PROFESSIONAL ENGINEERING CONTINUING EDUCATION

Wastewater Infrastructure in Coastal Florida

Inflow & Infiltration, High Groundwater, Sea-Level Rise & System Resilience

Self-Paced Course Study Guide

COURSE	CREDIT / CATEGORY
ENG-018	4 PDH / Area of Practice · Civil / Environmental

INSTRUCTOR Gerald Ward, P.E.

Superior Learning, LLC d/b/a BuilderCE

Course overview

Coastal wastewater collection systems operate across interacting hydraulic and service boundaries. Rainfall, shallow groundwater, tidal stage, sewer surcharge, pumping performance and access constraints can produce similar symptoms but require different investigations. This study guide connects measurable evidence to defensible rehabilitation and resilience decisions.

Learning objectives

- Distinguish sanitary base flow, groundwater infiltration, rapid inflow and rainfall-induced infiltration using monitored evidence.
- Explain how groundwater, tide, rainfall and station operation interact without assuming a fixed one-to-one relationship.
- Design an investigation integrating flow meters, rainfall, wells, tide, telemetry and targeted inspection.
- Compare source removal, rehabilitation, conveyance and lift-station measures against service objectives.
- Prioritize a resilience program with documented uncertainty, decision triggers and post-project verification.

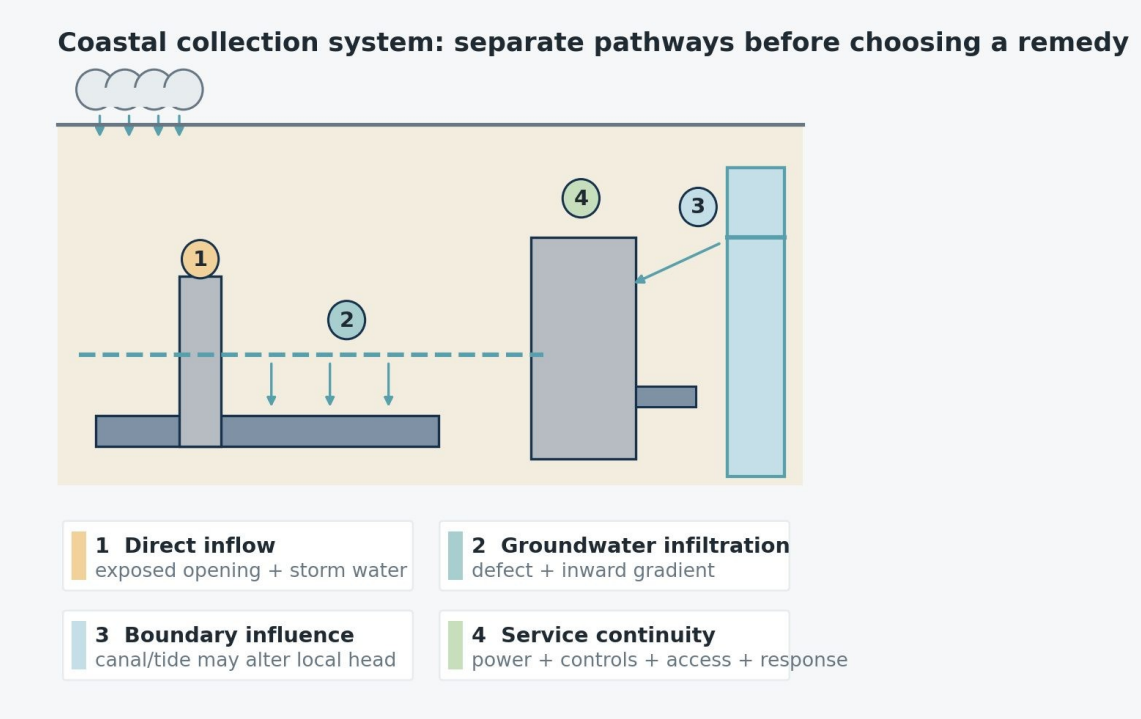
Study plan and navigation

MODULE	TIME	PRACTICAL FOCUS
1	35 minutes	Coastal boundaries and failure pathways
2	55 minutes	Flow decomposition and investigation design
3	40 minutes	High groundwater and tidal exposure
4	50 minutes	Rehabilitation, hydraulics and service continuity
5	30 minutes	Capital prioritization and verification
6	30 minutes	Integrated fictional utility case

Coastal boundaries and failure pathways

A collection system is an interconnected water boundary

A sanitary collection system has a designed path from building plumbing and laterals through gravity mains, manholes, lift stations, and force mains to treatment. Unwanted water can enter where the system is open to a source and the hydraulic gradient favors entry. Roof and yard drains, storm connections, uncapped cleanouts, and submerged manhole openings can deliver surface water rapidly. Cracks, joints, service-connection defects, and structural openings can admit groundwater or delayed stormwater. A high groundwater table makes some leakage persistent even after rain ends. EPA's CMOM guide separates measured flow into sanitary base flow, infiltration, and inflow; its terminology and examples support this diagnostic distinction. [1]



Instructional diagram 1. Coastal collection system and distinct flow entry paths.

The operator sees a combined hydrograph, not a labeled source. A peak occurring within hours of rainfall suggests rapid drainage connections or direct entry, but timing alone does not prove a particular defect. A multi-day recession may include drainage through soil and groundwater storage, wet weather infiltration, or operational effects. A persistent dry-season elevation in minimum night flow can suggest groundwater infiltration, a changed sanitary base load, a meter problem, or pump-control effects. The engineer starts with hypotheses, then asks what evidence would falsify each one.

Consider two similarly sized sewer basins. Basin A spikes sharply with storms and returns near its prior baseline by the next day. Basin B rises less abruptly but remains elevated for several days. Treating both as identical "I/I" projects obscures the choice of field methods. A smoke test or storm-connection survey may be useful in A; groundwater observations, manhole and pipe inspection, and longer flow monitoring may be more informative in B. Both may contain multiple pathways. The aim is to find controllable sources, not to force all additional flow into one label.

BuilderCE · ENG-018 · Professional Engineering Continuing Education

Sea level and groundwater are related locally, not universally

Relative sea level changes coastal boundary conditions, but the magnitude and timing of groundwater response depend on aquifer properties, distance from coast and canals, drainage controls, rainfall, pumping, and local topography. A USGS Broward County modeling study found particularly strong simulated groundwater response in eastern coastal areas and smaller sea-level response farther west under the analyzed scenarios. It is evidence for location-specific analysis, not a statewide conversion factor. [3] NOAA's scenario tools provide regional and local sea-level context; they do not replace site elevations and monitored groundwater levels. [4]

The engineer therefore avoids statements such as "a one-foot sea-level increase means every sewer sees one foot more groundwater." A sewer invert can remain above the water table while a nearby deeper lift-station structure has sustained exposure. A tidal canal can create a short-term hydraulic influence while the basin's annual groundwater pattern is driven mainly by rainfall. Survey datum and sensor datum must be consistent before comparing a tide gauge, well, manhole rim, and pipe invert. A plausible-looking graph built from inconsistent vertical datums can reverse the apparent direction of a gradient.

> Field exercise 1: List the datum, horizontal location, sampling interval, and known uncertainty for each of the following before plotting them on a common elevation graph: a NOAA tide-gauge record, a county groundwater well, a manhole invert surveyed five years ago, and a lift-station wet-well level. Which pairwise comparisons would you withhold until metadata are reconciled? Explain why.

Consequence is broader than capacity

Excess water consumes pipe and pump capacity and can increase treatment loading. It can also signal a route through which poor-quality groundwater or saline water enters parts of a system, with possible material, treatment-process, and maintenance consequences that require local confirmation. Independently, flooding can damage electrical controls, interrupt access, and remove power. A collection-system assessment therefore needs both a flow diagnosis and an asset-continuity diagnosis. EPA's flood guide and power-resilience guidance frame utility flood risk as an asset and service problem, not just a peak-flow problem. [5,6]

Hydraulic grade and the difference between entry and surcharge

An opening is a possible entry point only when the surrounding water level and sewer internal level create the appropriate gradient. When the internal hydraulic grade rises above the opening, the same defect may leak outward or remain hydraulically inactive for some portion of an event. A manhole with a submerged cover can receive surface water even if the adjacent pipe remains structurally sound. A cracked pipe below the groundwater table may admit water during low sewer levels but cease admitting it during surcharge. The sign and magnitude of exchange can change in time. This is why a condition image, a groundwater reading, and a flow trace need to be interpreted together rather than independently.

For screening, an engineer can sketch the sewer invert and crown, manhole rim, observed wet-weather surface elevation, estimated hydraulic grade, and groundwater level at the same time and datum. Mark uncertain values as ranges. If the groundwater well is 600 feet from a pipe in heterogeneous fill, its reading may not equal the head immediately outside the defect. If the sewer level is inferred from a downstream wet-well sensor, losses and upstream storage may make that inference weak. The sketch still forces the question: what hydraulic pathway could produce the observed flow, and what measurement would discriminate it?

Coastal boundary conditions can coincide. Rain may raise the shallow water table while tide raises a canal, and the station may lose power as inflow rises. Combining the largest recorded rain, tide, groundwater level, and outage as though they occurred in one historical event can mislead unless the

purpose is explicit. A deliberate stress test may use that combination, but it should be labeled as such. Operational calibration should instead use conditions actually observed during the monitored event.

Asset inventory as a hydraulic model of responsibility

An asset inventory should connect each branch to contributing land use, lateral ownership, access constraints, known manhole rim elevations, pump-station service area, force-main discharge point, and critical customers. Tributary-boundary errors can make a subbasin appear to produce too much sanitary flow. Unmapped interconnections, emergency bypasses, and operating changes can also make a correctly calibrated meter seem wrong. Record confidence in each field; an uncertain service area belongs in the investigation, not buried in a model appendix.

Take a low street adjacent to a tidal canal. Its sanitary line runs under a roadway with three manholes, and a deeper private lateral connects at the end. The road floods only during a compound rain and high-tide condition. A shallow pipe defect above typical groundwater could become important only during that event; the deeper lateral could admit groundwater for weeks; the manhole covers might be direct storm entry for an hour. A single intervention will not necessarily address all three. The engineer should first connect the time scales of measured flow to these plausible pathways.

> Module 1 decision exercise: For that street, propose one observation during rain, one during a high-water-table dry period, and one during station operation that would separate the three pathways. State a safety or access limitation for each observation. The exercise has no single required field method; the quality of the answer depends on whether each observation can change a decision.

Engineering deep dive: test the external-to-internal head difference

A pipe defect is a hydraulic opening, not automatically an infiltration source. At a given elevation, the sign of the pressure difference depends on the external groundwater head and the internal sewer hydraulic grade. For a simplified screening relationship, the available inward head is the external head minus the sewer's internal hydraulic grade at the defect. A positive difference supports an inward gradient, a negative difference supports an outward gradient, and a value close to zero signals limited head difference. None of these alone predicts a leakage rate: the size and continuity of the defect, surrounding soil and bedding, groundwater connectivity, and surcharging duration also matter.

Consider a fictional gravity sewer with an external water level at elevation +4.1 feet NAVD88. During dry-weather operation the internal water surface at a defect is +2.6 feet; a +1.5-foot inward head difference is plausible. During a storm the sewer surcharges and the internal level rises to +4.7 feet, changing the screening difference to -0.6 feet. It is therefore incorrect to carry the dry-weather infiltration rate unchanged through the whole event. A nearby observation well can only represent the defect's external head if its screen interval and local hydraulic connectivity are defensible.

A practical engineer's sketch should identify defect elevation, pipe crown and invert, local groundwater monitoring point, internal sewer level, datum, observation times, and which values are measured versus inferred. Link the sketch to a confidence register. The point of the calculation is to decide what to observe next; it is not an authorization to discharge wastewater to the environment or a substitute for engineering design.

State	External head (ft NAVD88)	Internal hydraulic grade (ft NAVD88)	Difference (ft)	Permitted inference
Example dry weather	+4.1	+2.6	+1.5	Inward gradient plausible
Example surcharge	+4.1	+4.7	-0.6	Inward gradient no longer supported

Hydraulic consequence: surcharge, storage, and interaction with the surface

A rainfall-related flow peak does not have to originate at the flooded location. Upstream inflow increases conveyance demand, while a downstream force-main restriction or reduced lift-station discharge may raise hydraulic grades across a separate portion of the basin. Two streets with similar rim elevations may overflow

differently because their hydraulic connections and available storage differ. An engineer should separate the origin of additional water from the location of the resulting service failure.

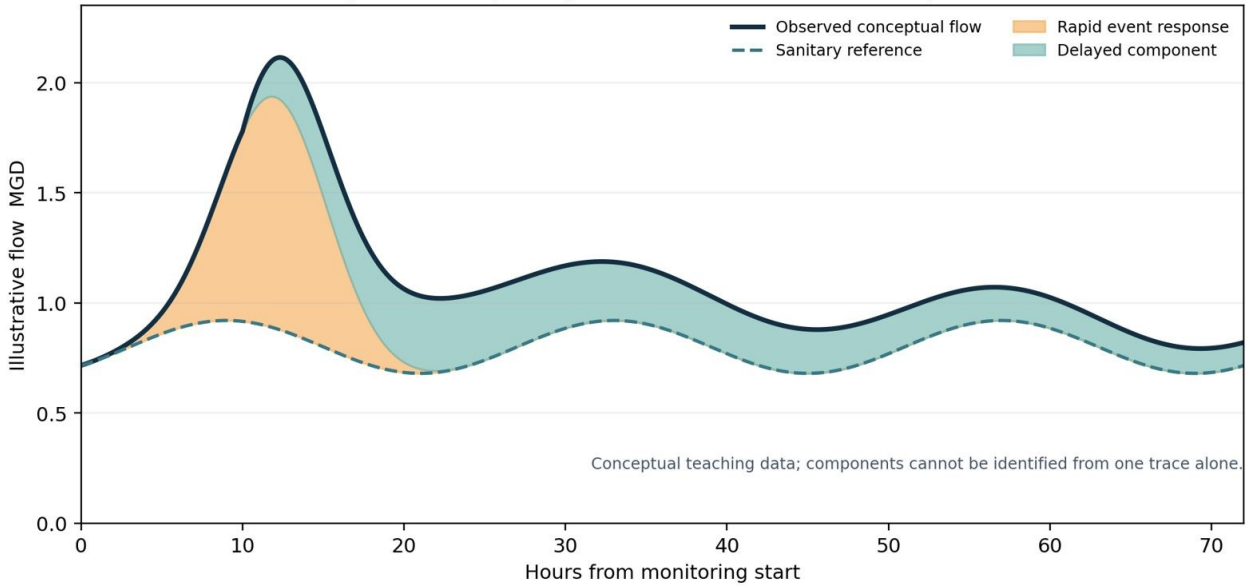
For a first network screen, inventory gravity reaches and known bottlenecks, pump operating states, upstream contributing area, lateral and manhole exposures, and overflow or service-call locations. Compare internal level traces at available monitoring points. A reach with high recorded depth but low added tributary flow may reflect downstream backwater; a station experiencing high flow without upstream surcharge may have residual hydraulic capacity. Those interpretations are hypotheses to validate with hydraulics, field observations, and telemetry.

During a compound event, document both a system service endpoint and the mechanism being investigated. Examples of endpoints are time above a facility-specific high-level alarm, number and duration of customer backups, minimum reserve time during a power interruption, and exposure of essential controls. An engineering finding should specify whether a proposed action removes an entry source, removes a hydraulic restriction, protects equipment, or improves emergency response. Conflating these functions leads to untestable scopes of work.

MODULE 2 | 55 MINUTES

Flow decomposition and investigation design

Figure 1 Interpreting a monitored wet weather response



Instructional diagram 2. Observed hydrograph versus rapid and delayed conceptual components.

Figure 1. Conceptual hydrograph. Use the shape to form testable hypotheses, not to assign a source from one trace.

Start with a data quality plan

Define the decision first: locate abnormal contributions, determine whether an existing station can maintain service for a selected event, or compare rehabilitation alternatives. Then define monitoring boundaries. Confirm upstream tributary area, bypasses, industrial contributors, station discharge relationships, meter maintenance, clock synchronization, and data gaps. Rainfall at a distant airport may miss a localized convective storm. A meter hydrograph should be checked against pump runtimes and wet-well levels where possible. An apparent “surge” can be a timestamp offset or a meter submerged outside its reliable measurement range.

A defensible program pairs flow and rainfall monitoring through representative dry and wet conditions and, where coastal influence is material, records relevant groundwater levels and tidal or canal stages. Temporary meters should be placed to distinguish subbasins rather than merely confirm that the plant receives wet-weather flow. Permanent station telemetry and treatment-plant influent are valuable context, but neither automatically isolates the contributing reach. EPA's CMOM guide emphasizes monitoring dry and wet weather flow, mapping, maintenance records, and targeted sewer system evaluation. EPA's SSOAP toolbox can help quantify rainfall-derived I/I and support capacity and pre/post rehabilitation analysis when the data and model assumptions are adequate. [1,2]

Read a hydrograph without overclaiming

For an initial screening, let Qobserved(t) = Qsanitary(t) + Qgroundwater(t) + Qwet-weather(t) + measurement/operating error. This is a conceptual decomposition, not a unique algebraic solution from one trace. Establish a dry-weather reference using comparable weekdays, seasons, and demand conditions. Inspect minimum-night patterns, daily cycles, antecedent rain, and station operation. During a storm, compare the event response with the expected sanitary pattern. The immediate excess, delayed tail, and new baseline are useful descriptive quantities, but physical attribution requires field evidence.

Fictional basin observation	Dry representative day	Rain-event day	Two days later
Daily volume through basin meter	0.80 MGD equivalent	2.20 MGD equivalent	1.25 MGD equivalent
Minimum hourly flow	0.28 MGD	0.55 MGD	0.47 MGD
Rainfall in prior 24 hours	0.0 in	2.8 in	0.0 in
Nearby groundwater elevation	1.1 ft local datum	1.6 ft	1.7 ft

These deliberately simplified observations show a storm-associated volume increase of 1.40 million gallons relative to a representative 0.80-MGD day and a 0.45-MGD-equivalent excess two days later. They do not establish that the full differences are removable I/I or that the groundwater change caused the later flow. Real analysis would use the actual interval data, multiple events, comparable sanitary demand, meter uncertainty, and accounting for upstream storage or pump operation. "MGD equivalent" is the 24-hour volume expressed as a daily rate; it is not a peak capacity requirement.

> Field exercise 2: The wet-weather day has a 2.20-million-gallon volume. If a candidate downstream station can convey 1.8 MGD continuously under the operating conditions used for screening, what is the nominal 24-hour volume deficit? The arithmetic is 0.40 million gallons, but it does not establish overflow volume: the actual station curve, upstream storage, inflow timing, parallel routes, and availability matter. Write two measurements needed before turning that screening difference into an engineering decision.

Match evidence to suspected pathway

Subbasin meters can narrow the search area. Nighttime inspections may reveal visible infiltration, while CCTV can document structural and service-connection defects. Manhole inspection can identify lid, frame, wall, bench, or pipe-seal entry. Smoke and dye testing can reveal some surface connections when conducted appropriately, and targeted private-lateral investigation may be needed where ownership and access permit. A CCTV defect score alone does not prove that a crack carries a measured volume. Inspection should be coordinated with groundwater level and weather so a dry-weather negative inspection does not falsely clear an intermittent defect. [1]

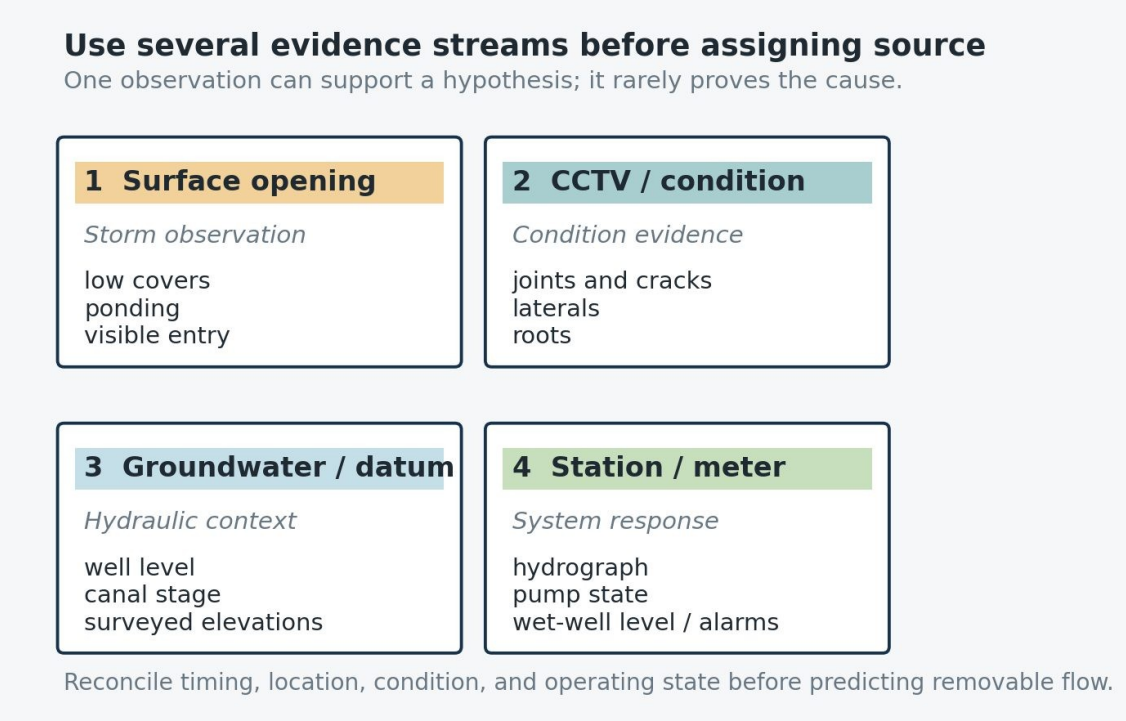
An effective investigation progresses from broad measurement to focused inspection, then validates the hydraulic benefit. A proposed lining program that covers every pipe in a district might leave the principal

manhole openings and laterals untouched. Conversely, replacing an entire trunk without proving it is the source may spend heavily on an asset that simply conveys flow originating upstream. The engineer should keep a hypothesis log that records predicted observations, actual findings, alternative explanations, and confidence.

Hypothesis	Evidence that would strengthen it	Evidence that would weaken it
Direct surface inflow at manholes or connections	Rapid storm response; observed submerged openings; dye or connection evidence	No storm response across several monitored events, with reliable meters
Groundwater infiltration at buried defects	Elevated dry-weather night flow with high water table; defects observed under wet conditions	Stable low flows despite sustained groundwater above the relevant defect elevations
Downstream station restriction	Rising upstream levels during peak despite available inflow; pump curve or telemetry discrepancy	Adequate measured discharge and an independently confirmed upstream bottleneck

Absence of a single observation is rarely definitive. For example, a low dry-weather flow during one season does not disprove seasonal groundwater infiltration. The table is a planning tool, not a diagnostic rule.

A monitoring design that can answer a capital question



Instructional diagram 3. Evidence streams: observation, inspection, hydraulic conditions and station performance.

Suppose a utility is considering rehabilitation of a 12-mile basin but can only afford detailed inspection of three miles this year. The monitoring plan should produce a ranked set of reaches, not merely a basinwide wet-weather peak. Place meters to bracket trunk segments and major laterals where practical, with enough hydraulic separation to resolve a difference larger than combined measurement uncertainty. Log rainfall near the service area and record station runtime, wet-well level, pump status, and any bypass. Make the clock and time zone explicit. Document the data review procedure for sensor drift, sediment, submergence, and telemetry gaps before calculating response ratios.

The difference between two metered locations is not automatically the flow entering between them. It can include unmetered sanitary service, temporary storage, timing shifts between hydrographs, and metering error. Align and route time series where needed. At a junction, a mass-balance screen can be informative if all major branches are measured and uncertainty is carried through. It becomes more reliable when repeated across events rather than inferred from a single maximum point.

At the first event-review meeting, plot rainfall hyetograph and sewer hydrographs on a common time axis. Mark event start, peak, recession and potential pump-state changes. Report the volume above a selected dry-weather reference and the basis for that reference. Also report a sensitivity range: for example, how the excess changes if the reference dry-weather day is chosen from a different representative weekday. This shows whether the proposed source-removal project depends on a fragile baseline assumption.

Derived metrics and their limits

A wet-weather peaking factor, Qpeak/Qdry-reference, is useful for comparison only if numerator and denominator refer to comparable points and time bases. Dividing a five-minute peak by a 24-hour average may be intentional, but it must be labeled; comparing it with a factor computed from hourly peaks is misleading. The volumetric response Vexcess = sum over intervals of max(0, Qobserved − Qreference) times interval duration is a screening metric. In a surcharged network it may omit unmeasured overflow or storage and may overstate externally sourced water if the reference sanitary pattern differs. Engineers should use it to direct inquiry, not to claim a recoverable volume without confirmation.

An event relationship across several storms can reveal whether response is stable or changes with antecedent conditions. If similar rainfall totals yield different flow, inspect intensity, spatial distribution, antecedent groundwater, tide, and station controls. A persistent high minimum-night flow as groundwater rises can suggest an infiltration pathway, but water use, industrial operations, and a meter offset remain alternatives. A model calibrated to one storm can fit a hydrograph with the wrong physical explanation. EPA’s SSOAP tools can organize RDII analysis, while engineering judgment is still required to choose basins, events, and meaningful post-rehabilitation comparisons. [1,2]

> Worked calculation: The fictional North Basin records 0.80 million gallons on a representative dry day. A monitored storm day totals 2.20 million gallons. The screening excess is 1.40 million gallons. If a proposed intervention is expected to reduce 30 percent of that screening excess for similar events, the illustrative reduction is 0.42 million gallons and the hypothetical resulting day is 1.78 million gallons. These values do not prove the intervention can achieve 30 percent, do not predict a peak, and do not measure an annual benefit. To estimate annual savings, one would need an event distribution, seasonal conditions, sanitary-load trends, plant energy/cost assumptions, and a verified intervention response.

Inspection methods answer different questions

Manhole inspection can document cover seating, inflow evidence, wall and pipe-penetration defects, structural condition, and maintenance access. CCTV can locate visible cracks, displaced joints, roots, deposits, and lateral connections along an inspected pipe. It may miss active leakage when the water table is below the defect or when visibility is poor. Smoke testing can identify some storm connections and openings, but a failure to observe smoke in a wet or submerged defect is not proof of no infiltration. Dye testing can test a suspected pathway with appropriate utility permissions. A targeted excavation or pressure test may be needed for a design decision where noninvasive observations are inconclusive. Select a method because it can distinguish hypotheses at an identified location, not because it is customary for every I/I project. [1,11]

Private laterals can dominate a local question but also change the governance of the remedy. The engineer needs to know whether the utility can inspect or repair them, what owner coordination is

required, and how suspected connections will be documented. A capital plan that assigns a large benefit to a private-lateral program with no access strategy is incomplete. Record the difference between technically identified work and work the utility is authorized to perform.

Uncertainty log

Use a compact log: data element, current estimate or observation, confidence, consequence if wrong, and next action. Examples include a missing gauge datum, an uncalibrated meter during surcharge, an assumed private-lateral boundary, and an unverified station pump curve. Order the next work by whether closing the uncertainty can change the recommended project. A perfect inventory is not necessary to make a defensible early repair; a multimillion-dollar capacity commitment normally demands more evidence.

> Module 2 field task: Prepare a one-page monitoring scope for a contractor or utility team. Define the decision it must support, the minimum synchronized measurements, event coverage, QA checks, deliverable plots, and criteria for an inconclusive result. Include a provision for documenting which data are not usable and why.

Data discipline: measurement uncertainty before a claimed flow source

Flow-meter subtraction is appealing but fragile. Suppose a calibrated-upstream screen reads 0.92 MGD and the downstream screen reads 1.08 MGD during a comparable interval. The arithmetic difference is 0.16 MGD. If independent one-standard-uncertainty estimates are 0.06 and 0.08 MGD, their root-sum-square combination is 0.10 MGD. This illustrative ratio is only 1.6, before accounting for unmetered branches, time lag, local storage, or correlated installation errors. The difference is a reason to investigate, not enough by itself to declare precisely 0.16 MGD of infiltration.

Use matched clocks and matching averaging windows. A station's daily pumped volume, a gravity meter's instantaneous flow and a treatment plant's plant-day total cannot be subtracted without reconciling their time bases and boundaries. For an event study, preserve the raw time series, flag data changed after sensor service, and record the interval used to compute each summary. Where meters can be affected by surcharge, partial depth, sediment or air entrainment, state those limitations explicitly.

A useful quality plan assigns each sensor a location, serial or station ID, measuring principle, inspection method, observed calibration or field-check result, vertical datum if relevant, collection clock, maintenance dates and data owner. An estimated uncertainty band is not a pass/fail tolerance; it keeps the proposed design change honest about what the evidence can resolve. Collect more events or reconfigure monitoring where uncertainty is greater than the improvement the utility intends to demonstrate.

Quantity	Illustrative estimate	Data-quality implication
Upstream flow	0.92 +/- 0.06 MGD	Check sensor range and time alignment
Downstream flow	1.08 +/- 0.08 MGD	Check operation, section and rating
Difference	0.16 MGD	Not uniquely infiltration
Combined independent uncertainty	sqrt(0.06^2 + 0.08^2) = 0.10 MGD	Also check systematic errors and storage

Hydrograph decomposition: daily totals, temporal fingerprints, and counterexamples

An event-day total minus a selected dry-day total is a screening measure of excess volume, not a removable-infiltration quantity. A dry reference should account for weekday and weekend demand, seasonal occupancy, industrial operations, permitted discharges and pump cycles. Its construction should be documented, preferably from multiple dry days under comparable operations. Similarly, an intense rain burst followed by a fast rise suggests a rapid pathway, but a slow recession could also reflect in-system storage or station controls rather than groundwater recharge alone.

A pragmatic event library retains at least the hyetograph, event start and end, antecedent dry period, groundwater level, tide reference, station pump status, any bypass, and data flags. When available, compare storms with similar cumulative rainfall but different 15-minute intensity, or with comparable rainfall and contrasting antecedent groundwater. The purpose is to search for discriminating conditions. If only the peak

differs, the engineer cannot automatically infer which source was repaired or which intervention will perform better.

A basin with no immediate flow response in one short storm may still have a delayed response during prolonged saturation. An inspection that fails to see active entry during a dry-weather CCTV visit cannot rule out a defect that opens hydraulically at high groundwater. Conversely, a striking CCTV crack does not prove it carries the majority of event water. Record whether a fact supports a source location, a possible pathway, or a quantified contribution; those are three different levels of evidence.

Investigating a possible private-lateral contribution

The jurisdictional and ownership boundary between public gravity mains and private building laterals should be written into the investigation scope. A utility may have excellent public-main lining records yet retain a large wet-weather response through roof drains, yard connections, defective lateral joints or submerged cleanouts. Private property access and local sewer ordinances determine what can be observed and corrected; a presumed source does not justify entry or disconnection without the appropriate authority and safety procedures.

Develop a tiered strategy: compare upstream and downstream flow at accessible public points; review smoke or dye testing applicability with trained personnel and property owners; inspect candidate connections under appropriate conditions; and verify each confirmed connection against the as-built sanitary and stormwater layouts. Maintain a finding classification of confirmed direct entry, suspected pathway requiring verification, condition defect without quantified entry, or no reliable evidence. That vocabulary avoids promoting a screening observation into an engineering fact.

For performance acceptance, document what was corrected, the observed before-and-after condition, any pipe or service testing, and the event comparisons needed to establish hydraulic benefit. A properly corrected improper connection may be justified by compliance even when its exact flow contribution remains uncertain; the engineering memorandum should distinguish that rationale from a monetized flow-reduction claim.

Florida collection-system action plan: turn diagnosis into a maintainable program

Florida Rule 62-600.705(2), F.A.C., requires domestic wastewater facility permittees to develop a collection-system assessment, repair and replacement action plan. The Florida DEP's current guidance describes a planning horizon of at least five years, evaluation of at least 25 percent of the system over that horizon, and annual implementation reporting by June 30 following the covered fiscal year after plan submittal. The required scope depends on the permitted facility and should be checked against the governing rule and current permit conditions. A project engineer should connect an individual I/I study to this larger planning and reporting framework instead of treating each investigation as a stand-alone report.

The plan's asset inventory is the common data backbone for public-main condition, maintenance, service complaints, flow observations, corrosion, lift stations, and hydrologic context. Larger facilities have specified GIS/electronic inventory requirements under DEP guidance. A sound capital program can therefore provide two deliverables from each field assignment: an immediate engineering decision and a reusable, quality-checked asset record that supports the next annual update.

Propose five-year assessment cohorts by consequence, uncertainty, access, known I/I history and practical work limits. Record how much of the network was assessed, methods used, observed results, repair and replacement work, and unresolved issues. Do not interpret the 25-percent minimum as a promise that the unassessed 75 percent is low risk. High-consequence station or overflow exposure may require earlier attention regardless of the nominal percentage already inspected.

Action-plan element	Minimum defensible engineering evidence
Inventory	Linked asset IDs, ownership and service boundaries
Condition and I/I assessment	Methods, dates, observed defects and confidence
Prioritized work	Consequence, intervention basis, dependencies
Resilience	Sea-level, flood and stormwater interface assumptions
Annual implementation	Work completed, fraction assessed, remaining risks and changes

Select condition-assessment methods by the fault hypothesis

A field program is not improved by ordering every available inspection technique. CCTV is effective for visual condition and service connection observations when the pipe is accessible and appropriately prepared; it is not a direct volumetric measurement of groundwater entry. Night-flow isolation can help localize a persistently elevated dry-weather contribution but requires adequate boundary definition. Smoke or dye testing may reveal improper stormwater connections when performed by trained and authorized personnel; it does not directly quantify subsurface inflow at a pressurized defect. Manhole inspection, focused leakage methods, sonar in filled reaches and targeted excavation each have distinct limitations.

Select the tool that can change the next capital decision. Before contracting, write the hypotheses, expected observations, access and safety limitations, acceptable data completeness, required deliverable format and criteria for inconclusive findings. A contractor report that assigns every defect a numerical severity but does not preserve station limits, dates, images and conditions cannot be easily used for reproducible rehabilitation prioritization.

Field work in sewers, manholes and pump stations may involve permit-required confined spaces, hazardous atmospheres, energized equipment, flowing water and public traffic. Investigation plans need competent safety and operating controls; this study guide does not provide entry or bypass procedures. Engineering review should confirm who has safe access authority, what work can be performed without entry, and how abnormal observations will be escalated.

Method	Best-supported finding	Important limitation
CCTV and visual inspection	Structural defect location and condition	Usually not volumetric source proof
Flow isolation/temporary meters	Subbasin contribution under measured conditions	Timing and boundaries critical
Smoke/dye testing	Suspected improper connections	Access, safety and authorization required
Groundwater wells and tide gauges	External hydraulic context	Must reconcile screen and datum
Station telemetry	Operating state and response	Pump calibration/logic must be checked

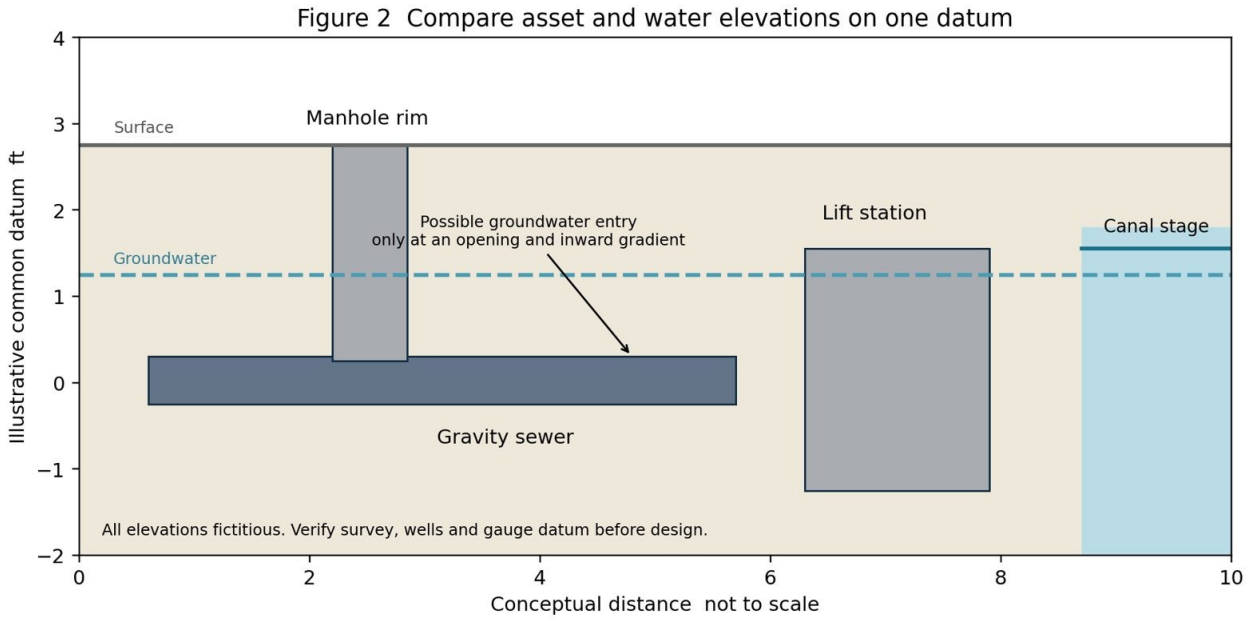
Design a calibrated model rather than a colorful hydraulic map

A hydraulic model can integrate spatially distributed capacity, but the number of nodes does not prove accuracy. Begin with a clearly defined use: demonstrate whether an existing station can meet an identified event, locate backwater and surcharge limits, or compare the incremental benefit of proposed source removal. Document the service area, dry-weather loads, pipe sizes and slopes, roughness assumptions, invert elevations, pumping logic, control settings, force-main constraints and downstream boundary conditions. Map each input to a survey, operating record or explicit assumption.

Calibrate against independent dry-weather and wet-weather measurements with known timestamps and conditions. A model that fits a single peak through arbitrary infiltration parameters may be non-unique: a different combination of surface inflow, storage and pump performance could produce a similar curve. Compare both the timing and magnitude of levels, flows and pump run states at multiple locations. Preserve a calibration residual table and use a separate event to test the model rather than using the same event for tuning and validation.

For a rehabilitation alternative, remove only source contributions supported by field evidence, then re-run the hydraulic scenario while holding other assumptions constant. Show whether the intervention changes peak surcharge elevation, total service-failure duration, and downstream load. Provide a sensitivity check around the most uncertain parameter. The engineer should state how the model supports a decision and which observations would invalidate its preferred explanation.

High groundwater and tidal exposure



Instructional diagram 4. Elevation datum reconciliation for pipe, groundwater, canal and manhole.

Figure 2. Conceptual section. Survey and sensor datums must be reconciled before a site-specific gradient is inferred.

Reconcile elevations before modeling pathways

Create a section view from the sewer invert and crown to ground, water table, canal stage, manhole rim, wet-well openings, and electrical equipment. Identify survey datum and uncertainty. A rising water table increases the head driving infiltration only where an actual hydraulic connection exists. Seal performance, joint movement, buried utilities, and service laterals influence entry. In some settings a tidally varying tailwater can reduce gravity drainage or change pump discharge head; its effect must be demonstrated for the specific network. One coastal trend curve cannot represent every branch.

Distinguish three time scales: event hours for intense rainfall and high tide; seasonal months for wet-season groundwater; and asset-life decades for changing boundary conditions. Build scenarios that combine the relevant conditions but do not automatically stack unrelated worst cases without explaining likelihood. A future boundary scenario should identify the chosen projection source, baseline year, datum, planning horizon, and what is held fixed. NOAA describes local variability and makes location-specific scenario tools available; USGS coastal studies show why groundwater response is spatially heterogeneous. [3,4]

> Field exercise 3: A trunk sewer invert is reported at +0.4 ft in one datum, a monitoring well at +1.0 ft in another, and the nearest tide gauge at +1.3 ft relative to its own chart datum. Can you infer an inward gradient of 0.6 or 0.9 ft? No. Write the metadata request needed to convert the readings to a common vertical datum, and name two reasons that a common-datum gradient still would not prove sewer entry.

Saltwater, corrosion, and process impacts require evidence

Higher conductivity at a station after a tide can be a useful screening observation, but conductivity is not a unique fingerprint of marine groundwater. Industrial inputs, reuse-water cross-connections, and sensor

calibration can alter readings. Pair trend evidence with sampling, network mapping, and source investigation before designing for saline intrusion. Materials and corrosion risks depend on concentration, exposure, ventilation, and equipment details. The appropriate conclusion may be “investigate” rather than “replace with corrosion-resistant materials everywhere.” The professional distinction is between a plausible mechanism and a verified design basis.

Observe the buried system and surface as one program

Sewer, drainage, roads, and electrical access share a flood environment, though their operators and funding streams may differ. If a station remains powered but the access road floods, a maintenance plan that assumes refueling on demand may fail. If a raised control panel remains dry but the wet-well hatch is submerged, the station’s hydraulic and electrical interfaces remain exposed. Draw the flood and water-table pathways at the asset level before selecting a generic “floodproofing” solution. EPA’s flood resilience guide supports this asset-centered approach. [5]

Groundwater time series and the sewer invert

A coastal groundwater well measures head at its screened interval, not every depth in the surrounding soil. The screen, aquifer confinement, fill layers, and local drainage structures matter. To use a well with a sewer alignment, document its construction and proximity; compare at common datum and time base; and note whether the question concerns persistent groundwater above a defect, rapid event response, or long-term trends. A line between two wells can be a useful conceptual transect but may conceal local gradients around a canal or pump. Geotechnical, utility and hydrogeologic information should be reconciled by qualified practitioners where design turns on these assumptions.

If the sewer invert is lower than a nearby groundwater measurement, an inward gradient at some opening is plausible; it is not sufficient proof of location, magnitude, or even entry while the sewer is surcharged. If a manhole rim is lower than observed surface water, direct entry is plausible only if openings permit it. Seal type and actual field condition matter. The practical output is a conditional pathway drawing: “when groundwater exceeds this elevation and sewer level is below it, inspect these lower joints and laterals,” rather than a categorical statement that all low sewers leak.

Coastal scenarios for asset-life decisions

Choose a planning horizon appropriate to the asset being evaluated. A short-lived controls retrofit and a buried force main with a much longer design life may need different scenario treatment. For each scenario, keep a ledger of baseline, year, relative sea-level source, groundwater model or local evidence, storm and tide assumptions, datum, asset elevation, and decision threshold. If a scenario is used only to prioritize additional study, a screening-level method may be sufficient. If it determines equipment elevation or a major construction program, sensitivity and site-specific review need to be stronger.

NOAA’s regional figures are not a single design allowance for a station in Florida. The engineer should use location-specific tools and distinguish relative sea level, local subsidence or uplift, canal control, and local drainage. A USGS Broward study found that coastal groundwater effects under its modeled scenarios differed substantially from inland effects. Transfer its methodological lesson—spatial heterogeneity and drainage interaction—to another utility; do not transfer its feet of groundwater change. [3,4]

Compound event worksheet

Prepare three analyses for a critical station. Observed calibration: use a historical event with synchronized rainfall, tide, groundwater, station and upstream flow to test whether the model reproduces observed level and pump behavior. Operational stress: vary one or two credible drivers, such as higher groundwater or a longer power interruption, to see which dependency fails first. Asset-life adaptation: use documented local future boundary scenarios to evaluate whether a planned renewal can be phased

or must be built differently now. The three analyses answer different questions; label their outputs accordingly.

For each analysis, ask whether access, telemetry and communications, electrical controls, incoming conduits, wet-well openings, force-main discharge conditions, and downstream treatment capacity remain functional. A station may meet a nominal pumping duty point while failing the system service objective because alarms cannot be received or fuel cannot arrive. Conversely, a temporary high groundwater level does not alone establish a permanent loss of station capacity.

> Module 3 exercise: A county report models elevated groundwater near one canal; the utility's only well is across a drainage divide. Explain why copying the county value to a sewer alignment is an unsupported inference. Propose a short monitoring transect and the asset elevations to survey. Identify the project decision that this work would inform.

Coastal time-series lag: avoid claiming a simple tide-to-sewer mechanism

A high tide, a nearby shallow-well rise and an elevated station flow can be correlated without being mechanically linked. Tide and groundwater may have shared meteorological drivers; a storm may raise the canal and groundwater while sanitary demand or pump operation changes. The correct next step is a joint time-series comparison and a physically plausible route of entry, not a conclusion based on visual correlation. The engineer should also reconcile the clock convention and vertical datums among tide, well, canal and sewer data before interpreting phase differences.

For a simplified phase screen, note the tide high-water time, nearby well peak time and corresponding flow response. If the well peaks two hours after tide in repeated dry-weather cycles but the sewer responds only in rainfall events, that finding weakens an assumption of a direct tide-to-sewer pathway. If tide-correlated conductivity changes persist under dry-weather conditions, verify the sensor and collect properly analyzed samples while checking industrial, reclaimed-water and housekeeping sources. Timing evidence can narrow the field investigation; it is not source identification by itself.

A spatial plan matters as much as a temporal one. Two piezometers on opposite sides of a canal may not represent the same hydrostratigraphic unit. Record well screen elevations, tidal connectivity, fill and soil stratigraphy, and the position of sewer joints and manholes. Where sampling suggests saline influence, assess material vulnerability, treatment implications and worker safety using site-specific results rather than using a generic conductivity threshold as a stand-alone diagnostic criterion.

Observed pattern	Reasonable interpretation	Required falsification check
Tide and well rise together	Hydraulic communication possible	Verify well elevation, response under no rain
Sewer flow rises only with rain	Rapid inflow may dominate	Check time alignment and storm drains
Conductivity rises after tide	Saline contribution possible	Sensor check, chemistry, other discharges

Scenario envelopes for buried assets and future service

Separate an observed calibration event, a near-term operational stress test and a longer-horizon asset-life scenario. An observed event is useful for checking whether the model reproduces recorded water levels and pump states. An operational stress test asks which safeguards fail when a plausible wet-weather and power/access combination occurs; it need not claim a precise probability. An asset-life scenario can bracket changing relative sea level and groundwater conditions while acknowledging locally uncertain aquifer behavior and future drainage works.

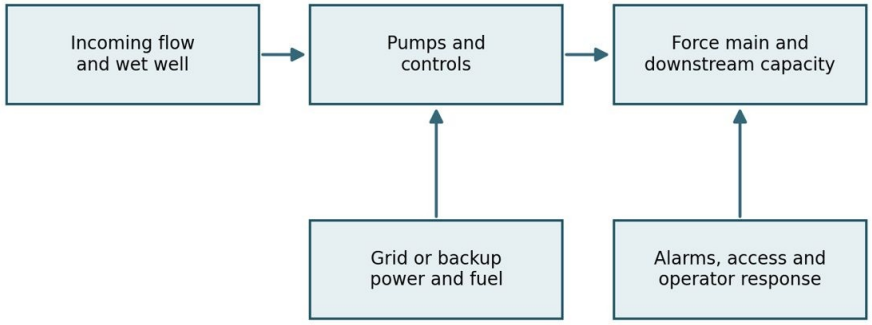
Use a scenario register with a source and date for every boundary. A rainfall assumption derived from a published design storm, a local tide gauge record and an engineering estimate of groundwater response should not be presented as an observed simultaneous event. Combining independent upper-percentile values may describe a deliberate severe stress test, but not a statistically defensible joint recurrence interval. Record whether the intent is design, resilience screening or emergency planning, and test sensitivity to the most consequential unresolved assumptions.

Asset design decisions should include retrofit and operational alternatives. Elevating an electrical enclosure may be viable, but the surrounding terrain, cable entries, vaults, ventilation, access road and portable-pump connection may remain exposed. A long-lived force main may require different protection than a communications replacement. Include a reassessment trigger, such as an updated datum survey, repeated high-water elevations or observed loss of station duty point, rather than implying one coastal projection settles the issue permanently.

MODULE 4 | 50 MINUTES

Rehabilitation, hydraulics, and service continuity

Figure 3 Lift station service depends on multiple paths



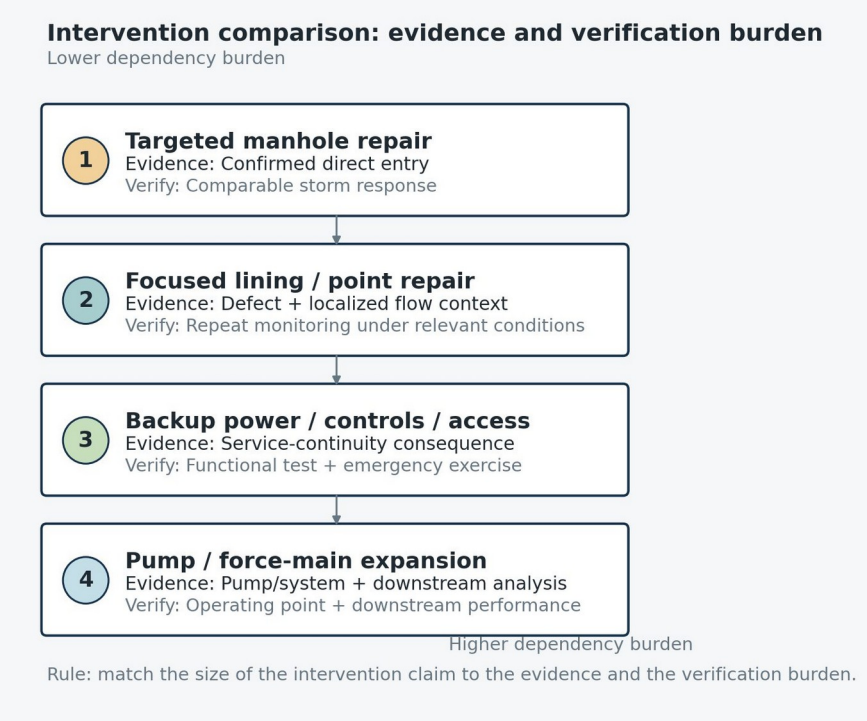
Instructional diagram 5. Service-continuity dependencies beyond pump capacity.

Figure 3. Station continuity requires both a hydraulic path and functioning power, controls and response.

Remove sources, recover capacity, or add capacity deliberately

Source control may include disconnecting improper storm connections, sealing or replacing defective manholes and laterals, grouting or lining eligible reaches, and repairing specific joints. The chosen method depends on structural condition, active groundwater, accessibility, private-property scope, and the demonstrated source. A rehabilitation measure can reduce inflow while leaving a structural or hydraulic bottleneck; a capacity expansion can convey unwanted water while leaving energy and treatment costs. Evaluate both separately. EPA’s CMOM guide calls for rehabilitation tied to capacity evaluation and documentation of results. [1]

Conveyance options include pipe upsizing or parallel relief, station capacity changes, wet-well control improvements, emergency storage, and operational changes. An upsized station can move a surge downstream into an already constrained force main or plant. A standby pump is useful only if the power and control chain and discharge path remain functional. Each option should be checked at the limiting component and at the downstream receiving system. Calculate with event hydrographs, pump curves, system curves, available storage, and allowable operating envelope, not only daily average flow.



Instructional diagram 6. Treatment alternatives ranked by evidence and verification burden.

Alternative	Primary intended benefit	Key uncertainty to close	Verification measure
Manhole and lateral source removal	Reduce rapid entry at identified locations	Share of event flow attributable to treated openings	Comparable monitored event response before and after
Targeted pipe rehabilitation	Reduce groundwater entry and restore asset condition	Defect-to-flow relationship and structural suitability	Night flow and inspected condition under comparable groundwater
Lift-station hardening and backup power	Maintain service during flood and grid interruption	Flood elevation, fuel logistics, transfer and controls	Documented commissioning and exercised outage procedure
Relief conveyance	Increase peak hydraulic capacity	Downstream capacity and induced operating effects	Model verification and commissioning trend

Do not total the benefits of independent projects as though they were additive without testing interactions. After source removal, a planned larger station may no longer be the best first capital project; if a station fails in storms because electrical equipment floods, sewer lining alone does not protect service.

Lift-station resilience is a chain of dependencies

Identify the service objective: maintain pumping through a defined outage and flood condition, recover within a specified time, or provide a safe controlled response if service cannot be maintained. Trace power from grid or generator through transfer equipment and controls to the pumps. Trace hydraulic flow through wet-well level, pumps, valves, force main, and downstream capacity. Trace human actions through alarms, remote telemetry, access, refueling, bypass connections, and emergency procedures. A generator capacity calculation that omits starting demand or a fuel plan that depends on an inundated route is not a complete continuity plan. EPA’s power resilience guide describes utility planning options, while Florida DEP describes a power outage contingency plan requirement for domestic wastewater facility permit applicants under Rule 62-600.705(1), F.A.C. [6,9]

In a design review, compare predicted flood elevations with openings and equipment elevations using the same datum. Assess access and maintainability after the water recedes. Protecting control panels above a selected flood level is one measure; it does not resolve submerged vents, incoming conduit, station buoyancy, or downstream backwater. The exact design and regulatory requirements are project-specific and require a fresh local review.

Regulatory boundaries

Florida DEP identifies Chapter 62-604, F.A.C., as the collection/transmission system rules and describes construction permitting for new or modified systems. It separately describes collection-system action plans under Rule 62-600.705(2) and power-outage contingency plans under Rule 62-600.705(1). These are regulatory checkpoints, not a claim that every repair requires the same permit or that the learner can determine filing status from this course alone. Verify the current rule text, existing facility permit, delegated authority, and project scope before selecting an approval path. ENG-019 will address permitting strategy in depth. [9,10]

How intervention performance can fail

Pipe lining can be structurally and hydraulically appropriate for some reaches, but it may leave laterals, connections, adjacent manholes, or external groundwater pathways untreated. Joint grouting may treat active leakage without resolving pipe deformation. A sealed manhole cover can remove a direct entry route but may create an access or ventilation issue if selected without checking the asset's requirements. Enlarging a pipe can reduce surcharge locally while transferring a larger hydrograph downstream. Backup power can keep a station running while a force-main break or flooded control interface still interrupts service. These are examples of design interactions, not reasons to avoid the measures. A sound alternatives analysis identifies the mechanism, boundary, downstream effect, constructability, and testable benefit of each option.

For a proposed source-removal project, define the treated population of assets and a testable response variable. "Line 4,000 feet" is an output quantity, not an outcome. A more meaningful outcome might be a reduction in comparable storm response, a lower persistent minimum-night flow during high groundwater, fewer high-level alarms under matched operating conditions, or a measured condition improvement. The outcome should be specific enough to evaluate after work. If the utility cannot yet define its baseline, the first phase is monitoring rather than a benefit claim.

Pump station operating envelope

Read pump capacity from a pump/system interaction at the relevant head and speed, not a nameplate flow alone. Static head, force-main friction, downstream pressure, wear and fouling, check-valve condition, and parallel-pump operation can change delivered flow. Wet-well storage can buffer a short peak, but should be evaluated with usable volume, controls, allowable levels, and inflow hydrograph. For an outage, the storage time before reaching an action level can be screened as usable volume divided by net inflow, with explicit assumptions; real inflow changes over the event, so a dynamic calculation may be required. A second pump's presence does not prove redundancy if both share the same electrical vulnerability.

> Illustrative storage screen: A station has 90,000 gallons of usable storage above a starting level and receives 1.2 MGD during an outage. At a constant inflow and no outflow, 1.2 million gallons per day equals 50,000 gallons per hour; 90,000/50,000 = 1.8 hours. This is an idealized warning interval, not a design acceptance result. The actual starting level, inflow hydrograph, infiltration, emergency pumping, alarms, permitted maximum level, and uncertainty can shorten it. It shows why an access plan or portable generator with a four-hour mobilization promise could be inadequate under that assumed condition.

Trace controls logic during high flow and power restoration. A high-level alarm should have a tested sensor, communication path, recipient, and escalation procedure. Generator or transfer equipment should be commissioned at a realistic pump demand. A bypass connection should be physically accessible and compatible with the utility's hoses and discharge strategy. If a station is in a flood zone, the pump's mechanical ability to run cannot compensate for submerged electrical components unless they are designed and protected for that condition. EPA's power resilience guide and Florida DEP's contingency-plan information support documenting such dependencies, while project design standards and permit conditions need their own review. [6,9]

Selecting an option under uncertainty

Use an alternatives table with the same basis for every option: problem addressed, expected service benefit, known interactions, capital and operating implications, feasibility, permitting checkpoint, construction outage, residual risk, and verification. Avoid false precision in benefit estimates when source contribution is not known. A small confirmed direct-inflow fix can proceed with a modest monitoring plan; a major relief sewer or station expansion should have a stronger hydraulic and downstream basis. A staged strategy can reserve space or interfaces for future adaptation without constructing all future capacity immediately.

> Module 4 exercise: Under the fictional Harbor Reach data, compare targeted manhole improvements, a three-mile lining contract, and a larger terminal pump. Which option can you justify now, which needs flow localization, and which needs downstream and pump-curve analysis? State the conditions that would reverse your initial ordering.

Pump and system operating point: why nameplate capacity is not usable capacity

A centrifugal pump operates where its characteristic curve intersects the system head requirement. Static lift, discharge pressure, pipe roughness, fittings, changing valve positions and simultaneous operation of other pumps can shift that intersection. A vendor's listed flow at one head is not proof that the installed station can achieve that flow during a high-head compound event. A screening curve can use Hsystem = Hstatic + kQ^2 for turbulent-friction approximation; actual selection requires a verified pump curve, fluid and pipeline conditions and applicable design criteria.

In an illustrative calculation, a station has 40 feet of static head and approximately 25 feet of friction at 1,000 gallons per minute; the screening system head at that flow is 65 feet. If the downstream pressure increases, the static component rises even when the inflow does not. A pump curve showing 1,000 gallons per minute at only 55 feet would not deliver the assumed 1,000 gallons per minute against 65 feet. The intersection must be recomputed. This example deliberately omits transient hydraulics, pump wear, air pockets and controls logic, all of which may govern a real system.

Document the service objective as a required flow-hydrograph and available system capacity over time. Check the treatment-plant, force-main and downstream-station constraints before proposing a larger pump. If two pumps discharge into a common force main, simultaneously operating both does not necessarily double total flow; the system curve rises as combined flow increases. Confirm the operational envelope with manufacturer data and field testing under authorized conditions, then preserve the resulting assumptions in the operating procedure.

Illustrative condition	Required head or capacity	Design lesson
Static lift	40 ft	Not equal to total dynamic head
Friction near 1,000 gpm	25 ft	Depends strongly on flow and pipe condition
System total at 1,000 gpm	65 ft	Must intersect actual pump curve
Example pump at 1,000 gpm	55 ft available	Assumed 1,000 gpm duty not achievable at 65 ft

A time-stepped outage test rather than a single average number

Average net-flow storage time is useful for initial screening but can be misleading during changing rainfall or partial pump operation. A more defensible simplified resilience check divides the outage into short steps, computes net inflow during each interval and integrates volume until the usable storage is exhausted. Keep separate the usable volume above the starting wet-well level, emergency pumping actually available at the operating head, and changes in inflow during the event. Never use the wet-well's entire geometric volume as emergency storage without checking alarm, overflow and safe operating elevations.

Take a fictional station with 60,000 gallons of verified available storage at the start of an outage. During hour 1, 850 gallons per minute enter and a portable pump delivers 400 gallons per minute: 27,000 gallons accumulate. During hour 2, 700 enter and 400 leave: another 18,000 gallons accumulate. During hour 3, 550 enter and 400 leave: another 9,000 gallons accumulate. Accumulated volume after three hours is 54,000 gallons, leaving 6,000 gallons. The test is a water balance, not a guarantee of safe operation; it assumes verified pump performance and ignores transients and changing wet-well geometry.

Next test the nonhydraulic dependencies: transfer-switch operation, generator starting, fuel delivery, portable-pump logistics, road passability, communications, staffing and safe access for repairs. State the latest time at which a crew must intervene, with an operational safety margin rather than planning to use every gallon of remaining storage. The utility should integrate these findings into its emergency response and collection-system action-plan updates.

Interval	Inflow (gpm)	Verified emergency outflow (gpm)	Added storage (gal)	Cumulative (gal)
Hour 1	850	400	27,000	27,000
Hour 2	700	400	18,000	45,000
Hour 3	550	400	9,000	54,000

Failure-mode and response matrix for a flooded station

A resilience review should identify the function that must survive, its probable failure modes, the evidence of detection and a feasible fallback. Electrical power, controls, fuel and communications are often treated as supporting equipment even though the station's hydraulic capacity is irrelevant if any essential link is unavailable. Rather than ranking only the replacement cost of each asset, assign consequences to loss of service, public-health exposure, environmental discharge, access constraints and restoration time.

For example, an elevated electrical panel may avoid shallow flooding, but a submerged access vault or blocked fuel truck route can still cause a prolonged outage. Test the whole service chain, including data and notification transmission, automatic restart after power restoration, availability of emergency connections, and whether portable equipment can be deployed when the street is impassable. Document which functions were physically observed or tested and which exist only in written specifications.

A field-ready review records the failure mode, initiation conditions, available detection, time to service impact, compensating measure, responsible operator, and evidence of verification. It should be reviewed after drills, actual outages, or capital changes. This practice improves decision traceability without claiming a universal risk-score threshold.

Failure mode	Detection	Response or design check
Power outage	ATS/generator status, station telemetry	Load test, fuel autonomy, tested connection
Road flooded	Field access routes and flood stages	Alternate access and supply staging
Communications down	Alarm receipt and independent check	Local indicators, alternate notification
Force-main bottleneck	Head/flow operating trace	System curve and downstream capacity

Rehabilitation work packages and construction acceptance

Rehabilitation is not a single product. Candidate methods include local manhole sealing and rehabilitation, joint repair, lateral connection correction, in-situ lining, replacement and reconstruction. Selection depends on the asset's structural condition, geometry, surrounding groundwater and loading, service laterals, hydraulic capacity, corrosion exposure, access and life-cycle maintenance needs. Pipe lining may reduce defect

exposure but it can also alter internal diameter and require precise reconnection of services; manhole and lateral inflow can remain after a main is lined.

The engineer should organize a field-ready work package around the mechanism being corrected. Include asset IDs, surveyed limits, existing and proposed connection details, groundwater/flow management approach, contractor submittals, inspection hold points, restoration requirements and postconstruction evidence. Design and permit requirements for bypass pumping, dewatering, traffic or environmental controls are project-specific and cannot be replaced by generic details. Verify operating constraints with the utility before restricting or diverting flow.

Acceptance is broader than a manufacturer's certificate. Use appropriate inspection and testing, reconnection records, observed leakage or defects under useful conditions, and completion surveys as specified for the selected method. A postconstruction wet-weather study can establish hydraulic benefit only after enough comparable conditions are recorded. Retain as-builts, submittals, equipment changes, service restoration records and unresolved exceptions in the asset inventory.

Scope element	Design evidence	Acceptance evidence
Defect location	Asset ID, chainage, mechanism	Location and corrected condition
Lateral interfaces	Owners, connections, service plan	Reconnection and restoration
Hydraulic performance	Prework level/flow and operating state	Matched-event or test observations
Records	Specifications, permits, submittals	As-built, test log, exceptions

Decision transparency when a risk score is uncertain

Risk scores are a way to organize discussion, not a substitute for documented failure modes. A high consequence rating might reflect a nearby school, hospital access, receiving-water sensitivity or inability to bypass a critical station; probability may be much less certain. Separate observed asset condition from estimated likelihood, and distinguish a detected problem from a modeled future condition. Where information is poor, a targeted survey or temporary monitoring phase can have more decision value than a large capital commitment.

Write funding recommendations using three layers: the service risk that must be reduced, the engineering evidence that links a proposed intervention to that risk, and the uncertainty or sensitivity that could change the recommendation. Record the consequences of waiting, but avoid claiming a specific return-on-investment from a speculative wet-weather infiltration volume. Alternatives that protect a failing generator, close a confirmed stormwater connection or update a permit-required plan may be justified by different benefits even if they compete for the same budget.

End each capital package with the acceptance gate: which field observation confirms installation, which performance outcome will be monitored after startup, and which department owns the resulting record. A capital decision without a verification pathway can neither validate the initial hypothesis nor guide the next five-year assessment cycle.

Capital prioritization and post-project verification

Rank risk and evidence, then phase investments

A capital list is stronger when it records failure mode, service consequence, asset condition, evidence confidence, available intervention, construction dependencies, and verification method. An inexpensive measure at a confirmed direct inflow opening can be an early action. A lift station serving a hospital district may warrant continuity work even if its I/I contribution is modest. A reach with severe suspected infiltration but poor monitoring may justify a targeted diagnostic phase before a large rehabilitation contract. The ranking is a decision record, not a universal weighted score.

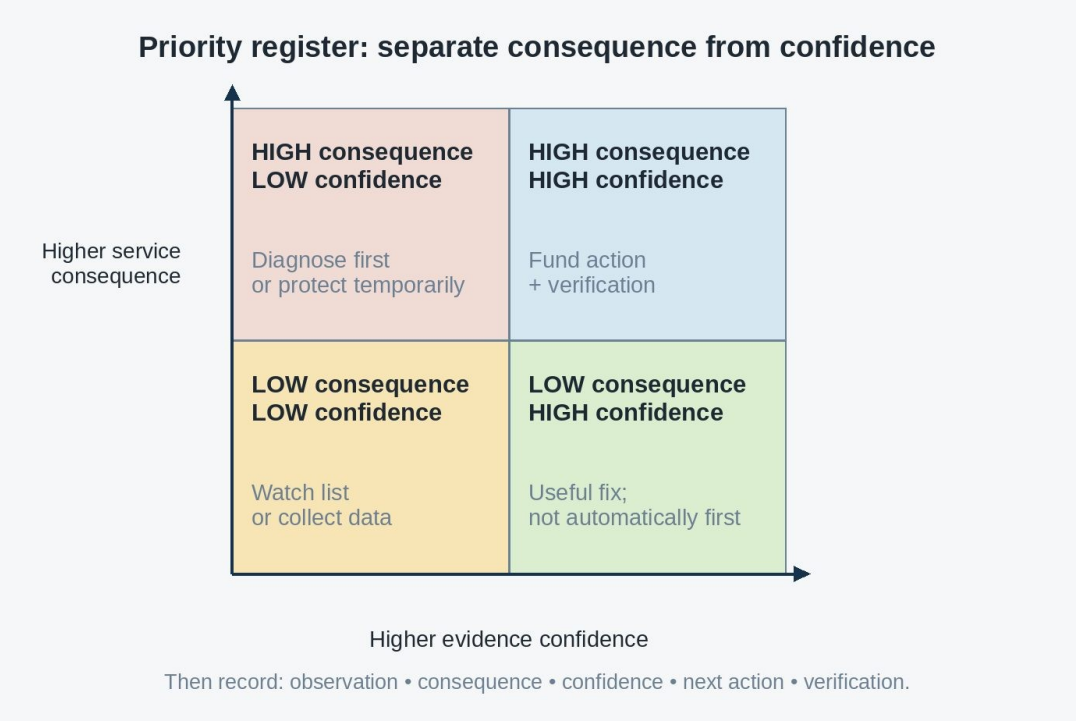
Use a staged program. First, protect known high-consequence points and correct clear illegal or direct connections through the appropriate utility processes. Second, meter and inspect unresolved basins. Third, implement targeted works and check the downstream system. Fourth, repeat monitoring in comparable seasons and events, update the hydraulic model, and revisit the capital list. This avoids treating “construction complete” as proof that wet-weather response improved. EPA’s SSOAP resource explicitly supports focused condition assessment and pre/post rehabilitation performance analysis. [2]

Verification design: Define a baseline and a success measure before work begins. For an I/I project, record comparable rainfall depth and intensity, antecedent wetness, groundwater and tide, sanitary load, meter quality, and station operation. Normalizing against these conditions may be needed; a post-construction dry season cannot fairly be compared with a pre-construction wet season. For a power project, document actual transfer, alarms, pump operation, communications, and realistic duration, rather than checking only the presence of a generator. If monitored benefit is lower than predicted, investigate remaining entry points and model assumptions instead of silently declaring the project successful.

An adaptive trigger

An asset-life plan should state what observation triggers the next decision. Example: if monitored minimum-night flow remains above a locally established baseline during high groundwater after targeted lining, inspect laterals and manholes in the same subbasin before expanding lining to the next trunk. If a selected flood scenario threatens the station control elevation within the planning horizon, evaluate relocation or elevation at the next major renewal. These are proposed engineering triggers; no numerical threshold here is a regulatory requirement. Document who owns the observation and the date of review.

A transparent priority register



Instructional diagram 7. Priority register separating consequence from evidence confidence.

Maintain one row per asset group or intervention, not one opaque rank for an entire basin. Include observed failure, confidence, service consequence, source contribution, remaining useful life or condition, feasible treatment, dependency on other projects, cost range with basis, and the next evidence gate. Separate the urgency of a service-continuity measure from its I/I reduction. For example, a flood-exposed station control panel may have high service consequence but zero expected I/I reduction. A leaking lateral cluster may have large I/I potential but depend on property access. Comparing them through one “gallons removed per dollar” score would hide the station risk.

When projects interact, sequence them to preserve learning. Repair confirmed direct openings; repeat flow monitoring under comparable weather; reassess the need for larger conveyance. In parallel, perform station continuity work if its consequence warrants action independent of I/I. Keep a budget for post-project monitoring and telemetry QA. A rehabilitation plan with no measurement afterward cannot establish how much capacity it recovered.

Adaptive capital pathway example

Year 0: Confirm high-consequence failure modes, reconcile elevation datums, establish meter QA and baseline, repair safely verifiable direct inflow. Year 1: Inspect the highest-response subbasins under relevant groundwater conditions, treat confirmed defects and laterals within authority, review station and force-main capacity. Years 2–3: Compare repeated event data, revise hydraulic model, execute only the capacity projects that remain necessary, and harden flood/power dependencies. At each major renewal: update local coastal boundary information, condition assessments, land-use changes, and critical-customer demands. The dates are illustrative; actual utility capital cycles differ.

This staged pathway does not mean waiting for certainty before addressing a known safety or service risk. It means distinguishing an urgent protective action from a long-term project whose benefit depends on unverified hydraulic claims. The decision memo should state what could change the plan. That makes later revision a controlled response to evidence rather than an unexplained reversal.

> Module 5 exercise: Build three priority-register rows from Harbor Reach’s supplied observations: low manholes, defective trunk joints, and terminal station controls. Give each a service consequence,

evidence confidence, next information item, and early action. Explain why an inexpensive “fix” with no ability to verify outcome may still rank below a diagnostic project.

Benefit verification and lifecycle screening: do not turn a model estimate into a claimed result

Post-rehabilitation verification begins before rehabilitation. Define which flow, level or service outcome is expected to change, the location and measurement method, and the event conditions under which it can be meaningfully tested. Compare pre- and post-project observations against rainfall amount and intensity, antecedent dryness, groundwater level, tide, customer demand and station operating state. If the post-project event is smaller, a lower peak alone does not prove hydraulic recovery. The independent quality assurance plan should specify which data will be excluded and why.

An illustrative operations screen may estimate the annual treatment cost associated with an assumed reduction in excess wet-weather volume, but the assumption must remain labeled. For instance, reducing a proven 0.12 MGD of additional flow on 90 comparable high-water days would be 10.8 million gallons per year. At an illustrative avoidable marginal cost of $1.20 per 1,000 gallons, the arithmetic benefit is $12,960 per year. This does not establish such a reduction is technically achievable; it excludes capital, field verification, energy, asset service life, infiltration recurrence and the fraction of expenses that truly vary with flow.

For each alternative report cost estimate basis, uncertainty and whether expected benefit is hydraulic, regulatory, operational or environmental. A critical overflow-risk correction can be worthwhile even if its measured flow reduction is small. Conversely, a high-cost trunk lining program should not be justified using a wet-day screening volume without source attribution and sensitivity analysis. A transparent recommendation identifies which assumption would reverse the preferred alternative.

Hypothetical screening input	Illustrative amount	Qualification
Additional flow removed	0.12 MGD	Must be established by investigation
Comparable wet-weather days	90 days/year	Event frequency must be supported
Annual avoided volume	10.8 million gallons	0.12 x 90
Avoidable marginal rate	$1.20/1,000 gal	Illustration only; not a tariff
Arithmetic annual benefit	$12,960	Not a net present value or verified savings

Sanitary sewer overflow reporting and engineering record continuity

Prevention of sanitary sewer overflows is a public-health and environmental obligation, not merely a capacity-optimization exercise. Florida DEP's wastewater incident reporting guidance identifies the Report of a Sanitary Sewer Spill or Overflow process and separate notification obligations; the online incident-reporting tool does not itself satisfy State Watch Office notification where otherwise required. Exact requirements depend on event characteristics, applicable rules and permits, and the current agency process. Designers should not convert a generic training case into a substitute for the permittee's incident response procedures.

A facility-oriented engineering record should preserve the time and place of an incident, observed level and flow conditions, estimated release pathway and duration with uncertainty, immediate controls, photographs or logs, and the steps taken to prevent recurrence. Clearly distinguish confirmed overflow volume from modeled or estimated volume. When a suspected overflow may have been caused by a station outage, retain alarms, power information, dispatch logs and repair chronology alongside hydraulic records.

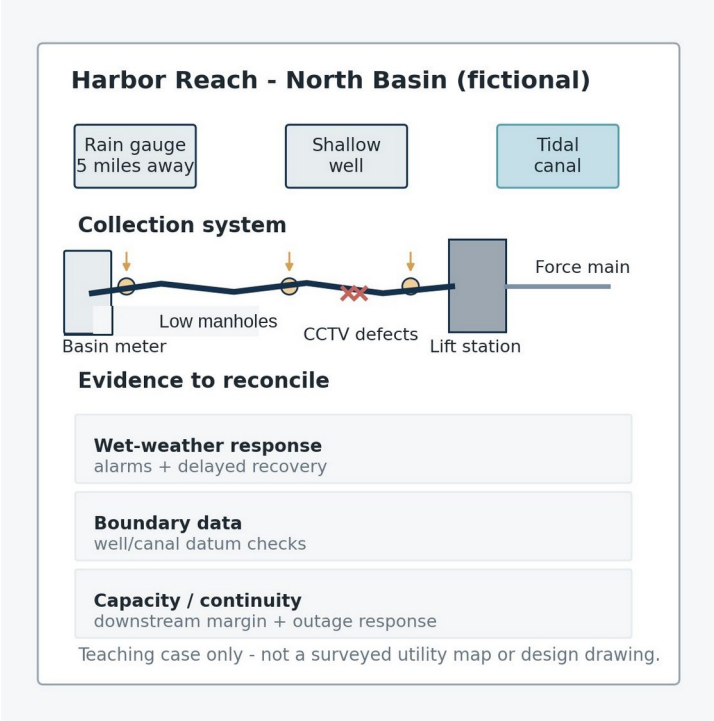
This feedback loop supports both emergency response and capital planning. Repeated releases at a location require investigation even if routine CCTV suggests good asset condition; field evidence can reveal interactions across power, telemetry and private sources. A high-quality post-incident review closes on an assigned preventive action, an evidence-based verification method and a management owner who can confirm completion.

MODULE 6 | 30 MINUTES

Integrated fictional case

Harbor Reach Utility

Harbor Reach is a fictional Florida coastal utility. Its North Basin includes 9 miles of gravity sewer, 620 manholes, 1,450 service laterals, and one terminal lift station with duty and standby pumps. The station discharges to a force main whose downstream peak-capacity margin is unverified. A low segment lies near a tidal canal. During the past year, the utility recorded two wet-weather high-level alarms and one access disruption; no overflow volume is confirmed in the supplied record. The available budget covers a diagnostic phase and one early intervention before the next capital cycle.



Instructional diagram 8. Fictional North Basin topology and evidence inventory.

Evidence supplied	Observation	Limit
Basin meter	Dry reference about 0.80 MGD equivalent; storm-day 2.20; day plus two 1.25	One event, clock and calibration review pending
Rain gauge	2.8 in over 24 h with a short intense burst	Gauge 5 miles away; spatial variability possible
Shallow well	Water rose from +1.1 to +1.7 ft local datum	Well screen and datum documentation incomplete
Canal gauge	High tide overlapped storm peak	Datum conversion not yet verified
Manhole inspection	Three low-lying covers with visible surface-water exposure	No flow-entry measurement yet
CCTV	Joint defects in one trunk; several laterals not inspected	CCTV performed during lower groundwater
Station log	High level for 38 minutes; one pump alarm	Pump discharge, power, and wet-well sensors need validation

Decision A — Working explanation. The sharp storm response supports investigation of direct inflow, especially at low-lying openings, while the sustained day-plus-two elevation supports investigation of

groundwater or delayed rainfall-derived infiltration. The station alarm could be a consequence of higher inflow, a pumping fault, or both. Tide is a plausible boundary factor but cannot be assigned a numeric contribution without reconciled elevations and repeat observations. Separate “observed,” “suspected,” and “unresolved” in the utility’s decision memo.

Decision B — First field phase. Verify the basin meter, station telemetry, and timestamps. Survey the well, canal reference, sewer inverts, manhole rims, and station openings to a common datum. Deploy two temporary upstream meters, a local rain gauge, and groundwater observations across several events. Inspect exposed manholes safely during appropriate storms and perform targeted CCTV and lateral investigation when groundwater conditions can reveal active entry. Review pump/system curves and downstream force-main constraints. Preserve field safety and access controls; no confined-space entry is implied by this exercise.

Decision C — One early intervention. If a safe, documented inspection confirms direct entry at specific low manholes, a targeted manhole improvement paired with before/after monitoring may be an appropriate early project. Do not declare it the highest-volume remedy from visible exposure alone. The parallel continuity action is to test the station’s alarm, pump availability, backup power plan, and access route. Which action is first depends on the verified service consequence, utility procedures, and available resources.

Decision D — Six-month memo. Use a three-tier decision log: confirmed defects to correct; diagnostic projects with an explicit question and required data product; and larger capacity or resilience concepts held until source contribution, station capability, downstream capacity, and boundary scenarios are better resolved. Pair each action with a verification plan using comparable conditions. The utility should also confirm current facility-permit obligations and the status of its collection-system and power-outage plans with appropriate counsel and regulators. [9,10]

Learner submission prompt

Write a 500–700-word engineering recommendation to Harbor Reach. Include (1) a flow-path hypothesis with at least two alternatives, (2) a monitoring plan that could distinguish them, (3) an early intervention and why it is reversible or evidence-supported, (4) one station-continuity action, (5) a post-project success measure, and (6) one uncertainty that could change the recommendation. Use only the supplied facts; mark any additional assumptions explicitly. Compare your answer to the worked decision sequence above. The exercise is formative and not a claim of individual design approval.

Case extension Two events with different boundary conditions

Three weeks after the first Harbor Reach storm, a second event produces 2.0 inches of rain over 24 hours. The basin day totals 1.55 million gallons rather than 2.20. The local groundwater well is 0.4 ft lower than in the first storm, the canal’s high tide occurs six hours after the rain peak, and the terminal station experiences no high-level alarm. These are fictional teaching data. They do not prove the tidal difference caused the lower response: rainfall intensity and location, antecedent moisture, base load, operating state, and meter quality could also differ. They do make a one-event calibration insufficient for a large investment decision.

The engineer should overlay the two events with consistent time zones; compare rainfall intensity, antecedent conditions and meter performance; and ask whether the slower recession differs as much as the peak. If the second event has a smaller rapid response but similar long tail, that can motivate separate direct-inflow and groundwater hypotheses. If the pump operated differently, a station state may explain part of the alarm difference. A conclusion of “the tide caused the extra 0.65 million gallons” would exceed the supplied evidence.

Case exercise 1: Develop three competing explanations for the event difference and identify one discriminating measurement for each. Rank them by ease of testing, not personal certainty. Case exercise 2: The utility asks to approve the three-mile lining contract immediately because CCTV found

defects. State a narrow decision that uses the findings without promising a volume reduction. Case exercise 3: A hurricane warning arrives while one pump is unavailable and portable power is planned. Trace the minimum operational decisions and escalation dependencies in the utility's approved emergency plan; do not invent a permit exemption or allowable overflow.

Suggested worked response

First stabilize and document station capability: pump availability, alarms, tested transfer or portable connections, fuel/access, and downstream hydraulic limits. Next resolve meter and datum quality so the utility can distinguish external flow from operating effects. A targeted manhole repair is justified if direct entry is confirmed and authorized, but it should be paired with monitoring. Broader lining should be focused on reaches with both condition and flow evidence, or justified separately on structural condition. A larger pump should be deferred until its operating point and downstream effect are established, unless an independent urgent service need is demonstrated. Each decision must have an owner, an evidence product, and a trigger for revision.

The objective is not to produce the “right” universal capital sequence. It is to keep the causal story, measurements, consequences, and project benefit coherent. Different utilities may reasonably choose different early work when critical-customer exposure, access, or existing permit conditions differ. A defensible memo says what is known and what would change the recommendation.

Applied engineering lab: reconstructing a wet-weather event

A single peak-flow number is not a diagnosis. Consider a fictional collection system where a representative dry day conveys 0.94 million gallons (MG), a storm day conveys 1.68 MG, the following day conveys 1.39 MG and day two conveys 1.13 MG. The rain gauge recorded a short intense burst, groundwater remained above its seasonal median, and a station control change occurred during the storm. These figures are instructional only and are not observed utility records.

MEASUREMENT	DAY 0	DAY +1	DAY +2
Collected flow (MG/day)	1.68	1.39	1.13
Excess above 0.94-MG dry baseline	0.74	0.45	0.19
Uncertainty that remains	Storm shape; pump state	GW / storage release	Sanitary baseline / GW

Subtracting 0.94 MG from 1.68 MG gives 0.74 MG of event-day volume above the chosen screening baseline. It does not establish 0.74 MG of recoverable groundwater infiltration. That extra volume could combine direct surface inflow, rainfall-derived infiltration, antecedent groundwater, changing sanitary demand, sewer storage, flow-meter uncertainty or changes in lift-station operation. Estimate measurement confidence before converting the screening difference to a capital benefit.

A defensible investigation begins by verifying meter calibration and data gaps, aligning event timestamps, confirming which station pumps operated and determining whether wet-well levels or force-main backpressure distorted measured or modeled flow. Pair the time series with rainfall intensity and duration, shallow wells surveyed to the same datum, canal/tidal elevation where relevant, and targeted manhole or lateral observations. A recurring immediate response supports a rapid pathway hypothesis; a delayed response can be consistent with shallow groundwater recharge but is not unique proof of a particular leaking asset.

> Decision exercise: Prepare a one-page evidence plan that distinguishes three claims: (a) excess volume measured above baseline, (b) source that is supported by the joint evidence, and (c) volume that an identified intervention could credibly remove. State what observation could falsify each

conclusion. A targeted manhole inspection can resolve an observed entry route; CCTV of a dry pipe defect, by itself, cannot quantify a wet-weather contribution.

Applied engineering lab: station continuity under stress

Resilience must be assessed as a service chain. A functioning pump is necessary but insufficient when the upstream wet well, incoming power, alarms, controls, communications, emergency access, backup fuel and receiving force main are all potential constraints. A control cabinet elevated above a flood design elevation improves one link, but does not establish that responders can reach the site or that generator fuel can be replenished during a multi-day road closure.

DEPENDENCY	CHECK BEFORE CREDITS ARE CLAIMED	SAMPLE EVIDENCE
Wet well and storage	Starting level; truly usable operating band	Trend logs, certified geometry
Emergency pumping	Measured pump/system operating point, not catalog maximum	Duty test, head/flow record
Power and controls	Transfer, alarms, cable penetrations	Commissioning and outage drill
Access and fuel	Flooded-route duration; fuel logistics	Flood map, supplier and route plan

For a first-pass outage screen, calculate net accumulation rather than dividing available storage by gross influent flow when a verified emergency pump continues to convey water. Convert all rates to consistent units and distinguish the best-case constant-flow duration from a dynamic hydrograph. Stress-test the answer with a higher incoming peak, reduced emergency pump capacity, a less favorable starting level and the possibility that the downstream force main cannot accept the flow.

A justified capital sequence matches the strength of the evidence to the irreversibility of the decision. Confirmed, readily accessed stormwater entry at a low manhole may justify a narrowly scoped repair and monitored response. A trunk lining commitment needs source localization, constructability, lateral interfaces and baseline data. Increasing the terminal pump requires checking the duty point against the actual system curve, force-main pressure limits, downstream station and treatment constraints, power demand, and the time-varying event hydrograph.

Verification exercise: Select one early source-removal measure and one station-continuity measure. Specify a baseline period, matched-event or normalized comparison conditions, acceptance metric, responsible owner, trend-data quality gate and a decision rule if the measured result is smaller than expected. Do not equate a lower post-project peak during a milder storm with recovered capacity without accounting for event intensity, groundwater, demand and station operations.

Additional station-outage storage scenario

If 90,000 gallons of usable volume remain above the current operating level, the total incoming flow is 1.2 million gallons per day (MGD) and a VERIFIED emergency pump removes 0.6 MGD, the net accumulation is 0.6 MGD. Convert to hourly inflow: 600,000 gal/day ÷ 24 h/day = 25,000 gal/h. Idealized time to exhaust usable storage is 90,000 gal ÷ 25,000 gal/h = 3.6 h. This is a constant-flow screening calculation, not an emergency operating guarantee.

Verification considerations: Confirm starting level, truly usable wet-well/storage volume, dynamic hydrograph, emergency pump duty point at the operating head, generator fuel/access logistics, alarm thresholds, downstream capacity and controlled discharge limitations. No engineered response should be based on the 3.6-hour figure without these checks.

Expanded applied laboratory: build a three-event evidence matrix

The final technical exercise links hydrograph interpretation to a decision that can be procured and independently reviewed. Use a fictional North Basin with three storm periods and a dry-weather reference of 0.80 million gallons per day. Event A yields 2.20 million gallons with an intense 15-minute rainfall burst and groundwater near a seasonal median. Event B yields 1.55 million gallons with slower rain and elevated groundwater. Event C yields 1.80 million gallons during high tide with an unusually long lift-station pump cycle and a suspected force-main pressure increase. These event volumes are hypothetical and intentionally not normalized to the same conditions.

First build a shared time base and a conditions table. Then record at least three competing explanations for the differences: rapid public or private direct inflow, delayed groundwater-related pathways, and restricted discharge/storage. Map a discriminating observation to each hypothesis. For example, a targeted manhole observation during Event A can document direct entry; paired groundwater and subbasin night-flow monitoring across Event B can test infiltration; station duty-point and downstream pressure measurements during Event C can test hydraulic restriction.

The decision memo should clearly state that 1.40, 0.75 and 1.00 million gallons of dry-day-relative difference are not estimates of repairable infiltration. They are screening volumes. Choose one near-term action supported by directly observed conditions and one diagnostic phase that can support the next capital decision. Specify what event normalization and field confirmation must occur before any promised MGD reduction can appear in a funding justification or performance claim.

Record	Event A	Event B	Event C
Day total (million gal)	2.20	1.55	1.80
Dry reference (million gal)	0.80	0.80	0.80
Screening excess (million gal)	1.40	0.75	1.00
Main condition	Intense rain burst	High groundwater	High tide; altered station state
Next test	Observed direct entry	Hydraulic gradient/lag	Duty point and downstream head

Field-ready measurement and decision register

Issue one controlled measurement register for the basin, not a set of unlinked technician spreadsheets. At a minimum it should list the decision to be supported, responsible engineer and utility contact, service area boundary, sensor placement, sampling interval and clock, flow rating and checks, groundwater screen and datum, tide station and datum, rainfall method, station telemetry, known outage periods, field observations and data retention location. The deliverable should be reproducible by a second engineer who did not attend the field investigation.

Define acceptance gates before work starts. Gate 1: all key instruments and location records are independently checked. Gate 2: enough differing events were observed to distinguish the principal pathways or the remaining uncertainty is acknowledged. Gate 3: a suspected source is localized with defensible evidence, not just a large total. Gate 4: a proposed correction has a testable performance basis and a practical safety/permitting path. Gate 5: post-construction conditions and data quality are adequate for an honest pre/post comparison.

The final recommendation should assign outcomes at the appropriate confidence level: confirmed, strongly supported, plausible and untested. An observed stormwater connection may justify immediate correction; an estimated groundwater contribution may justify a targeted monitoring phase; and a high-level alarm with a failing generator test may justify urgent continuity work even without proof of an infiltration source. Separate public-health urgency from asset optimization so that an uncertain flow model does not delay a clearly required protection.

Decision gate	Evidence required	If the gate is not met
Monitoring readiness	QA, datum, clock, asset IDs	Recheck sensor placement and baselines
Source inference	Multiple convergent observations	Keep alternative hypotheses open
Scope authorization	Intervention tied to a verified mechanism	Stage investigation instead of basin-wide repair

Benefit verification	Comparable pre/post event conditions	Report a measured difference, not proved savings

Integrating collection-system, stormwater, and transportation responsibilities

Coastal service failures frequently cross agency boundaries. A flooded road can interrupt generator refueling, a municipal stormwater project may change the hydraulic exposure of sewer manholes, and a private foundation drain can affect public collection-system performance. The engineer should document which entity owns each asset, which intervention has the authority to correct it, and whether the change shifts flooding to an adjacent property or downstream facility. This is especially important where a regional road or seawall improvement changes local drainage conditions over the life of a buried sanitary asset.

Create an interface register for projects that alter access elevation, tidal gates, canal stages, drainage outfalls, utility corridors, shoreline protection or electrical distribution. The register should include the controlling design drawing, responsible agency, construction date, expected effect on the wastewater study, data needed for verification and postconstruction update trigger. A regional project may materially alter the original sewer-system design assumptions without any physical work on the sewer itself.

This cross-agency treatment keeps coastal resilience from becoming a list of isolated asset hardening projects. Where causes are shared, a coordinated program can prevent redundant construction and provide stronger monitoring evidence. Where causes are not shared, the register makes that boundary clear and avoids assigning one agency responsibility for a mechanism outside its control.

Interface	Potential sanitary-system effect	Required coordination
Stormwater outfall/tidal gate	Altered surface flooding and canal stages	Local stormwater owner
Road elevation/access	Changed fuel and emergency reach	Transportation and emergency management
Waterfront works	Changed groundwater or boundary condition	Coastal and environmental teams
Private lateral/drain	Direct inflow and ownership constraints	Property owner and local ordinance

Additional primary references for the applied expansion

Florida DEP, Collection System Action Plans (Rule 62-600.705(2), F.A.C.): https://floridadep.gov/water/domestic-wastewater/content/collection-system-action-plans

Florida DEP, Wastewater Incident Reporting: https://floridadep.gov/water/water-compliance-assurance/content/wastewater-incident-reporting

U.S. EPA, Guide for Evaluating Capacity, Management, Operation, and Maintenance (CMOM) Programs at Sanitary Sewer Collection Systems: https://www.epa.gov/sites/default/files/2020-02/documents/cmom_guide_for_collection_systems.pdf

U.S. EPA (Region 1), Guide for Estimating Infiltration and Inflow (2014): https://19january2017snapshot.epa.gov/www3/region1/sso/pdfs/Guide4EstimatingInfiltrationInflow.pdf

NOAA National Ocean Service, VDatum and coastal water-level datum guidance: https://coast.noaa.gov/digitalcoast/tools/vdatum.html

Primary sources and regulatory references

The numbered sources support the corresponding statements in the manuscript. Federal guidance provides methods and context, not a substitute for current project permits, local design criteria or professional review. For project decisions, confirm the most recent editions and agency guidance; the examples here are for professional instruction.

U.S. EPA. Guide for Evaluating CMOM Programs at Sanitary Sewer Collection Systems. https://www.epa.gov/sites/default/files/2020-02/documents/cmom_guide_for_collection_systems.pdf

U.S. EPA. Sanitary Sewer Overflow Analysis and Planning Toolbox. https://www.epa.gov/water-research/sanitary-sewer-overflow-analysis-and-planning-ssoap-toolbox

U.S. Geological Survey. Potential for Increased Inundation in Flood-Prone Regions of Southeast Florida. https://www.usgs.gov/centers/cfwsc/science/potential-increased-inundation-flood-prone-regions-southeast-florida-response

NOAA. Sea Level Rise, report and local scenario tools. https://oceanservice.noaa.gov/hazards/sealevelrise/

U.S. EPA. Flood Resilience: A Basic Guide for Water and Wastewater Utilities. https://www.epa.gov/waterutilityresponse/flood-resilience-basic-guide-water-and-wastewater-utilities

U.S. EPA. Power Resilience Guide for Water and Wastewater Utilities. https://www.epa.gov/waterresilience/power-resilience-guide-water-and-wastewater-utilities

The cited technical publications support the wastewater collection and coastal-engineering methods discussed here. The hypothetical data and scenarios are original instructional examples, not surveyed or measured records.
Florida Board of Professional Engineers. License Renewal. https://fbpe.org/licensure/license-renewal/
Florida Department of Environmental Protection. Collection/Transmission System Power Outage Contingency Plans. https://floridadep.gov/water/domestic-wastewater/content/collectiontransmission-system-power-outage-contingency-plans
Florida Department of Environmental Protection. Collection System Action Plans and Domestic Wastewater Collection/Transmission System Permitting. https://floridadep.gov/water/domestic-wastewater/content/collection-system-action-plans ; https://floridadep.gov/water/domestic-wastewater/content/domestic-wastewater-collectiontransmission-system-permitting
U.S. EPA. Report on Condition Assessment Technology of Wastewater Collection Systems. https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P1008H44.TXT

Field desk reference: evidence before an I/I capital decision

The decisive issue is not merely whether excess water entered the basin, but whether independent observations are sufficient to select and verify a particular intervention. Preserve a controlled catchment map, consistent event time base, a quality-checked sensor register, alternative hypotheses and clear evidence ratings. An observed direct entry may justify repair; a rainfall-related total without source attribution justifies further diagnosis rather than a promised recoverable MGD value.

For capacity work, verify the pump and system operating points and downstream limits. For rehabilitation, identify the actual defect and interfaces with laterals and manholes, then specify meaningful construction and performance acceptance. For resilience work, examine the complete power-controls-fuel-access-communications chain. Each decision should have an assigned owner, construction or investigation gate, and a post-project observation plan.

Decision	Required evidence	Not sufficient
Boundary and datum	Linked asset survey and stage records	Unreconciled map
Flow source	Monitoring plus observation	Single CCTV defect
Station capacity	Field operating point and downstream check	Nameplate flow
Improvement claim	Comparable pre/post conditions	Unmatched peaks
Resilience	Tested service dependencies	One elevated cabinet

Course completion

Return to the BuilderCE course lesson page and select Continue to begin the separate online final examination. The required passing score is 70%; unlimited quiz retakes are available. The online examination and answers are intentionally not reproduced in this study guide.