe consequences: Tier 1 notification, state enforcement action, potential SDWA violations, civil liability for all affected customers' medical costs and damages, potential criminal liability if negligence is proven, mandatory program improvements, and severe loss of public trust that may take years to rebuild.

61. A — Total supply:  $6 \text{ cylinders} \times 150 \text{ lbs} = 900 \text{ lbs}$ . Days of supply:  $900 \div 85 = 10.6$  days. However, only the two connected cylinders (300 lbs, 3.5 days) are immediately available — the four reserve cylinders require manual connection. The operator should establish a reorder point that accounts for delivery lead time and maintains adequate safety stock.

62. C — The oscillation began immediately after the SCADA software update, strongly implicating the update as the cause. PID control parameters (proportional gain, integral time, derivative time) may have been reset to factory defaults or altered during the update. The excessive proportional gain causes the controller to overreact to each pressure change, creating the sustained oscillation. Restoring pre-update PID values should fix the problem.

63. B — Forcing deeper tank cycling on weekends replaces stagnant water with fresh supply. Lowering the high-level pump shutoff or raising the low-level pump start forces the tank to drain further before refilling, increasing the volume of water exchanged during each cycle. More turnover means less water age, higher residuals, and fewer DBP formation hours — directly improving Monday morning quality.

64. B — Compliance is based on the LRAA, not individual quarterly results. The LRAA of 0.074 is below the 0.080 MCL, so no violation has occurred. However, the 0.092 result is a serious warning — next quarter, the 0.068 drops out of the average and is replaced by the new result. If the new result is above 0.076, the LRAA will exceed 0.080 and trigger a violation. Immediate operational action is needed.

65. A — Cast iron and ductile iron pipes of the same nominal size have different outside diameters due to different manufacturing standards developed decades apart. CI pipe had thicker walls and larger OD. When connecting new DI to old CI, a transition coupling with different-sized gaskets or adjustable glands on each end accommodates the dimensional difference.

66. C — The operator must immediately isolate the damaged section by closing the nearest valves to stop the water loss. The contractor is responsible for repair costs, but the utility manages the operational response — isolation, repair coordination, disinfection, and return to service. The contractor should have called 811 before drilling and obtained a locate that would have identified the water main.

67. B — Elevated storage provides passive, gravity-fed pressure that works without electricity, pumps, motors, VFDs, or any mechanical equipment. During power outages, pump failures, or staffing shortages, the elevated tank continues delivering water under pressure through gravity alone. Ground-level storage requires active pumping — creating dependency on electrical and mechanical systems that can fail.

68. B — Generator starting batteries must be maintained on a continuous float/trickle charger that keeps them at full charge between monthly tests. The dead battery indicates either the charger failed, was disconnected, or was never installed. Battery voltage should be checked during every monthly test, and the charger's function should be verified. A dead battery during a power outage defeats the generator's purpose entirely.

69. A — Reusing 30-year-old pipe creates unacceptable risks: excavation and handling can crack the cement mortar lining and damage the exterior coating; mechanical joint gaskets that have been compressed for 30 years may not reseal after disassembly; the pipe's interior condition cannot be fully assessed; and the reinstalled pipe still has only 20-30 years of remaining life versus 50+ years for new pipe.

70. C — The elevated tank hitting its low-level alarm daily during peak demand — when it previously hit low level only during extreme events — means the 1,200 new connections have increased peak demand beyond the pump station's ability to keep up. The tank is providing more equalization than designed, and if growth continues, the tank will empty during peak demand.

71. D — New pipe interior contacts dirt, soil, groundwater, lubricants, insects, and hands during manufacturing, shipping, storage, and installation. These introduce bacteria and other contaminants. Disinfection (per AWWA C651) kills these organisms, and bacteriological testing confirms the main is microbiologically safe. This step protects public health before the first drop of water reaches a customer.

72. B — Cleaning and lining removes the interior tuberculation that has reduced the C-factor from 130 to approximately 50 over 50 years. The cement mortar lining provides a smooth interior surface with  $C \approx 140$ , dramatically reducing friction losses and restoring fire flow capacity. If the pipe structure is sound (no excessive wall loss), this is significantly less expensive than full replacement.

73. A — When two pumps operate in parallel, combined flow increases velocity in the shared discharge piping. Higher velocity increases friction losses approximately with the square of flow. This increased system head forces both pumps to operate at higher-head, lower-flow operating points on their curves. The deficit ( $1,500 - 1,320 = 180$  GPM) is consumed by the additional friction in common piping.

74. C — As the liquid chlorine level in the cylinder decreases, the gas pressure above the liquid drops proportionally. Lower gas pressure reduces the driving force through the chlorinator, decreasing the feed rate even though the chlorinator setting hasn't changed. The operator should check the cylinder weight (scale reading) and prepare to switch to a full cylinder when the current one is depleted.

75. D —  $\text{Power (kW)} = (\text{Flow in gal/min} \times \text{TDH} \times 8.34) \div (33,000 \times \text{pump eff} \times \text{motor eff}) \div 1.341$ . Simplified: approximately 199 kW. Daily energy =  $199 \times 24 = 4,776$  kWh. Daily cost =  $4,776 \times \$0.12 = \$573$ . This calculation demonstrates why pump efficiency matters — a 10% efficiency decline would increase this cost by approximately \$80 per day (\$29,000 per year).

76. B — A school with standard plumbing, cafeteria kitchen, and a fire sprinkler system without chemical additives represents a low-to-moderate hazard. A DCVA on the service line provides adequate protection for these connections. However, if the school adds science lab equipment with chemical connections or modifies the sprinkler system to include antifreeze or corrosion inhibitors, the hazard classification must be reevaluated.

77. A — A partially closed valve near a hospital restricts maximum flow capacity and reduces available fire flow. Under normal demand, the hospital may not notice the restriction. During a fire flow event requiring maximum flow, the partially closed valve becomes a critical bottleneck that could reduce pressure below the level needed for firefighting and hospital operations. The valve must be fully opened.

78. C — When frost penetrates below the pipe's depth of cover, the soil surrounding the pipe freezes. Frozen soil expands with tremendous force, applying external pressure to the pipe. Additionally, frost heave shifts the frozen soil mass, applying bending forces to rigid pipe. The 3-foot burial depth — below the 4-foot frost line — left these mains within the frost zone, exposing them to these forces.

79. D — The degraded solution (8.2% instead of 12.5%) still contains available chlorine — it's not useless, just weaker. The operator should increase the feed pump rate to compensate: if 10 gallons/day was needed at 12.5%, approximately 15.2 gallons/day is needed at 8.2% to deliver the same pounds of chlorine. Additionally, protecting the tank from heat and sunlight slows future degradation.

80. B — Chloramines are not removed by standard dialysis carbon filters — they require specialized catalytic carbon or vitamin C treatment. Home dialysis patients must be individually notified well in advance so they and their providers can upgrade their water treatment systems before chloraminated water reaches their homes. Inadequate notification could result in serious medical harm to dialysis patients.

81. C — Pressure drops at specific times (7:15, 12:00, 5:00, 6:30) that don't register at the pump station or tank indicate localized demand events. Large customers in the area — schools, businesses, or irrigation systems — operating on daily schedules create demand spikes that increase friction losses in the local mains. These losses are too small relative to the total system flow to register at distant SCADA points.

82. D — At 3/8-inch effective diameter, the galvanized steel service line has lost approximately 75% of its original internal area. No amount of flushing, chemical treatment, or pressure boosting can restore flow through hardened tuberculation in galvanized steel. The only solution is complete replacement with a new service line of adequate material and size.

83. A — Source water information empowers customers to understand where their water originates, what potential contamination sources exist near the source, and why specific treatment processes are used. This transparency supports the utility's relationship with the community and allows customers to make informed decisions about their water quality and any additional treatment they may want.

84. B — If the water main's internal pressure drops below the external pressure of surcharging sewage, contaminated water can be forced into the drinking water through push-on joint gaskets. The 2-foot separation provides minimal buffer. This is one of the most serious cross-contamination risks in distribution systems and is a primary reason for minimum separation distance requirements between water and sewer mains.

85. D — Both loss categories contributed to the 8% increase in NRW (5% real + 3% apparent). Addressing only one category leaves the other untreated. A leak detection program targets the larger real losses while a meter program targets the apparent losses. Implementing both simultaneously provides the greatest total NRW reduction and the fastest return to the previous 20% level.

86. C — Pump 2's check valve disc or spring has worn, causing the disc to close slowly after the pump stops. When flow reverses, the disc accelerates toward the seat and slams shut against the full velocity of the reverse flow, creating a water hammer pressure wave (the "bang"). Pump 1's check valve closes before significant reverse flow develops, preventing the slam. Replacing or repairing Pump 2's check valve resolves the problem.

87. A — The torn polyethylene section shows moderate pitting where the encasement failed, while the encasement-protected areas remain intact. This demonstrates that both protection systems are needed in severely corrosive soil: the polyethylene provides the primary passive barrier, and the cathodic protection provides secondary active defense at any points where the encasement is compromised.

88. B — An oxygen reading of 19.4% is below the OSHA minimum of 19.5% for safe confined space entry. The entrant must exit immediately. The cause of the oxygen decline — likely biological oxygen demand from residual organic matter or chemical consumption by the concrete — must be identified and addressed through increased ventilation before anyone re-enters.

89. D — The campus contains multiple high-hazard cross-connections — radioactive materials, veterinary pharmaceuticals, and laboratory chemicals. The protection level at the main interconnection must match the highest hazard present on the campus. An RPZ assembly is the minimum mechanical protection; an air gap provides absolute protection. The presence of radioactive materials may mandate an air gap.

90. C — Head loss ratio =  $(C_{\text{new}}/C_{\text{old}})^{1.85} = (140/50)^{1.85} = 2.8^{1.85} \approx 6.1$ . New head loss =  $25 \div 6.1 \approx 4.1$  feet. Cleaning and lining reduces friction loss by approximately 80-85%, transforming a main that produces 25 feet of loss into one producing only 4-5 feet. This dramatic improvement explains why rehabilitation can resolve long-standing pressure and fire flow problems.

91. A — Emergency response training builds the skills that cannot be developed during an actual crisis — rapid decision-making, proper safety procedures, team coordination, and correct operational sequences. The actions taken in the first minutes of an emergency determine whether the event is contained or escalates into a catastrophe. Training ensures operators respond correctly under the extreme stress of real emergencies.

92. B — The location and operability of the nearest isolation valves is the single most critical piece of information during a main break. Without knowing which valves to close, the operator cannot stop the water loss. Every minute of delay means more water wasted, more pressure lost, more property

damaged, and more contamination risk. Valve location knowledge drives the speed and effectiveness of every break response.

93. D — The operator's field experience provides essential input that engineers need: separate inlet/outlet (prevent short-circuiting), baffles/mixing (maintain water quality), adequate access (for maintenance), proper venting (screened and protected), overflow design (screened, directed discharge), SCADA instrumentation (level, temperature), cathodic protection (for steel), appropriate coating (for local water chemistry), and vehicle access (for maintenance equipment).

94. C — A six-month progressive residual decline with no treatment changes demands systematic investigation. A partially closed valve rerouting flow would increase water age. Growing biofilm would increase chlorine demand. A new leak would draw water away from the monitoring point's flow path. The operator must check all possibilities because the progressive nature indicates an ongoing change in system conditions.

95. A — Treatment plant first: securing chemicals and restoring treatment capability ensures that when water production resumes, the water is safe. Power restoration second: enables pumps and controls system-wide. Main breaks third: can be temporarily managed with valve isolation while higher priorities are addressed. Without safe treatment, restoring pressure distributes potentially unsafe water.

96. B — Station B's 25% higher energy consumption at similar system head with similar equipment indicates declining pump efficiency. Worn wear rings, eroded impellers, and increased internal clearances force the pumps to consume more energy to deliver the same net output. Pump efficiency testing would confirm the diagnosis, and rehabilitation (wear ring and impeller replacement) would reduce energy consumption.

97. D — Three consecutive monthly positives at the same site — even with negative repeats — indicates a persistent localized contamination source that is not being resolved by the distribution system's normal flow and disinfection. The investigation should examine the sampling tap, nearby infrastructure (dead ends, valve positions, service connections), and any potential contamination sources at or near the monitoring site.

98. C — Well 4 contributes the softest water (100 mg/L) to the blend. With Well 4 offline, only the three harder wells contribute — the blended hardness increases from approximately 190 to approximately 217 mg/L (weighted average of remaining wells). Customers may notice increased scale on fixtures, changes in soap lathering, and more mineral deposits in appliances.

99. A — Safety training must come before all other training because it protects the new operator's life from day one. Confined space atmospheres, trench cave-ins, traffic hazards, electrical energy, and chemical exposure can be lethal for untrained workers. Technical skills develop over time, but a single safety mistake on the first day in the field can be fatal.

100. B — Thirty years of institutional knowledge — unmapped infrastructure, informal procedures, recurring problems, community relationships — exists only in the superintendent's memory. Structured knowledge transfer sessions, GIS updates, SOP documentation, system tours, and briefings with the replacement capture this irreplaceable information before it is permanently lost. A questionnaire on the last day captures a fraction; consultant arrangements provide access but not comprehensive transfer.