

Six Questions That Rule Out a Cause: Eliminative Analysis in Forensic Engineering

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Abstract

We present a structured eliminative framework for forensic causal inference that evaluates candidate causes through six standardized reasoning questions: Necessity, Sufficiency, Exclusion, Consistency, Non-Uniqueness, and Constraint. Three questions are elimination-governing (their failure refutes and removes a candidate), one is admission-necessary but non-eliminating (its failure marks an evidentiary gap rather than refuting the cause), and two are non-governing (they characterize the surviving set and guide attribution without independently removing candidates). The method rests on a single principle: causation is not proven; it survives elimination. A cause is admissible when it has not been refuted under any governing condition and its required indicators are present in the evidentiary record. The framework assigns each candidate cause exactly one of three terminal dispositions: admissible, eliminated, or suspended, where suspension denotes a cause that is neither supported nor refuted because the differentiating evidence exists in principle but has not been collected.

We further formalize the framework as a discrete evidence-accretion system in which observation sets expand and the admissibility map carries observation sets to surviving cause sets. As evidence accretes, the eliminated set is monotone non-decreasing: once a cause is refuted it is never re-admitted (elimination monotonicity). A singleton surviving set corresponds to single-cause attribution; a non-singleton surviving set corresponds to a non-unique multi-cause outcome; and a cause held outside both the surviving and eliminated sets corresponds to suspended attribution, with a named differentiating-evidence pathway to resolution.

A worked forensic engineering case study involving CMU basement-wall inward displacement demonstrates the framework across eight enumerated candidate causes and yields a two-cause non-unique attribution with one suspended cause and explicit differentiating-evidence pathways to single-cause outcomes.

The result is a practically usable, adversarially defensible eliminative methodology together with a lightweight set-theoretic formalization that clarifies convergence, stability under further evidence, and the role of differentiating observations, without overstating the structure as more than the order theory of evidence accretion.

Keywords: eliminative inference, forensic engineering, causal admissibility, evidentiary sufficiency, monotone reasoning, evidence accretion, refutation versus evidence gap, adversarial defensibility.

Suggested classifications: cs.LO (primary); math.LO, stat.AP (cross-list candidates).

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1 Note on Terminology and Scope

This framework is a forensic-engineering methodology stated in the language of formal logic and elementary set theory. The primary application is single-event forensic engineering evaluations, with broader forensic-causal relevance arising from the eliminative structure rather than domain-specific mechanics. The six questions are predicates: each takes an observation set and a mechanism specification and returns a truth value. The conjunction of the governing predicates yields an admissibility verdict for each candidate cause.

The framework is eliminative. It does not select or construct a preferred cause; it removes candidates that cannot survive contact with the evidence and reports what remains. Where more than one candidate survives, the framework requires that they be distinguished by differentiating evidence rather than by narrative preference. Where a candidate is neither supported nor refuted, the framework holds it in suspension and names the evidence that would resolve it.

2 Core Principle

Causation is not proven. Causation survives elimination.

This principle aligns with falsification-based scientific reasoning, where hypotheses are not proven but survive attempts at refutation (Popper, 1963; Popper, 1959). It further reflects the distinction between inductive inference and eliminative reasoning identified in epistemology (Hume, 1748; Haack, 2009).

This distinction is not rhetorical. It defines the entire structure of the framework:

- Causes are removed when refuted by the observed conditions.
- No single reasoning question independently admits a cause.
- Admissibility is defined as survival under all governing conditions.
- A cause that has not been eliminated is admissible, not confirmed.

The framework does not select causes. It removes inadmissible causes until only supported candidates remain. Where multiple candidates survive, non-uniqueness constrains attribution. Where a candidate cannot be evaluated, attribution is suspended pending additional evidence or cause enumeration.

3 Why Elimination

When confronted with a failure, engineers naturally construct a causal path. A sequence of events is assembled that connects the proposed cause to the observed outcome in a way that feels logically complete. This is the dominant instinct in forensic analysis: build a chain, follow it forward, arrive at a conclusion. The chain feels like reasoning because it is organized, sequential, and ends somewhere definite.

But this approach contains a concealed risk. The mind that constructs the path also selects which path to construct. The path is not discovered, it is assembled. And once assembled, it is difficult to discard, because discarding it means admitting that the organizing structure of the entire analysis was chosen, not found.

This framework takes a different starting position. Rather than constructing a path toward a conclusion, it begins with all enumerated causes and asks which ones cannot survive contact with the observed evidence. Causation is not established by the path that is built. It is established by the causes that remain standing after all others have been removed.

3.1 Why Elimination Rather Than Construction

The alternative to path-building is constraint-based elimination. Instead of assembling a forward chain from cause to effect, the analyst identifies the conditions that any cause would have to satisfy in order to remain admissible, and then tests each proposed cause against those conditions.

This is not simply a different technique. It is a different epistemological posture. This posture is consistent with constraint-based and eliminative models of causal inference, where admissibility is governed by compatibility with observed evidence rather than narrative construction (Pearl, 2009; Dawid, 2000; Spirtes, Glymour, & Scheines, 2000; Halpern, 2016). In historical sciences, including forensic engineering, conclusions are derived from surviving hypotheses rather than controlled experimentation, further reinforcing the primacy of elimination over construction (Cleland, 2002). Eliminative inference has a long history in evidential reasoning more generally, where it is treated as a structured procedure for narrowing the space of admissible explanations rather than constructing a single preferred one (Schum, 1994; Anderson, Schum, & Twining, 2005). The path-building approach asks: what story connects this cause to this outcome? The elimination approach asks: what conditions would make this cause impossible, and are any of those conditions met?

The elimination approach is more defensible under adversarial interpretation because it does not depend on the selection of a particular narrative. It depends only on the logical relationship between observations, mechanisms, and constraints. A cause that survives all elimination conditions is admissible not because a story was told about it, but because no available evidence ruled it out.

3.2 Reasoning Questions

A reasoning question is a repeating pattern of evaluation applied to test whether a cause can be ruled out. The framework defines six. They divide into three logical roles:

- **Elimination-governing (refuting):** Sufficiency, Exclusion, Constraint. Each, if it fails, both blocks admission and eliminates the cause. Failure is an affirmative finding of incompatibility.
- **Admission-necessary, non-eliminating:** Necessity. It must hold for a cause to be admissible, but its failure produces an evidentiary gap rather than a refutation.
- **Non-governing:** Consistency and Non-Uniqueness. They characterize the surviving set without independently removing candidates.

This classification is developed formally in Section 6.5. The questions are predicates evaluated against a fixed observation set; their combination yields one of three dispositions for each cause (admissible, eliminated, suspended).

3.3 The Constrained Space

Admissibility exists within a bounded space defined by observation, mechanism, and constraint. This space is not infinite; it is defined by what has been observed, what is physically possible, and what temporal and spatial boundaries permit. The framework operates within this constrained space. It does not claim to establish truth in an absolute sense. It claims to identify which causes remain standing within the space of available evidence and known physical limits.

This is not a limitation of the framework. It is a definition of its proper scope. Forensic evaluation operates always within constrained spaces; the framework simply makes this constraint explicit.

4 Formal Structure of the Admissibility System

This section gives the elementary set-theoretic structure of the framework. It adds nothing to the operational content of Sections 4–14; it states precisely what the questions compute and how the result behaves as evidence accretes. It requires nothing beyond elementary set theory.

4.1 Observation and Cause Sets

Let Ω denote the universe of observations available, in principle, to the evaluation of a given case, and let $\mathcal{C}$ denote the enumerated set of candidate causes, with $|\mathcal{C}| = n$ and $n \in \{2, \dots, 8\}$ per the cardinality bound of Section 5. An observation set $O \subseteq \Omega$ is the set of observations collected and locked at a given evaluation step.

4.2 The Admissibility Map

For each cause C , the governing predicates of Section 6.3 determine admissibility under O :

$$\text{Adm}_O(C) \iff \text{Ind}(C, O) \wedge \text{Cap}(M, O) \wedge \neg \text{Contra}(O, C) \wedge \neg \text{Viol}(C).$$

The admissibility map $A : 2^\Omega \rightarrow 2^\mathcal{C}$ returns the surviving causes under a given observation set:

$$A(O) = \{ C \in \mathcal{C} : \text{Adm}_O(C) \}.$$

This is an ordinary set-valued function: it takes the evidence collected so far and returns the causes that survive the governing questions under that evidence.

4.3 Evidence Accretion

Forensic evaluation collects evidence over time. Observations are added, never retracted: $O_0 \subseteq O_1 \subseteq O_2 \subseteq \dots$. Evidence accretion refers to re-executed evaluations over time, whereas each individual evaluation uses a single locked observation set. At each step the surviving set $A(O_t)$ is recomputed. The order in which evidence is collected is, in general, the practitioner’s choice; the framework constrains what counts as admissible evidence but not the order of collection.

4.4 Elimination Monotonicity

Define the refutation predicate and the eliminated set under observation set O :

$$\text{Refuted}_O(C) \iff \neg \text{Cap}(M, O) \vee \text{Contra}(O, C) \vee \text{Viol}(C), \quad E(O) = \{ C \in \mathcal{C} : \text{Refuted}_O(C) \}.$$

Theorem 4.1 (Elimination Monotonicity). *For $O_1 \subseteq O_2$, $E(O_1) \subseteq E(O_2)$. Equivalently, the surviving set $S(O) = \mathcal{C} \setminus E(O)$ satisfies $S(O_2) \subseteq S(O_1)$. Once a cause is eliminated, no expansion of the observation set re-admits it.*

Proof. Each refuting condition is monotone non-decreasing in O : each, once true, stays true as observations are added and never retracted. If M cannot produce some observation in O_1 , it still cannot under $O_2 \supseteq O_1$; if an observation in O_1 contradicts $E(C)$, it still contradicts under O_2 ; if a constraint violation is established by O_1 , it remains established under O_2 . Hence $\text{Refuted}_{O_1}(C) \Rightarrow \text{Refuted}_{O_2}(C)$, so $E(O_1) \subseteq E(O_2)$, and taking complements gives $S(O_2) \subseteq S(O_1)$. $\square$

Why the guarantee is stated on E , not on the admissible set. The Necessity predicate $\text{Ind}(C, O)$ is monotone increasing: collecting a previously untested required indicator can change Ind from false to true, moving a cause from suspended to admissible. The admissible set $A(O)$ can therefore grow as gaps close, so it is not anti-monotone. What is monotone is the eliminated set $E(O)$, which only grows. The guarantee that forensic practice relies upon is that no eliminated cause is ever revived. The admissible set restricted to causes that are never suspended is anti-monotone as a special case, but the general guarantee is stated on E .

4.5 Three Terminal Dispositions

Every candidate resolves, under a given O , into exactly one of three states (Sections 6.2, 6.5):

- **Eliminated:** $\text{Refuted}_O(C)$ holds. Absorbing under evidence accretion (Theorem 4.1).
- **Admissible:** not refuted and fully supported, $\neg \text{Refuted}_O(C) \wedge \text{Ind}(C, O)$.
- **Suspended:** not refuted and not fully supported, $\neg \text{Refuted}_O(C) \wedge \neg \text{Ind}(C, O)$. A required indicator is untested; the cause is held pending its collection.

These three states are mutually exclusive and exhaustive, and they follow directly from the predicates with no procedural exception (Section 6.5).

4.6 Forced versus Evidence-Dependent Outcomes

From an initial observation set O_0 , different admissible evidence-collection choices can lead to different surviving sets. Let $R(O_0)$ denote the set of terminal surviving sets reachable from O_0 by collecting available evidence.

- If $R(O_0)$ is a singleton, the outcome is **forced**: no choice of which evidence to collect next changes the conclusion.
- If $|R(O_0)| > 1$, the outcome is **evidence-dependent**: the conclusion the practitioner reaches depends on which differentiating evidence is collected.

This distinction is the one structural notion the formalization contributes beyond the question-level account. It gives a precise meaning to the practitioner’s question “what additional investigation would change the conclusion?”, namely the differentiating evidence that separates the elements of $R(O_0)$ (Section 8.5). The case study of Section 18 is an evidence-dependent outcome: a two-cause surviving set with named single observations that would each force resolution to a single cause.

4.7 What the Formalization Is and Is Not

This formalization is the order theory of evidence accretion and nothing more. It states (i) what the questions compute (the admissibility map), (ii) how the result behaves under added evidence (elimination monotonicity), and (iii) when a conclusion is forced versus evidence-dependent. It is not a claim that the questions are anything other than logical predicates. A practitioner applying the framework needs only Sections 4–14; this section serves readers who want the formal guarantees stated explicitly.

5 Scope and System Classification

5.1 Framework Purpose

The framework provides a structured method for:

1. Enumerating all plausible causes for an observed condition
2. Testing each cause against fixed observation sets using explicit elimination criteria
3. Determining which causes are admissible (not eliminated) given available evidence
4. Resolving non-uniqueness when multiple causes remain admissible
5. Documenting elimination logic for adversarial review
6. Composing primitive reasoning questions into scalable higher-order forensic logic structures

5.2 System Classification

The framework applies to evaluations where:

- The causal hypothesis is enumerable (a discrete set of 2–8 candidate causes)
- Mechanisms can be modeled as discrete cause $\rightarrow$ mechanism $\rightarrow$ indicator chains
- Observed indicators are fixed before evaluation begins. “Fixed” means only that the set of actually observed indicators is closed; unobserved required indicators remain evidentiary gaps rather than negative findings.
- A single dominant mechanism (or a small enumerated set) is at issue, rather than densely coupled multi-factor causation

5.3 Domain Restriction

This framework is optimized for forensic engineering evaluations of single-event claims (wind damage, water intrusion, settlement, material failure) where the task is to determine whether observed conditions are attributable to the reported incident or to alternative mechanisms.

Applications beyond these constraints (complex multi-factor causation, systems with feedback loops, epidemic or cascade phenomena) require extended framework development not covered here.

5.4 Evidence Lock Requirement

Before evaluation begins, the observation set O must be finalized and locked. No observations may be added, removed, or modified during evaluation. This enforces evidence monotonicity (Section 14) and prevents bias-driven evidence curation.

If new observations are discovered after evaluation, the entire evaluation must be re-executed with the expanded observation set.

5.5 Interpretive Constraints

- Observations are treated as physical facts, not interpretations.
- Mechanism definitions are treated as fixed specifications, not flexible narratives.
- Indicator requirements are necessary conditions for support, not sufficient conditions for admission.
- Absence of a recorded indicator is, by default, an evidentiary gap (a Necessity failure), not affirmative evidence of absence; it refutes a cause only when a question independently establishes incompatibility.

6 Foundational Elements

6.1 Primitive Definitions

Observation (O): A documented, directly measured or photographed physical condition at the time of inspection. Examples: “CMU foundation wall displaced inward 2 inches below the diaphragm connection,” “Horizontal fracture between the seventh and eighth CMU courses,” “Sealant present at prior crack repair locations,” “Floor system level within one-quarter inch.”

Cause (C): A proposed mechanism or event that, if it occurred, could produce the observed conditions. Examples: “Long-term lateral soil pressure with intermittent hydrostatic loading,” “Acute hydrostatic loading from a discrete storm event,” “Foundation settlement,” “Mine subsidence.”

Mechanism (M): The physical process by which a cause produces effects. A mechanism specifies expected indicators if the cause occurred. Example: “Sustained lateral earth pressure on a below-grade CMU wall produces inward bowing concentrated at mid-height, horizontal fracture along bed joints, and stair-step cracking propagating from fracture endpoints.”

Expected Indicator Set $E(C)$: The complete set of physical indicators that would be observable if cause C had occurred.

Required Indicator Subset $I_N(C)$: The minimal set of indicators that must be present for cause C to be supported. $I_N(C) \subset E(C)$.

Admissibility: A cause C is admissible if it has not been refuted by any governing question and its required indicators are present. Admissibility is not confirmation; it is the absence of ruling-out evidence together with the presence of required support.

6.2 Evaluation States

For each cause C under evaluation:

- **Admissible:** Cause C is not refuted, and its required indicators are present.
- **Eliminated:** Cause C is refuted by at least one governing question (Sufficiency, Exclusion, or Constraint).
- **Suspended:** Cause C is not refuted, but at least one required indicator is untested (an evidentiary gap). Non-uniqueness is a property of the surviving set, not an additional per-cause disposition.
- **Non-unique:** Two or more causes are simultaneously admissible, and no differentiating observation has been collected to distinguish them.

6.3 Notation and Predicates

Governing Predicates (used in the admissibility determination):

- $\text{Ind}(C, O)$: All required indicators for C are present in O . (Necessity) Admission-necessary; non-eliminating.
- $\text{Cap}(M, O)$: Mechanism M is physically capable of producing all observations in O . (Sufficiency) Elimination-governing.
- $\neg \text{Contra}(O, C)$: Observations O do not contradict expected outcomes $E(C)$. (Exclusion) Elimination-governing.
- $\neg \text{Viol}(C)$: No temporal, spatial, or physical constraint is violated by C . (Constraint) Elimination-governing.

Admissibility Predicate:

$$\text{Adm}(C) \iff \text{Ind}(C, O) \wedge \text{Cap}(M, O) \wedge \neg \text{Contra}(O, C) \wedge \neg \text{Viol}(C)$$

A cause is admissible only if supported and unrefuted.

Refutation Predicate (drives elimination; Necessity is deliberately excluded):

$$\text{Refuted}(C) \iff \neg \text{Cap}(M, O) \vee \text{Contra}(O, C) \vee \text{Viol}(C)$$

Disposition: ELIMINATED if $\text{Refuted}(C)$; else ADMISSIBLE if $\text{Ind}(C, O)$; else SUSPENDED.

6.4 Compositional Structure of the Questions

The six questions are primitive local tests that compose into larger forensic-logic structures. At the local scale, each question evaluates a specific condition for a single cause:

- Necessity
- Sufficiency
- Exclusion
- Consistency
- Non-Uniqueness
- Constraint

At the global scale, the questions combine into the admissibility predicate, the attribution conditions (Section 9), and report-scale forensic reasoning. The composition is ordinary logical conjunction together with the set-valued admissibility map of Section 3; it is a compositional logical architecture, stated without metaphor. This structure permits scalability and formal extension while preserving monotonic elimination.

Accordingly:

- Primitive question $\rightarrow$ local admissibility test
- Conjunction of the governing predicates $\rightarrow$ global admissibility predicate
- Admissibility predicate $\rightarrow$ report-scale forensic architecture

6.5 The Role of Necessity: Admission-Necessary but Non-Eliminating

This subsection states the central logical point of the framework: Necessity is necessary for admission but does not govern elimination. Necessity is a conjunct of $\text{Adm}(C)$ because it governs admission, but it is deliberately excluded from $\text{Refuted}(C)$ because it does not govern elimination.

Why Necessity is treated separately. $\text{Ind}(C, O) \iff \forall i \in I_N(C) : i \in O$ is an epistemic statement about what the record contains, not an ontic statement about the world. A required indicator can be absent from O for two structurally different reasons:

- **Refutation.** The inspection examined the relevant condition and the required indicator is affirmatively incompatible with what was found. This is a genuine ground for elimination, but it is captured by the Exclusion question (an observation contradicts $E(C)$) or by Sufficiency (the mechanism cannot produce the observed pattern), not by Necessity. Refutation is an affirmative finding about the world.

- **Evidence gap.** The inspection did not test for the indicator. The record is silent. This is a statement about the inspection, not the mechanism, and it cannot ground elimination: “absence of evidence is not evidence of absence.”

A bare failure of Ind does not, by itself, distinguish these. Necessity failure alone therefore must not eliminate.

The question roles. The questions divide into two logical roles:

- **Elimination-governing (refuting):** Sufficiency, Exclusion, Constraint. Each, if it fails, both blocks admission and eliminates the cause. Failure is an affirmative finding of incompatibility.
- **Admission-necessary, non-eliminating:** Necessity. It must hold for a cause to be admissible, but its failure produces an evidentiary gap rather than a refutation.

The three reporting dispositions then follow directly from the predicates, with no procedural rule:

$$\text{disposition}(C) = \begin{cases} \text{ELIMINATED} & \text{if Refuted}(C), \\ \text{ADMISSIBLE} & \text{else if Ind}(C, O), \\ \text{SUSPENDED} & \text{otherwise.} \end{cases}$$

These three cases are mutually exclusive and exhaustive. ELIMINATED is checked first and is absorbing (Theorem 4.1). If a cause is not refuted, it is ADMISSIBLE when fully supported and SUSPENDED when a required indicator is merely untested. No separate “Necessity does not eliminate” rule is needed: it is a consequence of Refuted not containing Ind.

On the name “Necessity.” The question tests whether the required supporting indicators are present in the record. It is “necessary” in the sense that its satisfaction is necessary for admission, not in the sense of a logically necessary condition whose absence refutes. Readers from formal logic should read “Necessity” as required-indicator support, distinct from refutation. The practitioner-facing name is retained for continuity.

These dispositions are applied without exception throughout the case study of Section 18, as verified cause by cause in Section 18.12.

OPERATIONAL FRAMEWORK

7 Field Execution Flow

Question evaluation follows a fixed sequence of six steps:

Step 1: Evidence Lock

- Document all observations from field inspection.
- Compile historical imagery, prior inspections, or documents.
- Finalize the observation set O .
- Lock the observation set. No further evidence collection or modification permitted during evaluation.

Step 2: Pre-Evaluation Screening (Depth Control)

- Identify all plausible causes given the reported event and observed conditions.
- Limit enumeration to 3–8 causes; excessive enumeration reduces analytical depth.
- Classify causes into categories (reportable event, alternative mechanisms, pre-event conditions).

Step 3: Cause Enumeration

- Develop explicit mechanism descriptions for each enumerated cause.
- Define the required indicator set $I_N(C)$ for each cause.
- Define expected outcomes $E(C)$ for each cause.
- Document mechanism specifications before evaluation.

Step 4: Question Evaluation

- Apply the questions (Sections 8.1–8.6) to each cause in the sequence 1, 2, 3, 6.
- Document which question refutes each eliminated cause.
- Mark each cause admissible, eliminated, or suspended.
- Do not re-evaluate eliminated causes.

Step 5: Non-Uniqueness Check

- If one cause is admissible and all others are eliminated: proceed to conclusion formation.
- If multiple causes are admissible: apply differentiating evidence protocol (Section 8.5).
- If no differentiating evidence exists: multi-cause attribution (Section 10).

Step 6: Conclusion Formation

- Translate dispositions into report language (Section 10).
- Generate locked conclusions.
- Document the question-evaluation record for the report Discussion section.

8 The Six Questions

8.1 Question 1: Necessity (Required Indicator Test)

Definition: A cause C satisfies Necessity if all required indicators in $I_N(C)$ are present in the observation set O .

Formal Predicate:

$$\text{Ind}(C, O) \iff \forall i \in I_N(C) : i \in O$$

Role: Admission-necessary, non-eliminating.

Evaluation Rule:

- If all required indicators are present: $\text{Ind}(C, O)$ holds. Necessity is satisfied and contributes toward admissibility.

- If any required indicator is absent: $\text{Ind}(C, O)$ fails. Cause C is not eliminated on that ground; the failure is an evidentiary gap. The cause is eliminated only if an elimination-governing question (Sufficiency, Exclusion, or Constraint) independently refutes it; otherwise it is suspended. See Section 6.5.

Interpretation: Necessity asks: “Are the required supporting indicators present in the record?” It does not ask whether the mechanism is sufficient, nor whether anything contradicts it. Its failure removes support but does not, by itself, rule the cause out.

Field Example (Storm-Event CMU Foundation Damage):

Cause: Acute storm-event hydrostatic loading on March 30, 2026.

Required Indicators $I_N(C)$:

- Fresh fracture surfaces with bright, unweathered appearance
- Sudden onset of inward displacement coincident with the reported event
- Documented precipitation event of sufficient magnitude in the local area on or around the reported date
- Absence of evidence of prior cracking at the same locations

Observed Condition: Sealant material is present at mortar separation locations on the south CMU foundation wall, indicating prior repair activity. The crack at the kitchen backsplash exhibits a darkened and soiled appearance. NOAA Local Storm Reports register no precipitation event in the county during the reported period.

Necessity Evaluation: Required indicator “fresh fracture surfaces” is not present; required indicator “absence of prior cracking” is contradicted by the prior-repair sealant; required indicator “documented precipitation event” is contradicted by the NOAA record. $I_N(C)$ is not satisfied. Necessity is not satisfied. (The disposition of this cause is settled by the refuting questions that follow, not by Necessity.)

8.2 Question 2: Sufficiency (Capability Test)

Definition: A cause C satisfies Sufficiency if the associated mechanism M is physically capable of producing all observations in O .

Formal Predicate:

$$\text{Cap}(M, O) \iff \forall o \in O : M \text{ can produce } o$$

Role: Elimination-governing.

Evaluation Rule:

- If mechanism M is capable of producing all observations in O : $\text{Cap}(M, O)$ holds. Sufficiency is satisfied.
- If mechanism M cannot produce at least one observation in O : $\text{Cap}(M, O)$ fails. Cause C is eliminated.

Interpretation: Sufficiency asks: “Is this mechanism physically capable of producing all the conditions we observe?” It is purely a capability assessment; it does not test whether the mechanism would produce these specific conditions, only whether it could. Sufficiency is eliminative. If a mechanism cannot physically produce an observed condition, the cause is ruled out.

Field Example (Foundation Settlement at CMU Basement):

Cause: Foundation settlement (vertical bearing failure or soil consolidation).

Mechanism: Loss of vertical support beneath the footing produces downward displacement of the foundation, propagating into the supported floor system as differential vertical movement, misalignment of structural elements, and offsets at supported connections.

Expected Observations if M occurred:

- Differential vertical movement of the supported floor system, measurable as out-of-level conditions
- Misalignment of foundation-supported structural elements
- Vertical displacement of foundation-supported components
- Disconnection or vertical offset between the top of the foundation wall and the floor diaphragm it supports

Actual Observations:

- Floor system levelness measured within one-quarter inch across all accessible locations (no differential vertical movement)
- Top of CMU foundation wall remains connected to the first-floor diaphragm
- No misalignment of foundation-supported structural elements
- Inward (horizontal) displacement of below-grade walls without corresponding vertical movement

Sufficiency Evaluation: Mechanism M (foundation settlement) is not capable of producing horizontal inward displacement of below-grade walls while simultaneously producing none of its required differential-vertical-movement indicators. $\text{Cap}(M, O)$ fails. Cause is eliminated by Sufficiency.

8.3 Question 3: Exclusion (Contradiction Test)

Definition: A cause C satisfies Exclusion if no observation in O actively contradicts the expected outcomes $E(C)$.

Formal Predicate:

$$\neg \text{Contra}(O, C) \iff \nexists o \in O : o \text{ contradicts } E(C)$$

Role: Elimination-governing.

Evaluation Rule:

- If no observation contradicts $E(C)$: $\neg \text{Contra}(O, C)$ holds. Exclusion is satisfied.
- If at least one observation contradicts $E(C)$: $\text{Contra}(O, C)$ holds. Cause C is eliminated.

Interpretation: Exclusion asks: “Is there direct evidence that rules this cause out?” It is the most direct form of falsification. Unlike Sufficiency, which tests capability, Exclusion tests whether observations actively contradict the expected pattern. An affirmatively absent required indicator, examined and found incompatible, is an Exclusion failure; this is how “refutation by absence” enters the framework as elimination rather than as a Necessity matter. Exclusion is eliminative. If an observation directly contradicts the expected outcomes of a cause, the cause is ruled out.

Example (Storm-Event vs. Long-Term Lateral Loading on CMU Wall):

Cause A: CMU foundation wall inward displacement caused by the reported storm event of March 30, 2026.

Expected Outcomes $E(C_A)$:

- Fresh fracture surfaces with bright, unweathered appearance at new cracks

- Sudden onset of displacement temporally coincident with the reported event
- Absence of prior repair activity at the affected crack locations
- Documented precipitation event of sufficient magnitude in the local area on the reported date

Cause B: CMU foundation wall inward displacement caused by long-term lateral soil pressure with intermittent hydrostatic loading.

Expected Outcomes $E(C_B)$:

- Inward displacement at mid-height of long-span basement walls under sustained lateral load
- Horizontal fracture along bed joints with stair-step propagation at termini
- Aged appearance of cracks and possible evidence of prior repair activity at older crack locations
- No requirement for a single discrete triggering event

Observed Condition:

- Sealant material present at mortar separation locations on the south CMU foundation wall, consistent with prior repair activity
- Kitchen backsplash crack exhibits a darkened and soiled appearance, indicating it has been present for a period of time
- NOAA Local Storm Reports register no precipitation event in the county during the reported period
- Bilateral inward displacement at both north and south walls with horizontal fracture between the seventh and eighth CMU courses

Exclusion Evaluation for Cause A (Storm Event): The observation of sealant from prior repair activity directly contradicts $E(C_A)$, which expects “absence of prior cracking” at affected locations. The aged appearance of the kitchen backsplash crack contradicts $E(C_A)$ ’s requirement for “sudden onset.” The NOAA record contradicts $E(C_A)$ ’s requirement for a “documented precipitation event.” $\text{Contra}(O, C_A)$ holds. Cause A is eliminated by Exclusion.

Exclusion Evaluation for Cause B (Long-Term Lateral Loading): Observations are consistent with $E(C_B)$. No contradiction. $\neg \text{Contra}(O, C_B)$ holds. Cause B is not eliminated by Exclusion.

8.4 Question 4: Consistency (Compatibility Assessment)

Note: Consistency is included in the framework but does not appear in the governing admissibility predicate (Section 6.3). It serves as a pattern-compatibility filter for non-governing assessment. See Section 13 for the role of consistency vs. admissibility.

Definition: A cause C is consistent with observations if O and $E(C)$ exhibit pattern similarity or compatibility, even if some observations are not fully explained.

Interpretation: Consistency is non-governing. It generates plausibility ($\text{Plaus}(C)$) but does not affect admissibility. A cause can be admissible (not refuted, supported) but not consistent (low pattern match). Conversely, a cause can be highly consistent (pattern-matching) but not admissible (fails Sufficiency or Exclusion).

8.5 Question 5: Non-Uniqueness (Differentiation Requirement)

Definition: If two or more causes are admissible under the current observation set, non-uniqueness applies. The evaluation does not immediately suspend; instead, a differentiating evidence protocol is applied.

Formal Condition:

$$\exists C_i, C_j : \text{Adm}(C_i) \wedge \text{Adm}(C_j) \wedge (C_i \neq C_j)$$

Differentiation Protocol:

1. **Identify differentiating evidence:** Search the observation set O for any observation O_d that would eliminate one cause but not the other.
2. **If differentiating evidence exists:** Verify that O_d is present and documented. Apply it to eliminate one cause, leaving a single admissible cause.
3. **If no differentiating evidence exists in O :** Determine whether differentiating evidence exists but was not collected (evidence gap). Document the gap.
4. **If evidence gap exists:** Suspension protocol (Section 11.3) is invoked. Evaluation is suspended pending collection of the missing evidence.
5. **If no differentiating evidence exists or is obtainable:** Multi-cause attribution (Section 10) is invoked.

Field Example (Lateral-Soil Loading vs. Mine Subsidence):

Scenario: Both LATERAL-SOIL-PRESSURE and MINE-SUBSIDENCE mechanisms are admissible based on a partial observation set in which differential vertical movement of the supported floor diaphragm has not yet been measured.

Differentiating Observation: Floor-system levelness survey using a self-leveling laser level across all accessible locations of the supported diaphragm.

If the survey shows variation greater than approximately one-quarter inch across the structure footprint: Lateral soil pressure (which does not produce differential vertical movement) is eliminated; mine subsidence becomes uniquely admissible pending screening of mine workings.

If the survey shows the floor system within approximately one-quarter inch of level: Mine subsidence (which requires broad-area vertical settlement) is eliminated; lateral soil pressure becomes uniquely admissible.

If the survey is not performed or its results are not documented: Non-uniqueness persists. Multi-cause attribution language is used in conclusions, or the evaluation is suspended pending collection of the missing measurement.

8.6 Question 6: Constraint (Boundary Condition Test)

Definition: A cause C satisfies Constraint if no temporal, spatial, or physical constraints are violated by the mechanism's operation.

Formal Predicate:

$$\neg \text{Viol}(C) \iff \neg [\text{Viol}_T(C) \vee \text{Viol}_S(C) \vee \text{Viol}_P(C)]$$

Role: Elimination-governing.

Where:

- $\text{Viol}_T(C)$: Temporal constraint violated (mechanism operates outside allowable time window)
- $\text{Viol}_S(C)$: Spatial constraint violated (mechanism cannot operate at observed location)
- $\text{Viol}_P(C)$: Physical constraint violated (mechanism violates material limits, energy conservation, etc.)

Evaluation Rules:*Temporal Constraint Violation:*

- Mechanism requires duration D (e.g., 6 months for progressive deterioration)
- Time window between alleged event and observation is T (e.g., 34 days)
- If $T < D$: $\text{Viol}_T(C)$ holds. Cause is eliminated.
- If $T \geq D$: $\text{Viol}_T(C)$ does not hold.

Spatial Constraint Violation:

- Mechanism's physical extent is E (e.g., wind vortex with 50 ft diameter)
- Distance from alleged mechanism location to damage location is D
- If $D > E$: $\text{Viol}_S(C)$ holds. Cause is eliminated.
- If $D \leq E$: $\text{Viol}_S(C)$ does not hold.

Physical Constraint Violation:

- Mechanism produces energy output E_m (e.g., kinetic energy of 50 mph wind)
- Observed damage requires energy E_d (e.g., kinetic energy of 70 mph wind)
- If $E_m < E_d$: $\text{Viol}_P(C)$ holds. Cause is eliminated.
- If $E_m \geq E_d$: $\text{Viol}_P(C)$ does not hold.

Field Example (Pre-Event vs. Event Causation at CMU Foundation):

Cause: Inward displacement of the CMU foundation walls was caused by the reported storm event of March 30, 2026.

Temporal Constraint: Sealant material is observed at mortar separation locations on the south CMU foundation wall, indicating that crack repair activity occurred prior to the reported event. The current property occupant has resided at the property for approximately three years and reports performing no foundation-related repairs during that period; the sealant therefore predates the three-year occupancy interval. The kitchen backsplash crack exhibits a darkened and soiled appearance consistent with an extended period of presence.

Temporal Window: Prior repair activity predates the March 30, 2026 event by no less than three years.

Constraint Evaluation: Physical evidence (sealant from prior repairs, aged crack appearance) demonstrates that portions of the observed cracking predate the reported event by several years. The mechanism (a single-event response) cannot operate retroactively. $\text{Viol}_T(C)$ holds. Cause is eliminated by Constraint.

9 Global Admissibility and Attribution

9.1 System Identity

The admissibility system is deterministic: given a fixed observation set O and a fixed set of candidate causes, the dispositions are unique and reproducible. Different evaluators applying the same questions to the same observations and mechanisms will arrive at the same conclusions.

9.2 Global Admissibility Predicate

A cause C is admissible if and only if it is supported and unrefuted:

$$\text{Adm}(C) \iff \text{Ind}(C, O) \wedge \text{Cap}(M, O) \wedge \neg \text{Contra}(O, C) \wedge \neg \text{Viol}(C)$$

No cause is admissible by partial satisfaction. Failure of any elimination-governing question eliminates; failure of Necessity alone suspends (Section 6.5).

9.3 Multi-Observation Coherence Requirement

Admissibility requires that a cause's mechanism is compatible with all observations in O , not merely a subset.

$$\text{Adm}(C) \Rightarrow \forall o \in O : o \in E(C) \vee o \text{ is compatible with } E(C)$$

A cause cannot achieve admissibility by explaining only a subset of the observation set.

9.4 Question Application Sequence

Questions are applied in the sequence 1, 2, 3, 6:

1. **Necessity:** Establishes whether required indicators are present, and records any gap. Non-eliminating.
2. **Sufficiency:** Tests whether the mechanism is capable of producing the observations. Eliminative.
3. **Exclusion:** Tests whether observations contradict expectations. Eliminative.
4. **Constraint:** Tests whether constraints are violated. Eliminative.

Necessity is evaluated first to record support and identify gaps, but, being non-eliminating, never terminates evaluation on its own; the refuting questions follow. Non-Uniqueness (Question 5) is applied after the governing questions, to determine attribution among survivors, not as an intermediate gate.

9.5 Attribution Conditions

Single-Cause Attribution:

$$\text{Attr}(O, C) \iff \text{Adm}(C) \wedge [\forall C' \neq C : \text{Elim}(C')]$$

One cause is admissible; all others are eliminated. (Suspended causes, if any, are reported separately.)

Multi-Cause Attribution:

$$\text{Attr}(O, \{C_1, \dots, C_n\}) \iff [\forall i : \text{Adm}(C_i)] \wedge [\nexists C' : \text{Adm}(C') \wedge C' \notin \{C_1, \dots, C_n\}]$$

Multiple causes are admissible; no other cause is admissible.

Suspended Attribution: Attribution is suspended when at least one cause is suspended (unrefuted, unsupported), when all enumerated causes are eliminated, or when no cause can be evaluated. Evaluation is deferred pending new evidence or cause re-enumeration.

10 Translation to Report Language

10.1 General Principles

When question evaluation concludes, dispositions are translated into report language. The translations below are templates; specific wording must be adapted to the case facts.

10.2 Single-Cause Attribution Template

When: One cause is admissible; all others are eliminated.

Template: “Vatterott Engineering concludes that the observed conditions [location/system] are attributable to [cause description with mechanism]. [Additional mechanism detail if needed].”

Example: “Vatterott concludes that the inward displacement of the CMU foundation walls, and the associated earth movement, are the result of long-term lateral soil pressure, plus intermittent hydrostatic pressure, rather than the result of an acute storm-event response.”

10.3 Multi-Cause Attribution Template

When: Two or more causes are admissible; no differentiating evidence exists.

Template: “Vatterott concludes that the observed conditions [location/system] are attributable to either [Cause A description] or [Cause B description]. Available evidence does not differentiate between these mechanisms. [Optional: Additional investigation into [specific gap] would be required to distinguish between these causes.]”

Example: “Vatterott concludes that the observed inward displacement of the CMU foundation walls is attributable to either long-term lateral soil pressure with intermittent hydrostatic loading, or to long-term lateral soil pressure combined with corrosion of embedded reinforcement reducing wall flexural capacity. Available evidence does not differentiate between these mechanisms. Additional investigation, including coring of the wall to confirm the presence, condition, and cross-sectional area of any embedded steel, would be required to distinguish between these causes.”

10.4 Suspended Attribution Template

When: All enumerated causes are eliminated, or evidence is insufficient to evaluate any cause.

Template: “Vatterott concludes that the causation of the observed conditions cannot be determined from available evidence. The following information limitations restrict the analysis: [specific gaps]. [Optional: Additional investigation into [specific area] would be required for causation determination.]”

Example: “Vatterott concludes that causation of the observed CMU foundation wall inward displacement cannot be definitively determined. The following information limitations restrict the analysis: no pre-event photographic documentation of the foundation interior is available, and floor-system levelness measurements were not obtained at the time of inspection. Floor levelness measurement using a self-leveling laser level, collection of pre-event documentation, and screening of mine-workings records for the parcel would be required for causation determination.”

10.5 Conditional Attribution Template

When: Cause attribution is conditional on a specific assumption or observation.

Template: “Vatterott concludes that if [condition] is true, the observed conditions are attributable to [cause]. If [condition] is not true, observed conditions are attributable to [alternative cause].”

Example: “Vatterott concludes that if a future floor-levelness survey demonstrates differential vertical movement exceeding one-quarter inch across the structure footprint, mine subsidence cannot be excluded as a contributing mechanism, and the observed conditions would be attributable in part to broad-area ground deformation. If a future floor-levelness survey confirms levelness within one-quarter inch, the observed conditions are attributable to long-term lateral soil pressure with intermittent hydrostatic loading and not to mine subsidence.”

11 Procedural Protocol

11.1 Evaluation Phases

Phase 1: Intake and Evidence Lock

- Document all available observations.
- Lock the observation set O .
- Develop mechanism definitions.

Phase 2: Question Evaluation

- Apply the questions to each enumerated cause.
- Document the disposition (admissible, eliminated, or suspended) for each cause.
- Record the specific question that refutes each eliminated cause.

Phase 3: Attribution and Conclusion Formation

- Determine attribution outcome (single, multi, or suspended).
- Generate locked conclusions.
- Prepare the discussion section with the question-evaluation record.

11.2 Re-Evaluation Protocol

If new observations are discovered after Evidence Lock:

1. Document the new observations.
2. Determine whether they materially affect the evaluation.
3. If material: Execute Phase 2 (Question Evaluation) with the expanded observation set O' .
4. Document which previously admissible causes are now eliminated (if any).
5. Issue a supplemental evaluation document with revised conclusions.

Note: By elimination monotonicity (Section 14), no previously eliminated cause can be revived. New evidence can only eliminate survivors or close gaps, moving a suspended cause to admissible or to eliminated.

11.3 Termination Conditions

Evaluation terminates when:

- One cause is uniquely admissible (single attribution)
- Multiple causes are admissible with no differentiating evidence (multi-cause attribution)

- All causes are eliminated, or none can be evaluated (suspended attribution)
- A re-evaluation protocol is triggered (new evidence discovered)

12 Quick Reference

12.1 Question Evaluation Checklist

For each enumerated cause C :

- ☐ **Necessity:** Are all required indicators in $I_N(C)$ present in O ? (support; non-eliminating)
- ☐ **Sufficiency:** Is mechanism M capable of producing all observations in O ? (refuting)
- ☐ **Exclusion:** Do observations actively contradict $E(C)$? (refuting)
- ☐ **Constraint:** Are temporal/spatial/physical constraints violated? (refuting)

Disposition: ELIMINATED if any refuting question fails; else ADMISSIBLE if Necessity holds; else SUSPENDED.

12.2 Predicates (Quick Form)

$$\text{Adm}(C) \iff \text{Ind} \wedge \text{Cap} \wedge \neg \text{Contra} \wedge \neg \text{Viol}; \quad \text{Refuted}(C) \iff \neg \text{Cap} \vee \text{Contra} \vee \text{Viol}.$$

12.3 Attribution Decision Tree

For each cause: is it Refuted (not Cap, or Contra, or Viol)?

YES -> ELIMINATED.

NO -> is Necessity (Ind) satisfied?

YES -> ADMISSIBLE.

NO -> SUSPENDED.

Across causes:

Exactly one ADMISSIBLE, rest ELIMINATED -> single-cause attribution (9.2).

Two or more ADMISSIBLE, no differentiator -> multi-cause attribution (9.3).

Any cause SUSPENDED / none admissible -> suspended attribution (9.4).

12.4 Typical Evaluation Sequence

1. Lock observations (Section 8.1, Step 1)
2. Enumerate causes (Step 3)
3. For each cause, apply Necessity, Sufficiency, Exclusion, Constraint in order
4. Document the disposition and the refuting question for each cause (cumulative record)
5. Apply non-uniqueness protocol if needed (Section 8.5)
6. Generate conclusion per attribution outcome (Section 10)

12.5 Key Definitions (At-a-Glance)

Term	Definition
Admissible	Cause is not refuted; required indicators present.
Eliminated	Cause is refuted by Sufficiency, Exclusion, or Constraint.
Suspended	Cause is not refuted; a required indicator is untested.
Necessity	Required indicators present in the record. (Admission-necessary; non-eliminating.)
Sufficiency	Mechanism is capable of producing all observations. (Refuting.)
Exclusion	Observations do not contradict expected outcomes. (Refuting.)
Constraint	No temporal/spatial/physical constraints are violated. (Refuting.)
Non-Uniqueness	Multiple causes are simultaneously admissible. (Non-governing.)
Admissibility	A cause is admissible iff it is supported and unrefuted.

VALIDATION & GUARANTEES

13 Critical Rules

The following rules govern all evaluations:

13.1 No Cause Is Admissible Without All Governing Conditions

$\text{Adm}(C)$ requires $\text{Ind}(C, O) \wedge \text{Cap}(M, O) \wedge \neg \text{Contra}(O, C) \wedge \neg \text{Viol}(C)$

Failure of any refuting question eliminates the cause; failure of Necessity alone suspends it.

13.2 No Question Independently Admits a Cause

Passing one question does not admit a cause; admissibility requires all governing conditions jointly. The asymmetry: the three refuting questions (Sufficiency, Exclusion, Constraint) are both admission-necessary and elimination-sufficient, while Necessity is admission-necessary but not elimination-sufficient. Necessity failure routes a cause to SUSPENDED unless a refuting question independently establishes ELIMINATED. See Section 6.5 for the full statement.

13.3 Consistency Is Non-Governing

Consistency (pattern-matching between observations and expected outcomes) generates plausibility but does not contribute to the admissibility predicate. A cause can be highly plausible but inadmissible (if it fails Sufficiency or Exclusion). A cause can be admissible but inconsistent.

13.4 Elimination Is Irreversible Within an Evaluation

Once a cause C is eliminated at any step t in the evaluation sequence, it remains eliminated at every subsequent step $t' > t$. No cause may be reconsidered or re-evaluated within a single evaluation.

13.5 The Observation Set Is Fixed

No observations may be added, removed, or modified during evaluation. The observation set O is locked before evaluation begins and does not change.

13.6 All Observations Must Be Coherent With Admissible Causes

An admissible cause must be compatible with all observations in O , not merely a subset.

14 Monotonicity Guarantees

14.1 Monotonic System Definition

The system is monotone with respect to evidence in the following precise sense: as the observation set expands, the eliminated set only grows, and no eliminated cause is re-admitted. The admissible set is not monotone, because a suspended cause may become admissible when its evidentiary gap closes; the guarantee is therefore stated on elimination, not on admission.

14.2 Elimination Monotonicity Theorem

Theorem: For $O_1 \subseteq O_2$, the eliminated sets satisfy

$$E(O_1) \subseteq E(O_2), \quad E(O) = \{C : \text{Refuted}_O(C)\}, \quad \text{Refuted}_O(C) \iff \neg \text{Cap}(M, O) \vee \text{Contra}(O, C) \vee \text{Viol}(C).$$

No addition of observations to O can revive a previously eliminated cause.

Proof: It suffices to show each refuting condition is monotone non-decreasing in O .

Sufficiency. $\neg \text{Cap}(M, O_1)$ means M cannot produce some $o \in O_1$. Since $O_1 \subseteq O_2$, that $o \in O_2$ also, so $\neg \text{Cap}(M, O_2)$. Adding observations can only raise the capability requirement, never lower it.

Exclusion. $\text{Contra}(O_1, C)$ means some $o \in O_1$ contradicts $E(C)$. That o remains in $O_2 \supseteq O_1$, so $\text{Contra}(O_2, C)$. Observations are not retracted, so contradictions persist.

Constraint. $\text{Viol}(C)$ under O_1 is established by observations and specifications present in O_1 ; those persist in O_2 , so $\text{Viol}(C)$ under O_2 .

Hence $\text{Refuted}_{O_1}(C) \Rightarrow \text{Refuted}_{O_2}(C)$, giving $E(O_1) \subseteq E(O_2)$. ■

14.3 Why Necessity Is Not in the Theorem

Necessity (Ind) is monotone increasing: a previously untested required indicator can be collected and found present, turning Ind from false to true and moving a cause from SUSPENDED to ADMISSIBLE. It therefore does not contribute to the eliminated set and is correctly excluded from Refuted. The admissible set is therefore not anti-monotone — it can grow as gaps close — so the defensible guarantee is elimination monotonicity, stated on E .

14.4 Practical Implications

1. **No cause can be re-admitted:** Once a cause is eliminated in the presence of observation set O , no expansion of O can revive that cause.
2. **Eliminations are stable:** An elimination drawn under a smaller observation set remains valid under any larger set.
3. **Gap closure is one-directional into a decision:** Collecting a missing indicator moves a suspended cause to admissible (indicator present) or to eliminated (a refuting question now fails), never back from eliminated.

14.5 Temporal Monotonicity Enforcement

Within a single evaluation, once a cause is eliminated at step t , it remains eliminated at all subsequent steps $t' > t$. The elimination record is part of the evaluation record and may not be selectively revised.

15 Edge Cases and Resolution Rules

15.1 Cause Is Supported Under Necessity but Fails Sufficiency

Scenario: All required indicators are present, but the mechanism cannot produce all observations.

Resolution: Cause is eliminated by Sufficiency. (Support is not sufficient for admissibility.)

15.2 All Causes Are Eliminated

Scenario: Every enumerated cause is refuted by at least one governing question.

Resolution: Attribution is suspended (Section 10 template). Evaluation is deferred pending new evidence or re-enumeration of causes.

15.3 Required Indicator Is Absent

Scenario: The Necessity test shows $I_N(C)$ is not fully present; at least one required indicator is missing.

Resolution: Necessity is not satisfied. This does not eliminate the cause. If a refuting question (Sufficiency, Exclusion, or Constraint) independently establishes incompatibility, the cause is eliminated; otherwise it is suspended.

Rationale: Absence of evidence is not evidence of absence. The absence of a required indicator may indicate that evidence collection was incomplete, not that the cause is impossible. The disposition is read directly from Refuted and Ind (Section 6.5): refutation by absence is captured by Exclusion or Sufficiency and routes to ELIMINATED; an untested gap routes to SUSPENDED.

15.4 Mechanism Could Produce Observations But Not at This Location/Time

Scenario: Mechanism M is capable of producing observed indicators, but spatial or temporal constraints prevent it from operating at the observed location/time.

Resolution: Cause is eliminated by Constraint. (Capability alone is not sufficient if constraints are violated.)

15.5 Observation Pattern Is Consistent But Sufficiency Is Not Met

Scenario: Observations are pattern-compatible with expected outcomes $E(C)$ (high consistency), but mechanism M is not capable of producing all observations (Sufficiency fails).

Resolution: Cause is eliminated by Sufficiency. (Consistency is non-governing; it does not protect against sufficiency failure.)

15.6 Two Causes Both Survive; No Way to Differentiate

Scenario: Causes C_1 and C_2 are both admissible. Available evidence does not include any observation that would eliminate one but not the other.

Resolution: Multi-cause attribution (Section 10 template). Conclusions acknowledge both causes as

admissible.

Optional: If differentiating evidence exists but was not collected, document the evidence gap. Evaluation may be suspended pending collection (Section 11.3).

15.7 New Evidence Contradicts Observation Lock

Scenario: After evaluation begins, new evidence is discovered that contradicts the locked observation set.

Resolution: Do not revise the locked set. Instead, document the contradiction, re-lock the observation set with explicit notation of the conflicting observation, and re-execute evaluation with the revised O .

16 Synthesis

The framework provides a deterministic method for forensic causal analysis. By eliminating inadmissible causes rather than building paths toward preferred conclusions, the framework enforces evidence-based reasoning and defensibility under adversarial review.

Key characteristics:

1. **Elimination-based:** Causation is not proven; causes are removed until supported candidates remain.
2. **Deterministic:** Given fixed observations and mechanisms, the dispositions are unique and reproducible.
3. **Monotone in elimination:** New evidence cannot revive an eliminated cause; eliminations are stable under evidence expansion.
4. **Transparent:** Dispositions are documented and reproducible; no hidden reasoning steps.
5. **Bounded:** Admissibility is defined narrowly as survival under all governing conditions, not as positive proof.

The framework does not eliminate subjectivity from forensic analysis; mechanism definitions, indicator requirements, and constraint specifications all involve judgment. But it structures that judgment and makes it explicit and testable.

APPENDICES & FORMAL REFERENCE

17 Formal Logic Reference

17.1 Classification of the Questions

Elimination-Governing (refuting) Predicates:

- $\text{Cap}(M, O)$: Sufficiency
- $\neg \text{Contra}(O, C)$: Exclusion
- $\neg \text{Viol}(C)$: Constraint

Admission-Necessary, Non-Eliminating Predicate:

- $\text{Ind}(C, O)$: Necessity (required-indicator support)

Non-Governing Descriptors:

- $O \sim E(C)$: Consistency (pattern-matching) $\rightarrow \text{Plaus}(C)$
- Non-Uniqueness: differentiation among survivors

17.2 Necessity, Formal Expression

$$\text{Ind}(C, O) \equiv \forall i \in I_N(C) : i \in O$$

Role: Admission-necessary; non-eliminating. Failure marks an evidentiary gap (routes to SUSPENDED unless a refuting question independently eliminates the cause).

Interpretation: All required indicators must be present for support. If any required indicator is absent, $\text{Ind}(C, O) = \text{false}$ and the cause is not, on that ground alone, eliminated.

17.3 Sufficiency, Formal Expression

$$\text{Cap}(M, O) \equiv \forall o \in O : M \text{ can produce } o$$

Role: Elimination-governing. If $\text{Cap}(M, O) = \text{false}$, cause C is eliminated.

Interpretation: Mechanism M must be physically capable of producing every observation in O . If M cannot produce at least one observation, the cause is ruled out.

17.4 Exclusion, Formal Expression

$$\neg \text{Contra}(O, C) \equiv \nexists o \in O : o \text{ contradicts } E(C)$$

Role: Elimination-governing. If $\text{Contra}(O, C) = \text{true}$, cause C is eliminated.

Interpretation: No observation in O may actively contradict the expected outcomes $E(C)$. If even one observation contradicts $E(C)$, the cause is ruled out.

17.5 Constraint, Formal Expression

$$\neg \text{Viol}(C) \equiv \neg [\text{Viol}_T(C) \vee \text{Viol}_S(C) \vee \text{Viol}_P(C)]$$

Role: Elimination-governing. If $\text{Viol}(C) = \text{true}$ (any violation type), cause C is eliminated.

Interpretation: No temporal, spatial, or physical constraints may be violated by C . If any constraint is violated, the cause is ruled out.

17.6 Global Admissibility Predicate

$$\text{Adm}(C) \equiv \text{Ind}(C, O) \wedge \text{Cap}(M, O) \wedge \neg \text{Contra}(O, C) \wedge \neg \text{Viol}(C)$$

Interpretation: A cause is admissible if and only if it is supported (Necessity) and unrefuted (Sufficiency, Exclusion, Constraint).

17.7 Refutation Predicate and Disposition

$$\text{Refuted}(C) \equiv \neg \text{Cap}(M, O) \vee \text{Contra}(O, C) \vee \text{Viol}(C)$$

Necessity is deliberately excluded from Refuted. Disposition: ELIMINATED if $\text{Refuted}(C)$; else ADMISSIBLE if $\text{Ind}(C, O)$; else SUSPENDED.

17.8 Multi-Observation Coherence Rule

$$\text{Adm}(C) \Rightarrow \forall o \in O : o \in E(C) \vee o \text{ is compatible with } E(C)$$

Interpretation: Admissibility requires that a cause is compatible with all observations in O , not merely a subset.

17.9 Attribution Conditions

Single-Cause Attribution:

$$\text{Attr}(O, C) \iff \text{Adm}(C) \wedge [\forall C' \neq C : \text{Elim}(C')]$$

Multi-Cause Attribution:

$$\text{Attr}(O, \{C_1, \dots, C_n\}) \iff [\forall i : \text{Adm}(C_i)] \wedge [\nexists C' : \text{Adm}(C') \wedge C' \notin \{C_1, \dots, C_n\}]$$

Suspended Attribution:

$$\exists C : \neg \text{Refuted}(C) \wedge \neg \text{Ind}(C, O) \quad \text{or} \quad [\forall C : \text{Elim}(C)].$$

17.10 Elimination Monotonicity Theorem

Theorem (Elimination Monotonicity):

$$O_1 \subseteq O_2 \Rightarrow E(O_1) \subseteq E(O_2).$$

Proof: Each refuting condition ($\neg \text{Cap}$, Contra , Viol) is monotone non-decreasing in O , because observations are added and never retracted (Section 14). The disjunction Refuted is therefore monotone non-decreasing, so E grows with O . Necessity is monotone increasing and non-refuting, hence excluded from E ; it governs only the admissible/suspended split among survivors. *QED.*

Remark. The guarantee is stated on the eliminated set E rather than on the admissible set Adm . Because Necessity is monotone increasing — closing an evidence gap can move a suspended cause to admissible — Adm is not anti-monotone; the stable, defensible guarantee is therefore elimination monotonicity on E .

17.11 Temporal Monotonicity

$$\text{Elim}_t(C) \Rightarrow \text{Elim}_{t'}(C) \quad \forall t' > t$$

Interpretation: Once a cause is eliminated at evaluation step t , it remains eliminated at all subsequent steps.

17.12 Notation Reference Table

Symbol	Category	Meaning
C	Variable	A proposed cause under evaluation
O	Variable	The set of observed physical indicators (fixed)
M	Variable	Mechanism associated with cause C

Symbol	Category	Meaning
$E(C)$	Function	Expected outcome set if C occurred
$I_N(C)$	Function	Required indicator subset ($I_N(C) \subset E(C)$)
O_d	Variable	Differentiating evidence subset
$A(O)$	Map	Admissibility map; surviving causes under O
$E(O)$	Set	Eliminated set under O
$R(O_0)$	Set	Terminal surviving sets reachable from O_0
$\text{Adm}(C)$	Predicate	Cause C is admissible
$\text{Refuted}(C)$	Predicate	Cause C is refuted (eliminated)
$\text{Elim}(C)$	Predicate	Cause C is eliminated
$\text{Ind}(C, O)$	Governing (support)	Necessity: required indicators present; non-eliminating
$\text{Cap}(M, O)$	Governing (refuting)	Sufficiency: mechanism capable
$\text{Contra}(O, C)$	Governing (refuting)	Exclusion: observation contradicts $E(C)$
$\text{Viol}_T(C)$	Governing (refuting)	Temporal constraint violated
$\text{Viol}_S(C)$	Governing (refuting)	Spatial constraint violated
$\text{Viol}_P(C)$	Governing (refuting)	Physical constraint violated
$\text{Viol}(C)$	Governing (refuting)	Any constraint type violated
$\text{Plaus}(C)$	Non-Governing	Plausibility (pattern-matching)
$O \sim E(C)$	Relation	Compatibility (pattern match)
$\wedge$	Logical	Conjunction (AND)
$\vee$	Logical	Disjunction (OR)
$\neg$	Logical	Negation (NOT)
$\Rightarrow$	Logical	Implication (if...then)
$\iff$	Logical	Equivalence (if and only if)
$\forall$	Quantifier	For all
$\exists$	Quantifier	There exists
$\notin$	Question	Not an element of

18 Case Study Worked Example: CMU Basement Foundation Wall Inward Displacement

18.1 Case Summary

Property: Single-family residence (constructed 1942), [subject property; street address redacted], St. Louis County, Missouri. Wood-framed one-story structure atop a CMU foundation enclosing a basement. Detached garage on lot. **Reported Event:** Storm event on or about March 30, 2026, alleged to have caused earth movement and inward shifting of basement foundation walls. **Inspection:** April 13, 2026 (14 days post-event). **Observed Condition:** Inward displacement of north and south CMU basement walls below the connection to the first-floor diaphragm, with horizontal fractures between the seventh and eighth CMU courses and stair-step cracking at the ends of the horizontal cracks. Crack at kitchen backsplash directly above the north CMU wall. Hairline crack in plaster of an adjacent interior wall. No differential vertical movement of the supported floor system.

18.2 Evidence Lock

Locked Observation Set O:

- North CMU foundation wall displaced inward approximately 2 inches below the connection to the first-floor diaphragm
- South CMU foundation wall displaced inward approximately 1 3/4 inches below the connection to the first-floor diaphragm
- Top of foundation wall remains connected to the first-floor diaphragm at both north and south walls
- Inward displacements present as rotation of wall components about the bottom of the wall (at the floor slab) and the top of the wall (at the wood floor diaphragm), consistent with bending failure near mid-height rather than shearing failure
- Horizontal fractures present between the seventh and eighth CMU courses on both the north and south walls
- Additional horizontal fracture between the eighth and ninth CMU courses on the south wall
- Stair-step cracking present at the ends of the horizontal cracks on both walls
- Sealant material observed at mortar separation locations on the south CMU foundation wall, consistent with prior repair activity
- Crack along the kitchen backsplash directly above the location of the north CMU inward displacement; crack exhibits darkened and soiled appearance
- Hairline crack in plaster of interior wall within four feet of the exterior north wall
- Floor system levelness measured with self-leveling laser level remained within approximately one-quarter inch of variation across all accessible locations
- No measurable horizontal or vertical displacement of the supported floor system observed
- Interior drainage components present: baseboard drain system and sump pump within the basement
- Localized depressed soil elevations present at the foundation perimeter at both north and south wall segments, spanning several square yards each, capable of permitting surface water collection adjacent to the foundation
- Exterior gutters and downspout extensions observed functioning to direct surface water away from the structure at all other locations
- NOAA Local Storm Reports for St. Louis County, Missouri between January 1, 2026 and April 1, 2026 record no rain events within the county; nearest reported events occurred on March 5, 2026 in St. Louis County (rain) and Jefferson County (rain), both more than 20 miles from the property
- No NOAA-recorded precipitation event in St. Louis County on March 30, 2026
- Property age: 84 years at time of inspection (constructed 1942)
- Property occupant resided full-time for approximately 3 years prior to inspection; no related repairs or improvements reported by occupant within that period

- No mortar petrography, soil chemistry sampling, ferrosan / cover meter survey, coring, or piezometer data collected during inspection (relevant to mechanisms requiring chemical or subsurface characterization)

18.3 Cause Enumeration

The candidate causes enumerated below are drawn from the regional mechanism inventory for CMU basement-wall inward displacement in the Cisne/Hoyleton claypan landscape of St. Louis County, Missouri, restricted to mechanisms with at least moderate plausibility for the subject property given its construction era, geology, and reported event. Per Section 5, enumeration is bounded at the mechanism-family level (six to eight discrete causes), with sub-mechanisms folded into the mechanism description. Each cause is assigned a unique mechanism specification and required indicator set before evaluation begins.

Cause 1 (C-1): Long-term lateral soil pressure on below-grade CMU foundation walls, augmented by intermittent hydrostatic pressure from localized water accumulation at the foundation perimeter. *Mechanism M-1:* Sustained earth pressure from retained backfill loads the below-grade walls perpendicular to the wall plane. Localized depressed soil elevations at the foundation perimeter permit episodic surface water collection adjacent to the wall during precipitation, augmenting the sustained lateral pressure with intermittent hydrostatic loading. Combined loading exceeds the flexural capacity of the unreinforced or lightly reinforced CMU wall, producing inward displacement and horizontal fracture below the top-of-wall restraint, with stair-step cracking propagating from the ends of the horizontal fractures into adjacent bed and head joints.

Cause 2 (C-2): Acute structural response to the reported storm event of March 30, 2026. *Mechanism M-2:* A discrete precipitation event on March 30, 2026 produces a sudden hydrostatic pressure increase or earth movement against the CMU foundation walls. The single-event response is expressed as fresh fracture surfaces and abrupt onset of inward displacement temporally coincident with the event.

Cause 3 (C-3): Foundation settlement or vertical bearing failure. *Mechanism M-3:* Loss of vertical support beneath the footing, soil consolidation, or differential bearing capacity causes the foundation to settle vertically. Settlement produces measurable out-of-level conditions in the supported floor diaphragm, misalignment of structural elements, and vertical displacement of foundation-supported components.

Cause 4 (C-4): Mine subsidence (sag-trough or pit-type) associated with abandoned coal workings beneath St. Louis County. *Mechanism M-4:* Failure of underlying mine pillars or roof produces broad-area ground deformation. Sag-trough subsidence imposes horizontal ground strains transmitted through soil and backfill into the foundation; pit-type subsidence locally undermines a portion of the footing. Either form produces system-wide differential movement: arc-correlated ground cracks in the yard or pavement, differential settlement of one corner relative to others, out-of-level conditions in the supported floor system, and damage distributed across multiple structural elements rather than concentrated at the below-grade walls.

Cause 5 (C-5): Smectitic clay swell pressure from the Cisne/Hoyleton claypan backfill. *Mechanism M-5:* Wet-dry cycling of expansive clay in the backfill produces swell pressure perpendicular to the wall plane during wet periods (typically spring) and shrinkage cracks during dry periods. Repeated cycles ratchet the wall progressively inward over years. The mechanism produces the same general loading direction as M-1 (sustained lateral push), distinguished from M-1 only by its physical origin (clay swelling vs. earth-pressure-plus-water) and by characteristic seasonal cyclicity.

Cause 6 (C-6): Frost heave at the upper portion of the wall. *Mechanism M-6:* Freezing of saturated backfill within the frost zone (approximately 18–24 inches below grade in mid-Missouri)

produces ice lensing and lateral expansion against the upper portion of the wall. Top-down loading rotates the wall inward at the top, producing a non-symmetric displacement profile concentrated in the upper third of the wall span. Effect is asymmetric with exposure (worse on the north or shaded side).

Cause 7 (C-7): Tree-root surcharge or differential desiccation. *Mechanism M-7:* Tree roots near one wall either generate localized surcharge load or differentially desiccate the soil on one side, producing asymmetric lateral push or asymmetric soil shrinkage. The mechanism produces unilateral wall displacement on the side adjacent to the tree, with the opposite wall remaining undisplaced.

Cause 8 (C-8): Long-term chemical degradation of the wall system (sulfate attack on mortar, capillary-rise-driven mortar deterioration, and/or corrosion of any embedded steel reinforcement). *Mechanism M-8:* Chronic exposure of mortar joints to sulfate-bearing groundwater (or mildly acidic groundwater from pyrite oxidation) progressively reduces mortar bond strength along bed joints. If the wall contains embedded joint reinforcement or vertical rebar, corrosion of the steel further reduces flexural capacity and produces rust expansion that splits surrounding grout/mortar. The wall's capacity to resist sustained lateral earth pressure declines monotonically over decades; a load combination previously resisted becomes a failure load. Indicators include rust staining at cracks, pickable mortar with petrographic evidence of leaching/ettringite/thaumasite, low grout pH, and elevated soil/groundwater sulfate.

18.4 Evaluation: Cause 1 (Long-Term Lateral Soil Pressure with Intermittent Hydrostatic Loading)

Necessity: Ind(C-1, O). *Required Indicators $I_N(C-1)$ for sustained lateral loading mechanism:*

- Inward displacement below the connection to the first-floor diaphragm
- Bending-mode failure (rotation about top and bottom of wall, not shearing)
- Horizontal fracture at or near mid-height of the wall span
- Stair-step cracking propagating from the ends of horizontal fractures
- Localized condition at the foundation perimeter capable of permitting episodic water accumulation against the wall
- Absence of differential vertical movement (loading is perpendicular to the wall plane, not vertical)

Actual Observations O:

- Inward displacement of approximately 2 inches (north) and 1 3/4 inches (south) below the connection to the first-floor diaphragm: PRESENT
- Bending-mode failure with rotation about the floor slab and the wood diaphragm: PRESENT
- Horizontal fractures between the seventh and eighth CMU courses (and additionally between the eighth and ninth on the south wall): PRESENT
- Stair-step cracking at the ends of the horizontal cracks: PRESENT
- Localized depressed soil elevations spanning several square yards at both north and south wall perimeters: PRESENT

- Floor system within one-quarter inch of level across accessible locations; no horizontal or vertical displacement of supported floor system: PRESENT (i.e., absence of differential vertical movement is documented)

Necessity Evaluation: All required indicators in $I_N(\mathbf{C-1})$ are present in O .

Result: $\text{Ind}(\mathbf{C-1}, O) = \text{true}$. Necessity is satisfied. Cause C-1 advances to Sufficiency.

Sufficiency: $\text{Cap}(\mathbf{M-1}, O)$. *Mechanism M-1 Capability:* Can sustained lateral earth pressure, augmented intermittently by localized hydrostatic loading at perimeter depressions, produce the observed inward displacement, horizontal fractures between the seventh and eighth CMU courses, stair-step cracking at fracture endpoints, kitchen backsplash crack with darkened/soiled appearance, and absence of supported-floor displacement?

Analysis:

- Sustained lateral earth pressure on a below-grade CMU wall produces a flexural moment with maximum near mid-height when the wall is restrained at both top and bottom. The seventh-to-eighth-course location is consistent with mid-height in a typical 8-to-9-foot basement wall. Mechanism M-1 is capable of producing horizontal fracture at this location.
- Stair-step cracking at the ends of horizontal fractures is the expected propagation pattern when the bed-joint failure plane reaches the head joints at the wall returns: the crack steps along the path of weakest mortar, alternating between bed and head joints. Mechanism M-1 is capable of producing this pattern.
- Intermittent hydrostatic pressure from localized perimeter depressions augments sustained earth pressure during precipitation. The two-sided nature of the failure (both north and south walls displaced) is consistent with bilateral perimeter conditions and not with a unilateral acute event.
- The crack at the kitchen backsplash, located directly above the north CMU inward failure and exhibiting a darkened/soiled appearance, is consistent with progressive minor distress accumulating over time rather than recent acute formation. Mechanism M-1, operating over years, is capable of producing such delayed superficial expression at the upper interior finish.
- The mechanism produces no vertical displacement of the supported floor system, because the loading is perpendicular to the wall plane and the footing is not displaced. Observed floor levelness within one-quarter inch is consistent with this.

Result: $\text{Cap}(\mathbf{M-1}, O) = \text{true}$. Sufficiency is satisfied. Cause C-1 advances to Exclusion.

Exclusion: $\neg \text{Contra}(O, \mathbf{C-1})$. *Expected Outcomes $E(\mathbf{C-1})$:*

- Inward bowing concentrated at mid-height of long-span basement walls
- Horizontal fracture along bed joints in the mid-height region
- Stair-step propagation at fracture termini
- Aged appearance of cracks (sustained or repeated loading, not single-event); evidence of prior repair activity at older crack locations
- No fresh fracture surfaces uniquely datable to a single recent event
- No differential vertical movement of the supported floor system
- Bilateral expression at parallel walls subjected to comparable backfill conditions

Actual Observations O:

- Inward displacement at mid-height with bending failure mode: Compatible
- Horizontal fractures between seventh and eighth CMU courses: Compatible
- Stair-step cracking at fracture endpoints: Compatible
- Sealant material at mortar separation locations on the south wall, indicating prior repair activity: Compatible (portions of the cracking predate the reported event)
- Darkened and soiled appearance of the kitchen backsplash crack, indicating it has been present for a period of time: Compatible
- Floor system within one-quarter inch of level: Compatible
- Bilateral inward displacement at both north and south walls: Compatible

Exclusion Evaluation: No observation in O contradicts $E(C-1)$.

Result: $\neg \text{Contra}(O, C-1) = \text{true}$. Exclusion is satisfied. Cause C-1 advances to Constraint.

Constraint: $\neg \text{Viol}(C-1)$. *Temporal Constraint:*

- Sustained lateral soil pressure is a continuous loading condition; the mechanism operates over the service life of the wall.
- Property age: 84 years (constructed 1942). Time available for cumulative loading: 84 years.
- Sealant at prior repair locations indicates portions of cracking developed before the most recent occupancy interval (~ 3 years).
- $\text{Viol}_T(C-1)$? No. The mechanism's operating time scale is fully accommodated by the property's service history.

Spatial Constraint:

- The mechanism operates at any below-grade location where retained backfill loads the wall plane. The observed displacements at both north and south walls are spatially consistent with the bilateral perimeter conditions documented at the foundation.
- $\text{Viol}_S(C-1)$? No. Spatial extent of mechanism matches spatial extent of observations.

Physical Constraint:

- Lateral earth pressure on an 8-to-9-foot below-grade CMU wall under saturated backfill is well within the published range of loadings observed to produce inward displacement and bed-joint cracking in unreinforced or lightly reinforced CMU. Combined sustained-plus-intermittent loading magnitudes are physically capable of producing the observed displacement of approximately 1 3/4 to 2 inches at the wall mid-height.
- $\text{Viol}_P(C-1)$? No. Physical limits of the mechanism are not violated.

Constraint Evaluation: No constraint is violated.

Result: $\neg \text{Viol}(C-1) = \text{true}$. Constraint is satisfied.

Global Admissibility: Cause 1.

$$\text{Adm}(C-1) \iff \text{Ind}(C-1, O) \wedge \text{Cap}(M-1, O) \wedge \neg \text{Contra}(O, C-1) \wedge \neg \text{Viol}(C-1) \iff \text{true} \wedge \text{true} \wedge \text{true} \wedge \text{true}$$

$\text{Adm}(\text{C-1}) = \text{true}$.

Result: Cause C-1 (long-term lateral soil pressure with intermittent hydrostatic loading) is **admissible**.

18.5 Evaluation: Cause 2 (March 30, 2026 Storm Event)

Necessity: $\text{Ind}(\text{C-2}, O)$. *Required Indicators $I_N(\text{C-2})$ for acute storm-event mechanism:*

- Fresh fracture surfaces with bright, unweathered appearance at new cracks or new material separations
- Sudden onset of inward displacement temporally coincident with the reported event
- A documented precipitation event of sufficient magnitude in the local area on or around March 30, 2026 to elevate hydrostatic loading
- Absence of evidence of prior cracking at the same locations

Actual Observations O :

- Sealant material at mortar separation locations on the south CMU foundation: indicates prior repair activity, contradicting “absence of prior cracking”
- Darkened and soiled appearance of the kitchen backsplash crack: indicates the crack has been present for a period of time, contradicting “sudden onset”
- NOAA Local Storm Reports register no rain event in St. Louis County between January 1 and April 1, 2026; nearest events on March 5, 2026 are more than 20 miles distant
- No fresh, bright fracture surfaces uniquely datable to March 30, 2026 are present in O

Necessity Evaluation:

- Required indicator “fresh fracture surfaces”: NOT PRESENT
- Required indicator “sudden onset coincident with reported event”: NOT PRESENT (prior repair sealant and aged backsplash crack contradict)
- Required indicator “documented precipitation event”: NOT PRESENT (no NOAA-recorded event in St. Louis County)

Result: $\text{Ind}(\text{C-2}, O) = \text{false}$. Necessity is not satisfied. Per Section 8.1, failure of Necessity does not independently eliminate C-2; the cause advances to Sufficiency.

Sufficiency: $\text{Cap}(\text{M-2}, O)$. *Mechanism M-2 Capability:* Can a single precipitation event on March 30, 2026 produce the observed pattern of bilateral inward displacement with sealant-bearing prior-repair cracks, an aged backsplash crack, no fresh fracture surfaces, and no NOAA record of precipitation in St. Louis County on the alleged date?

Analysis:

- A single-event mechanism requires fresh, event-coincident fracture indicators. The observed cracks include sealant from prior repairs and a kitchen backsplash crack with darkened/soiled appearance, both predating any March 30, 2026 event. Mechanism M-2 cannot produce evidence of prior repair activity.
- A single-event mechanism requires the event to have occurred. NOAA Local Storm Reports register no precipitation event in St. Louis County during the reported period. Mechanism M-2 cannot operate without the triggering input.

- Even granting an unrecorded local event, the mechanism produces fresh fracture surfaces. Such surfaces are absent.
- Mechanism M-2 cannot produce the observed pattern: it cannot generate prior-repair sealant, cannot generate aged crack appearance, and cannot operate without a documented triggering event.

Result: $\text{Cap}(\text{M-2}, O) = \text{false}$. Sufficiency is not satisfied. Cause C-2 is **eliminated**.

18.6 Evaluation: Cause 3 (Foundation Settlement)

Necessity: $\text{Ind}(\text{C-3}, O)$. *Required Indicators $I_N(\text{C-3})$ for foundation settlement mechanism:*

- Differential vertical movement of the supported floor system, measurable as out-of-level conditions
- Misalignment of foundation-supported structural elements
- Vertical displacement of foundation-supported components
- Disconnection or vertical offset between the top of the foundation wall and the floor diaphragm it supports

Actual Observations O :

- Floor system levelness measured within one-quarter inch across all accessible locations: NOT PRESENT (i.e., differential vertical movement is not observed; observation contradicts the required indicator)
- Top of CMU foundation wall remains connected to the first-floor diaphragm: NOT PRESENT (i.e., disconnection or vertical offset is not observed)
- No misalignment of foundation-supported structural elements documented

Necessity Evaluation:

- Required indicator “differential vertical movement”: NOT PRESENT
- Required indicator “disconnection at top-of-wall connection”: NOT PRESENT
- Required indicator “misalignment of supported elements”: NOT PRESENT

Result: $\text{Ind}(\text{C-3}, O) = \text{false}$. Necessity is not satisfied. Cause C-3 advances to Sufficiency.

Sufficiency: $\text{Cap}(\text{M-3}, O)$. *Mechanism M-3 Capability:* Can a vertical settlement mechanism produce inward displacement of below-grade walls without producing any of its expected differential-vertical-movement indicators?

Analysis:

- Settlement mechanisms transmit force vertically into the supported structure. The structural response is differential vertical movement, expressed as out-of-level floor systems, misaligned elements, and offsets at supported connections.
- Mechanism M-3 is not capable of producing horizontal inward displacement perpendicular to the wall plane while simultaneously producing no vertical displacement at the supported floor diaphragm. The two outcomes are incompatible: if M-3 were operative, the laser-level survey would have registered displacement above one-quarter inch.

Result: $\text{Cap}(\text{M-3}, O) = \text{false}$. Sufficiency is not satisfied. Cause C-3 is **eliminated**.

18.7 Evaluation: Cause 4 (Mine Subsidence)

Necessity: $\text{Ind}(\mathbf{C-4}, O)$. *Required Indicators $I_N(\mathbf{C-4})$ for mine subsidence mechanism:*

- Broad-area ground deformation visible in surface features (yard, pavement, sidewalks, driveway)
- Differential vertical movement of one portion of the structure relative to another, measurable in the floor diaphragm
- Out-of-level conditions in the wood main-floor diaphragm
- System-wide damage distribution: cracking and displacement at multiple structural elements, not localized to the below-grade walls
- For pit-type: a ground-surface pit or asymmetric loss of footing support

Actual Observations O :

- Floor system within one-quarter inch of level: NOT PRESENT (i.e., differential vertical movement not detected)
- Damage limited to inward displacement of foundation walls; no system-wide structural damage documented: NOT PRESENT (system-wide indicators absent)
- No documented arc-correlated ground cracks, no surface pit, no asymmetric footing loss in O

Necessity Evaluation:

- Required indicator “broad-area ground deformation”: NOT PRESENT
- Required indicator “differential vertical movement”: NOT PRESENT
- Required indicator “system-wide damage distribution”: NOT PRESENT

Result: $\text{Ind}(\mathbf{C-4}, O) = \text{false}$. Necessity is not satisfied. Cause C-4 advances to Sufficiency.

Sufficiency: $\text{Cap}(\mathbf{M-4}, O)$. *Mechanism M-4 Capability:* Can mine subsidence produce localized inward displacement of basement walls confined to mid-height bending of the CMU below the diaphragm, with the floor system level to within one-quarter inch and no system-wide structural distress?

Analysis:

- Sag-trough subsidence imposes horizontal ground strain over a broad area. Where transmitted through backfill into a foundation, it produces displacement, but the same ground strain field also produces measurable vertical settlement of the building (typically several inches across the structure footprint) and arc-correlated surface damage. Neither is observed.
- Pit-type subsidence undermines the footing locally, producing rotation or settlement of one portion of the foundation rather than bilateral mid-height bending of two opposing walls. The observed pattern (parallel north-south walls with similar mid-height failure) is not the expected response to a localized pit.
- Mechanism M-4, in either form, cannot produce the observed condition (bilateral mid-height bending of below-grade walls without any accompanying differential vertical movement of the supported floor system or surface evidence of ground deformation).

Result: $\text{Cap}(\mathbf{M-4}, O) = \text{false}$. Sufficiency is not satisfied. Cause C-4 is **eliminated**.

18.8 Evaluation: Cause 5 (Smectitic Clay Swell Pressure)

Necessity: $\text{Ind}(\mathbf{C-5}, O)$. *Required Indicators $I_N(\mathbf{C-5})$ for clay-swell mechanism:*

- Inward displacement perpendicular to the wall plane
- Bending-mode failure with horizontal fracture in the mid-height region
- Backfill containing expansive (smectitic) clay capable of generating swell pressure on wetting

Actual Observations O :

- Inward displacement of approximately 2 inches (north) and 1 3/4 inches (south) below the diaphragm connection: PRESENT
- Horizontal fractures between the seventh and eighth CMU courses on both walls: PRESENT
- Property is located within the Cisne/Hoyleton claypan landscape of St. Louis County, which contains expansive smectitic clay capable of producing swell pressure: regionally documented (no site-specific Atterberg or swell test was performed)

Necessity Evaluation: All required indicators in $I_N(\mathbf{C-5})$ are present in O at the level supported by the regional geology and the documented displacement and fracture pattern. The site-specific confirmation of expansive clay (Atterberg limits, swell test) was not collected and is therefore inferred from regional context rather than measured.

Result: $\text{Ind}(\mathbf{C-5}, O) = \text{true}$ (with the noted inference). Necessity is satisfied. Cause C-5 advances to Sufficiency.

Sufficiency: $\text{Cap}(\mathbf{M-5}, O)$. *Mechanism M-5 Capability:* Can clay swell pressure from expansive backfill produce the observed bilateral mid-height inward displacement, horizontal fractures between the seventh and eighth courses, and stair-step cracking at fracture endpoints?

Analysis:

- Smectitic clay swell pressure acts perpendicular to the wall plane and produces a flexural moment with maximum near mid-height when the wall is restrained at top and bottom. Mechanism M-5 is capable of producing horizontal fracture at the observed location.
- The mechanism produces stair-step propagation at fracture endpoints by the same path-of-weakest-mortar argument applicable to Mechanism M-1.
- Bilateral expression is consistent with bilateral exposure to claypan backfill, which is plausible in the Cisne/Hoyleton landscape.
- The mechanism produces no vertical displacement of the supported floor system, consistent with the observed floor levelness.

Result: $\text{Cap}(\mathbf{M-5}, O) = \text{true}$. Sufficiency is satisfied. Cause C-5 advances to Exclusion.

Exclusion: $\neg \text{Contra}(O, \mathbf{C-5})$. *Expected Outcomes $E(\mathbf{C-5})$:*

- Inward bowing concentrated at mid-height
- Horizontal fracture along bed joints in the mid-height region
- Stair-step propagation at fracture termini
- Possible seasonal worsening (wet-spring) and partial recovery (dry-summer); ratcheted progression over years

- No fresh fracture surfaces uniquely datable to a single event
- No differential vertical movement of the supported floor system

Actual Observations O:

- Inward displacement at mid-height with bending failure mode: Compatible
- Horizontal fractures between seventh and eighth CMU courses: Compatible
- Stair-step cracking at fracture endpoints: Compatible
- Seasonal cyclicity is not documented in *O* (a single inspection was performed in April; no multi-season monitoring): not contradicted, not confirmed
- No fresh fracture surfaces uniquely datable to March 30, 2026: Compatible
- Floor system within one-quarter inch of level: Compatible

Exclusion Evaluation: No observation in *O* contradicts $E(C-5)$.

Result: $\neg \text{Contra}(O, C-5) = \text{true}$. Exclusion is satisfied. Cause C-5 advances to Constraint.

Constraint: $\neg \text{Viol}(C-5)$.

- *Temporal:* 84-year service history accommodates multi-year ratcheting. $\text{Viol}_T(C-5)$? No.
- *Spatial:* Mechanism operates anywhere expansive backfill abuts the wall; bilateral expression is consistent. $\text{Viol}_S(C-5)$? No.
- *Physical:* Documented swell pressures from smectitic clay backfill are physically capable of producing the observed displacement magnitudes on a CMU wall of the subject's geometry. $\text{Viol}_P(C-5)$? No.

Result: $\neg \text{Viol}(C-5) = \text{true}$. Constraint is satisfied.

Global Admissibility: Cause 5. $\text{Adm}(C-5) = \text{true}$.

Result: Cause C-5 (smectitic clay swell pressure) is **admissible**.

Note on differentiation from C-1. Mechanisms M-1 and M-5 produce identical observable outcomes at the level of the locked observation set *O*: inward bilateral mid-height bending, horizontal fractures between the seventh and eighth courses, stair-step propagation, no differential vertical floor movement. The distinguishing observations (seasonal monitoring, soil Atterberg limits and swell test results, water content of backfill across seasons, piezometer data) were not collected. C-1 and C-5 are therefore non-uniquely admissible under *O*. This non-uniqueness is resolved in Section 18.12 per the Section 8.5 differentiation protocol.

18.9 Evaluation: Cause 6 (Frost Heave)

Necessity: $\text{Ind}(C-6, O)$. *Required Indicators $I_N(C-6)$ for frost-heave mechanism:*

- Top-down loading from frost-zone expansion against the upper portion of the wall
- Non-symmetric displacement profile with inward tilt concentrated in the upper third of the wall span
- Asymmetric expression dependent on solar exposure (worse on north or shaded side)
- Seasonal cyclicity: opens during winter freeze, closes or partially closes during spring thaw

Actual Observations O:

- Displacement profile is bending-mode at mid-height (rotation about top and bottom of wall), not top-rotation: NOT PRESENT
- Bilateral expression at both north and south walls with similar magnitude: NOT PRESENT (i.e., asymmetry by exposure is not observed)
- Inspection conducted on April 13 (post-thaw) shows persistent displacement, not seasonal recovery: NOT PRESENT (seasonal closure is not observed)

Necessity Evaluation: Required indicators are absent.

Result: $\text{Ind}(C-6, O) = \text{false}$. Necessity is not satisfied. Cause C-6 advances to Sufficiency without elimination.

Sufficiency: $\text{Cap}(M-6, O)$. *Mechanism M-6 Capability:* Can frost-heave loading produce the observed bilateral mid-height bending pattern with similar magnitudes at parallel north and south walls?

Analysis: Frost-heave loading is concentrated at the frost zone (approximately the upper 18–24 inches of soil) and produces a top-rotation displacement profile. The observed mid-height bending profile is not the expected response to frost-zone loading. Furthermore, frost-heave effects are asymmetric with solar exposure; the north (shaded) wall and the south (sun-exposed) wall would not be expected to show similar displacements. Granting some capability of the mechanism to produce partial mid-height response in unusual configurations, the bilateral symmetry with similar displacement magnitudes (1 3/4 in. vs. 2 in.) at oppositely exposed walls is not a pattern frost heave is capable of producing.

Result: $\text{Cap}(M-6, O) = \text{false}$ (the bilateral, similar-magnitude, mid-height profile is incompatible with frost-zone loading). Sufficiency is not satisfied; however, this finding is reinforced more directly by Exclusion.

Exclusion: $\neg \text{Contra}(O, C-6)$. *Expected Outcomes E(C-6):*

- Top-rotation displacement profile with separation at the sill plate / top-of-wall connection
- Asymmetric expression across north vs. south wall by solar exposure
- Seasonal closure observable post-thaw

Actual Observations O:

- Top of foundation wall remains fully connected to the first-floor diaphragm at both walls (no sill-plate separation): contradicts $E(C-6)$
- Bilateral, similar-magnitude displacement at north and south walls: contradicts $E(C-6)$
- Persistent displacement observed in April (post-thaw): contradicts $E(C-6)$

Exclusion Evaluation: Multiple observations actively contradict $E(C-6)$.

Result: $\text{Contra}(O, C-6) = \text{true}$. Exclusion is not satisfied. Cause C-6 is **eliminated**.

18.10 Evaluation: Cause 7 (Tree-Root Surcharge or Differential Desiccation)

Necessity: $\text{Ind}(C-7, O)$. *Required Indicators $I_N(C-7)$ for tree-root mechanism:*

- Vegetation (tree of sufficient size) located in proximity to one foundation wall
- Asymmetric, one-sided lateral push or one-sided soil desiccation pattern

- Unilateral wall displacement on the side adjacent to vegetation

Actual Observations O:

- No tree adjacent to either of the affected walls is documented in *O* (no observation of vegetation in proximity to the foundation that would generate root surcharge)
- Bilateral inward displacement at both north and south walls with similar magnitude: NOT PRESENT (i.e., asymmetric one-sided push is not observed)

Necessity Evaluation: Required indicator “asymmetric expression” is absent; required indicator “vegetation in proximity” is unsupported by *O*.

Result: $\text{Ind}(\text{C-7}, O) = \text{false}$. Cause C-7 advances to Sufficiency without elimination.

Sufficiency: $\text{Cap}(\text{M-7}, O)$. *Mechanism M-7 Capability:* Can a tree-root mechanism produce bilateral, similar-magnitude inward displacement of two parallel opposing walls?

Analysis: Tree-root surcharge or differential desiccation operates from a localized source (the root zone of a single tree or cluster). The mechanism produces unilateral effects on the wall closest to the source. To produce the observed bilateral pattern with similar displacement magnitudes (1 3/4 in. and 2 in. on opposite walls), the mechanism would require the unlikely configuration of two trees of comparable size on opposite sides of the property at comparable distances, neither of which is documented in *O*. In the absence of such a configuration in *O*, Mechanism M-7 cannot produce the observed bilateral expression.

Result: $\text{Cap}(\text{M-7}, O) = \text{false}$. Sufficiency is not satisfied. Cause C-7 is **eliminated**.

18.11 Evaluation: Cause 8 (Long-Term Chemical Degradation of the Wall System)

Necessity: $\text{Ind}(\text{C-8}, O)$. *Required Indicators $I_N(\text{C-8})$ for chemical-degradation mechanism:*

- Pickable, friable, or visibly eroded mortar at bed joints
- Rust staining at cracks (if embedded steel is present and corroding)
- Petrographic evidence of mortar leaching, ettringite, thaumasite, or sulfate attack
- Grout or mortar pH measurably below normal range
- Elevated soil or groundwater sulfate concentration in the foundation environment
- Cracking pattern correlated with reinforcement spacing (if joint reinforcement or vertical rebar is corroding)

Actual Observations O:

- No observation of pickable, friable, or visibly eroded mortar is documented in *O* (the observation set neither confirms nor excludes this; the inspection did not include mortar probing)
- No observation of rust staining at cracks is documented in *O* (likewise neither confirmed nor excluded)
- No mortar petrography was performed
- No mortar/grout pH was measured
- No soil or groundwater sulfate testing was performed
- No ferroskan, cover meter survey, or coring to identify reinforcement was performed

Necessity Evaluation: None of the required indicators are present in O . However, the absence of these indicators in O reflects the absence of testing rather than negative findings: the Necessity failure here indicates an evidence gap, not refutation of the cause.

Result: $\text{Ind}(C-8, O) = \text{false}$. Per Section 8.1 and Section 15.3, failure of Necessity does not independently eliminate C-8; the cause advances to Sufficiency.

Sufficiency: $\text{Cap}(M-8, O)$. *Mechanism M-8 Capability:* Can long-term chemical degradation of mortar joints and/or corrosion of any embedded steel reduce wall capacity sufficiently that sustained lateral earth pressure produces the observed bilateral inward displacement, horizontal fractures between the seventh and eighth courses, and stair-step propagation?

Analysis:

- Chronic mortar deterioration in a sulfate-bearing or mildly acidic environment progressively reduces bed-joint flexural capacity over decades. A wall on the margin of capacity at design load will eventually fail under unchanged service loading once mortar capacity drops sufficiently.
- The 1942 construction date (84 years of service) provides ample time for the mechanism to operate.
- Mechanism M-8 is capable of producing the observed displacement profile and fracture pattern, but does so by reducing the wall's ability to resist the loading mechanism of either C-1 or C-5. M-8 is therefore a capacity-side mechanism that compounds with the lateral-loading mechanisms (M-1, M-5) rather than acting as an independent loading mechanism.

Result: $\text{Cap}(M-8, O) = \text{true}$ (capability cannot be excluded from O alone). Sufficiency is satisfied. Cause C-8 advances to Exclusion.

Exclusion: $\neg \text{Contra}(O, C-8)$. *Expected Outcomes $E(C-8)$:*

- Visible mortar deterioration where exposed for inspection
- Possible rust staining at cracks if embedded steel is corroding
- Cracking pattern that may correlate with reinforcement spacing if reinforcement is present and corroding
- Monotonic, non-seasonal worsening of displacement over years

Actual Observations O :

- Observation set O does not document mortar deterioration; the inspection did not include mortar probing
- Observation set O does not document rust staining; the inspection did not include directed examination for staining
- Reinforcement spacing was not characterized in O
- A single inspection was performed; monotonic vs. seasonal pattern is not established in O

Exclusion Evaluation: No observation in O actively contradicts $E(C-8)$. The expected indicators are not refuted; they are not tested.

Result: $\neg \text{Contra}(O, C-8) = \text{true}$ (with the noted evidence gap). Exclusion is satisfied. Cause C-8 advances to Constraint.

Constraint: $\neg \text{Viol}(\text{C-8})$.

- *Temporal:* 84-year service history accommodates the long time scale (decades) required for chemical degradation. $\text{Viol}_T(\text{C-8})$? No.
- *Spatial:* Mechanism operates anywhere mortar joints are exposed to aggressive groundwater; bilateral expression is consistent. $\text{Viol}_S(\text{C-8})$? No.
- *Physical:* Documented sulfate-attack and corrosion processes are physically capable of producing the observed degradation in the regional environment. $\text{Viol}_P(\text{C-8})$? No.

Result: $\neg \text{Viol}(\text{C-8}) = \text{true}$. Constraint is satisfied.

Global Admissibility and Suspension: Cause 8. The four governing predicates evaluate as follows under O :

- $\text{Ind}(\text{C-8}, O) = \text{false}$ (evidence gap; required indicators not tested for)
- $\text{Cap}(\text{M-8}, O) = \text{true}$ (capability cannot be excluded from O)
- $\neg \text{Contra}(O, \text{C-8}) = \text{true}$ (no contradicting observations)
- $\neg \text{Viol}(\text{C-8}) = \text{true}$ (no constraint violations)

Per Section 9, admissibility requires support (Necessity) together with the three refuting predicates not failing. With $\text{Ind}(\text{C-8}, O) = \text{false}$ due to absent testing rather than refutation, C-8 is not admissible under the locked observation set, but is also not eliminated: neither Sufficiency nor Exclusion nor Constraint has refuted the mechanism, and the Necessity failure reflects an evidence gap rather than evidence of absence (Section 15.3). This is the Section 8.5 evidence-gap pattern: differentiating evidence (mortar petrography, grout pH, sulfate testing, ferroskan/coring) exists but was not collected. Per Section 11.3 termination conditions, the appropriate disposition is suspension pending evidence collection, not elimination. Equivalently, in the disposition rule of Section 6.5: $\neg \text{Refuted}(\text{C-8}) \wedge \neg \text{Ind}(\text{C-8}, O) \Rightarrow \text{SUSPENDED}$.

Result: Cause C-8 is **suspended**. It is neither admitted nor eliminated under the current observation set.

18.12 Attribution Outcome

Admissibility Summary:

Cause	Disposition	Eliminating / Status Question
C-1 (long-term lateral soil pressure with intermittent hydrostatic loading)	ADMISSIBLE	All governing questions satisfied
C-2 (March 30, 2026 storm event)	ELIMINATED	Sufficiency
C-3 (foundation settlement)	ELIMINATED	Sufficiency
C-4 (mine subsidence)	ELIMINATED	Sufficiency
C-5 (smectitic clay swell pressure)	ADMISSIBLE	All governing questions satisfied
C-6 (frost heave)	ELIMINATED	Exclusion
C-7 (tree-root surcharge / differential desiccation)	ELIMINATED	Sufficiency
C-8 (long-term chemical degradation)	SUSPENDED	Evidence gap (Necessity untested; Sufficiency / Exclusion / Constraint not refuted)

Verification of the disposition logic. Every disposition above is read directly from the predicates of Section 6.5: ELIMINATED where Refuted(*C*) holds (C-2, C-3, C-4, C-6, C-7); ADMISSIBLE where the cause is not refuted and is supported (C-1, C-5); SUSPENDED where the cause is not refuted and not supported (C-8). No procedural exception is invoked at any point; the treatment of Necessity reproduces the full case outcome on its own.

Non-Uniqueness Check (Section 8.5):

Two causes are simultaneously admissible: C-1 and C-5. Per the differentiation protocol:

1. **Differentiating evidence search.** Observations that would distinguish M-1 from M-5 include: soil Atterberg limits and swell test results (would confirm or deny smectitic clay activity), seasonal monitoring of displacement (clay swell predicts wet-spring/dry-summer cyclicity; sustained earth pressure is monotonic), water-content profiling of backfill across seasons, and piezometer data from the backfill zone. None of these were collected.
2. **Evidence gap classification.** The differentiating observations are obtainable through additional investigation but were not part of the inspection. This places C-1 vs. C-5 in the Section 8.5 step 3 disposition: documented evidence gap.
3. **Disposition.** Two paths are available under the framework:
 - a. *Multi-cause attribution (Section 10).* Conclude that the observed conditions are attributable to either M-1, or M-5, or a combination of the two, with available evidence not differentiating among these mechanisms. Recommend additional investigation for definitive attribution.
 - b. *Suspension pending evidence collection (Section 11.3).* Defer attribution until soil/seasonal data are obtained.

Suspended-Cause Disposition (C-8): Cause C-8 (long-term chemical degradation) is suspended pending mortar petrography, grout pH measurement, soil/groundwater sulfate testing, and characterization of any embedded reinforcement (ferroscan, cover meter, or coring). If C-8 is later supported, attribution becomes a three-way multi-cause case.

Recommended attribution disposition. Multi-cause attribution between C-1 and C-5 is the appropriate framework outcome under the locked observation set, with explicit suspension of

C-8 pending further investigation. Suspension of the full attribution (Section 11.3 termination) is also defensible if the attributing party prefers to defer until differentiating evidence is collected.

18.13 Report Language Translation

Conclusions (rigorous framework application):

1. “Vatterott concludes that the basement foundation was not damaged from the storm event of March 30, 2026.”
2. “Vatterott concludes that the inward displacement of the CMU foundation walls, and the associated earth movement, are attributable to one or more of the following mechanisms acting on the below-grade walls: (a) long-term lateral soil pressure augmented by intermittent hydrostatic pressure from localized perimeter water accumulation, or (b) sustained swell pressure from expansive smectitic clay in the backfill, or a combination thereof. Available evidence does not differentiate between these mechanisms. Soil testing (Atterberg limits, swell tests), seasonal monitoring of displacement, and piezometer data from the backfill zone would be required for definitive attribution between (a) and (b).”
3. “Vatterott further notes that long-term chemical degradation of the wall system, including possible sulfate attack on mortar, capillary-rise-driven mortar deterioration, and corrosion of any embedded steel reinforcement, cannot be excluded from the available evidence and may be a contributing capacity-side mechanism. Mortar petrography, grout pH measurement, soil and groundwater sulfate testing, and characterization of any embedded reinforcement (ferroscan, cover meter, or coring) would be required to evaluate this mechanism.”

Comparison to the Issued Report. The issued report concluded that the inward displacement is “the result of long-term lateral soil pressure, plus intermittent hydrostatic pressure,” which corresponds to admission of C-1 alone. Rigorous application of the framework to the locked observation set produces a multi-cause attribution between C-1 and C-5 with C-8 explicitly suspended. The divergence is not a contradiction: the issued report’s conclusion remains within the admissible set produced by the framework. The framework’s stricter outcome reflects the framework’s requirement that competing admissible causes be distinguished by differentiating evidence rather than narrative selection. Where differentiating evidence has not been collected, the framework’s preferred outputs are multi-cause attribution language or evidence-gap suspension, not single-cause attribution.

Discussion (representative language for a framework-compliant report). “The observed bilateral inward displacement of the CMU foundation walls, with horizontal fractures between the seventh and eighth courses and stair-step cracking at fracture endpoints, is consistent with the expected response of below-grade CMU walls subjected to sustained perpendicular loading. Two loading mechanisms are admissible from the evidence collected: long-term lateral earth pressure augmented by intermittent hydrostatic loading from localized perimeter water accumulation, and sustained swell pressure from expansive smectitic clay in the backfill characteristic of the Cisne/Hoyleton landscape of St. Louis County. The available evidence does not differentiate between these mechanisms, both of which produce the observed displacement profile, fracture pattern, and absence of differential vertical floor movement. The presence of sealant at mortar separations on the south foundation wall and the darkened and soiled appearance of the kitchen backsplash crack indicate that portions of the observed cracking predate the reported event. Floor system levelness measured within one-quarter inch across accessible locations, together with the unbroken connection of the foundation wall top to the first-floor diaphragm, eliminates differential vertical

movement and, consequently, foundation settlement and mine subsidence as causes of the observed conditions. The displacement profile (bilateral mid-height bending of similar magnitude at parallel walls) eliminates frost heave (which would produce top-rotation and asymmetry by exposure) and tree-root mechanisms (which would produce unilateral expression). NOAA Local Storm Reports register no precipitation event in St. Louis County during the reported period, and no fresh fracture surfaces uniquely datable to March 30, 2026 are present, eliminating the reported storm event as the cause of the observed conditions. Long-term chemical degradation of the mortar and possible corrosion of any embedded reinforcement cannot be excluded from the inspection record alone; this mechanism may compound the loading mechanisms by reducing wall capacity over the 84-year service life and can be evaluated only through directed sampling and testing not performed during the inspection.”

18.14 Outcome Structure of the Case

Under the locked observation set O and the cause enumeration $\mathcal{C} = \{C-1, \dots, C-8\}$, the surviving (admissible) set is

$$A(O) = \{C-1, C-5\},$$

a two-cause non-unique attribution, with C-8 suspended and the remaining causes eliminated. The result is evidence-dependent rather than forced (Section 4.6): from the evidence actually collected, the set of terminal surviving sets reachable by collecting further available evidence is

$$R(O) = \{ \{C-1, C-5\}, \{C-1\}, \{C-5\} \},$$

and which one is reached depends on which differentiating observation is collected. From the differentiating-evidence list of Section 18.12:

- A documented seasonal-monitoring observation showing wet-spring/dry-summer cyclicity in displacement would resolve the surviving set to $\{C-5\}$.
- Soil Atterberg-limits or swell-test results showing absence of expansive smectitic clay activity in the backfill would resolve it to $\{C-1\}$.
- Piezometer data inconsistent with the perimeter water-collection mechanism of C-1 would resolve it to $\{C-5\}$.
- Water-content profiling showing monotonic (non-seasonal) loading would resolve it to $\{C-1\}$.

Each named differentiator forces resolution to a single cause; the two-cause surviving set persists only under the policy of collecting none of them. This is a precise statement of the practical situation: the multi-cause attribution is the framework’s correct output for the observation set actually collected, and the path to a unique attribution runs through specific named additional measurements.

Cause C-8 (long-term chemical degradation) sits outside both the surviving set and the eliminated set. Its required indicators are untested (an evidence gap), so it is suspended; collecting them would move it either to admissible (yielding a three-cause surviving set $\{C-1, C-5, C-8\}$, if its indicators are present and nothing refutes it) or to eliminated (if Sufficiency, Exclusion, or Constraint then fails).

The sequence of dispositions is therefore: a two-cause surviving set, an evidence-dependent boundary parameterized by named differentiating evidence, and a separate suspended cause awaiting its own evidence. The framework’s recommended report language in Section 18.12, multi-cause attribution between C-1 and C-5 with C-8 explicitly suspended, is the direct encoding of this outcome structure: surviving set of cardinality two $\rightarrow$ multi-cause attribution; unsupported-but-unrefuted cause $\rightarrow$ suspended attribution; singleton surviving set $\rightarrow$ single-cause attribution.

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This paper presents a methodology for systematic evaluation of causation in forensic engineering claims. It does not constitute legal, engineering, or professional advice.