WillItMap Theory Manual

Field methods, data workflows and reproducible calculations

Document WIM-TM-001 · Revision v49 · 6 November 2026



Keep observed evidence distinct from interpretation and calculated results.

This edition covers the application from collecting an outcrop to inspecting structural populations, screening mechanisms, evaluating defined slope models, and preserving the result. Numbered procedures and original worked examples expose the arithmetic between inputs and outputs.

Part	Purpose
F · Field methods	Projects, outcrops, location/orientation capture, descriptions, RMR, GSI, discontinuities and rock-mass inputs.
K · Structure and kinematics	Stereonets, imports, population statistics, joint sets, density, structural tools and possible failure mechanisms.
D · Data and mapping	Slope ratings, geology context, desktop records, GIS/export, offline storage, account backup, recovery and deletion.
S · Slope theory	Retained detailed geometry, force equilibrium, moments, strength, water and worked slope calculations.
E · Extended calculations	Engineering workflow, bolts, patterns, load locations, sampling, fits, combinations and reports.

Edition basis: unpublished local candidate v1.35.4, paired with Field Use Guide v47, finite-block mechanics 1.3 and reinforcement model 1.2. The source-bound release and deployment evidence identify the tested and published builds separately. Earlier issued manuals and their verification archives remain retained.

Numerical checks establish agreement for the specified equations and examples. They do not certify field accuracy, suitability for every project or professional approval. Unresolved whole-slope flexure and other model boundaries are explicitly retained.

Contents · 1

Choose a section here or use the PDF bookmarks. Original slope calculations are retained under S; the added workflows and methods use F, K, D and E.

Section	Page
I1. How to use this manual	12
I2. Coverage, evidence and release status	13
I3. First use and finding the right workspace	14
I4. Paired manuals and release boundaries	15
I5. Enter a planar section and resolve input problems	17
I6. Build the slope model in a visible sequence	18
I7. Inspect geometry and assign property snapshots	19
I8. Review completeness before calculation	20
I9. Preserve drafts, cases and property libraries	21
I10. Translate field geometry into a documented model	22
I11. Read adjacent guidance without inventing an input	23
I12. Follow the desktop slope workflow	24
I13. Read results, studies and the calculation report	25
I14. Independently reproduce a detailed calculation report	26
I15. Record integrity and explicit assumptions	28
K21. Portable source populations and identity	29
K22. Orientation boundaries, filters and sampling	30
E30. Factored combinations and incipient toppling	31
I16. Current geometry, review and recovery	32
I17. Editing, identity and recovery contracts	33
K23. Reproducible populations and exported provenance	34

Contents · 2

Choose a section here or use the PDF bookmarks. Original slope calculations are retained under S; the added workflows and methods use F, K, D and E.

Section	Page
E31. Model displays remain tied to current inputs and results	35
I18. Editing and output scope in app v1.21.4	36
I19. Read the six-step live model without mistaking it for a result	37
I20. Device backup, online state and desktop file scope	38
I21. Online backup and paused deletion review	39
F19. Optional mapping groups and coverage	40
F1. Field records: context, observation and interpretation	41
F2. Location, elevation, units and provenance	42
F3. Manual plane orientation and north reference	43
F4. Phone orientation: collection method and quality limits	44
F5. Phone orientation: reproducible coordinate calculation	45
F6. Structural-set mean and angular scatter	46
F7. Lithology, weathering and exposure descriptions	47
F8. Observed intact strength and visual GSI	48
F9. RMR: strength, RQD and spacing ratings	49
F10. RMR: condition and groundwater selections	50
F11. RMR: orientation adjustment categories	52
F12. RMR: worked sum and consistency checks	53
F13. Discontinuity records and Barton parameter evidence	54
F14. Barton shear screen: scale, stress grid and worked point	55
F15. Hoek–Brown field inputs and calculation handoff	56

Contents · 3

Choose a section here or use the PDF bookmarks. Original slope calculations are retained under S; the added workflows and methods use F, K, D and E.

Section	Page
F16. Geological domains and survey sessions	57
F17. Survey completeness and dimensional checks	58
F18. Visible trace length and censored endpoints	59
K1. Structural analysis: establish the input population	60
K1A. Import joint labels without losing their provenance	61
K2. Orientation vectors and stereonet projection	62
K3. Great circles, intersections and the live field plot	63
K4. Filters, exclusions, set interpretation and adoption	64
K5. Axial means and descriptive orientation statistics	65
K6. Fisher estimates: formula, eligibility and hand calculation	66
K7. Automatic joint-set clustering and its limits	67
K8. Density contours: distinguish the two implementations	68
K9. Survey bias, weighted means and rose diagrams	69
K10. Geometric constructions and rotations	70
K11. Scanline spacing and geometric line RQD	71
K12. Oriented-core conversion and survey interpolation	72
K13. Kinematic screening 1: daylighting and planar sliding	73
K14. Kinematic screening 2: flexural toppling	74
K15. Kinematic screening 3: intersection and single-plane wedges	75
K16. Kinematic screening 4: direct and oblique toppling	76
K17. Kinematic workflow, denominators, complete runs and sensitivity	77

Contents · 4

Choose a section here or use the PDF bookmarks. Original slope calculations are retained under S; the added workflows and methods use F, K, D and E.

Section	Page
K18. Structural verification evidence and remaining boundaries	79
K19. Pair scope: recorded context and physical meaning	80
K20. Pair denominators: reproduce a scoped count	81
K24. Default stereonet grouping and observation identity	82
D1. Independent slope ratings: inputs and formulas	83
D2. Slope-rating choices: A through I	84
D3. Slope-rating choices: J through Q	85
D4. Slope-rating choices: R through BB	86
D5. Rating totals: reproducible hand calculation	87
D6. Published geology: lookup and interpretation	88
D7. Static geology image and topographic background	89
D8. Coordinates, units and provenance in exports	90
D9. Choose the right export and verify the file	91
D10. Restore, merge and recover without losing context	92
D11. Local saves, drafts and offline readiness	93
D12. Accounts and online backup: operating sequence	94
D13. Conflicts, account limits and retention	95
D14. Deletion choices and shared-device precautions	96
D15. Desktop workspace: review and edit saved data	97
D15A. Read the desktop review areas and their scope	98
D16. Desktop maps, mean bedding and scoped packages	99

Contents · 5

Choose a section here or use the PDF bookmarks. Original slope calculations are retained under S; the added workflows and methods use F, K, D and E.

Section	Page
D17. Preserve survey, domain and trace evidence	100
S1. Basis and scope	101
S2. Conventions and dimensional control	102
S3. Planar geometry	103
S4. Wedge geometry and size	104
S5. Translational equilibrium	105
Worked planar case P01: construct the block	106
Worked planar case P01: resolve the forces	107
Worked planar case P06: combine every load	108
Worked wedge W01: solve its plane intersections	109
Worked wedge W01: areas, volume and weight	110
Worked wedge W01: contacts, movement and FS	111
S6. Joint shear-strength laws	112
S6A. Choose joint strength from evidence	113
S6B. Additional waviness: reproduce the distinction	114
Worked example: joint shear resistance	115
S7. Water forces and moments	116
Worked groundwater case P22: integrate the wet base	117
Worked face H01: calculate a water-force lever arm	118
S8. Isolated-block forces and moments	119
Worked B1. Dry isolated block	120

Contents · 6

Choose a section here or use the PDF bookmarks. Original slope calculations are retained under S; the added workflows and methods use F, K, D and E.

Section	Page
Worked B2. Support force and its moment	121
Worked B3. Change only support height	122
S9. Interacting-column recurrence	123
Worked T1. Three columns: body forces	124
Worked T2. Transfer, audit and solve F	125
S10. Search, contact checks and flexure	126
S10A. Local bending calculation, step by step	127
S11. Reinforcement and FS definitions	128
Worked S1. Support case: geometry and forces	129
Worked S2. Active and passive are different ratios	130
S12. Rock-mass interpretation	131
Worked example: Hoek–Brown material	132
S13. Uncertainty and descriptive statistics	133
Worked example: uncertainty bookkeeping	134
S14. Bench scenarios and numerical limits	135
Worked example: catch-bench arithmetic	136
S15. Source register and traceability	137
E1. Build a reviewable slope case	138
E2. Geometry options and wedge sizing	139
E3. Water definitions and external loads	140
E4. A bolt: position, crossing and embedment	141

Contents · 7

Choose a section here or use the PDF bookmarks. Original slope calculations are retained under S; the added workflows and methods use F, K, D and E.

Section	Page
E5. Available axial force along the bolt	142
E6. Passive orientation and tension/shear choice	143
E7. Patterns and shotcrete arithmetic	144
E8. Locate loads on interacting columns	145
E9. Scalar distributions used in studies	146
E10. Work one draw from each distribution	147
E11. Sampling, correlations and scenario meaning	148
E12. Sensitivity, combinations and report packages	149
E13. Fitted distributions and CDF distance	150
E14. Regression and rank correlation	151
E15. Explicit design factors: calculation order	152
E16. Work a design-value ratio by hand	153
E17. Search geometric bolt spacing	154
E18. Check the bolt-spacing recommendation	155
E19. Bench geometry beyond finite wedges	156
E20. Work a bench-width scenario	157
E21. Compound filters preserve the full study	158
E22. Anchor direction: from the head into the slope	159
E23. Independent service resistance and applied support force	160
E24. Steel design, lock-off and proof loads: a separate screen	161
E25. Preserve qualification evidence and inspect the audit	162

Contents · 8

Choose a section here or use the PDF bookmarks. Original slope calculations are retained under S; the added workflows and methods use F, K, D and E.

Section	Page
E26. Published bolt materials: selection is not system design	163
E27. Calculate a steel limit and preserve edited product data	164
E28. Trial length, geometric embedment and bonded resistance	165
E29. Read bolts and patterns on the current model geometry	166
K25. Query, include and remove individual observations	167
K26. Large kinematic runs and complete exports	168
S17A. Overhanging block-toppling section geometry	169
S17B. Hand calculation for a supported overhang	170
S17C. Independently solve a five-column overhang	171
I22. Manual contact inputs and scope feedback	172
K27. Equal-angle stereonet: construction, grid and hand checks	173
K27A. Inverse query, 10-degree grid and projection consistency	174
I23. Locate controls without changing the analysis basis	175
I24. Numerical agreement in portable report replay	177
I25. Keep the plot, population and interpretation in view	178
I26. Inspect the slope model without assigning an assumption	179
I26A. Inspect the water-area preview and its active input	180
I26B. Inspect reinforcement without assigning a design value	181
I27. Mode relevance, stale calculations and phone boundaries	182
I28. Clear actions and field keyboard affordances	183
I29. Strength-law round trips and location completeness	184

Contents · 9

Choose a section here or use the PDF bookmarks. Original slope calculations are retained under S; the added workflows and methods use F, K, D and E.

Section	Page
S17D. Exact-factor and conditioning audits for toppling	185
I30. Wet footprints for planar head-water modes	186
K28. Live kinematics on the analysis stereonet	187
I31. Predictable model rotation and pointer ownership	188
I32. Retained survey geometry and reproducible case settings	189
I33. Embedded tools and selection lifecycle	190
I34. Interface appearance and engineering meaning	191
I35. Accessible controls and enlarged text	192
I36. Discontinuity averages and embedded field references	193
I37. Read the detailed calculation worksheets	194
I38. Contact branches, support geometry and recoverable edits	195
I39. Resolve orientation evidence before analysis	196
I40. Reviewable field actions and backup comparisons	197
I41. Field navigation without changing engineering evidence	198
I42. Orientation authority, drafts and repeat observations	199
I43. Supported classification and interpretation limits	200
I44. Automatic phone declination: model and provenance	201
I45. Switch layouts while keeping unfinished work	202
I46. Current audit: save, recovery and observation identity	203
I47. Current audit: numerical corrections and worked checks	204
I48. Current audit: inputs, source freshness and limits	205

Contents · 10

Choose a section here or use the PDF bookmarks. Original slope calculations are retained under S; the added workflows and methods use F, K, D and E.

Section	Page
I49. Geology access from the Field Map	206
I49A. Field Map control example	207
I50. Mobile appearance and input readability	208
I51. Choose the geology image area by panning	209
Additional sources · 1	210
Additional sources · 2	211

I1. How to use this manual

Begin with the observed record and the question being asked. A rock description is evidence; a joint-set assignment is an interpretation; a kinematic flag is a geometric screen; a factor of safety belongs to a stated load and mechanical model. These products should not be exchanged without an explicit basis.

To reproduce a result	Do this in order
1 · Identify the population	Record project/outcrop/set, active filters, included IDs, feature type and north reference. Do not average bearings directly across 0°/360°.
2 · Preserve original inputs	Separate missing values from zero. Keep observation units, GPS accuracy/source, manual overrides and parameter-selection notes.
3 · Follow the exact convention	Use the stated coordinate order, normal hemisphere, sign, contact side and definition of FS. Identically named quantities can use different conventions in different models.
4 · Calculate in discrete steps	Build geometry, calculate loads, solve reactions, evaluate resistance, then form the ratio or classification. Each worked page provides intermediate checkpoints.
5 · Apply domain checks	Check daylight, contact, validity, denominators and missing inputs. A null/unresolved result is not safe.
6 · Compare and preserve	Carry unrounded values; round once at the end. Save inputs and result together, then export the package needed for later reproduction.

Use degree mode for printed trigonometry; use natural logs ln and base-10 logs log10 only where specified. Most worked examples show at least nine significant figures for checkpoints. The objective is agreement within stated numerical/rounding tolerances, not bit-for-bit identity from a hand calculator.

Section identifiers F/K/D/S/E are stable references. Existing slope chapters are now S1–S15; their worked examples retain original case IDs such as P01, W01 and T08. References [R1]–[R12] belong to the original slope source register; additional source identifiers are listed at the end.

I2. Coverage, evidence and release status

Phone and desktop layouts present different workflows over related records. The phone emphasizes rapid observation and live orientation; the desktop emphasizes maps, tables, imports, filters and analysis. Device capabilities and connectivity still determine which operations can run.

Evidence tier	What this edition establishes
Source review	Descriptions were traced to the current field, structure, kinematic, rating, geology, data and engineering modules and their visible controls.
Worked arithmetic	Original examples were independently calculated and checked against program outputs. Checks and exact input values are retained in accompanying local evidence files.
Regression checks	The application regression suite tests defined behaviors and failure paths. A passing suite is not proof of every input, browser or device.
Field validation	Synthetic orientation poses do not calibrate a particular phone. Verify compass, inclination, GPS and the actual contact method against independent field references.
Account / external services	Offline and backup workflows describe implementation and configured defaults. This work did not inspect or change live account permissions, provider quotas, email delivery or map-service availability.

Corrections exposed while making the steps explicit

Release v1.11.6 corrects the physical-phone-normal conversion, which could reverse dip direction by 180°. Independent known-plane poses check the corrected boundary. Manual inputs and stored historical measurements are not automatically altered; corroborate older phone readings against field notes, geometry or a compass before analysis.

The RMR slope-orientation choices now include the published −60 very-unfavorable adjustment, while retaining −50 and existing records. The field section distinguishes observation, category selection and computed rating. Legacy records remain unchanged unless explicitly edited.

This reconciliation also corrects legacy rainfall units, invalid material inputs, orientation/export consistency and incomplete reinforced-wedge equilibrium. Statistical summaries exclude lift-only ratios from sliding factors while preserving every raw result. Regression and browser checks cover these paths; their bounded cases do not prove universal correctness.

Public primary sources support theory and field methods. Implementation-specific cutoffs and worksheet choices are identified as such. Separate internal software-comparison records are not the independent acceptance basis and are not reproduced here.

I3. First use and finding the right workspace

Open the app online initially so its local files can be installed and cached. Read the Terms of Use before accepting. Acceptance is stored in that browser with its version/time; it is not identity-verified server consent. Declining does not delete existing observations. Terms can be reopened from Data.

Control / workspace	Use
View: Auto / Field / Desktop	Auto follows screen width. Field gives the compact collection workflow; Desktop gives tables, maps and analysis. Choosing a view does not create a separate dataset.
Project / outcrop context	Check both before saving observations. The visible active context determines where field measurements and descriptions belong.
Collect / Map / Analyse / Data	Primary phone navigation. Collect opens the notebook, outcrop details, Readings and Joints; Map shows saved locations; Analyse opens scientific tools and geology references; Data manages backup/export and settings.
Other field tools	Open Joints and Strength test from Collect, independent Slope rating and Kinematics from Analyse, and Terms of Use from Data.
Desktop analysis	Geology workspace presents saved maps, records and a linked stereonet. Save or discard table draft edits before Stereonet analysis. Imported structural populations and saved engineering cases remain explicitly identified.
Field display	Data > Settings offers dark/daylight appearance and standard/large/extra-large text. These change presentation, not saved measurements or calculations.
Reference charts	Open the relevant field reference, use zoom or Fit width, and pan/scroll for detail. A reference view does not enter an observation for you.

Grant location or orientation permission only when using that feature. GPS acquisition and compass/orientation are distinct services: one may work while the other is unavailable. Manual orientation entry remains available when sensor readings cannot be independently confirmed.

An update is downloaded separately from the active field session. Save records, close every open app window/tab and reopen to activate it. The app deliberately avoids reloading an unsaved field form. Clearing browser data is not an update step and can remove local observations.

I4. Paired manuals and release boundaries

Theory v49 and Field Use Guide v47 describe app v1.35.4. Theory explains implemented calculations; the field guide groups observations into complete protocols. It is not a separate calculation implementation.

Field protocol	Theory counterpart / boundary
1. Establish and describe outcrop	F: record identity, location/provenance, descriptions. D: map context and exports.
2. Bedding and joint populations	F: orientation and phone conventions. K: poles, means, sampling and kinematics.
3. Complete RMR	F: exact RQD/spacing endpoints, combined condition, groundwater, adjustment and sum.
4. One joint: Barton-Bandis	F: joint evidence and shear screen. S/E: strength in an engineering model. No closure/stiffness or automatic rebound-to-JCS conversion.
5. GSI and Hoek-Brown	F and S: observed GSI, MPa UCS, mi, disturbance, applicability and calculated parameters.
6. Slope screening	K: geometric possibility. S/E: separate equilibrium models, geometry and limits.
7. Preserve the field record	D: saved records, GIS/CSV, full backup, account sync and deletion scope.
8. Independent slope hazard	D1-D5: worksheet categories/formulas and missing values. Independent assessment identity; not an outcrop RMR or slope FS.

This edition updates device backup and recovery (I20-I21), optional mapping groups (F19) and opening Stereonet colors (K24). Desktop data and structural-analysis guidance remains in D15-D15A/K1. Optional Joint set/Interpreted set imports and explicit reviewed adoption remain in K1-K1A/K4. Prior observation/context protocols, diagnostics, factors, bolt search, bench scenarios and filters remain in F16-F18/K19-K20/D17/E15-E21. The five-step reinforcement procedure, independent service/steel checks and live geometry remain in E22-E29 and I6-I10. Field observation protocols and the zero-additional-waviness recommendation are retained. I46-I48 document the current numerical, validation and recovery corrections.

Whole-slope block-flexure FS remains withheld. Kinematic flexural-toppling screening is a different geometric calculation and does not validate a flexural equilibrium FS. Finite numerical and synthetic-browser checks do not establish physical-phone calibration or universal engineering validity.

Open and save the manuals: under Data > Help & manuals, expand Manuals & field guidance. Field use guide v47 and Theory & calculation manual v49 open as PDFs in a new tab. Internet is needed; before fieldwork, save each PDF to Files or Downloads and verify it opens offline. On iPhone, use Share then Save to Files. Neither manual is part of the automatic offline app download; the app links show their current file sizes.

Both PDFs match this release. F16-F18 retain survey/domain and trace procedures; K19-K20 retain pairing definitions; D17 retains schema-6 and export guidance. F13-F14/S6/S6A-S6B retain the distinction between descriptive waviness, the additional term and angle addition. These fields preserve observations without adding a strength law, automatic weighting or inferred three-dimensional

persistence. Public documents contain methods and procedures; internal comparison records remain separate.

Every app release must review and version both manuals, update the crosswalk and verify reviewed source/artifact hashes. Rerun examples when implementation or assumptions change. A matching version label alone is not reconciliation.

I5. Enter a planar section and resolve input problems

In Slope stability, choose the planar model and Geometry. The model represents one vertical section, with its bearing pointing downhill. New cases use one Section dip direction for the slope, failure plane and inclined upper ground; their dips are separate inclinations measured within that same section.

Step	What to do and why
1. Choose the section	Record its downhill bearing, north reference, location and geological basis. A map bearing is not a dip angle.
2. Enter geometry	Slope height is vertical; slope dip and failure-plane dip are from horizontal within the chosen section. Upper-ground dip describes the ground behind the crest. Use each field diagram; it is a definition sketch, not calculated geometry.
3. Check field observations	A true dip measured on an oblique plane cannot simply be relabeled as a section dip. The app does not calculate apparent dip automatically. Supply an explicitly interpreted, justified section or select another appropriate model.
4. Resolve legacy/imported conflicts	The panel preserves and displays conflicting saved/source directions. Review the section bearing and all three inclinations, check the interpretation acknowledgment, then choose Apply the shared section direction. This changes the analysis case, not the original field readings.
5. Follow validation links	Use Review and Calculate to inspect the consolidated input checks. Select a linked issue to open its setup step; recognized main fields receive focus. Correct evidence or model assumptions and review again. A blank is not zero.
6. Review the result	For a dry planar block without a rear crack, the failure plane must dip outward less steeply than the face and more steeply than the upper ground to close the section. Rear cracks and advanced editors add their own conditions. Read the engine result and limitations.

Changing a conflict-free planar Section dip direction updates all three case bearings. Flat upper ground has no controlling bearing until inclined. Wedges are three-dimensional and may have different plane directions; do not force wedge bearings to match. Applied loads also require their actual directions rather than blanket alignment.

Field diagrams are available offline with the cached app. The consolidated review includes water, reinforcement, materials and extended inputs, while final calculation still performs its mechanical checks. An unresolved model returns an explanation; it must not be interpreted as safe.

I6. Build the slope model in a visible sequence

The slope workspace is a separate engineering interpretation. Describe the slope and upper ground, choose the intended mechanism and establish the north reference, location and evidence. A field measurement or joint-set mean supplies an orientation, not a complete finite block, pressure state or strength law.

Setup action	Interpretation and retained boundary
Select orientations early	In Geometry, choose an available observation or interpreted mean for the selected release contact. Review the population and north reference. Enter the slope face separately; manual contact angles remain available when field data do not represent the case.
Name each surface	Model surfaces & assignments keeps stable roles such as Slope face, Failure plane and Joint 1 alongside the optional descriptive name. A name does not establish a contact, move a plane or change its mathematical role.
Complete dimensions	Use the definition diagrams and entered units. Planar height is vertical; two-joint wedge H1 is vertical toe-to-crest height at Joint 1; isolated-block height is normal to its base; toppling column width is normal to the joints. These dimensions are not interchangeable.
Review contact properties	Use supported case-specific inputs or deliberately apply a named property snapshot. I7 explains copying, evidence and overrides. A common name does not make different surfaces mechanically equivalent.
State loads and water	Inspect the explicit water, seismic, reinforcement, external-load and design-factor summaries. A collapsed section is not evidence that its contribution is zero.
Review, calculate, preserve	Open Review setup, follow issues and inspect assumptions (I8), then Calculate and inspect the mechanical result. Save case and export its input/result package after review.

Orientation choices capture their source observations. Later field edits do not automatically refresh the case. Review or reselect the source deliberately. A manual analysis change does not rewrite field observations. Source and case north references must agree.

Planar analysis still uses one interpreted section bearing (I5). Changing that bearing is not an automatic apparent-dip conversion. For an oblique observed plane, establish justified section angles and preserve the measured true orientation separately. The setup workflow does not remove that requirement.

For planar and two-joint wedge cases, enter rear-crack geometry under Geometry and its pressure/head definition under Water & loads. These controls edit the same case, not two independent cracks. The explicitly positioned basal-wedge crack remains with its geometry editor and crosslink. Surface names also label the computed model and report figure; they do not change its shape or colors.

I7. Inspect geometry and assign property snapshots

The setup figure now uses entered geometry. Its vertices/faces come from the same geometry adapter as the calculated model preview. Planar, block and toppling side elevations preserve section proportions; a wedge uses an oblique or plan view. Horizontal and vertical axes share one feet-to-drawing scale. Auto-fit can make a larger model fill the same screen area: read the feet scale and volume. Vertical span = max(z_i) - min(z_i) for current vertices; it is not necessarily H1 or block-normal height. Oblique/plan views foreshorten some lengths and angles. On desktop, Show input diagram opens the additional setup sketch in the input column; Hide input diagram closes it. Live geometry remains separately visible at the right. The compact phone view retains its visible setup sketch.

Incomplete or invalid geometry clears the previous shape and shows the geometry reason. The geometry adapter retains the selected toppling mode's base/column restrictions while allowing unfinished strength inputs. The separately collapsed definition sketch remains illustrative and not to scale. A drawn body is geometry only, not evidence of correct strength, water, support engagement, feasible equilibrium or an accepted FS. The separate model preview and final calculation retain those distinct checks and limits.

Property operation	Exactly what it means
Create or update a profile	Under Named contact properties, open Create or update a property set. Capture supported contact strength with a distinct name and evidence. Save, copy or update changes only the library. Apply is separate.
Apply to a contact	Copy the selected profile's values, identity, revision and evidence into that case's selected contact. Orientation, geometry, water and unrelated contacts retain their separate inputs.
Edit the contact afterward	A changed value is a local contact override. The original assigned snapshot remains available for comparison; case-specific values govern calculation.
Edit the library afterward	An existing case does not track that change. Review the changed library copy and deliberately apply it if appropriate. If the library copy is unavailable, the assigned evidence remains. Keep values as manual removes the assignment, not the current values.
Respect compatibility	Named intercolumn profiles and the verified block-toppling recurrence require zero intercolumn cohesion. Nonzero cohesion stays manual within the block-flexure diagnostic; it does not establish an accepted whole-slope FS. Toppling profiles do not add nonlinear strength or waviness.

A profile is not proof of applicability. Record feature/test IDs, scale, intended shear direction, stress interval, condition and water basis. Do not reuse one surface's peak or residual parameters merely because another has the same rock name. S6A-S6B and Field Protocols 4 and 6 retain the evidence and double-counting checks.

The local workspace permits up to 100 profiles. Each requires a distinct name (case-insensitive) and nonblank evidence. Library storage is scoped to the signed-in account on that browser, or the local workspace when signed out; it is not an online shared material library.

I8. Review completeness before calculation

The setup review collects independent checks before calculation: primary and extended geometry inputs, north/source consistency, contact-strength parameters, water definitions, external loads, reinforcement, design factors and attached rock-mass interpretation. Invalid advanced groups can be reported while primary inputs are still incomplete. A completed input set is not an engineering approval.

Review item	Required response
Missing or invalid input	Open its correction link. Recognized main fields are focused; subsystem links open the corresponding editor. Correct evidence or assumptions, then review again. Blank is not zero; an unsupported value should remain unresolved.
Orientation interpretation	Check the captured source and any difference between it and the current angles. A section or set interpretation can be deliberate, but its rationale must be recorded.
Water and seismic summary	Confirm the actual pressure/head model, external ponding and kh/kv values. Dry or zero action is an assumption to justify, not a consequence of leaving a panel closed.
Support and external loads	Check counts, forces, locations and active choices. A listed support is not proof that it intersects the moving block or can mobilize the entered resistance.
Design factors	Distinguish characteristic inputs from an enabled factor basis. Read the factored case and residual mechanical checks; avoid applying a factor twice.
Warnings and unsupported models	Read unresolved geometry, missing evidence and diagnostic-only flexure warnings. No result must be treated as safe solely because an input check passed.

Readiness does not solve all the later mechanical conditions. Calculate still checks the model's supported contacts, finite geometry, stress state, force/equilibrium conditions and support engagement. A setup can be complete and still produce no admissible result. Advanced studies must use the same valid input basis and preserve every rejected or unresolved scenario.

Save after deliberate changes. Export all slope cases preserves saved case inputs, source selections and assigned property snapshots; it does not export unfinished drafts or the complete reusable profile library. Use Export property library separately for reusable profiles. I9 explains transfer and a local-save conflict. Field-data upload is not a backup of these local engineering cases.

This release changes the geometry presentation and preserves the selected toppling mode in its shape-only adapter. It does not add apparent-dip conversion, a new strength law, automated three-dimensional persistence, a groundwater-flow solution or an accepted whole-slope flexural FS. The retained S/E equations and their limits remain controlling.

I9. Preserve drafts, cases and property libraries

Operation	Stored meaning and boundary
Switch mechanism normally	The mechanism selector reopens that model's local draft. Start another mechanism with this slope copies only slope/upper-ground inputs, their names and north into a new planar/wedge target. It does not infer contacts or properties.
Existing target draft	The slope-copy action offers Open existing draft or Cancel slope copy. Existing target inputs are not replaced. Save/export deliberate alternatives rather than treating the single draft per mechanism as a case history.
Export all slope cases	Saved, validated case bundle with assigned snapshots; neither every draft nor the full reusable profile library. Import through the saved-case importer and review each case.
Export property library	Separate reusable-profile bundle from current memory. Import property library file adds valid profiles, skips identical repeats and gives ID/name conflicts distinct imported copies. Existing cases, assignments and profiles are not overwritten. Apply remains explicit.
Export current draft JSON	Methods & exports preserves the current unfinished input for manual recovery. It is not a validated case and has no automatic draft-import control.
Calculation package	Preserves the calculated case, result, version and evidence for review. It is not a substitute for saving unfinished work or exporting unused library profiles.

Local-save conflict: if another tab changed the workspace, retain the conflicted tab while exporting its needed saved cases, current draft and property library. Export property library reads the current in-memory profiles, including a new profile that failed to save. Reopen the safely stored workspace under the same account, import the valid library bundle, inspect imported copies and explicitly apply the intended profile. Save the reviewed case. There is no automatic merge of unfinished case drafts or recovery of invalid legacy cases.

Incomplete loading values: No seismic action requires explicit finite zeros for both kh and kv; blank, null or invalid coefficients open the prescribed-coefficient editor. For an imported draft with invalid stored mean pressures hidden by a derived groundwater model, Use groundwater-derived contact pressures is an explicit repair. It requires valid groundwater/ponding definitions and replaces only invalid stored means with zero placeholders; the solver still derives actual pressures. The placeholders do not make the model dry.

Short-height screens: use Setup step to navigate when Back/Next are hidden, and the model toggle to recover editor space. Scroll the active editor and follow issue links to the actual input. Layout changes do not alter calculation inputs, assumptions or equations.

I10. Translate field geometry into a documented model

Field Protocols 6.2.1-6.2.4 bridge the exposure and the model. Mark the local toe, crest, upper ground, face bearing, section and potential release surfaces in a located sketch. Preserve measured orientations/points separately from interpreted hidden continuation, representative sections and release boundaries. A trace length alone establishes neither a finite width nor three-dimensional persistence. A mapped or kinematically possible mechanism is a candidate for analysis, not a declaration of failure.

Use a supported idealization: a planar prism needs its basal section and releases; a finite wedge needs the intersecting planes and bounding geometry; an isolated block differs from interacting columns. Toppling requires the supported base/column geometry, not only steep into-slope orientations. Irregular or benched ground is not silently flattened. Document a defensible local reach/section or use another suitable method; the bench-comparison and diagnostic flexure limits remain unchanged. FHWA-HI-99-007 (1998), Rock Slopes, and FHWA detail-line mapping Part G are supporting field-to-analysis reading, not evidence for a specific site.

Synthetic planar geometry, no strength or loads supplied. Take H = 30 ft, face dip beta = 70 degrees, basal dip alpha = 35 degrees, flat upper ground and width b = 10 ft. Both planes dip south at 180 degrees true, so the chosen north-south section contains their true dips. No apparent-dip conversion or rear crack is used. Width and basal continuation are explicit teaching assumptions; a real case needs release and continuity evidence.

Step, x positive uphill from toe	Calculation and result
1. Set the toe	(x,z) = (0,0). Elevation here is a local relative coordinate, not GPS altitude.
2. Locate crest at z = H	x_c = H / tan(beta) = 30 / tan(70 degrees) = 10.919107 ft.
3. Locate basal / upper intersection	x_r = H / tan(alpha) = 30 / tan(35 degrees) = 42.844440 ft.
4. Form the triangular section	Upper length = x_r - x_c = 31.925333 ft; basal length = H / sin(alpha) = 52.303404 ft.
5. Find area and volume	A = H(x_r - x_c)/2 = 478.879998 ft2; V = A b = 4788.799976 ft3.
6. Compare with live geometry	Vertical span 30 ft; volume about 4788.80 ft3. Use unrounded values; auto-fit screen size is not a physical dimension.

The independent hand geometry and actual adapter agree for this case. It tests the stated idealized construction only; it is not evidence that a natural surface is continuous or released. No unit weight, friction/cohesion, water pressure, seismic action or support capacity is inferred, and no FS is supplied. Obtain and document those separately before the mechanical calculation. A displayed body is not a stability result.

I11. Read adjacent guidance without inventing an input

Expandable guidance beside field and engineering inputs explains the quantity, units, collection or selection method, and applicable source. Open the nearby help before entering an unfamiliar number. Existing charts and grouped protocols remain available. A quoted range is context, not a default or a measured value.

Input family	Meaning of the help
Outcrop, RMR and rock-mass inputs	Retain observed hardness, independent visual GSI, core versus outcrop RQD and test-based parameters as distinct evidence. Dropdowns do not make an unobserved condition known.
Barton-Bandis	Characterize one actual joint and shear direction; retain JRC method/scale, joint-wall JCS, friction basis and effective stress. Raw rebound readings are all retained and arithmetically averaged; there is no automatic rejection or JCS conversion.
Kinematics	Slope dip/bearing, shared friction and lateral window define a geometric screen. An editable lateral limit is not a measured plane, failure probability or FS.
Independent slope hazard	Definitions identify vertical height, slide-axis length, transverse road width, along-road exposure, annual rainfall and block dimension versus volume. The supplied worksheet variant, including its categories and caps, remains the arithmetic basis.
Engineering case	Geometry, water, loads, strength and reinforcement require their own evidence and consistent units. A typical ground-anchor inclination or steel percentage cannot establish site-specific resistance.

Help text and bundled reference diagrams remain available with the installed offline app. External source links require internet; save required publications separately. Manuals are separate PDF downloads and must also be saved before leaving coverage. Neither opening help nor viewing a chart selects a value or revises saved observations.

Reinforcement now follows five groups: choose the system; select bar and steel properties; place and aim; establish length and anchorage; set loading and review. Published bar values can initialize the steel component, while site bond, embedment and system evidence remain separate decisions (E22-E28). The workflow does not provide automatic anchor design, displacement-dependent mobilization, a bond test or a verified full-slope flexure model.

I12. Follow the desktop slope workflow

The desktop slope workspace groups workflow navigation, current inputs and the actual geometry view. It is a separate engineering interpretation of observations; opening it does not turn a field outcrop into a validated slope case. The same Geometry, Materials, Water & loads, Reinforcement, Review setup and Results sequence remains available on compact screens. The view does not infer missing measurements or an acceptable design basis.

Review area	What to do
Case and mechanism	Identify the current case, model, north reference and source population before editing. Existing source snapshots do not automatically refresh from changed field observations.
MODEL WORKFLOW	Work through the six named steps. The four-group completeness indicator describes Geometry, Materials, Water & loads and Reinforcement; it is not a factor of safety or engineering acceptance. Follow issue links to the actual field.
Current inputs	Read the active section title and units. Show input diagram reveals the additional setup sketch; nearby definitions explain inputs. Trial geometry and published steel presets are editable assumptions, not measured site evidence.
Live geometry	Inspect the entered block, feet scale, dimensions, supports and surface names. Focus model enlarges this view; Restore split view returns the inputs alongside it. Automatic fit is not an actual size change.
Calculate and preserve	Calculate after completing the model, inspect the result and assumptions, then Save case. Export a slope case file for independent backup; field cloud sync does not include these cases.

The model may remain visible while inputs are incomplete. Valid shape alone does not establish valid contact strength, groundwater, support mobilization or admissible equilibrium. Invalid geometry must clear the old shape; old calculated results must not stand in for changed inputs. Recalculate after edits before interpreting or exporting a current result. I5-I11 and S/E retain the exact conventions and limits.

Saved cases, Advanced studies and Methods & exports remain separate destinations in the workflow rail. Jump to current inputs and Jump to live model provide keyboard navigation. Phone collection remains the compact field workflow. Smaller analysis windows keep the controls in a stacked or scrollable arrangement; use Setup step and Show model / Hide model. Original field measurements, units and equations are unchanged by the desktop layout.

I13. Read results, studies and the calculation report

A result belongs to the current calculated case and its stated mechanism. Read status and limitations before the FS or ratio. Missing, rejected, diagnostic or unresolved outcomes are not a safe result. Sliding, overturning and strength-reduction factors have their stated definitions; the unresolved whole-slope block-flexure threshold remains outside an accepted equilibrium FS.

Output or operation	Interpretation / preservation
Results	Inspect status, governing mode, geometry/volume, forces and any contact or reinforcement checks. The displayed summary does not replace the detailed audit.
Saved cases	The catalog stores input and source snapshots. Displayed comparisons are recalculated with the current method; loading does not silently update source observations. Export all slope cases preserves the saved inputs, not every draft or reusable property.
Advanced studies	Sensitivity & uncertainty, applicable Joint combinations and Bench comparison are optional studies with their own input basis and result exports. Complete and review the current case first.
Filters and rejected scenarios	A filtered result table is a view of the original study. Preserve excluded, rejected and unresolved outcomes and the original denominator. Export the complete study alongside any filtered view.
Calculation report	Enter identifying metadata, then Generate report. Generation snapshots and recalculates the current case. Changing report metadata invalidates the generated preview and downloads until generation is repeated.
Report downloads	Download calculation package ZIP preserves the report package; Download printable report and Print / Save PDF serve reading/printing. Optional studies are exported separately and are not automatically added to the single-case report.

On desktop the report metadata and paper preview are presented beside one another; compact screens present the controls before the preview. Confirm the displayed case and generated content before delivery. Record version, assumptions, input sources and review limitations; a polished report is not engineering approval. E12 and the subsequent worked sections explain the retained calculation/report content.

Preserve each distinct artifact deliberately: original field observations, reviewed analysis population, saved slope cases, reusable property library, complete study outputs and the calculation package. Their scopes differ. Neither a populated desktop panel nor an exported report proves the local engineering case was synchronized online.

I14. Independently reproduce a detailed calculation report

Detailed calculation report is a separate action in Reports in the slope workflow tools. The standard Calculation report remains available for a shorter review package. Both freshly calculate a captured case; neither promotes a rejected or diagnostic result to an accepted factor of safety. Optional sensitivity, uncertainty, joint-combination and bench studies remain separate exports.

Read in this order	What the record provides
Case and decision basis	Version/build, north reference, geometry, original inputs, material snapshots, loads, support assumptions, status and limitations. Factored results retain entered values and their transformations.
Numbered calculation worksheets	Equation, actual numerical substitution, readable result with units; expandable exact arithmetic, source basis and implementation module. Where a recorded solver value exists, an absolute reconstruction difference is printed. Source references distinguish published mechanics from implementation conventions.
Exact input and output appendices	Complete nested records, including alternatives, contact checks, toppling trials, support qualifications and unresolved outcomes. Null means unavailable, never zero.
Computational method appendix	Exact line-numbered computational dependency closure, including geometry clipping, branch selection, numerical tolerances and stopping criteria. Shared dependencies can include unused functions. Source disclosure supplements rather than replaces the explanatory worksheets.
Portable reproduction files	case_snapshot.json and result.json preserve the comparison. discrete_calculations.csv/json preserve numbered rows. calculation_sources.json includes exact source and SHA-256 hashes. reproduce.mjs creates a new directory and compares every result using that bundled source.

For a hand check, select a worksheet quantity and trace its operands back to the geometry, force components or preceding step. Carry full precision until the comparison. The reading copy uses up to six significant digits. Expanded exact arithmetic and the companion files retain round-trip decimal representations of binary64 arithmetic. A hand calculation should reproduce the engineering result to the displayed engineering precision; rounded inputs and platform-specific transcendental functions need not yield bit-identical final digits.

The worked-calculation presentation follows the WillItWall pattern: a short purpose, mathematical formula, actual substitution, result with units and visible source basis. Native MathML typesets supported short fractions, powers and subscripts offline. Unsupported or long expressions remain in exact linear notation; no inferred algebra, input conversion or solver evaluation occurs in the renderer. The existing feet, lbf and psi basis is retained. Null results stay unavailable; whole-slope flexure remains unresolved.

For software reproduction, extract the ZIP into a writable directory and run node reproduce.mjs with Node.js 22 or later. The script verifies bundled source hashes, writes computational modules into a newly created reproduction directory, recalculates the captured case and checks every result. It makes no network requests. This establishes repeatability of that implementation, not an independent validation of its engineering assumptions.

Worksheet coverage includes planar intersections and section area; final face triangulation and wedge volume; weight, loads, contact equations and strength; water head integrals and pressure first moments; bolt intersection, capacity and force components; outcrop material averaging and the Hoek-Brown envelope; and toppling forces, moments, thrust constraints, elastic-section diagnostics and bisection. Follow the exact method appendix for conditional clipping, rejected contact alternatives and numerical guards that are not all expanded into separate hand-calculation rows. Whole-slope flexure remains unresolved and receives no accepted FS.

Published equations are identified beside their uses. FHWA Rock Slopes Reference Manual (1998) supports the limit-equilibrium framework; Goodman and Bray (1976) supports interacting block toppling; Barton and Choubey (1977) supports rough-joint shear; Hoek, Carranza-Torres and Corkum (2002) supports the rock-mass criterion; FHWA GEC 4 (1999), section 5.3.8, supplies scoped prestressing steel limits. Model extensions and computational conventions are explicitly identified and must not be attributed wholesale to these references.

The detailed package can be substantially longer than the standard report. Read or print it on a suitable device. Review exported case notes and source observations before sharing; these are intentionally preserved. This release does not change physical measurement protocols, mechanical solver equations, units or the cloud schema.

I15. Record integrity and explicit assumptions

Current app v1.35.4 is paired with Theory v49 and Field Use Guide v47. The preceding WIM01-WIM41 review is retained; this edition also addresses the follow-up contracts in I17, K23 and E31. A regression pass establishes the tested contract; it is not universal engineering validation, physical sensor calibration or professional acceptance. Original observations, interpreted populations and design assumptions remain separate.

All physical distances are stored and displayed in feet. Supported legacy metre outcrops and measurements are converted at every ingestion path, including automatic cloud downloads and conflict acceptance: feet = metres / 0.3048. Thus 10 m = 32.8083989501 ft and 100 m elevation = 328.083989501 ft. The original remote comparison baseline is retained; canonical feet are queued for upload. The ft-v1 marker prevents a second conversion. A previously mislabelled ft-v1 number cannot be inferred reliably: check its original evidence.

Legacy orientation migration requires an actual finite strike and a dip from 0 through 90 degrees. Blank/null/whitespace, nonnumeric or out-of-range dips are rejected before normalization; they are not manufactured into zero or clamped to vertical. Review a rejected backup against its source. Never invent observations to pass a validator.

Barton-Bandis requires an explicit scale basis. Blank means incomplete. With JRC=10, JCS=1000 psi, residual friction=30 degrees and effective normal stress=100 psi, explicitly using assessment-scale values gives tau=100 tan[10 log10(1000/100)+30]=83.9099631177 psi. Selecting scale correction with L0=1 ft and Ln=10 ft gives 68.5142532933 psi by the retained length equations. Different lengths alone do not establish which interpretation is correct.

Removing an RMR override recomputes only ratings supported by observations. Valid category-only RQD/spacing entries remain. For R4 strength=7, RQD=17, spacing=10, condition=25 and Damp=10, base RMR=69; adjustment -25 gives 44. A documented strength override to 12 instead gives 74/49. Clearing that reason returns 69/44, not missing RQD/spacing. Explicitly clearing a measured source and deliberately choosing Use observations are separate operations.

K21. Portable source populations and identity

A portable analysis captures the field observations required by the current source and every saved field view, including their project identities. A saved P1 view remains P1 after export under P2 or all-project scope. The designated field snapshot supplies field views; imported-only views do not acquire that snapshot, and live field observations are not duplicated by it. Inspect population counts after any restore.

Up to 100 imported datasets may coexist with one designated portable field snapshot. The ordinary imported-dataset limit remains 100. Imports retain the 10,000-row,256-column and 64 KB raw-row guards; the normalized portable row, including original cells and headers, must fit 160,000 serialized characters. Portable files retain the 15 MB text limit. Export validates the actual restore contract before download. Notes and original cells are preserved rather than discarded to meet a limit.

Within-outcrop means and source-contribution counts use stable outcrop identity with project context. Duplicate display codes in different projects remain different localities. Imported codes without stable IDs are scoped to their source dataset; rows without an outcrop identity are not silently pooled. Across-outcrop interpreted-set means remain a separate deliberate selection. For two outcrops both labelled OC-01 with 30/180 and 70/180 planes, within-outcrop choices remain 30/180 and 70/180;50/180 is only an explicitly combined interpretation.

Statistics CSV is normalized: one row per interpreted set and contributing outcrop identity, with outcrop_source_id, outcrop_label and outcrop_count beside repeated set statistics. Sum contribution counts within each set, not repeated set totals. OC-01 and OC_01 remain distinct without dynamically generated colliding column names. This is a schema change for downstream spreadsheets.

Adoption retains immutable sourceProvenance, including original observation identity, revision, survey, geological domain, reach and original cells. Compatible target assignments are retained. An incompatible survey/domain requires an explicit review choice to retain that context as provenance only; it is not blindly assigned to an unrelated outcrop. Recovered project copies remap a discontinuity source-measurement link when the corresponding measurement is copied. Legitimately missing historical sources remain historical links.

K22. Orientation boundaries, filters and sampling

Exact horizontal planes have no unique dip direction; reciprocal vertical dip directions describe the same axial plane. Flexural-toppling screening withholds a direction-side classification at exact horizontal/vertical boundaries. Direct-toppling base screening excludes an exactly horizontal plane from direction-dependent zones. Boundary warnings explain that unclassified is unresolved, not stable. Nearby nondegenerate planes retain the ordinary angular tests.

Geographic bedding symbols require verified true-north means. Homogeneous magnetic or unknown-reference statistics remain available as descriptive orientations, but their map marker is qualified rather than rotated as an unqualified true-north bedding symbol. Historical observations are not automatically corrected by today's project declination.

Numeric equals/not-equals compares numbers for numerical fields: 45, 45.0 and 4.5e1 select the same dip. Blank is not zero; text outcrop code 045 remains different from 45. Inclusive circular direction ranges 350-360 and 350-0 both include canonical north 0. Range 0-360 means the full circle; 0-0 means north only. Ordinary dip intervals are not circular. Desktop numeric columns sort saved numbers, numeric strings and draft strings numerically, preserving natural text-ID ordering.

A valid orientation remains usable when optional latitude/longitude is incomplete. The incomplete location is retained for review and is not a mapped coordinate pair; never fabricate the missing coordinate. Complete 0/0 remains valid. Portable analysis preserves the partial original values and does not exclude the plane solely for its incomplete location.

An observed zero-break scanline is different from missing observations. Explicitly select Confirmed complete interval: no natural discontinuities observed, with complete interval length/orientation/reference, and retain an empty fracture list. A complete sound 10 ft line gives frequency 0 and geometric RQD 100 percent under the retained strict greater-than 0.328084 ft segment rule. An interval at or below that threshold gives 0 percent. This geometric estimate is not measured recovered-core RQD.

Sensor smoothing windows contain one correction frame. Changes in north reference, applied declination or heading source invalidate previous samples; a capture cannot label an average of magnetic and newly true-north samples as one corrected reading. Null declination and explicitly entered zero remain distinguishable. This software guard does not establish physical-phone accuracy.

E30. Factored combinations and incipient toppling

Joint combinations preserve the complete enabled design-factor set, its name, material/load categories and audit through the template, pair calculation, loaded case and exports. A design-value ratio is labelled as such. In the retained symmetric wedge fixture (planes 50/119 and 50/241, flat upper face, friction 35), the unfactored FS 1.63249775477 becomes 0.816248877383 when the friction-tangent divisor is 2 and other factors are 1. Pair enumeration must reproduce the same factored ratio; it cannot silently revert to conventional FS.

Toppling bench assessment first compares the valid computed FS with the selected design target. A case already at or above target does not require a mobilized debris geometry to establish belowDesign=false. Below-target cases require a qualified participating-column scenario. Numerical bisection can return the stable side of incipient equilibrium within force tolerance; a stable label alone does not establish absence of an incipient mechanism.

Participating columns comprise those labelled sliding/toppling plus stable-side columns at a limiting condition: nonzero basal demand with abs(abs(base shear)-base shear capacity) <= forceTolerance; or abs(moment residual without base reaction - tensile joint moment capacity) <= forceTolerance times column width. The recorded solver tolerance is used, not a user-chosen relaxation. Stable columns away from these conditions are excluded. Retain each column ID and recorded mode in the scenario audit.

Volume = sum(width times height times depth) over those rectangular midpoint columns. Backbreak = max(0, upper-corner x minus H cot(slope angle)). For the retained dry example H=9.85/0.3048 ft, face 58.65, base 30, joints 64 into slope, width 1.75/0.3048 ft, depth 1/0.3048 ft, friction 31 and gamma 25(6.365880354)pcf: FS=0.912016044906. IDs 1-8 participate; incipient toe1 contributes 34.6493057402 ft3. Total 1651.699443049 ft3 and backbreak 15.0410293704 ft.

For swelling K=1.5 and repose 38, C=cot(38)-cot(58.65)=0.670736199728. S=sqrt(2 K V C / depth); pile height=S/C=47.4523523919 ft exceeds H=32.3162729659 ft. Therefore retain FS and geometry but withhold spill width and recommendation. This is a potential fragmentation scenario, not a progressive-collapse or runout prediction. Whole-slope flexure remains excluded.

Independent single-column control: height 10 ft, face 60, upper 0, overall base 30, joints 70 into slope, width 20 ft, depth 3 ft, dry/friction-only. Its effective basal inclination is 20 degrees and FS=tan(phi)/tan(20). At phi 35, FS=1.92380440065; target 1.5 passes the ratio comparison without debris dimensions, while target 2 requires dimensions and can still have an unresolved resting-deposit width.

I16. Current geometry, review and recovery

Explicitly reselecting a geometry-based bolt preset evaluates current slope geometry. A normal to a 60-degree face dipping toward 0 has inward trend 180 and downward plunge 30. Editing the slope does not silently change an existing manual bolt; reselect the preset deliberately. An overhanging wedge uses the retained physical face side: the horizontal inward bearing follows its geometric inward normal, not an unconditional dip-direction-plus 180 shortcut. Unsupported normal-plunge guidance remains withheld; engagement still requires a geometric intersection.

Changing any clustering setting invalidates completed and pending suggestions. Recompare after changing maximum set count, minimum membership or maximum angular distance. A late worker result cannot revive an obsolete acceptance button. A suggestion computed at 35 degrees is not evidence for a displayed 1-degree limit.

Desktop discontinuity bearings respect each row's orientation mode. The derived bearing is read-only; edit the authoritative bearing or explicitly change the mode. Reviewed changes are validated before saving. Undo restores editable source observations and regenerates derived ratings/bearings, so Dry (15) to Wet (7) can return to Dry (15) without writing a read-only rating.

Quoted tab-separated clipboard cells retain embedded newlines/tabs and escaped quotes as one cell. Malformed quoted input is rejected before staging any edits; bounds and read-only checks still apply. Review & save remains required. Changing import convention preserves explicit column mappings and Not imported choices. A new file or pasted content invalidates prior acceptance immediately, and stale file reads cannot replace newer content or filenames.

Cancel/Clear explicitly discards the matching discontinuity draft; recovering an unfinished existing edit restores its cancel control. Repeated Load latest saved records (retain form drafts) does not replace a retained edit with unchanged baseline fields. Save completion clears only the submitted unchanged draft; newer same-context or different-context input survives. Manual coordinate edits invalidate pending GPS, and photo conversions remain bound to the original form instance.

Creation defaults apply only to new records. Existing deliberately blank project dates or slope IDs stay blank during refill and notes-only edits. Older valid complete backups merge as coherent project versions rather than combining older parents with incompatible newer children. A cloud conflict can atomically accept required nonconflicting dependent updates only after owner/revision and graph checks, with a pre-conflict recovery snapshot. Exact local/cloud convergence clears the obsolete matching conflict; a newer local edit remains pending. These guards do not promise conflict-free concurrent editing.

Selected independent slope GIS exports include the supported slope-backup envelope and selected IDs. GIS numeric discontinuity orientations are numeric properties; genuine legacy strike text remains text. Independent slope ratings still use their separate workflow and backup. Keep an independent export before consequential edits or recovery, and verify a restored file without deleting the only original.

I17. Editing, identity and recovery contracts

This edition retains preceding repairs and corrects WIM68 desktop editor refresh while a Notes cell is open. Source-bound checks distinguish numerical, storage-adapter, browser and independent evidence; none is professional certification or physical-phone calibration.

An observation location is one complete latitude/longitude pair. A partial pair is retained as source evidence but never combined axis-by-axis with its parent. A map may use a complete parent-outcrop pair, labeled by its source, or omit the point. Zero is a valid coordinate. Imported outcrop identities include dataset/project context, so equal display codes from different sources remain separate selectable points. Near the antimeridian, display longitudes use a consistent neighboring world copy; saved coordinates and GIS coordinates are unchanged.

A date-only slope inspection field defaults to the local calendar day when a genuinely new assessment is created, even when the page has remained open overnight. Existing dates and deliberate blanks stay unchanged. Event ordering uses parsed instants: 2026-11-01T01:45:00-07:00 is 08:45 UTC and precedes 01:15:00-08:00, which is 09:15 UTC. Newest selection, Undo and backup-review counts compare these instants; an equal instant is not newer. Equal instants keep source order; missing/invalid timestamps sort before dated observations and are not invented.

Desktop numerical equality uses the column schema: 0, 0.0 and -0 compare equal, but missing does not equal zero. Text identifiers retain spelling. Copy rows quotes TSV tabs, line breaks, quotes and blanks; possible formulas receive a leading apostrophe, while numerical cells remain signed. Paste on a table cell stages a grid for review; paste inside an open input, textarea or editable region belongs to that editor, not neighboring records. Review and Undo apply to staged grid edits. Multiline editors preserve line breaks. A refresh from another tab waits while an input, select or Notes editor is open; staged text and the Escape baseline remain. Escape cancels the edit without changing the prior saved/draft baseline.

An explicitly cleared unified Comments field stays blank. Historical notes remain provenance and do not repopulate the active comment. Undo restores the previous combined visible comment when applicable. Pressing Enter to open an imported cell does not type into its editor. Subsequent intentional Enter presses inside a text editor add line breaks. Supported imported text fields, including Observer and source labels, retain their line breaks on an untouched Save; preserving raw original cells alone is not a substitute for preserving the active value. A mapped blank feature remains unspecified when adopted into field observations; only an unmapped feature column receives the initial Joint import default. Original cells remain retained. Numeric fields are parsed from their input text separately: changing latitude alone preserves an unchanged numeric longitude, including zero. Blank optional coordinates stay null; validation does not invent a paired coordinate.

In the field layout, keyboard focus scrolls a covered control above the fixed bottom navigation. This applies to ordinary field controls at short effective viewports and larger text. It does not move focus or alter input values, and does not apply to modal dialogs or the desktop workspace. Native phone keyboard and operating-system zoom behavior still require device acceptance.

Merge keeps recovery material from every imported full backup in a separate recovery archive with its source filename/export time. Identical recovery content is deduplicated; conflicting same-key drafts remain separate source snapshots. Empty/absent incoming recovery does not erase earlier recovery. These snapshots are preserved for recovery/export rather than automatically applied over active work. Explicit Replace has its separate replacement semantics. Cloud scans follow server ordering and reject repeated IDs without applying a different client text collation.

K23. Reproducible populations and exported provenance

Density contours are bound to the current plotted row identities and orientations. Changing assignments, exclusions or filters so the population changes removes prior contours and invalidates pending work before rendering or figure export. A late worker result cannot restore a previous population. Table, CSV, plot count and contour count must describe the same current subset; changing only selection with the same population does not change density mathematics.

Updating a named saved view preserves its position and selects the saved view explicitly. Reopening the same local file is allowed; cancel events from a child file chooser do not close the analysis workspace. Import content still requires a fresh valid preview before acceptance.

Analysis CSV provenance uses original_1_header/original_1_value, original_2_header/original_2_value and subsequent numbered pairs. Exact header spelling is a value, so Dip and dip from different datasets cannot collide as normalized schema names. Each row retains its source and dataset identity. General export collision detection remains active for unrelated ambiguous record keys. GIS relationship tables include their declared nullable join columns even when a child table is empty or every foreign key is unassigned; do not infer that a blank relationship is a real assignment.

E31. Model displays remain tied to current inputs and results

When groundwater replaces crack/contact mean pressures, the geometry editor is refreshed from the same active inputs. Editing geometry evidence afterward cannot reinstate an older hidden crack pressure. The explicit correction action for invalid replaced pressures likewise refreshes the editor; directly entered custom pressures remain editable under the chosen model.

For an isolated block, a calculated active-support arrow uses the support application point from the current calculation result. If the input height is H and the application fraction is f, the point is the base point plus f H along the block-height direction; this is not necessarily f H vertical elevation. For H=10 ft and f=0.75, the displacement along that direction is 7.5 ft. Geometry-only previews do not claim calculated force placement. Reports and live calculated views use the same result point.

Uncertainty histogram bins and sample counts are unchanged. The horizontal axis spans the returned finite numerical range, allowing narrow distributions to remain visible. The factor-one reference is drawn in range or explicitly identified at the edge as outside the shown range; it is not a design threshold. The report vertical-span dimension uses a dedicated label lane separated from surface-number markers. Graphics do not change geometry, force equilibrium, failure volume or calculated factors.

Transparent photo/sketch attachments are flattened over a white background before the existing JPEG resizing/compression step, retaining dark marks. File names and captions remain attached to their original form instance. Installed reference images can open in their own offline tab through the service-worker cache; unknown paths are not replaced with the app shell. Manuals remain separately saved downloads rather than part of automatic offline installation.

I18. Editing and output scope in app v1.21.4

A field record, an unfinished form draft, a Desktop staged edit, and an analysis interpretation have separate persistence boundaries. A draft kept on the device is not a saved observation. A Desktop table can display staged values while its linked plot and CSV/GIS exports use saved records. Analysis assignments are local interpretations until explicit reviewed adoption. Cloud verification and a prepared downloaded file are separate states; neither follows solely from a successful local Save.

Desktop filters use the declared column type. For a numeric export longitude, -105 and -105.0 are equal, while a blank coordinate is not zero. Export latitude, export longitude and elevation in feet are derived read-only numeric columns; the corresponding field coordinates remain the source. Text identifiers such as OC01 and OC1 remain different strings. Comparisons and exports use the current filtered or selected saved population; no observation is changed by filtering.

In stereonet analysis let P be all valid plotted rows after source and filters, and S the selected row IDs. Most engineering actions use P when S is empty, otherwise the intersection P with S. Assign/unassign and Include/Exclude use S itself, so an excluded selected row can still be included again. On-screen accepted statistics show P; rows and set-statistics CSV use the chosen all-plotted or selected-plotted scope. SVG/PNG figures use all accepted plotted rows, even when CSV scope is selected. A cluster preview may display temporary assignments over all P, but exports retain accepted assignments until the suggestion is accepted.

An explicitly copied Structure measurement transfers its orientation, north reference and classification state. Selecting an Unspecified source clears a prior positive Plane Type in the destination; the reviewer may then classify deliberately before Save. Historical legacy dip-direction text such as N20E remains an active textual bearing through a Comments-only save. It is not silently converted to numeric direction; switching orientation convention remains a deliberate review action.

Independent slope-rating Slope angle is descriptive context and may contain a range such as 45-60 degrees. This text is not a numeric worksheet score and the editor does not infer one representative angle. Project Date and Override date entered in Desktop accept only real YYYY-MM-DD calendar dates or explicit blanks. Previously stored ambiguous historical text is displayed for review and retained through unrelated edits; no locale-dependent conversion is guessed.

Recent description choices sort saved timestamp instants before applying the six-choice limit. Offset spellings and UTC spellings of the same instant are equivalent for ordering; the stored timestamp text and descriptions are not rewritten. These changes affect editing, filtering and presentation, not geotechnical equations, numerical model output or the original field measurements.

I19. Read the six-step live model without mistaking it for a result

The Live Geometry figure is a projection of the current input geometry, not a second solver. The same finite block or generated toppling columns are reused as setup moves through Geometry, Materials, Water & loads, Reinforcement, Review setup and Results. Rotating, panning, zooming or changing visible layers does not change a recorded input or calculate a new case.

Active step	What the figure displays / what it does not establish
1 Geometry	Current retained block vertices, named faces, actual dimensions and volume. Invalid or absent geometry clears the old shape. Dashed surrounding faces extend the entered slope or upper-ground planes for visual context only; they are not surveyed terrain or analyzed mass.
2 Materials	Colors and labels identify contact faces carrying entered friction/cohesion or other selected contact laws. Rock unit weight applies to the whole block. Colored contact faces do not create interior lithologic zones or infer properties from adjacent outcrops.
3 Water & loads	Blue polygons show entered groundwater/ponding wetted faces, using the same convex-face pressure integration geometry as the mechanical method when a complete valid water definition exists. An entered mean pressure colors its contact face; a purple surface shows an entered face pressure and an arrow indicates an entered point-load direction. These are input previews, not solved resultants. Invalid hydraulic assumptions show a message rather than a fabricated water surface.
4 Reinforcement	Entered individual shafts and bounded bolt-pattern head positions appear with geometric engagement status. A visible shaft does not prove steel, bond, service or global stability capacity. Prescribed support with no bolt geometry has no shaft to draw.
5 Review setup	Combined geometry, contacts, water/load input previews and bolt layout help detect inconsistent assumptions. The four-group readiness check is still separate; a complete drawing is not a valid or accepted solution.
6 Results	Only a current Calculate result adds the computed status/mode, reported FS or design ratio, force arrows and available calculated hydraulic polygons. Rejected or diagnostic results retain their qualifications in the result panel; an old result is removed when inputs change.

The contextual gray planes are affine extensions of already entered boundary faces by a fixed display scale about each face centroid. They are excluded from every modelGeometry input, volume, weight, contact, water integration, support interaction and FS computation. Isolated-block mode extends its entered base plane; toppling has no invented surrounding-ground plane. Toggle Show surrounding slope to compare the analyzed mass alone. The exact field hillside still needs mapping or survey evidence.

For water preview, the app first validates mode, faces, unit weight, Hu, elevation/gradient and a stated basis. It then intersects each selected modeled face with the entered surface and paints the resulting wetted polygon. For ponding, the same operation is limited to modeled slope and upper-ground faces. In custom mean-pressure mode, the corresponding modeled contact is marked without inventing a water-table elevation. The result stage prefers calculated hydraulic integrations when present. This visual coupling changes no pressure calculation, force balance, moment, support check or acceptance rule.

I20. Device backup, online state and desktop file scope

Data separates Saved on this device from Online backup. One Save full device backup action captures every local project, independent saved slope assessment, unfinished slope draft and supported recovery material. File preparation is not proof that the operating system saved it. The prepared-file card keeps download and supported Share / Save to Files, the captured time, file SHA-256 and I saved this file acknowledgement together.

The acknowledgement is bound to that file hash, snapshot time, record digests and backup owner. It does not advance the snapshot to the time of clicking or verify the cloud. For saved field and slope records, the displayed new/changed count compares current record digests with that snapshot: even an edit with an unchanged timestamp is detected. Deletions and unfinished work require their own review. A fresh file remains necessary before clearing; a zero changed-record count is not a universal recovery test.

Workspace / control	Exact scope
Data > Recover from a device backup	Safe merge by record ID. Review counts and approve; conflicting project graphs and recovery content are retained.
Desktop > Files & recovery > Project CSVs / Project package JSON	Only the selected field project. A project JSON file does not contain independent slope assessments.
Desktop > Files & recovery > All slope assessments & drafts CSV	All independent saved assessments and unfinished drafts on this device, including the older legacy draft; independent of selected project.
Desktop > Files & recovery > Download GIS ZIP package	Every local field project and independent saved slope assessment, with matching JSON backups.
Desktop table > GIS / CSV selection	The current filtered/selected saved table population. It is separate from the all-device package.
Desktop > Files & recovery > Choose JSON backup	Advanced merge/replace controls retain their existing validation, confirmations and recovery semantics.

Appearance and text size are in Data > Settings. The paired manuals and sensor limitations are in Data > Help & manuals. Save PDFs separately for offline access; they are not precached with the app. Load latest saved records (retain form drafts) appears when saved data changed elsewhere; it reloads saved field forms while retaining modified drafts. A form reload does not upload or establish cloud equality.

I21. Online backup and paused deletion review

Online backup shows one primary next action: sign in, enable backup for the owning account, sync waiting changes, review conflicts, review a paused deletion, or compare the cloud copy. More backup actions & recovery retains diagnostics, restore and sign-out. Sign-in establishes identity; enable backup associates this device; upload drains work; Check cloud data reads and compares saved records; Restore cloud records merges active remote data. None of these actions substitutes for another.

Delete or clear data keeps Clear this device only separate from Delete from this device and cloud. The confirmation lists exact local saved records, slope drafts and applicable remote targets, including cloud-only records. Account, local/cloud snapshots and unfinished-form state are checked again before a destructive operation. Local-only clearing removes the upload queue and cannot finish a pending remote deletion.

A paused deletion is not completion even when local lists are empty. Review remaining deletion reads the active cloud inventory, outstanding queue and parent-child blockers, showing whether each dependent child is local, cloud-only, queued or conflicted. The review does not upload or delete. Resolve related conflicts or restore cloud-only records for review, then retry sync while retaining the queue. Parent deletion remains child-first and revision/account guarded.

Only a guarded readback with no active account records, no outstanding changes and no local saved targets can mark the bulk operation verified. Recovery histories, downloaded files and other devices may retain copies; verification is not secure erasure or account deletion. The optional online service, its limits and offline queues retain their previous contracts. These UI and safety checks do not change a geotechnical equation or cloud schema.

F19. Optional mapping groups and coverage

Field > Mapping method & coverage (optional) describes a shared scanline, exposed window or collection approach at an outcrop. Skip it for ordinary individual measurements. A saved group retains its survey ID and per-observation assignments; collapsing the panel or changing an outcrop note does not remove them. Domain and reach remain optional context. Group names such as Lower bench scanline 1 identify the collection effort, not a joint set.

Method	Enter / confirm before complete coverage
Reconnaissance / selected critical joints	Collection name, selective approach, visibility/access limits and coverage. Selective observations are not a representative random sample.
Systematic scanline	Positive length (ft), trend and plunge (degrees), known north reference and visibility limits. Complete requires length, both orientation components and known north.
Systematic window	Positive exposed width and height (ft), face dip and direction (degrees), known north reference and visibility limits. Complete requires dimensions, both face angles and known north.

Relevant inputs appear beside the chosen method, with their units and completeness requirements before Coverage. Existing unrelated geometry remains under Other recorded geometry (retained); choosing another method does not erase it. The measurement/discontinuity Mapping group (optional) selector records the saved group ID. The group north reference describes sampling geometry and does not rotate an observation.

These metadata do not calculate RQD, infer missing fractures, apply orientation-bias weighting or link automatically to the separate Engineering scanline dataset. F16-F18 retain the dimensional checks, trace censoring and source relationships; K retains the explicit analysis methods. Preserving collection effort and visibility is consistent with the discontinuity-survey procedure in USBR Chapter 7 [FC2].

F1. Field records: context, observation and interpretation

A project contains outcrops; each outcrop contains structural sets, orientation measurements and discontinuity observations. An outcrop is the field locality and parent record. A set groups observations such as Bedding, J1 or J2; its name alone does not establish a statistically distinct population. Station reference is optional. The independent Slope rating form has its own records and is described separately.

Stage	Action and stored meaning
1. Project	Choose the project before entering observations. Header fields are name, date, county, route, nearest milepost, default Slope ID, personnel and notes. Leave the correction override blank for automatic WMM2025 phone correction. If the project prescribes a correction, record its east-positive value, date and basis.
2. Outcrop	Create a unique outcrop ID within the project; save its location, descriptions and assessment inputs. IDs are compared without case. A new outcrop receives an Unassigned structural set when needed.
3. Structural set	Choose or create a set and feature type. Record bedding separately from joints when that distinction is observed. Keep conflicting or transitional structures identifiable.
4. Measurement	Select the active outcrop and set, check north reference, then save manual strike/dip or capture a usable sensor reading. Each saved measurement is a separate observation.
5. Discontinuity	Record the plane, persistence, aperture, infill, wall condition and test evidence. Copying an orientation from Structure creates a snapshot, not a permanently linked observation.
6. Review	Check the saved record, location provenance, missing fields and implausible orientations. Use the stereonet to inspect populations; a tight cluster alone does not establish correctness.

Save, draft and completeness have different meanings

Typing updates recoverable form drafts. Restore fills the form; Save commits the record. A recovered form is not a newly saved observation until saved. The notebook’s location/lithology prompts are limited completeness checks, not a geotechnical review or confirmation that all design parameters were observed.

Separate observed facts from interpretations in their respective text fields. Record sample/test and external photo references so another mapper can trace the observations. Systematic traverses and multiple viewing directions reduce selection bias; collecting only the most accessible faces can omit important discontinuities [F3, F4].

Optional attached photos and sketches

Attachments retain the filename and an editable caption. The app redraws the image with its longest edge at most 1,600 pixels and JPEG quality 0.75; it is a compressed working copy, not preservation of the original file or its georeferencing metadata. Keep original georeferenced photographs separately. The Data chapter explains export behavior.

$$\text{Scale} = \min(1, 1600/\max(\text{width},\text{height})); \quad 4000 \times 3000 \text{ px} \rightarrow 1600 \times 1200 \text{ px}$$

F2. Location, elevation, units and provenance

The location button requests browser geolocation with high accuracy enabled, no cached fix requested, and a 20-second timeout. The browser may use GNSS, Wi-Fi or another location service. The app label “GPS” identifies this capture route; it does not certify the hardware or a survey method [F1].

Quantity	Stored field behavior	Interpretation
Latitude / longitude	Decimal degrees; form rounded to 7 decimals	Browser coordinates use WGS 84. Decimal places do not establish positional accuracy.
Altitude	Browser metres × 3.280839895; form rounded to 0.1 ft	The API defines height above the WGS 84 ellipsoid. No geoid or vertical-datum transformation is applied.
Accuracy	Browser horizontal accuracy × 3.280839895; rounded to 0.1 ft	API horizontal accuracy radius, nominally 95% confidence. It is not vertical accuracy.
Capture time / source	Time the callback updates the form; source gps	This is not the provider’s fix timestamp. Manual location edits clear capture time and accuracy.

Worked conversion

Altitude = 100 m × 3.280839895 = 328.0839895 ft → 328.1 ft

Horizontal accuracy = 8 m × 3.280839895 = 26.24671916 ft → 26.2 ft

40.123456789°, −105.123456789° → 40.1234568°, −105.1234568°

Null altitude or accuracy remains blank; missing values are not zero. The app does not retain altitudeAccuracy, a vertical datum field, or the provider timestamp. State the intended datum in notes if elevation is used for engineering work.

How a strike–dip measurement gets its location

At capture/save, a measurement copies the currently saved outcrop latitude, longitude, altitude, accuracy and location-capture time. Its source is inherited-outcrop. This is not a fresh fix at the exact plane, and a later outcrop-location edit does not move previous measurement snapshots. Save the appropriate outcrop location before measuring, and use separate outcrops where spatial separation matters.

Lengths in these field forms are feet. Angles are degrees and coordinates are decimal degrees. Pressure units remain explicitly labelled: Barton inputs use psi; Hoek–Brown UCS uses MPa. A feet label never means a pressure unit.

F3. Manual plane orientation and north reference

Strike is the horizontal line within a plane; dip is its steepest downward inclination. WillItMap stores right-hand-rule (RHR) strike: looking along the strike bearing, the plane dips to the right. Bearings are clockwise from the stated north reference. Dip ranges from 0° to 90°. This convention follows the field-mapping definition described in the USBR manual [F4].

Dip-direction azimuth D = wrap360(S + 90°); RHR strike S = wrap360(D − 90°)

wrap360(x) = ((x mod 360°) + 360°) mod 360°

Input convention	Example	Saved numerical meaning
Manual Structure	S = 290°, dip = 60°	D = wrap360(380°) = 20°; strike stays 290°.
Discontinuity RHR	N70W, dip 60°	N70W = 360° − 70° = 290°; D = 20°.
Discontinuity dip direction	D = 20°, dip = 60°	S = wrap360(−70°) = 290°.
North correction	Magnetic strike 350°; correction +15°	True strike 5°; true dip direction 95°. Dip remains unchanged.

Manual Structure accepts numerical strike 0–360° and normalizes 360° to 0°. Its selected north reference is stored; the project declination is not silently applied to a manual value. If the compass was already corrected, do not apply the same correction again.

The desktop north-correction operation requires an explanatory note, preserves the original orientation, adds the entered signed offset and records the selected reference. Positive offset rotates the azimuth clockwise. The input offset resets after applying it so an unrelated later edit does not apply it twice.

Special orientations and legacy text

A horizontal plane has no physically meaningful strike or dip direction; the internal inverse routine uses a numerical placeholder. A exactly vertical plane has two equivalent dip sides 180° apart; compare its strike line modulo 180°. Near vertical, a small genuine tilt can change the dip side.

Discontinuity legacy fields can retain text such as “60 NE”; the numeric dip is read, but a compass suffix is not a separate validated constraint on the selected dip direction. Use the explicit RHR or dip-direction mode and check the resolved bearings. When both bearings are supplied, the app checks perpendicularity within 0.1° modulo 180°, not an independently observed dip side.

F4. Phone orientation: collection method and quality limits

Phone orientation is an experimental browser measurement route. Synthetic plane checks do not calibrate particular iPhone or Android devices. Corroborate readings against an independent compass/clinometer and known surfaces. Where the permission API exists, the app requests absolute orientation access, including the magnetometer; denied access leaves listeners disabled. Manual entry remains available.

Step	Procedure and implementation behavior
Prepare	Enable motion/orientation access; permission may be required on iPhone. Move away from metal and check the displayed correction source and an independent bearing.
Contact	Hold the phone back flush to the representative rock plane. A case or projecting camera can prevent flush contact; do not substitute the phone edge for the selected plane.
Steep planes	At 70–90°, rotate the phone sideways within the plane so its top points across the face, not upward. The physical plane must stay the same.
Read quality	Missing orientation/heading or failed compass calibration prevents strike capture. A dip-only result does not contain a usable bearing.
Capture	Hold still, inspect strike/dip/dip direction and quality, then capture. Poor-quality capture asks for confirmation; confirmation does not improve the measurement.

Numerical quality gates

For the iPhone top-edge heading route, let H be the horizontal magnitude of the phone's unit top-edge vector. $H < 0.12$ prevents capture; $0.12 \le H < 0.30$ is poor. Any negative compass heading or heading accuracy is invalid [F10]. Over the averaging window, the worst reported compass uncertainty above 25° is poor; above 15° through 25° is fair. Averaged dip ≥ 85° downgrades an otherwise good result to fair. Missing accuracy metadata does not prove a small angular error.

The sensor manager retains up to 30 samples, uses at most the latest 12 no older than 1.5 seconds, and rejects a stale latest reading. It averages axial planes rather than arithmetically averaging bearings. If that mean is ambiguous, it falls back to the latest usable reading; this is not a confident mean of a broad population. Captured metadata contains quality, sample count and the last raw Euler event, not the entire sample history.

Corrected release and older records

Release v1.11.6 corrects a 180° sensor dip-direction error at the browser-to-storage boundary. Existing records are not rewritten. Earlier phone orientations warrant corroboration or recollection; do not rotate every historical record. New readings carry sensorOrientationConvention = physical-enu-to-stored-v2. Older phone records without this marker or an explicit orientation-edit timestamp carry a review warning. An edit records user action, not independent field verification. Synthetic checks do not establish physical-device accuracy.

F5. Phone orientation: reproducible coordinate calculation

W3C device axes are x to the right, y toward the top, z out of the screen in the device's standard orientation. Changing portrait/landscape viewport does not redefine these axes. Rotations are intrinsic Z–X′–Y″ [F2]. Apple defines a magnetic compass heading; WebKit passes magneticHeading with default portrait top-edge reference [F10, F11]. The app also interprets absolute heading as magnetic and adds declination; verify the provider's reference independently.

For a = α, b = β, g = γ, abbreviate $c_a = \cos a$ and $s_a = \sin a$, and similarly for b and g. Matrix rows are East, North, Up; columns are the rotated device x, y, z axes. Trigonometry below uses degrees.

$R_1 = [c_a c_g - s_a s_\beta s_g, -c_\beta s_a, c_g s_a s_\beta + c_a s_g]$

$R_2 = [c_g s_a + c_a s_\beta s_g, c_a c_\beta, s_a s_g - c_a c_g s_\beta]$

$R_3 = [-c_\beta s_g, s_\beta, c_\beta c_g]$

The back normal is minus column 3. Rotate its horizontal components by the heading correction, then reverse all components if needed to obtain physical upward normal (E,N,U), U ≥ 0. For clockwise correction δ: E′ = E cos δ + N sin δ; N′ = N cos δ − E sin δ. The iPhone route aligns the predicted top-edge heading $\text{atan2}(R_{12},R_{22})$ to its supplied compass heading plus declination. The absolute route applies declination directly.

Physical upward normal → dip = acos U; D = wrap360[atan2(E,N)]

Persisted geological normal fields use n = −N, e = −E, u = U. This historical storage convention is reflected in planeNormalFromStrikeDip and the inverse formula D = atan2(−e,−n); it must not be mistaken for a physical ENU normal. The correction is made only when ingesting a new sensor event.

Known-plane check: 30° down to the east

α = 0°, β = 0°, γ = 30° → device x = (0.8660254038, 0, −0.5)

Physical upward normal = (E,N,U) = (0.5, 0, 0.8660254038)

Dip = acos(0.8660254038) = 30°; D = atan2(0.5,0) = 90°; S = 0°

With +12° east declination, D = 102° and S = 12°; dip remains 30°. The opposite phone face or rotation within that plane gives the same axial plane. Independent physical-frame checks cover 3,600 constructed attitudes, both faces, arbitrary in-plane spins, portrait/landscape viewports, magnetic/true references and iPhone near-upright rejection; dips include 70°, 85°, 89.9° and 90°.

F6. Structural-set mean and angular scatter

Planes are axial observations: a normal and its negative represent the same plane. Averaging bearings directly fails near north wrap and vertical crossings. The app builds an orientation scatter matrix and takes its principal eigenvector. This is an implemented descriptive estimator, not a confidence region or proof that one geological set exists.

For RHR strike S and dip d: $D = \text{wrap360}(S + 90°)$

$v = (n,e,u) = (-\sin d \cos D, -\sin d \sin D, \cos d)$; $|v| = 1$

$A = \Sigma\, v_i v_i^T$; $A\,m = \lambda_1 m$; $|m| = 1$; $\lambda_1 \geq \lambda_2 \geq \lambda_3$

The upper-hemisphere principal direction m is inverted to the mean plane. If $\lambda_1 - \lambda_2 < 0.05n$, the app withholds a mean; n is count. This is a software ambiguity convention. Mixed north references, malformed members, or stored normals differing axially by more than 0.1° from their paired strike/dip also withhold a mean. The latter is a representation-consistency check, not sensor accuracy. Uniformly unknown references retain a descriptive mean labelled unknown.

$\theta_i = \text{acos}(|v_i \cdot m|)$; angular RMS = $\sqrt{[\Sigma\, \theta_i^2/n]}$

Choose $q_i = v_i$ if $v_i \cdot m \geq 0$, otherwise $-v_i$; $\bar{r} = |\Sigma\, q_i|/n$

Worked group: three true-north planes

Input	Stored normal (n,e,u)	Angle from mean
Strike 0°, dip 30°	(0, −0.5000000000, 0.8660254038)	10°
Strike 0°, dip 40°	(0, −0.6427876097, 0.7660444431)	0°
Strike 0°, dip 50°	(0, −0.7660444431, 0.6427876097)	10°

$\lambda_1 = 1 + 2\cos^2 10° = 2.9396926208$; $\lambda_2 = 2\sin^2 10° = 0.0603073792$

$\lambda_3 = 0$; $\lambda_1 - \lambda_2 = 2.8793852416 > 0.05 \times 3 = 0.15$

Mean: S = 0°, d = 40°, D = 90°; RMS = $\sqrt{(200/3)} = 8.1649658093°$

$\bar{r} = (1 + 2\cos 10°)/3 = 0.9898718353$

RMS uses n, not n−1; it is a root mean squared angular deviation, not the usual unbiased scalar sample standard deviation. $\bar{r}$ is dimensionless and near one for a concentrated group. Do not average distinct populations merely because these statistics can be calculated.

F7. Lithology, weathering and exposure descriptions

These fields preserve field observations; choosing a descriptive term does not assign a strength, density, friction angle or geologic age. The USBR field manual treats consistent rock and discontinuity descriptions as the foundation for engineering interpretation [F3, F4]. Record the scale and representativeness of the observed exposure.

Field	Available approach / interpretation
Lithology	Common sedimentary, igneous and metamorphic names, recent project values, or a custom description. Mixed lithologies is available; describe proportions and contacts where material.
Formation	Observed or interpreted formation name. Keep the map-derived source and uncertainty distinguishable from a field identification.
Weathering	Fresh; Slightly Weathered; Moderately Weathered; Highly Weathered; Completely Weathered. No percentage algorithm or automatic GSI/RMR deduction is applied.
Color / texture	Select a common term or retain the description. Grain-size terms, crystalline, porphyritic, clastic, glassy, vesicular, foliated, banded and massive are descriptive choices.
Depth to rock	New outcrops default to 0 ft to represent exposed rock. Override with observed regolith thickness, or clear to unknown. The default is not a subsurface determination.
Exposure length / height	Enter feet. Describe what was actually exposed; a visible trace length is not necessarily full joint persistence.
Notes / interpretation	Keep observed features, engineering interpretation, sample IDs and external photo references traceable.

Selection method

Describe fresh interior and weathered surface separately where they differ. Check whether a strength test or hammer observation samples intact material, joint-wall material, or altered infill; these are different inputs. Avoid treating a general lithology dropdown as a substitute for that distinction.

A bedding set and two to six joint sets may be useful field groups, but the number of sets is a mapping decision, not fixed by the app. Record minor or critical orientations when they may control a slope even if they do not dominate the dataset. Sampling direction, visibility and inaccessible planes can bias apparent frequency [F4].

Simple depth example

Exposed rock observed → depth 0 ft; 2.5 ft measured cover → depth 2.5 ft

Unknown depth → blank, not 0. A later outcrop edit should retain that distinction. The software does not extrapolate depth between outcrops or calculate bedrock elevations from this field. Interpret such surfaces separately with an appropriate spatial and geologic model.

F8. Observed intact strength and visual GSI

Observed hardness means intact rock field-strength grade R0–R6, not Mohs mineral hardness. Use the adjacent field chart and record the actual response. The UCS bands are approximate characterization guidance; selecting a grade does not supply an exact laboratory UCS [F5, F6].

Grade / approximate UCS	Field response used by the guide	RMR strength score
R0 · 0.25–1 MPa	Thumbnail indentation	0
R1 · 1–5 MPa	Knife peeling; firm hammer-point impact crumbles material	1
R2 · 5–25 MPa	Knife peeling difficult; firm hammer point makes a shallow indentation	2
R3 · 25–50 MPa	Not peeled with a knife; one firm hammer blow fractures a specimen	4
R4 · 50–100 MPa	More than one hammer blow needed to fracture	7
R5 · 100–250 MPa	Many hammer blows needed to fracture	12
R6 · >250 MPa	Hammer produces chips only	15

The grade is categorical. A boundary value such as 50 MPa does not uniquely identify a field grade without the assessment basis. A numerical tested UCS can be retained separately in the Hoek–Brown section and can support an independent RMR strength selection. The app does not choose the midpoint of a grade’s range.

GSI is observed, not calculated from RMR

Observe rock-mass block structure/interlocking and discontinuity surface condition, then use the GSI reference chart to select an assessed value from 0 to 100. Record the representative zone and uncertainty in notes. The app stores that visual observation; it does not derive GSI from RMR, joint count, hardness or a lithology name [F6, F7].

Example: the mapper selects GSI 45 for an observed jointed rock mass. The stored GSI remains 45 if groundwater or an RMR orientation category changes. A later Hoek–Brown calculation consumes this observed value but does not revise it.

GSI and intact grade describe different scales. A strong intact block can occur in a poor-quality jointed mass. A dominant bedding, joint or foliation plane can govern stability even when a rock-mass strength calculation is available; use the appropriate discontinuity model.

F9. RMR: strength, RQD and spacing ratings

The five base ratings are strength, RQD, discontinuity spacing, discontinuity condition and groundwater. This implementation uses the broad RMR table reproduced by FHWA, with its explicitly defined software endpoint choices [F5]. Ratings are empirical classification scores, not measured strengths or factors of safety.

Independent strength category	Rating	Input basis
UCS >250 MPa	15	Test or supported assessment
UCS 100–250 MPa	12	Same
UCS 50–100 MPa	7	Same
UCS 25–50 MPa	4	Same
UCS 5–25 MPa	2	Same
UCS 1–5 MPa	1	Same
UCS <1 MPa	0	Same; R0 represents the 0.25–1 MPa field grade

Numerical RQD used by code	Rating	Shared-boundary examples
90 < RQD ≤ 100%	20	RQD = 90 → 17
75 < RQD ≤ 90%	17	RQD = 75 → 13
50 < RQD ≤ 75%	13	RQD = 50 → 8
25 ≤ RQD ≤ 50%	8	RQD = 25 → 8
0 ≤ RQD < 25%	3	RQD = 24.99 → 3

Numerical spacing in ft used by code	Rating	Shared-boundary examples
Spacing > 6.56168	20	6.56168 → 15
1.96850 < spacing ≤ 6.56168	15	1.96850 → 10
0.65617 < spacing ≤ 1.96850	10	0.65617 → 8
0.19685 ≤ spacing ≤ 0.65617	8	0.19685 → 8
0 ≤ spacing < 0.19685	5	0.10 → 5

The listed feet thresholds are the actual rounded constants used in code. Measured RQD or spacing sets its rating; category-only selection leaves the measurement blank. RQD is entered, not calculated from core runs or converted from volumetric joint counts. Record its method and applicability to the mapped exposure.

F10. RMR: condition and groundwater selections

The app uses one combined discontinuity-condition category. It does not independently total persistence, aperture, roughness, infill and weathering subratings. Evaluate the whole category in the context of the governing set and retain the detailed discontinuity observations [F5].

Condition score	Implemented category	Units / use
30	Very rough, discontinuous, closed; fresh walls	Qualitative combined assessment
25	Slightly rough; aperture <0.00328 ft; slightly weathered walls	0.00328 ft approximates 1 mm
20	Slightly rough; aperture <0.00328 ft; highly weathered walls	Same aperture convention
10	Continuous: slickensides, thin gouge <0.01640 ft, or aperture 0.00328–0.01640 ft	0.01640 ft approximates 5 mm
0	Continuous: soft gouge >0.01640 ft or aperture >0.01640 ft	Record infill type and actual thickness when observed

These are dropdown descriptions, not a program that parses each descriptor into a score. At a category boundary or where observations fit different parts of multiple categories, document the selected basis; the broad table does not remove the need for engineering judgment. Do not infer a condition score from JRC alone.

Observed groundwater	Rating	Interpretation
Dry	15	Observed condition at the assessed exposure
Damp	10	Same
Wet	7	Same
Dripping	4	Same
Flowing	0	Same

Selecting the groundwater description sets the corresponding rating. The broad FHWA table also describes inflow and pressure-ratio alternatives, but this app’s field classification uses the observed-condition choice. It does not convert a water pressure or flow rate to that rating. A wet-season design assumption or measured pressure belongs in the applicable analysis inputs.

Example contribution

Slightly rough, tight, slightly weathered walls → condition rating 25

Damp observed groundwater → groundwater rating 10; contribution = 25 + 10 = 35

Blank is unassessed. Zero is a valid poor-condition or flowing-water rating and participates in a complete base sum. Without every base rating, the app withholds the base RMR.

F11. RMR: orientation adjustment categories

Orientation adjustment depends on the proposed application, not simply the absolute strike/dip. The user selects the category relative to the excavation or foundation. The application does not derive the category from the stored orientations. The following combines every implemented dropdown choice [F5, Table 9-6].

Adjustment	Category / application
0	Very favorable — all applications
−2	Favorable — tunnels/mines or foundations
−5	Favorable — slopes; fair — tunnels/mines
−7	Fair — foundations
−10	Unfavorable — tunnels/mines
−12	Very unfavorable — tunnels/mines
−15	Unfavorable — foundations
−25	Fair — slopes; very unfavorable — foundations
−50	Unfavorable — slopes
−60	Very unfavorable — slopes; available since v1.11.6

The same −25 adjustment represents two different application/category combinations. Preserve the intended application in the record or accompanying notes; a score by itself cannot distinguish fair slopes from very unfavorable foundations.

The added −60 category does not change the existing −50 category or previously saved selections. This is the complete table available in app v1.11.7. The classification still requires the mapper or designer to judge favorability relative to the proposed works.

These RMR adjustments are distinct from kinematic admissibility and from a limit-equilibrium factor of safety. A rating reduction alone does not establish that a plane daylights, has sufficient persistence, or forms a removable block. Use the orientation and slope-analysis procedures for those questions.

F12. RMR: worked sum and consistency checks

This example uses the exact rating definitions on the preceding pages. Keep observations and their selected ratings together so the sum is reproducible; zero is a valid rating and blank means unassessed.

Worked outcrop

R4 → 7; RQD 80% → 17; spacing 1.0 ft → 10; condition → 25; Damp → 10

Base RMR = 7 + 17 + 10 + 25 + 10 = 69

Fair slope: adjusted RMR = 69 − 25 = 44

Very unfavorable slope: adjusted RMR = 69 − 60 = 9

Orientation may be left unassessed: the base can be complete while adjusted RMR remains blank. An unsupported orientation score also withholds the adjusted result while leaving a valid base. The sum is not clamped to zero; no rock-mass class or strength is inferred. Existing −50 selections are not upgraded to −60.

Conflicting observations

If observed hardness, measured RQD/spacing or groundwater disagrees with its rating, an unresolved conflict withholds the total. A documented override permits a different listed strength, RQD or spacing category; it cannot authorize an undefined score, invalid RQD or negative spacing. Groundwater stays linked. Independent strength can differ from field hardness. Original inputs are retained for review.

In this example, retaining RQD 80 but entering rating 3 creates a conflict and no total. If a documented override is deliberately supplied, base = 7 + 3 + 10 + 25 + 10 = 55 and fair-slope adjusted = 30. This is an auditable override, not the ordinary RQD conversion.

F13. Discontinuity records and Barton parameter evidence

The Discontinuity tab logs observations on a particular plane and provides a Barton–Choubey shear-strength screen with optional Barton–Bandis length scaling. It is not a complete joint normal-closure, shear-displacement or coupled stiffness model. A structural set's representative values still require a sampling and assessment decision.

Observation / input	What to collect and what the app does
Plane identity / orientation	Plane type, optional station reference, rock type, RHR or dip-direction orientation and north reference. Copying a Structure measurement preserves a snapshot that can subsequently be edited.
Geometry / contact	Persistence and aperture in feet, roughness, infilling, wall weathering, water condition, photo reference, frequency text and slope ID. Describe censored visible trace lengths rather than implying full persistence.
JRC	Select 0–20, or an exact decimal, with method and intended shear/profile direction. Record profile length L_0 and assessment length Ln when scale correction is used.
JCS_0	Enter positive joint-wall compressive strength in psi and its laboratory, calibrated rebound, site-test or estimate basis. Legacy "JCS(R)" text is not treated as this numerical strength.
Friction φ	Select residual friction, or basic friction for fresh unweathered surfaces; enter degrees and a determination method. Required $0 \le \varphi < 70°$.
Contact / stress	Confirm unfilled rock-to-rock contact. Enter positive effective normal-stress bounds in psi, their basis, and water-pressure assumptions. Infill and asperity dimensions are retained observations, not an automatic model selector.

Rebound observations are not a strength conversion

Enter accepted rebound readings separated by commas, spaces or semicolons, with hammer, direction, moisture and calibration notes. The app accepts 0–100 and reports count, mean and range without statistical rejection. Empty tokens at separators are ignored; an explicitly entered zero remains a reading. Joint-wall and fresh-reference lists stay separate.

Readings 30, 32, 34, 36 → n = 4; mean = 132/4 = 33; min = 30; max = 36

No automatic rebound-to-JCS or rebound-to-friction correlation is applied. Profile comparison, hammer corrections and estimates need supporting evidence [F8, F9]. Preserve roughness direction and scale; neither the description nor JRC automatically creates an additional slope-model waviness term. See S6A and Field Protocol 4.3A.

F14. Barton shear screen: scale, stress grid and worked point

JRC is dimensionless; JCS and effective normal stress σ′ are psi; lengths L_0 and Ln are feet; φ is degrees. Effective stress is supplied by the user, so the calculator does not subtract water pressure again. With scaling off, entered JRC and JCS already represent the assessment scale [F8, F9].

$r = Ln/L_0 \geq 1$; $JRCn = JRC_0\ r^{(-0.02\ JRC_0)}$; $JCSn = JCS_0\ r^{(-0.03\ JRC_0)}$

$\theta = \varphi + JRCn \log_{10}(JCSn/\sigma')$; $\tau = \sigma' \tan \theta$

One reproducible point

Inputs: $JRC_0 = 10$, $JCS_0 = 1{,}000$ psi, φ = 30° residual friction, unfilled rock-to-rock contact, $L_0 = 1$ ft, Ln = 10 ft, scaling on; minimum = maximum effective stress = 100 psi.

$r = 10/1 = 10$; $JRCn = 10 \times 10^{(-0.2)} = 6.309573444802$

$JCSn = 1{,}000 \times 10^{(-0.3)} = 501.1872336273$ psi

$\log_{10}(501.1872336273/100) = 0.700000000000$

$\theta = 30 + 6.309573444802 \times 0.7 = 34.41670141136°$

$\tau = 100 \tan(34.41670141136°) = 68.5142532933$ psi → 68.51 psi

With scale correction off for the same original JRC/JCS/stress, θ = 40° and τ = 83.9099631177 psi. This contrast is a scale-model consequence, not an extra factor of safety.

Stress-grid definition and guards

For unequal bounds, $\sigma_i = \exp[\ln \sigma min + (\ln \sigma max - \ln \sigma min)i/20]$, i = 0…20

For 10–1,000 psi, endpoints are 10 and 1,000 and the middle is 100 psi. Equal bounds give one point. Logs are evaluated separately to avoid ratio overflow. Points with σ′ > JCSn, θ outside 0–70°, or unrepresentable shear magnitude are excluded as null. Nonfinite scale ratios or underflowed scaled strength are rejected. Blank or unknown friction-basis or scale choices require review; they are not silently interpreted as valid defaults.

No stiffness, closure, dilation, peak-displacement or shear-history calculation is implemented here. The selected friction angle is not a calculated kinematic threshold. This field shear screen has no additional-waviness input. When transferring its JRC/JCS to a slope case, keep their scale basis and use No additional waviness unless independent evidence supports the separate contribution; see S6A-S6B.

F15. Hoek–Brown field inputs and calculation handoff

The field form estimates generalized Hoek–Brown rock-mass parameters from observed GSI, numerical intact UCS σci, intact constant mi and disturbance D [F7]. It uses the same GSI observation shown above; no second GSI estimate or automatic RMR conversion is introduced. Applicability must be confirmed as a jointed mass without a dominant weakness plane controlling failure.

Input	Selection and retained basis
GSI · 0–100	Visual rock-mass observation; describe the assessed zone.
0 < σci ≤ 100,000 MPa	Laboratory UCS, calibrated point-load correlation, site result or supported estimate. A field grade alone does not create a numerical UCS.
0 < mi ≤ 1,000	Triaxial fit or rock-type reference estimate. Selecting a reference supplies its central value; overrides retain a basis. Reference ± values are spread, not confidence limits.
D · 0–1	Disturbance from blasting and stress relief, not weathering. Record the affected zone and whether the scenario is representative.

D guide	Scenario
0	Undisturbed; controlled tunnel blasting/TBM; minimally disturbed mechanical or hand tunnel excavation
0.5	Squeezing tunnel with floor heave and no temporary invert
0.8	Severe local tunnel damage from poor blasting
0.7	Controlled small-scale civil-slope blasting with stress relief; large open-pit mechanical excavation with stress relief
1	Poor civil-slope blasting; large open-pit production blasting and stress relief

$$mb = mi \exp[(GSI-100)/(28-14D)]; \; s = \exp[(GSI-100)/(9-3D)]$$

$$a = 0.5 + [\exp(-GSI/15) - \exp(-20/3)]/6; \; \sigma cm = \sigma ci \; s^{a}$$

Example: GSI 45, σci 50 MPa, mi 10, D 0 gives mb = 1.4025603373, s = 0.0022180849043, a = 0.5080857391, and unconfined rock-mass strength σcm = 2.2412967393 MPa. With D = 1 and the other inputs unchanged, σcm = 0.4745303965 MPa. Intermediate values and a confined envelope point are worked in the retained Hoek–Brown slope-calculation chapter.

UCS/mi maxima above are shared software bounds, not geologic validity ranges. Unrepresentable computed parameters or missing determination methods withhold results. Dominant structural control is not applicable. Foliated reference mi may describe tests normal to foliation, not sliding along it. This field form does not calculate equivalent c–φ or assign design strength without assessment.

F16. Geological domains and survey sessions

An outcrop is the parent locality. A geological domain is a project-scoped interpretation of a rock unit, structural zone or other justified grouping; it does not replace the outcrop ID. A survey session describes one collection effort at one outcrop. Similar set names or nearby coordinates do not establish the same domain or a physical connection.

Record / control	Meaning and saved scope
Project: Geological domains	Name and Geological basis / boundaries describe the interpretation. IDs are meaningful within their project. Create and save the project before assigning its domain.
Outcrop: geological context	Default domain and Slope reach / segment supply starting values for new observations. A reach is an explicitly named slope segment; use consistent spelling where the same segment is intended.
Outcrop: survey session	Name; reconnaissance, selected critical joints, systematic scanline or systematic window; exposure orientation, north, dimensions, visibility threshold, coverage and notes. A survey belongs to one outcrop.
Measurement / discontinuity	Survey ID, domain ID and slope reach are recorded on each saved observation. Selecting a survey fills domain/reach, which can be overridden. Later changes to parent defaults do not reassign saved observations.
Legacy / imported observations	Missing context stays unassigned. Present-day outcrop defaults are not evidence of the conditions during an older observation. Assign context only after checking its source.

A domain or survey referenced by saved records cannot simply be removed. Reconcile assignments deliberately; changing a name or description preserves the identity. The selected survey's north reference describes its measurement frame but does not rotate orientations or replace the observation's own north reference.

The method and survey coverage describe how evidence was collected. They do not apply automatic Terzaghi weights, reconstruct unobserved joints, infer representative sampling or certify that the exposure was safe to access. Existing explicit structural-analysis weighting tools remain separate choices. USBR discontinuity surveying guidance [FC2] supports preserving collection method, geometry and visibility limits.

F17. Survey completeness and dimensional checks

Choose the collection method before calling a survey complete. Reconnaissance and selected critical joints are deliberately selective; a recorded count is not a random sample. For a systematic survey, state its physical extent and threshold before collecting its observations. Complete within stated limits describes coverage of that specified survey, not completeness of the rock mass.

Input / validation	Accepted meaning
All survey sessions	Name and collection method are required. Coverage may be complete, partial or not assessed. Unknown values remain blank/unknown instead of invented zeros.
Complete scanline	Positive Survey length (ft), Scanline trend and plunge, and known true/magnetic Survey north reference are required. Trend is 0 to less than 360 degrees; plunge is 0 to 90 degrees.
Complete window	Positive Window / exposure width and height (ft), both Exposed face dip and dip direction, and known true/magnetic Survey north reference are required. Dip is 0 to 90 degrees; direction is 0 to less than 360 degrees.
Paired orientations	Enter both exposed-face dip/direction or neither. Enter both scanline trend/plunge or neither. Partial or unassessed surveys can omit the complete-survey requirements but must still have valid supplied values.
Visibility threshold	Smallest trace reliably visible (ft) is nonnegative when entered. Zero is an explicit claim, not the default for an unassessed detection limit. Positive dimensions describe the actual survey, not automatically the entire slope.
Survey limits	Visibility, access and survey limits identify covered intervals, omitted faces, interrupted sections, instrument/reference information and the endpoint sketch or external survey sheet.

Example: a 20-ft systematic scanline trends 090 degrees and plunges 0 degrees relative to true north. A reliably visible trace threshold of 0.5 ft and a soil-covered interval from 8 to 11 ft belong in the record. If the stated survey requires that hidden interval, mark Partial / interrupted and explain the missing coverage. Do not relabel it complete because the accessible portions have many readings.

Saving a survey does not calculate corrected spacing, RQD, fracture intensity, detection probability or a statistical weight. Existing scanline calculations require their own ordered intersections and explicit inputs (K11). No minimum observation count guarantees an adequate structural model. Field Use Guide steps 1.2A and 2.0 give the collection sequence; [FC2] gives the wider survey procedure.

F18. Visible trace length and censored endpoints

A discontinuity now has numeric Visible trace length (ft), Length basis, two endpoint categories, Trace direction on the plane and Trace evidence / endpoint notes. The older Length / Persistence text remains separate and is never parsed into a new numeric observation. A surface trace is not full three-dimensional persistence.

Observation	Interpretation and validation
Measured / estimated visible trace	State how the visible length was determined. A positive finite numeric length is required when entered; zero is not a valid measured trace. The basis alone does not prove completeness.
Terminates in intact rock	The mapped trace appears to end within the exposed rock. This records an observed termination; it does not prove a strength or continuity for a buried rock bridge.
Terminates against another joint	Record the intersecting feature and which endpoint is involved. Physical intersection at this exposure does not establish a complete removable block.
Beyond exposure / behind cover	Either endpoint makes a stated numeric length a lower bound. The form selects Visible length minimum - full extent unknown; validation rejects a conflicting measured/estimated basis.
Unknown / not checked	Retain uncertainty. A selected length basis cannot prove an endpoint. A visible length with unassessed endpoints is not a complete persistence measurement.
Strike / dip / oblique	Record the direction of the trace on the plane. A visible apparent trace cannot be silently treated as down-dip persistence. Notes retain photo/sketch IDs, direction and any segmentation.

censored trace: true exposed-plane extent is at least the visible length; a finite upper bound is not established

Example: 12 ft of one trace is visible. End 1 terminates against bedding; end 2 disappears behind soil. Save 12 ft, Visible length minimum - full extent unknown (stored basis lower-bound), those two endpoint categories and Oblique / other, plus the photo/sketch reference. This does not enter 12 ft as a failure-plane persistence limit in the slope solver and does not add cohesion or rock-bridge resistance.

USBR [FC1], printed pp. 101-103, requires trace direction, observable length, end conditions and exposure size. These fields preserve that evidence. No automatic bridge-strength, connectivity, three-dimensional persistence or stereological correction is applied. Field Use Guide repeats the recording method inside both RMR and Barton-Bandis protocols.

K1. Structural analysis: establish the input population

The Structure tab records measurements and shows a live stereonet at the active outcrop. The desktop structural workspace combines saved observations with imported rows, interprets sets and opens Cases & tools. Its Cases & sensitivity panel evaluates orientations only; the separate slope-equilibrium workspace calculates forces and factors of safety. Keep these two analyses distinct.

Step 1 — Import CSV or paste spreadsheet cells

Choose Import CSV / paste rows. Select the header option, choose the orientation convention and actual north reference, then Read columns. Map Dip plus Dip direction or RHR strike; map Outcrop and Joint set (optional) when supplied. The parser accepts comma, tab or semicolon separators, quoted cells, escaped quotes, embedded newlines and a leading BOM. Header aliases are suggestions: inspect the mapped columns. Expand How joint sets are imported for the classification and storage explanation. K1A explains original versus interpreted set labels.

Step 2 — Apply conventions explicitly

dip direction = wrap360(RHR strike + 90°)

true direction = wrap360(magnetic direction + east-positive declination)

Declination is applied only to magnetic imports. A nonzero correction labels the result true; a zero correction retains magnetic. Unknown references can be plotted and grouped manually, but automatic clustering and engineering analysis require one known common reference. An analysis-only reference override also needs a written reason; zero rotation changes the label only.

Input check	Accepted domain	Action
Dip / azimuth	0–90° / 0–360°	360° is normalized to 0°
Latitude / longitude	±90° / ±180°	Both present or both absent
Spacing / persistence	Nonnegative finite lengths	Meters ÷ 0.3048 → feet
Elevation	Any finite number	Meters ÷ 0.3048 → feet

Step 3 — Review and retain provenance

Preview import lists errors and possible duplicates; errors prevent Add reviewed dataset, including invalid angles, overlong set labels and overflow during feet conversion. Review original Joint set and initial Interpreted set beside each orientation. Original cells, headers, convention, units, source row and declination remain available. Current dip direction, RHR strike and any cached pole stay consistent after correction, editing or rotation. Duplicate orientations are flagged, not removed; a set label is not a reason to discard a row. Coordinates are optional for plotting.

Example ST22: RHR strike 350°, dip 45°, magnetic north and +10° declination give dip direction 90° true. Elevation 3.048 m becomes 10 ft; spacing 0.3048 m becomes 1 ft. The original strike remains 350°. Import limits are 10,000 rows, 100 imported datasets plus one designated portable field snapshot, 5 MB text/file, 256 columns and 64 KB text per row.

K1A. Import joint labels without losing their provenance

A joint-set label records a supplied classification, not an independently calculated population. Import can carry that label alongside each dip, dip direction and outcrop. The initial editable interpreted group is seeded from the label so its poles can be reviewed immediately.

Dip	Dip direction	Outcrop	Joint set	Initial group
45	120	OC1	J1	J1
47	125	OC1	J1	J1
70	220	OC1	J2	J2
50	130	OC2	(blank)	Unassigned

Use the first four columns as a CSV/spreadsheet example; Initial group is an explanation, not an additional required column. In the importer, read the columns, confirm their mappings, then Preview import. The optional set column may be absent, and blank cells remain unassigned. Surrounding spaces are trimmed and case is preserved: J1 and j1 are different labels. With headerless data, map Outcrop and Joint set explicitly after Read columns. Set labels have a 120-character limit; overlong labels are errors rather than silently shortened identifiers.

Keep supplied and interpreted classifications distinct

Joint set is retained as the original fieldSet and appears as Observed set in the structural table/export. Newly accepted imports seed the assignment once; existing saved analyses are not retroactively regrouped. The analysis assignment can be revised or cleared without rewriting that supplied label. An optional Interpreted set column (including exported analysisSet) explicitly supplies the analysis assignment instead; when mapped it takes precedence, even when the cell is blank. That blank preserves an intentionally unassigned interpretation on export and reimport.

Identical interpreted labels combine within the selected population, including across selected outcrops. OC1 J1 and OC2 J1 are not thereby proven to be the same geological set or a continuous joint. Filter to the relevant outcrop, or give distinct local populations distinct labels before a combined interpretation. Review feature type, north reference, sampling method and geological domain before calculating means or using engineering tools.

Add reviewed dataset adds an analysis dataset. An Outcrop cell is imported provenance; it does not automatically create, attach to or synchronize a field outcrop/measurement record. Save/export the analysis using its own controls and verify the retained rows and observed/interpreted labels. Explicit later adoption is a separate reviewed operation (K4); an unassigned interpretation does not silently regain its original J1 label. No strength parameter, continuity, persistence or safety conclusion is inferred from a label.

K2. Orientation vectors and stereonet projection

Use degrees at the interface. For trigonometry convert degrees to radians. A bearing increases clockwise from north; plunge is positive downward. These equations use east, north, down (E,N,D), unlike the east/north/up force coordinates in the slope chapters. The lower hemisphere is a choice of representation; a plane remains unchanged when its normal is reversed.

$$l(T,P) = (\sin T \cos P, \cos T \cos P, \sin P)$$

pole trend $T_p = \text{wrap360}(\theta + 180°)$; pole plunge $P_p = 90° - \alpha$

$$p(\alpha,\theta) = (-\sin\alpha \sin\theta, -\sin\alpha \cos\theta, \cos\alpha)$$

Here α is plane dip, θ is dip direction, T is line trend and P is line plunge. The down-dip line is $l(\theta,\alpha)$; its dot product with p is zero. For a lower-hemisphere unit pole, $\alpha = 90° - \text{asin}(pD)$, $\theta = \text{wrap360}[\text{atan2}(pE,pN) + 180°]$. Horizontal-plane azimuth is physically undefined; a displayed 0° direction is a convention.

Equal-area and equal-angle drawings

$$r_{EA} / R = \sqrt{2} \sin[(90° - P)/2]$$

$$r_{EQ} / R = \tan[(90° - P)/2]$$

$$x = x_c + r \sin T; \quad y = y_c - r \cos T$$

The normalized primitive radius is one. The actual SVG uses R=140 and center (160,160). The minus sign in y puts north at the top of the screen. Equal-area radius follows by equating disk area fraction r^2/R^2 to the hemisphere cap fraction $1 - \sin P$. Equal-angle follows the stereographic projection of a sphere. Both place a vertical line at the center and a horizontal line on the rim.

Hand example ST01–ST03

RHR strike 0° and dip 60° give $\theta = 90°$, pole $T = 270°$, $P = 30°$. The pole is (−0.8660254038,0,0.5). Default equal-angle radius is $140/\sqrt{3} = 80.8290376865$, giving (x,y)=(79.1709623135,160). Optional equal-area radius is $140/\sqrt{2} = 98.9949493661$, so (x,y)=(61.0050506339,160). Changing projection changes these pixels, not the plane or its classifications. K27 derives the projection and its grid independently.

Field, live, linked desktop, interpretation and kinematic plots open on equal angle (Wulff). Explicit equal area (Schmidt) remains available. All layers and cursor inverses use the selected projection. Projection foundations: Snyder (1987), USGS Professional Paper 1395. The normalized hemisphere equations and examples here are independently derived.

K3. Great circles, intersections and the live field plot

Step 1 — Construct a great circle without singular azimuths

A plane trace is the set of lines lying in that plane. Let a=l(θ−90°,0°) be the strike direction and b=l(θ,α) the down-dip direction. They are perpendicular unit vectors. Sweep the lower half-circle, then project each line:

$$v(t) = a \cos t + b \sin t,\ 0° \le t \le 180°$$

The implementation samples 181 points at 1° steps. An exactly horizontal plane is instead drawn as the full rim with 181 samples at 2° spacing. A vertical plane remains a complete diameter, avoiding undefined trend at the vertical midpoint. ST04 checks an east-dipping vertical plane: endpoints (160,20),(160,300), midpoint (160,160).

Step 2 — Find the line common to two planes

$$w = p1 \times p2;\ l = w / |w|;\ \text{reverse } l \text{ if its down component is negative}$$

$$T = \text{wrap360 atan2}(lE,lN);\ P = \text{asin}(lD)$$

$$\text{acute interplanar angle} = \text{acos}|p1 \cdot p2|$$

The cross product is orthogonal to both plane normals. Its algebraic sign is immaterial because the intersection is an axis. If $|w|<10^{-9}$, the program labels the pair parallel/undefined and removes it from the intersection denominator. Horizontal intersection trends are also axial: a reciprocal trend describes the same horizontal line.

Hand example ST06

Two planes dip 60° toward 150° and 210°. Symmetry fixes their downward intersection trend at 180°. In that section, $\tan P=\tan 60°\cos 30°=1.5$, giving $P=56.3099324740°$. Their normal dot product is $\cos^2 60°+\sin^2 60°\cos 60°=0.625$; the acute angle is $\text{acos}0.625=51.3178125465°$.

Use the live plot while measuring

Choose all measurements at the active outcrop or the active set only. Each saved pole gets its set color and symbol; the newest valid timestamp has a dashed ring. Select a pole or use the measurement list to inspect strike, dip, source and reference. Next nearby point cycles overlapping poles within 14 SVG units. Show the selected great circle to see whether the plane matches the exposure.

Invalid orientations are omitted with a count; stored records are unchanged. Mixed/unknown north and poor recorded sensor quality produce warnings. Older phone orientations can carry an explicit review flag: corroborate them in the field or recollect; never automatically rotate historical records. The flag follows analysis, plots and exports. A shared north label does not establish a correct sensor bearing. The live plot shows saved measurements; a coherent cluster does not prove compass accuracy or geology.

K4. Filters, exclusions, set interpretation and adoption

Step 1 — Define what the calculation includes

Select field data, imported datasets or both; restrict field rows to a project and select applicable outcrops. Feature and text search further restrict the domain; Unspecified includes missing or blank feature labels. Rules combine with all (AND) or any (OR). Text comparisons are case-insensitive; numeric greater/less are strict and between includes both ends. Dates use parsed timestamps. Dip-direction between can cross north: 340°–20° includes 350° and 10°, excludes 180° (ST24).

Click column headings to sort; choose visible columns and page through 50 rows at a time. Sorting changes order, not membership. The table, map and poles share selection. Click a pole, draw a screen circle or freehand polygon, or use row checkboxes; Shift adds to a selection. A screen circle is a drawing selection, not a constant angular cone.

Step 2 — Keep observations and interpretations distinct

Exclude selected rows removes them from plotted/statistical/clustering populations while retaining them. Show excluded rows makes them visible in the table only; Include selected again reverses exclusion. Select possible duplicates flags exact matching orientations at the same outcrop/type; repeated measurements can be real observations. Review before exclusion.

Assign selection to a set writes an analysis interpretation. Giving part of a set another name splits it; giving multiple selections the same name merges them. Copy observed sets initializes the interpretation from field labels. Select angular outliers flags rows with axial angle strictly greater than the entered threshold from their assigned set mean; it does not delete them.

Step 3 — Reuse a view or proceed to engineering

Saved views preserve source, project, filters, layers, coloring and excluded-row display. Interpretations remain in the analysis session. When selected rows exist, clustering uses selected plotted rows; otherwise it uses all plotted rows. Cases & tools uses its explicit Engineering input scope, initially All plotted measurements. Check the included count and north-reference warning before running.

Step 4 — Adopt only a reviewed interpretation

Imported cells can be edited inside analysis; existing field observations are edited in the main workspace. Explicit adoption can attach reviewed imports to existing outcrops and change interpreted field-set assignments, after review and APPLY confirmation. Automatic matching uses a supplied outcrop ID exclusively and respects a supplied project ID; without an outcrop ID, its code must match uniquely. Stale or ambiguous identity requires an explicit target, which the user can choose to override imported metadata. An intentionally blank interpreted set stays unassigned and uses the neutral Imported observations container if attached. Existing field observations cannot be reassigned to a blank interpretation. Field orientation values are not overwritten by analysis-only north corrections; missing imported coordinates remain missing.

Undo analysis edit preserves recent analysis snapshots, bounded to 20 entries and about 16 MB. Export analysis file creates a portable snapshot including eligible field data, imports, assignments, exclusions and saved views; its limit is 15 MB and 10,000 total rows. Analysis settings/cases are local until exported. This workflow is distinct from synchronizing adopted field records.

K5. Axial means and descriptive orientation statistics

Do not average azimuth numbers: 359° and 1° are close, and reciprocal poles describe the same plane. Build unit poles pi and the symmetric scatter tensor Q. Let λ1≥λ2≥λ3 and e1 be its leading unit eigenvector:

$$Q = \Sigma\, p_i p_i^T;\ Qe_1 = \lambda_1 e_1$$

The program withholds a unique mean when $\lambda_1 - \lambda_2 < 0.05N$. This is an application screening threshold, not a significance test. Field orientationStats uses e1 itself as the mean pole. Desktop setStatistics uses e1 only to select consistent signs and then forms a resultant mean:

$$q_i = \text{sign}(p_i \cdot e_1)\, p_i;\ S = \Sigma q_i;\ R = |S|;\ m = S/R;\ \bar{R} = R/N$$

$$a_i = \arccos|p_i \cdot m|;\ \text{angular RMS} = \sqrt{[\Sigma a_i^2/N]}$$

The observed angular P95 is the sorted angle at index ceil(0.95N), using one-based indexing; it is not an interpolated percentile or inferential bound. Desktop normalized eigenvalues are λi/N, and outcrop contributions count the valid rows from each outcrop.

Why two mean values can differ

For dips 20°,20°,50° all toward 180°, the field tensor estimate is $\alpha_Q = \tfrac{1}{2}\text{atan2}[2\sin 40° + \sin 100°, 2\cos 40° + \cos 100°] = 29.5533026754°$. The desktop resultant estimate is $\alpha_R = \text{atan2}[2\sin 20° + \sin 50°, 2\cos 20° + \cos 50°] = 29.8960906390°$. Both retain direction 180° (ST09/ST10). They optimize different criteria; the difference is not rounding.

Input and ambiguity rules

Desktop statistics omit invalid rows and count the valid population, but flag mixed or unestablished north. Field statistics instead return no mean when any member is invalid, references are mixed, or a cached pole disagrees with its saved orientation. An all-unknown field population can retain a descriptive mean explicitly labeled unknown. The desktop axial mean remains descriptive when inferential cones are withheld.

For repeated copies of one orientation, R=N and concentration is unbounded. For competing perpendicular populations, the tensor may have no unique leading axis. Neither a forced arithmetic mean nor an arbitrary direction chosen by an eigenvector tie is a defensible set direction. Record the population and estimator with exported statistics.

K6. Fisher estimates: formula, eligibility and hand calculation

Fisher (1953) supplies the spherical distribution framework. Mean confidence uses the finite-sample concentrated-Fisher approximation after axial sign alignment. Variability uses estimated concentration. These labels describe approximate cones; they are not exact finite-sample confidence coverage for arbitrary axial or multimodal data.

$k = (N-1)/(N-R)$

approximate confidence95 = acos[1 - (N-R)/R x (20^(1/(N-1)) - 1)]

approximate variability95 = acos[1 + ln(0.05)/k]

Confidence describes uncertainty of a mean under the assumed sampling model. Variability describes the modeled spread of individual orientations. Neither is the observed P95. Mean cosine is bounded to [-1,1]; an invalid variability cosine yields no cone.

Eligibility check	Required condition
Sample and reference	$N \geq 5$; exactly one known true or magnetic reference
Unique tensor axis	$\lambda 1 - \lambda 2 \geq 0.05N$
Concentration and shape	$\bar{R} \geq 0.8$; $\lambda 2/\lambda 3 \leq 4$
Nonidentical readings	$N - R \geq 10^{-10}$

For the shape ratio, $\lambda 3 \leq 10^{-10}$ with $\lambda 2 > 10^{-10}$ is treated as infinite; if both are negligible the ratio is one, but identical-data concentration remains undefined. These eligibility thresholds are software screening choices, not a formal Fisher goodness-of-fit test. Repeated readings of one surface do not create independent samples.

Hand example ST07 — eight poles on a 10° circle

Enter eight planes all dipping 10°, directions 0°,45°,90°,135°,180°,225°,270°,315°, all true north. By symmetry the pole mean is vertical, so the mean plane is horizontal. The horizontal vector components cancel.

$R = 8\cos 10° = 7.8784620241$; $\bar{R} = 0.9848077530$

$\lambda/N = (\cos^2 10°, \frac{1}{2}\sin^2 10°, \frac{1}{2}\sin^2 10°)$

$\lambda/N = (0.9698463104, 0.0150768448, 0.0150768448)$

$k = 7/(8 - 7.8784620241) = 57.5951668442$

confidence95=7.3602742425°; variability95=18.5608027961°

Every observed angle is 10°, so RMS=P95=10°. This symmetric circle checks arithmetic, not coverage for natural joint populations. JS values agree with the independent calculation.

K7. Automatic joint-set clustering and its limits

What the optimizer solves

Choose a maximum of 1–8 sets. The workspace compares each k up to that maximum, requiring at least two measurements per requested set, valid orientations and one known common north reference. It uses axial fuzzy c-means with exponent m=2. Each center cj is a unit axis, so its sign is irrelevant.

$$d_{ij}^2 = 1-(p_i \cdot c_j)^2 = \sin^2(\text{axial angle})$$

$$u_{ij} = d_{ij}^{-2} / \Sigma_h d_{ih}^{-2};\ J = \Sigma_i \Sigma_j u_{ij}^2 d_{ij}^2$$

The implementation floors dij at 10^{-7}. If one or more centers have this zero-distance floor, membership is shared equally among those centers and is zero for others. For each j, update cj as the principal eigenvector of $\Sigma_i u_{ij}^2 p_i p_i^T$; this maximizes the corresponding weighted axial alignment.

Reproduce the numerical procedure

Fitting uses at most 2,500 systematically spaced rows, indices floor(iN/2500). Three deterministic starts choose initial rows at one-third intervals; further centers are selected by largest distance to the nearest existing center. Each start runs at most 60 updates or stops when the largest axial center movement is below 10^{-5} degrees. Keep the start with the smallest J; sort centers by mean-plane dip direction.

Every input row is then assigned to its largest membership, provided membership≥the entered threshold and axial angle≤the entered maximum. Defaults are 0.55 and 35°. Otherwise it remains unassigned. Membership measures relative affinity, not probability of correct geological classification. Maximum-k comparison selects the greatest available silhouette as a suggestion; the user must accept it.

$$\text{silhouette}(i) = [b(i)-a(i)] / \max[a(i),b(i)]$$

a is mean axial angle to sampled members of the same best-label group; b is the smallest mean to another group. At most 300 systematic rows are used. Singleton contributions are zero in the final sample average. Silhouette uses best labels even for rows rejected by membership/angle thresholds. Coincident centers or a suggested group with fewer than two accepted rows suppress the score.

Hand check ST11 and interpretation

Four copies of plane 30°/90° and four copies of 60°/270° have perpendicular poles. With k=2, own sine distance is zero, other distance is one, membership is one, both accepted counts are four and silhouette is one. This exact synthetic recovery checks a simple case; it does not prove recovery of overlapping natural sets. Input order affects systematic samples and initialization.

A subset suggestion preserves other rows and avoids their existing set names; its preview and accepted assignments agree. Explicitly assign a shared name to merge sets. Review geology, spread and ambiguous rows before acceptance. The axial objective adapts fuzzy clustering; the original Euclidean FCM paper does not define these engineering interpretations.

K8. Density contours: distinguish the two implementations

Basic interpretation plot: relative peak density

The basic stereonet uses up to 2,000 systematically sampled valid poles, a 37×37 screen grid inverted through the selected projection and a 10° Gaussian angular bandwidth. At each lower-hemisphere grid direction v, the axial distance is ai=acos|v·pi|:

$$z(v)=\Sigma\exp[-ai^2/(2\times10^{\circ 2})];\ \text{displayed density}=z(v)/\max\text{grid } z$$

Contours at 0.2,0.4,0.6,0.8 mean 20/40/60/80% of the grid peak. They are not percent of observations. Changing a dataset, its order or bandwidth can change the relative peak scale. Marching-square edge interpolation draws segments between sampled cells; the contour is a discretized display.

Engineering plot: spherical counting or normalized smoothing

Choose counting-circle area A%=0.5–5, method and projection, then Update plots. The UI uses a 45×45 grid; the calculation allows 9–81 points per side and at most 10,000 rows, using every row. Let f=A%/100, wi=1 or the recorded survey weight, and W=Σwi.

$$\text{Schmidt}(v)=100\ \Sigma wi\ I(|v\cdot pi|\geq 1-f)/W$$

A spherical cap of angular radius a occupies fraction 1−cosa of the hemisphere. Therefore a=acos(1−f): a 1% circle has a=acos0.99=8.10961445599°. The implementation includes the boundary with a 10^{-12} cosine allowance. It counts on the sphere rather than drawing a fixed-radius screen circle.

$$\kappa=1/f;\ K(c)=f\kappa\exp[\kappa(c-1)]/[1-\exp(-\kappa)],\ c=|v\cdot pi|$$

$$\text{Fisher-smoothed}(v)=100\ \Sigma wi\ K(|v\cdot pi|)/W$$

For a uniform axial population, c is uniform on [0,1] and $\int_0^1 K(c)dc=f$. Thus the smoothing scale is equivalent percent per counting circle, with expected background A%, not a probability density whose displayed integral is 100%. This κ is a selected bandwidth, unrelated to the fitted set-statistics k.

Hand check ST15

Use a horizontal plane with weight one and a vertical plane with weight two. At the center, the first pole coincides and the second is 90° away. A 1% Schmidt count is 100×1/3=33.3333333333%. Fisher smoothing adds the explicitly normalized exp(−100) tail, numerically the same at displayed precision. Contours are A%,2A%,4A%,8A%; projection changes drawing/grid sample locations, not the spherical counting rule.

K9. Survey bias, weighted means and rose diagrams

Step 1 — Describe the survey that actually sampled the joints

Traverse weighting is appropriate to a complete systematic survey with recorded geometry. Opportunistic outcrop mapping and selected critical joints are not complete surveys. Paste exactly one unique assignment per included row: a line trend/plunge or a planar traverse dip/direction. Terzaghi (1965) identifies directional sampling bias; the following incidence measures define this implementation.

$$\text{linear incidence } q = |p \cdot t|; \text{ planar incidence } q = \sqrt{[1-(p \cdot n\text{survey})^2]}$$

$$\alpha\text{incidence} = \arcsin q; \; w = 1/\max[q, \sin \alpha\text{min}]$$

p is the joint pole, t the traverse line and nsurvey the traverse-plane pole. The UI defaults αmin to 15° and accepts 1°–89.9°. A cap is reported when αincidence<αmin. The cap is a chosen regularization; a blind or undersampled orientation cannot be reconstructed merely by giving its few observations high weight.

Step 2 — Check a weight by hand

ST12: a north horizontal line crossing a vertical east-west plane has q=1, α=90°, w=1. ST13: that line is parallel to a horizontal plane, q=0, so a 15° cap gives w=1/sin15°=3.8637033052. ST14: a plane with 30° dip against a horizontal survey plane has q=sin30°=0.5 and w=2.

Step 3 — Interpret the weighted result

$$Qw = \Sigma wi \; pi \; pi^{T}; \; Sw = \Sigma wi \; \text{sign}(pi \cdot e1w) pi; \; mw = Sw/|Sw|$$

$$N\text{effective} = (\Sigma wi)^2/\Sigma wi^2$$

The weighted mean is withheld when its leading tensor gap is less than 0.05Σwi. No Fisher cone is inferred from the weight sum. Equal weights of two on the eight-plane ST07 population give total weight 16 but effective N=8, unchanged mean (ST08). Engineering kinematic counts remain unweighted. Weighted density is unavailable for a preview-rotated copy because the recorded traverse would also require a justified transformation.

Rose diagrams

A dip-direction rose adds each row to one azimuth bin. A strike rose uses wrap(θ−90°) and its reciprocal, so total counts are doubled. Bin edges use floor(angle/width); width must divide 180°, with UI choices 5°,10°,15°,30°. Weights apply when selected. Petal radius is proportional to √(bin/maxbin), making petal area proportional to count. ST16: one north strike adds one to the 5° bin and one to 185° in a 10° rose.

K10. Geometric constructions and rotations

Engineering stereonet tools can add planes, lineations and cones, paste trend/plunge rows, measure an acute plane angle/intersection, and preview a rotated copy. These are geometric constructions; they do not create a failure model. A maximum of 50 constructions is retained. Use dip/direction for planes, plunge/trend for lines, and a half-angle for cones.

Cone construction

For a unit cone axis a, choose any orthogonal unit b and c=a×b. The small circle at half-angle h is traced parametrically:

$$v(t)=a\cosh + (b\cos t+c\sin t)\sinh$$

The implementation samples 145 positions and reverses upper-hemisphere vectors. It splits the trace when the hemisphere sign changes so the drawing does not connect unrelated rim positions. A confidence cone, variability cone and manually added cone can look similar but have different meanings.

Rotation convention

Positive rotation is clockwise while looking along the physical axis of advance. Because (E,N,D) is left-handed, the algebraic Rodrigues cross-product term is v×a, not a×v:

$$v_{rot} = v\cos\omega + (v\times a)\sin\omega + a(a\cdot v)(1-\cos\omega)$$

Axis trend accepts 0°–360°, plunge 0°–90° and rotation −360°–360°. Re-express each rotated pole as a lower-hemisphere axis before converting it to a plane. ST17: rotate plane 40°/0° by +90° about the downward vertical. The result is 40°/90°, preserving dip and all interplanar angles.

Workflow and preservation

Choose Preview rotated copy to update the plot only. Restore original plot returns to the included rows. Add rotated copy creates new imported IDs while retaining original IDs, interpreted sets, pre-rotation orientation and rotation parameters. Current strike/dip/direction and cached poles remain coherent. Existing field observations stay unchanged. Rotation edits invalidate a preview; its survey weighting is reset to raw.

Apparent dip: explanatory relation, not a separate UI tool

$$\tan\alpha_{apparent} = \tan\alpha\cos(T_{section}-\theta)$$

This follows by restricting a plane elevation equation to a vertical section. For a 60° plane, a section 30° from dip direction has apparent dip $\operatorname{atan}(\tan 60°\cos 30°)=56.3099324740°$. The app uses the equivalent vector test for daylighting. It does not currently expose a standalone apparent-dip conversion form, and slope equilibrium does not silently convert an oblique joint into an aligned section. Supply an explicitly interpreted section where that model requires one.

K11. Scanline spacing and geometric line RQD

Step 1 — Enter a complete interval

Under Traverses & core, paste id,distanceFt,dip,dipDirection,analysisSet. Enter the interval start/end and line trend/plunge. Distances must be inside a positive-length interval and must be distinct; coincident positions require review instead of counting repeated readings as separate fractures. Include all natural breaks that intersect the interval, not only the selected structural sets.

Step 2 — Form intact segment lengths

positions = [start, all strictly interior fracture positions, end]

$l_i = \text{position}_{i+1} - \text{position}_i$; frequency = $N_{interior}/(end - start)$

geometric RQD = $100\ \Sigma(l_i \text{ if } l_i > l_{threshold})/(end - start)$

The default $l_{threshold}=0.1/0.3048=0.3280839895$ ft (100 mm). Exact-threshold segments are excluded with a 10^{-12} ft comparison allowance. End segments are included; a fracture exactly at an interval boundary does not add an interior break. The core calculation API can accept another threshold, but the current UI uses this default.

Step 3 — Correct adjacent same-set spacing

$s_{normal} = s_{apparent}\ |p_{mean} \cdot t_{line}|$

For each named set, sort its intersected positions and pair successive members. Obtain the desktop axial resultant mean of each pair, then multiply measured distance along the line by the absolute pole/line dot product. Unassigned or nonunique paired means give no true-spacing value. This assumes the adjacent same-set pair represents locally compatible planes; it does not estimate fracture persistence.

Hand example ST21

A 1 ft north horizontal scanline contains natural breaks at 0.2 and 0.5 ft, both in J1 with dip 60° toward north. Segment lengths are 0.2,0.3,0.5 ft. Only 0.5 exceeds 0.3280839895 ft, so geometric RQD=50%. Interior frequency=2/1=2 breaks/ft. Same-set apparent spacing is 0.3 ft; true spacing=$0.3 \sin 60° = 0.2598076211$ ft.

What the value does and does not mean

The number assumes a complete, sound, fully recovered interval and correctly distinguished natural breaks. It is not measured core RQD when recovery, weathering, mechanical breaks or incomplete observation are unknown. Field RMR inputs must retain the observation basis. Select the actual common true/magnetic north reference for the traverse and all pasted planes; mixed references must be reconciled first.

Export scanline results preserves parsed source rows, interval start/end, line trend/plunge, north reference, threshold and calculated summary. These inputs also accompany the complete engineering report. Changing any input invalidates the displayed result and requires recalculation.

K12. Oriented-core conversion and survey interpolation

Define the convention before entering data

Alpha is the acute angle between the plane and the core axis. Beta is clockwise from the reference to maximum down-core dip, looking along advance. Reference offset is clockwise from top of core (0° top, 180° bottom). Plunge is positive down; hole surveys also permit upgoing negative plunge. These conventions must match the instrument log; an unrecognized beta convention cannot be corrected by a generic sign assumption.

Step 1 — Interpolate the hole direction

Paste survey depth,trend,plunge and core id,depth,alpha,beta,reference. All depths are in feet; survey depths must be unique. One station supplies a constant direction; multiple stations bracket the core depth with no extrapolation. Let a,b be unit advance vectors at bracketing depths and f the fractional depth:

$$\Omega=\arccos(a\cdot b);\ f=(\text{depth}-\text{deptha})/(\text{depthb}-\text{deptha})$$

$$t=[a\sin((1-f)\Omega)+b\sin(f\Omega)]/\sin\Omega$$

Nearly identical directions use a directly; nearly antipodal directions are rejected as ambiguous. This is spherical direction interpolation, not a minimum-curvature borehole-position calculation. ST18: horizontal survey trends 350° at depth 0 ft and 10° at 100 ft give north (0°) at query depth 50 ft, not arithmetic azimuth 180°.

Step 2 — Resolve the core plane

$$up=(0,0,-1);\ top=\text{normalize}[up-(up\cdot t)t]$$

$$radial=\text{rotate}(top,\ t,\ \text{reference}+\text{beta})$$

$$p=t\sin(\text{alpha})-\text{radial}\cos(\text{alpha})$$

Convert p to a lower-hemisphere plane. For a vertical hole, top is undefined; the implementation instead uses the supplied survey trend as a horizontal reference. The UI requires reference offset zero in that case. Alpha accepts 0°–90° and beta/reference 0°–360°.

Two hand checks

ST19: a horizontal north hole has t=(0,1,0), top=(0,0,−1). With alpha=30°, beta=reference=0°, p=(0,0.5,0.8660254038), giving pole 0°/60° and plane 30°/180°. ST20: alpha=30°, beta=reference=0°, hole trend=0°, plunge=90°. Thus t=(0,0,1), radial=(0,1,0); p=(0,−0.8660254038,0.5), giving plane 60°/0°.

Preview converted rows and check a known plane before adding them as a new analysis dataset. IDs must be nonempty and unique. The preview shows the first 100 rows; export contains the converted rows and original alpha/beta, depth, reference, interpolated hole direction and chosen north reference. Input edits invalidate the preview.

K13. Kinematic screening 1: daylighting and planar sliding

Kinematic analysis asks whether orientations meet specified geometric/friction screens. It does not calculate factor of safety, forces, cohesion, persistence, connectivity, water pressure, support, failure probability or deformation. Source selection and set interpretation can change results as much as the entered slope angle. USACE EM 1110-1-2908 Chapter 8 provides the broader distinction between rock-slope geometry and stability analysis.

Define the inputs and the exact daylight test

Let β be slope dip ($0<\beta\leq 90°$), θs slope dip direction, φ friction angle ($0\leq\varphi<90°$), and L lateral limit ($0\leq L\leq 90°$). Bearings lie in 0°–360°. The included observations must have one recorded, known north reference; enter the slope bearing in that frame. The app reads the reference automatically. There is no confirmation checkbox; mixed or unknown frames still require explicit review. For any line trend T and downward plunge P, let Δ be the shortest unsigned bearing difference from θs:

$$G(T,P;\beta,\theta s)=\sin P\cos\beta-\cos P\sin\beta\cos(T-\theta s)$$

$$\text{daylights if and only if } G<-10^{-9}$$

G is the dot product of the line with the inward-side slope pole in the lower-hemisphere convention. Negative G puts the line outward through the free face. In the forward half-space this is equivalent to P below $\operatorname{atan}(\tan\beta\cos\Delta)$; the dot form also handles vertical faces without tan90°.

Planar candidate: all three conditions must hold

$$\alpha>\varphi+10^{-9}\text{ degrees};\ G(\theta,\alpha;\beta,\theta s)<-10^{-9};\ \Delta(\theta,\theta s)\leq L$$

The lateral boundary is inclusive, whereas equal friction and equal daylight boundaries are excluded. The two numerical tolerances have different units: one is an angular comparison in degrees; one is a dimensionless dot product. The screen presumes release is possible around the mapped plane but does not establish actual release surfaces.

Hand example KI-P01–P05

Use slope 60°/180°, $\varphi=30°$, $L=20°$. Plane 40°/180° passes: $G=\sin(40°-60°)=-0.3420201433$ and $40>30$. A 30° plane fails the friction equality; a 60° plane fails daylight equality. A 40°/200° plane passes exactly at the lateral limit because G remains negative; 40°/201° is excluded laterally.

Plane counts divide by all valid included measurement planes (or interpreted means if chosen). A nonqualifying pole is not proof of safety under other failure mechanisms. Individual planes can satisfy more than one reported family; counts are not mutually exclusive.

K14. Kinematic screening 2: flexural toppling

Apply the slip-limit geometry

The screen looks for steep planes dipping into the slope, within the chosen lateral sector. It reduces the slope angle by friction and tests the plane pole against that reduced slope. Let $\psi=\beta-\varphi$, and use the pole trend $T_p=\theta+180°$ and plunge $P_p=90°-\alpha$:

$$\psi > 0$$

$$\Delta(\theta,\theta_s+180°) \le L$$

$$G(T_p,P_p;\psi,\theta_s) < -10^{-9}$$

Also require 10^-9 < dip < 90 - 10^-9 degrees; exact horizontal/vertical boundaries have no unique direction-side result and are explicitly unresolved. All three nondegenerate conditions must hold. In the aligned section $\theta=\theta_s+180°$, the third condition is $90°-\alpha<\beta-\varphi$, or $\alpha>90°-\beta+\varphi$. For oblique but laterally included poles, the code uses the full G test rather than applying that aligned scalar inequality unchanged.

Hand example KI-P06–P09

Retain slope $\beta=60°$ toward 180°, $\varphi=30°$, $L=20°$. Plane $\alpha=75°$ toward0° dips into the slope. Its pole is $T=180°$, $P=15°$; the reduced slope is $\psi=30°$. Thus $G=\sin(15°-30°)=-0.2588190451$, and the plane qualifies. Dip60° gives pole plunge30° on the slip limit and is excluded.

Plane	Lateral separation	Outcome
75° / 0°	0°	Qualifies
60° / 0°	0°	Slip-limit equality: excluded
75° / 20°	20°	Qualifies at lateral edge
75° / 21°	21°	Outside lateral sector

Interpretation and the plot

The reduced-slope great circle shows the slip limit; critical poles are ringed. Investigate column/slab behavior, basal release, spacing and continuity. The count does not model flexural rigidity, tensile fracture, interlayer forces, toe restraint or block compatibility.

A flexural orientation flag supplies no whole-slope factor of safety. The separate equilibrium modules and their flexure limitations remain applicable. Orientation poles do not establish all geometry or material properties needed for mechanics.

Changing φ changes the slip-limit geometry. That φ must be an appropriate interpreted friction input for this screening purpose; a pressure-dependent rough-joint peak strength is not automatically interchangeable with a constant kinematic friction angle.

K15. Kinematic screening 3: intersection and single-plane wedges

Step 1 — Construct a valid pair intersection

Use the normalized cross product described earlier. Parallel pairs have no unique intersection. Pair scope controls whether measurements from different outcrops or interpreted sets may be combined. A mathematical intersection of remotely collected planes does not establish a physical wedge.

Step 2 — Primary intersection screen

primary if and only if $G(T,P;\beta,\theta s)<-10^{-9}$ and $P>\varphi+10^{-9}$ degrees

For planes 60°/150° and 60°/210° against slope 60°/180°, φ=30°, the intersection is 180°/56.3099324740°. It lies above friction and below slope, so primary qualifies. Neither individual down-dip vector daylights the oblique slope section, so the single-plane flag is false (KI-W01).

Step 3 — Additional single-plane candidate screen

secondary if and only if daylight at β AND NOT daylight at slope angle φ

eligible plane i if and only if $\alpha i>\varphi+10^{-9}$ AND $G(\theta i,\alpha i;\beta,\theta s)<-10^{-9}$

single-plane flag if and only if (primary OR secondary) AND at least one eligible plane

The eligible-plane test has no planar lateral restriction. Primary and single-plane flags may both be true. The either-screen flag is their logical union; do not add their counts. NOT daylight includes the friction-plane boundary/tolerance band, while primary uses the strict plunge threshold. This exact distinction matters in reproducing boundary examples.

Hand example KI-W02 — secondary region

Choose α=atan(tan20°/cos60°)=36.0523887324°, with plane directions 180° and 300°. Their intersection is 240°/20°. Against slope 60°/180°, the apparent slope in that direction is atan(tan60°cos60°)=40.8933946491°; the apparent friction plane is atan(tan30°cos60°)=16.1021137520°.

The 20° line daylights through the 40.8934° apparent slope and lies above the 16.1021° apparent friction plane: secondary is true. Primary is false because 20°<30°. Plane 1 dips 36.0524° toward 180°, exceeding 30° friction while daylighting 60°. Therefore the single-plane and union flags are true.

This screen identifies a qualifying dip vector on a bounding plane; it does not solve which contact actually releases. Force equilibrium, positive contact reactions and a finite connected block must be established in the wedge mechanics model. Background shading for single-plane/union plots shows only the primary intersection region because the secondary flag also depends on the two source planes.

K16. Kinematic screening 4: direct and oblique toppling

Direct-toppling screening separately counts intersections that could define inward-inclined columns and poles of potential basal release planes. It does not match a joint pair to a base plane, locate a column or calculate moments. Positive counts in both populations do not establish coincidence.

Exact implemented regions

For either an intersection or a candidate base-plane pole, let T,P be its lower-hemisphere trend/plunge. Let $\delta=\Delta(T,\theta s+180°)$, measured from the inward horizontal bearing:

primary if and only if $\delta \le L$ and $P>90°-\beta+10^{-9}$

oblique if and only if $\delta>L$ and $\delta<90°-10^{-9}$ and $P>90°-\varphi+10^{-9}$

An exactly vertical pole (P >= 90 - 10^-9 degrees) has no defined trend and is excluded from these direction-dependent zones with a boundary warning. Primary takes precedence. Its threshold uses slope dip; the oblique threshold uses friction. The oblique region is a screening choice, not a force-derived or universally sufficient toppling condition.

Hand examples for slope 60°/180°, φ=30°, L=20°

T / P	Reason	Classification
0° / 40°	δ=0; 40>30	Primary
0° / 30°	Equals primary plunge limit	Excluded
20° / 40°	δ equals20° lateral limit	Primary
40° / 65°	20<δ<90; 65>60	Oblique
40° / 60°	Equals oblique plunge limit	Excluded
90° / 80°	δ=90° boundary	Excluded

KI-W03 uses joint dips α=atan(tan40°/cos30°)=44.0953127267° toward 30° and 330°. Symmetry yields intersection 0°/40°, a primary column candidate. Independently, a plane 50°/180° has pole 0°/40° and qualifies as a primary base candidate. Their geometric compatibility is deliberately not asserted.

Denominators and limitations

Intersection counts divide by tested nonparallel in-scope pairs; base counts divide by included planes. Base regions include potentially sliding and nonsliding release orientations. Other inward-dipping release geometries are not exhaustively searched.

The checks confirm classification arithmetic, not column dimensions, intercolumn forces, rotational compatibility or empirical adequacy of the oblique zone. Mechanical toppling chapters address modeled forces and moments within their stated scope.

K17. Kinematic workflow, denominators, complete runs and sensitivity

Choose the intended population

Phone Kinematics starts with all outcrops in the active project; no checked outcrops means all. Engineering starts with all plotted measurements in the current source/filter scope, independently of incidental pole selection. Explicit Engineering input scope can restrict it to selected plotted measurements. Both start with all measurement pairs; set assignments are optional. Interpreted means and narrower pairing remain deliberate options. Means require every row assigned and every set uniquely defined. Context keys survive only where every member shares that value; K19-K20 give the current scope predicates and examples.

candidate pairs = N(N−1)/2

tested = candidates − scope-excluded − parallel

Same outcrop uses matching project/outcrop IDs for app records; K19 explains imported/legacy namespaces and the added survey/domain scopes. Different interpreted sets requires nonempty different set IDs. Pair scopes do not alter plane-count denominators. KI-N01/N02 uses a=b=40/180 degrees at A, set J1; c=60/150 degrees at B, J2; d=60/210 degrees at B, J3, all in one project. Inputs: slope 60/180 degrees, friction 30 degrees, lateral limit 20 degrees. All pairs gives 6 candidates, 1 parallel and 5 tested. Same outcrop gives 4 excluded, 1 parallel and 1 tested. Two planar candidates remain 2/4 in both runs.

Computation traverses every candidate pair; display is limited

Limit	Value	What it limits
General pair run	No fixed pair cap	Every pair from the loaded population
Complete critical export	Batched local results	Complete qualifying rows, not just examples
Background markers	About 3,000	Systematic display only
Critical examples	First 1,000 per flag	Counts remain complete

N(N−1)/2 must remain an exact safe integer. There is no fixed 200,000 or 2,000,000 candidate ceiling. The engineering worker writes qualifying rows to temporary local storage in awaited batches of up to 2,048, rather than accumulating all row objects in memory. Device quota, runtime and supported source-file limits remain real constraints; a failed run is not reported as complete. Background stride is ceil(candidatePairs/3000), selecting by original pair index. Parallel/excluded pairs can make the plotted sample smaller. No sampled-pair estimate replaces the calculated counts.

Sensitivity and saved cases

Sweep slope dip, direction, friction or lateral limit. Step must be at least 0.1°; at most 73 steps are permitted, with no aggregate candidate-pair ceiling. Values are start+i×step through the last value not exceeding end; direction wraps through 360°, with sweep end allowed through 720°. The plotted percentage uses the correct per-mode plane/intersection denominator. Defaults are examples, not site inputs.

Saved cases retain a source signature and must be restored against matching measurements, references, interpreted sets and outcrops. Inputs invalidate stale results. Export included-row CSV, complete critical CSV, sensitivity CSV and the complete analysis JSON; SVG/HTML reports are readable companions, not substitutes for the source population and settings. Percentages remain orientation fractions.

K18. Structural verification evidence and remaining boundaries

The structural arithmetic suite executes 50 original cases and 169 comparisons, rerun against the reconciled production modules. Every comparison passed. Expected JSON comes from closed-form geometry, regular spherical populations, exact intervals and classification truth tables, sealed before the production adapter ran. Separate reconciliation checks cover 308 import/calculation/export cases and 29 real-browser workflow assertions. No commercial result supplies an expected answer.

Evidence group	Original construction	What it checks
Vectors / plot geometry	Vertical/horizontal traces; symmetric pair	Projection positions, plane intersection and angle
Statistics / sets	8-point pole ring; asymmetric3-point set; orthogonal clusters	Resultant vs tensor means, approximate cones, basic cluster recovery
Survey / tools	Known incidences, fixed-axis rotation, core special cases	Weights, density scale, spacing/RQD, core convention
Kinematics / data	Exact boundary examples, hand-counted pairs, literal CSV table	Four families, scope counts, caps, import and wrapped filters

verify_structure_v03.py --prefix reconciliation-structure preserves this rerun in reconciliation-structure-expected/actual/results.json; the JS adapter only calls app modules. Historical v03 evidence remains unchanged. The driver fails on discrepancies. Most arithmetic tolerances are 2×10^{-7} absolute, with 3×10^{-6} near zero angles; booleans/text match exactly. structure-reconciliation-test.mjs and reconciliation-structure-browser.mjs record the additional round trips and UI checks.

What these checks do not establish

These checks do not establish physical sensor calibration, formal Fisher coverage, arbitrary cluster recovery, every possible failure mechanism, every browser/device, or security. The browser tests use synthetic localhost data and exercise phone/desktop input, editing, filtering, workers, clustering, rotation and downloads. Direct-toppling oblique and secondary-wedge regions remain screens requiring separate mechanical justification. A hand case supports its tested path, not every application.

Practical review before relying on a plot

Retain the coordinate/north basis, chosen population, exclusions, interpreted sets, weighting assignments, projection/density settings and run inputs with the result. Inspect at least one original record against its plane/pole position and one known intersecting pair. State whether a mean is the field tensor estimate or desktop aligned-resultant estimate. Examine warnings rather than replacing unavailable statistics with zero.

The current implementation has no standalone apparent-dip editor, no statistical lineation clustering (lineations can be added as constructions), no finite-sample inferential claim for weighted sets, and no force-based factor of safety in the kinematic workspace. These are explicit scope boundaries.

K19. Pair scope: recorded context and physical meaning

A kinematic intersection is calculated from two plane orientations. It does not prove those planes physically meet. Phone and desktop kinematics default to Same outcrop; choose a wider pairing only with an explicit geological basis. Scope is applied before intersection tests and does not change the individual-plane population.

Pair scope	Required matching recorded context
Same outcrop	Matching nonempty outcrop IDs, with matching project IDs for app records. Imported/legacy namespace rules below prevent unrelated known datasets being joined.
Same recorded survey / exposure	Same nonempty project, outcrop and survey IDs. This is one recorded survey, not automatic proof of adjacency.
Same geological domain and slope reach	Same nonempty project and geological domain IDs, and the same nonempty slope-reach text. Observations can come from multiple outcrops.
Different interpreted sets (hypothetical pairing)	Different nonempty interpreted set IDs. This pairs populations and does not prove co-occurrence.
All selected pairs (hypothetical pairing)	Every candidate pair in the selected population is considered, subject to parallel-plane and other geometric checks. Spatial co-occurrence is not required.

Matching unknown values are not a matched survey/domain/reach. Older observations without those assignments are excluded by the new context scopes, not retroactively assigned from an outcrop. Same outcrop uses a matching imported dataset ID when either row has that namespace but lacks a complete project match; for older rows with neither namespace on both rows, matching outcrop IDs retain historical compatibility. Review that older association rather than treating it as established spatial evidence.

For an interpreted mean, each context key is retained only if every member has the same value. Member IDs, revisions and available location snapshots remain evidence; coordinates are not averaged into a supposed block location. A mixed or missing key can exclude the mean under a context-restricted scope. Inspect the members before interpreting its intersection.

Review the source context shown for a candidate: project/outcrop, survey, domain/reach, observation IDs/revisions and available coordinates. A recorded context is not a physical intersection, and a kinematically critical orientation fraction is not the probability of a site failure. Subsequent slope equilibrium still requires independently justified finite geometry, strength, water, loading and release conditions.

K20. Pair denominators: reproduce a scoped count

candidate pairs C = N(N - 1)/2

tested intersections T = C - scope-excluded pairs E - in-scope parallel pairs P

critical intersection fraction = 100 ncritical/T; individual-plane fraction = 100 ncritical-plane/N

A zero tested denominator has no supported intersection percentage. Scope-excluded and parallel counts remain visible; they are not interpreted as stable pairs. The individual-plane modes use the valid input planes and are not reduced to the pair denominator.

Plane	Outcrop	Survey	Domain / reach	Dip / direction
a	A	S1	D1 / R1	40 / 180 degrees
b	A	S1	D1 / R1	40 / 180 degrees
c	B	S2	D1 / R1	60 / 150 degrees
d	B	S3	D2 / R2	60 / 210 degrees

All four records belong to the same project and use the same known north reference. There are six candidate pairs. Only a-b is parallel. Same outcrop keeps a-b and c-d: E=4, P=1, T=1. Same recorded survey keeps only a-b: E=5, P=1, T=0. Same domain and reach keeps a-b, a-c and b-c: E=3, P=1, T=2. All selected pairs gives E=0, P=1, T=5.

This example checks pair membership and counting; it makes no claim about physical intersection or failure. With the existing KI-N01 planar setup (slope 60/180 degrees, friction 30 degrees, lateral limit 20 degrees), the two 40/180 planes remain 2/4 planar candidates under all four scopes. The planar denominator is not T.

Exports preserve scope, source observations and context together with the candidate/excluded/parallel/tested counts. Record filtering, displayed examples and mean construction must remain distinguishable from the original raw collection. Existing candidate caps apply before scope filtering; a narrow scope does not authorize an unlimited pair run. The scope predicates and this worked count define implementation choices, not a new rock-strength model.

K24. Default stereonet grouping and observation identity

Each time Stereonet analysis opens, Color by starts at Observed set, including previously cached analyses. A new analysis also starts with saved field observations and All features; existing source selections and filters are retained. The grouping uses the recorded field set label, such as J1 or J2; bedding without a set label is grouped as Bedding. A joint with no recorded set remains Unassigned joint. Colors are a display convention, not proof that similarly named sets are continuous, coplanar or mechanically equivalent across outcrops.

Projection opens at equal angle (Wulff), with equal area (Schmidt) available explicitly. The analyst may change Color by to Interpreted set, Outcrop, Lithology, Feature type or Source file. An interpreted set is a separately editable analysis assignment and never silently rewrites the field-observed label. Saved views retain their explicit display settings when loaded. Ordinary reopening uses Observed set and equal angle while preserving the existing filters, source IDs, imports, interpretations and views. Filtering, cluster acceptance and engineering source selection continue to use their separately shown populations and explicit decisions.

D1. Independent slope ratings: inputs and formulas

Open Analyse > Independent slope rating. This tab implements the supplied USMP worksheet, separately from projects, outcrops, structural measurements and the engineering slope models. A rating is an asset-priority score: larger values indicate poorer assessed conditions. It is neither a failure probability nor a factor of safety. The worksheet variant is identified separately from the broader federal program [D-USMP].

Choose New assessment, enter a name, rater, date, weather and road reference, then record geometry/traffic and select the categorical ratings. Use current GPS location fills only the beginning latitude/longitude; it does not update an outcrop, infer the ending point, calculate length, or capture elevation. Complete the ending location manually when applicable. Coordinates are decimal degrees; lengths and rainfall are feet, event volume ft^3, speed mph and AADT vehicles/day.

Continuous scores: use $E(x)=\min(81, 3^x)$

$C=E(\sqrt{(L_{affected}/25)})$; $H=E(\sqrt{(AADT/50)})$.

$K_{slide}=E(L_{axial}/25)$; $K_{rock}=E(H_{slope}/25)$.

$V=E((44-B_{road})/8)$.

$\text{Exposure } (\%)=(AADT/24)(L_{slope}/5280)(100/v)$; $W=E(\text{Exposure}/12.5)$.

$\text{PDSD } (\%)=100\ S_{available}/S_{required}$; $X=E((120-\text{PDSD})/20)$.

Speed v (mph)	Required sight distance (ft)	Speed : distance continuation
25; 30; 35	375; 450; 525	40 : 600; 45 : 675
50; 55; 60	750; 875; 1,000	65 : 1,050

The square-root scores equal 3, 9, 27, 81 at affected lengths 25, 100, 225, 400 ft and AADT 50, 200, 450, 800. K reaches those scores at 25, 50, 75, 100 ft. V does so at widths 36, 28, 20, 12 ft; W at 12.5, 25, 37.5, 50%; X at PDSD 100, 80, 60, 40%. Only the listed speeds are supported; no interpolation is made.

Blank/invalid required inputs propagate an incomplete result; explicit zero length/AADT produces a continuous score of 1. Wide roads or very long sight distance can produce scores below 1; the worksheet does not impose a minimum of 3. All continuous scores are capped at 81 in this app.

D2. Slope-rating choices: A through I

Each row below is a complete four-band scoring guide. Choose the descriptive option; these categories have no additional multiplier. A, B, D, E, F and G also offer N/A=0. Blank means unassessed, not zero. I has no N/A option. Values below reproduce the supplied worksheet as displayed in feet.

Category	3 points / 9 points	27 points / 81 points
A. Road width affected	3: 0–5%. 9: 6–25%.	27: 26–50%. 81: 51–100%.
B. Slide / erosion effects	3: visible crack, slight deposit or minor erosion. 9: 1/12 ft offset, 0.5 ft deposit or intermediate travel impact.	27: 2/12 ft offset, 1 ft deposit or major travel impact. 81: 4/12 ft offset, 2 ft deposit or severe travel impact.
D. Ditch effectiveness	3: good catchment. 9: moderate.	27: limited. 81: no catchment.
E. Rockfall history	3: few, intermittent/few times yearly or no history available. 9: occasional, several times yearly.	27: many during seasonal periods. 81: constant through the year.
F. Block size / event volume	3: 1 ft / 81 ft^3. 9: 2 ft / 162 ft^3.	27: 3 ft / 243 ft^3. 81: 4 ft / 324 ft^3.
G. Impact on use	3: full use, minor delays. 9: partial use with short 15,840 ft / 30-minute detour.	27: blocked, long (>30 min) detour or closure <1 day. 81: blocked, no detour or closure >1 week.
I. Slope drainage	3: dry/well drained, controlled runoff. 9: intermittent water, moderately well drained/controlled.	27: water usually present, poorly drained/controlled. 81: water always present, very poorly drained/uncontrolled.

F is a selected rating, not an automatic result of the typed Block length or Block / event volume fields. The paired values retain the source rubric's size/volume alternatives; they are not a cube-volume equation. Since 1 yd^3=27 ft^3, its first 3 yd^3 volume band becomes 81 ft^3. Apply the complete category description and document the field judgment.

Catchment width, ditch depth, slope angle, typed block size/volume and contextual notes remain recorded observations. They do not independently change the calculated score unless the relevant rating selection changes. The drainage distinction is intentional: "usually" is 27; "always" is 81.

D3. Slope-rating choices: J through Q

J is derived from numeric annual rainfall when rainfall is entered; the dropdown becomes unavailable. Clear that numeric field to choose a band manually. Shared rainfall boundaries use the lower band. L, M, N, O, P and Q permit N/A=0; J does not.

Category	3 points / 9 points	27 points / 81 points
J. Annual rainfall	3: 0 to 10/12 ft inclusive. 9: >10/12 to 2.5 ft inclusive.	27: >2.5 to 5 ft inclusive. 81: >5 ft.
L. Thaw stability	3: unfrozen / thaw stable. 9: slightly thaw unstable.	27: moderately thaw unstable. 81: highly thaw unstable.
M. Instability maintenance	3: every 10 years. 9: every 5 years.	27: every 2 years. 81: every year.
N. Movement history	3: minor movement / sporadic creep. 9: up to 1/12 ft annually / steady annual creep.	27: up to 0.25 ft per event / one event yearly. 81: >0.25 ft per event, >0.5 ft annually or more than one event yearly.
O. Rockfall maintenance	3: normal scheduled maintenance. 9: patrol after every storm.	27: routine seasonal patrols. 81: year-round patrols.
P. Structural condition, case 1	3: favorable. 9: random.	27: adverse/discontinuous. 81: adverse/continuous.
Q. Rock friction, case 1	3: rough/irregular. 9: undulating.	27: planar. 81: clay-filled / slickensided.

Interpret the inputs, not just the resulting color

Case 1 addresses structural condition and friction; case 2 on the following page addresses erosion-related condition. The rockfall hazard uses the greater complete pair, P+Q or R+S. Both pairs must be explicitly assessed, including justified N/A choices. The app does not infer joint persistence, shear strength or field likelihood from these selections.

A rainfall number is a feet depth: 24 inches must be entered as 2 ft. Historical assessments without a feet marker used inches for rainfall only. Phone opening, desktop display/editing and analytical CSV/GIS export convert that value once (24 → 2 ft); newly typed desktop values are already feet. Original JSON backups preserve original values and markers. An invalid nonblank rainfall value makes its rating incomplete instead of using an old selected band. Older combined block-size text remains verbatim because its units may be ambiguous.

D4. Slope-rating choices: R through BB

R and S allow N/A=0. Y, Z, AA and BB always use one of the four listed point bands. Monetary values are category descriptors in dollars, not cost estimates produced by the app.

Category	3 points / 9 points	27 points / 81 points
R. Erosion structure, case 2	3: few differential-erosion features, undistributed. 9: occasional features, widely distributed.	27: many, large/numerous features. 81: major features with severe overhangs or oversteepening.
S. Differential erosion, case 2	3: small difference, near environmental equilibrium. 9: moderate difference, features develop over a few years.	27: large difference, noticeable yearly face changes. 81: extreme difference, rapid or continuous face changes.
Y. Right-of-way effects	3: no implications. 9: minor effects beyond right of way.	27: private property affected, no structures. 81: structures, roads, railway, utilities or parks affected.
Z. Environmental / cultural effects	3: none. 9: likely effects / no historic properties affected.	27: likely adverse effects / finding of no adverse effect. 81: current adverse effects / adverse effect.
AA. Maintenance complexity	3: routine in-house effort. 9: in-house maintenance / special project.	27: specialized equipment or contractor. 81: complex or dangerous effort, location or contract.
BB. Event cost	3: $0–2,000. 9: $2,000–25,000.	27: $25,000–100,000. 81: >$100,000.

Worksheet scope and limits

This is the supplied USMP rating-sheet variant. The federal reference [D-USMP, Appendix A/B] also discusses trail alternatives, qualitative use/economic importance, continuous block-size scoring and certain continuous-score caps of 100. Those alternatives are not implemented here: H uses entered AADT only; V is road width; X uses roadway decision sight distance; F remains categorical; continuous scores cap at 81.

Do not call the app a complete implementation of every USMP procedure. Scoring verification proves the declared worksheet arithmetic, not that an input is a suitable field judgment or that a particular agency accepts this variant. A saved incomplete assessment remains incomplete; saving does not certify it.

D5. Rating totals: reproducible hand calculation

1. Sum the declared categories without extra weights

Preliminary landslide=A+B+C+G+H; preliminary rockfall=D+E+F+G+H.

Hazard landslide=A+B+C+I+J+K_{slide}+L+M+N.

Hazard rockfall=D+E+F+I+J+K_{rock}+O+max(P+Q,R+S).

Risk=G+H+V+W+X+Y+Z+AA+BB; final=corresponding hazard+risk.

There is no averaging or rescaling. Categories G/H appear in preliminary screening and in risk; the final adds hazard to risk only, so preliminary scores are not added again. Both final totals have an upper bound of 1,458 for the implemented 81-point cap and categorical choices. Highest hazard compares hazard totals only.

2. Enter this independent example

Choose the 3-point option for every categorical input. Enter affected length 100 ft; AADT 200; slope height 75 ft; axial slide length 50 ft; road width 28 ft; slope length 5,280 ft; speed 40 mph; available sight distance 480 ft; rainfall 2 ft. Rainfall overrides J to 9. All other descriptive fields and coordinates can be recorded without changing these totals.

C=3^√(100/25)=9; H=3^√(200/50)=9; $K_{slide}=3^2=9$; $K_{rock}=3^3=27$.

V=3^((44−28)/8)=9; required sight=600 ft; PDSD=100×480/600=80%; $X=3^2=9$.

Exposure=(200/24)(5,280/5,280)(100/40)=20.83333333%;
W=3^(20.83333333/12.5)=6.240251469.

Hazard landslide=3+3+9+3+9+9+3+3+3=45.

Hazard rockfall=3+3+3+3+9+27+3+max(6,6)=57.

Risk=3+9+9+6.240251469+9+3+3+3+3=48.24025147.

Result	Independent / app core	Displayed form
Preliminary slide / rock	27 / 21	27.00 / 21.00
Final slide / rock	93.24025147 / 105.2402515	93.24 / 105.24

Final classes are Good below 200, Fair from 200 through 400 inclusive, Poor above 400. Both examples are Good. Blank totals show Incomplete. The field form displays and saves totals to two decimals; desktop recalculation can store more digits. Class decisions use the unrounded calculation. Recompute from inputs when reproducing a result.

D6. Published geology: lookup and interpretation

Choose a saved outcrop with coordinates, then open Geology. The location banner distinguishes the saved outcrop from a temporary GPS preview. Use current GPS requests the device location without changing the outcrop. Use saved outcrop returns to its saved coordinates; Open field observations returns to the editable observations.

1. Choose the sampling footprint

Search area	Locations requested	Interpretation
Selected location	One point	Maps intersecting that coordinate
1,000 ft or 5,280 ft	Center plus eight compass points	Sampled ring, not a complete areal search

Look up / refresh geology requests the Macrostrat map-unit API, then source citations and lithology definitions [D-MACRO]. Nearby samples use a spherical great-circle construction with radius 6,371,008.8 m and exact feet conversion. For example, 5,280 ft=1,609.344 m; from (0°,0°), the north sample is latitude 0.01447315831°, longitude 0°. Units encountered between sample points can be missed.

2. Read each interpretation and its source

Cards show formation/stratigraphic name, mapped age, original lithology, indexed rock types and the published description when supplied. Expand Source, map detail, and notes for authors, year, publisher, polygon/source IDs and original publication links. Detailed/local categories appear before regional, continental and global maps. An exact scale ratio is not invented when the service supplies only a broad category.

Overlapping maps may describe different surficial and bedrock interpretations. Their combined list is not a stratigraphic column and does not prove that every rock is exposed. No returned unit means no result from this service, not absence of rock. Check GPS uncertainty, cover, the source legend and the outcrop itself. Source text retains its original units; no mapped interpretation is written into your observations automatically.

3. Retain the reference you used

Cancel lookup stops a request and retains the previous result. Download references CSV records query/sample coordinates, map IDs, descriptions, citations, source links and retrieval time. New lookups and source links require internet. Previously completed lookups are cached by exact coordinates and chosen distance, up to 100 entries within a 3,000,000-character limit; older entries can be removed. A 30-day age notice requests review, not automatic invalidation.

Only query coordinates are sent to Macrostrat by this feature; project names and observations are not included. References are separate from cloud backup and field/GIS exports. Save the references CSV if provenance must survive cache eviction or clearing this device.

D7. Static geology image and topographic background

In Field Map → Geology references → Geology image, choose 2,000, 5,280 or 10,560 ft across, then Create / refresh image. The red target marks the selected saved location or GPS preview. North is up. Translucent geologic polygons come from Macrostrat; the background is USGS The National Map—USGS Topo [D-MACRO; D-TOPO].

The image is a separate reference product

The numbered legend is derived from polygons visible in the image, not the eight nearby lookup samples. Expand units for description, lithology, age and source; use original-source links for map-sheet detail. Small polygons may be too small for a number on the image but remain in the legend. Untinted areas mean missing geologic polygon coverage. Repeated unit names and map-sheet seams do not necessarily represent distinct geological contacts.

The app requests vector geology tiles at an appropriate zoom and a 640×640 USGS raster covering the same Web Mercator extent. The map projection is EPSG:3857. Approximate center-latitude ground span is computed from a sphere of radius 6,378,137 m: projected span ≈ width_{ft}×0.3048/cos(latitude). The displayed width and scale bar are local approximations, not a surveyed distance or a georeferenced raster deliverable.

Latitude must be between 85°S and 85°N. Native geology/topography detail is limited by the source and selected zoom; enlarging a screenshot creates no new geological information. Contacts can be generalized, obscured or uncertain. Topographic labels, contours and original descriptions keep their source units. No vertical datum correction or surveyed contact positioning is performed.

Save and use it offline

After generation, Download image PNG retains the image with full legend/attribution; supported phones also offer Share / Save image. Confirm the file is actually in Files or Downloads. Cancel image stops a request without replacing a previous saved image. A generated-but-not-cached notice means download it before leaving.

The local image cache holds up to 50 coordinate/width combinations and 16,000,000 serialized characters, with older entries removable as it fills. An image older than 30 days receives an age notice. These are application cache limits, not guaranteed device capacity. Saved images include both layers offline; new images need both online services. A failure or timeout does not establish absence of geological coverage.

The requested surrounding area is sent to Macrostrat and USGS. Geology images are not part of the field JSON backup, GIS ZIP or cloud backup; clearing device data clears their cache. Keep PNGs and source references separately. The desktop’s interactive map has its own live tile behavior and is not a promise that every viewed area is cached for offline use.

D8. Coordinates, units and provenance in exports

The record hierarchy is Project → Outcrop → Structural set → Measurement. Discontinuities belong to the project and outcrop. Slope assessments are independent. Stable IDs preserve these relationships across names, exports and backup; do not join datasets only by a displayed outcrop code.

Quantity	Saved/exported convention	Meaning
Horizontal coordinates	WGS84 decimal degrees	GeoJSON order [longitude, latitude]
GeoJSON geometry	Two-dimensional Point	Elevation remains an attribute, not Z
Physical field lengths	Feet for ft-v1 records	Includes elevation, GPS accuracy, spacing
Stress / strength	Hoek–Brown UCS: MPa; Barton–Bandis: psi	Use the field-specific data dictionary
Angles / speed / ratios	Degrees; mph; dimensionless or percent	Preserve the declared field unit

Coordinate selection is explicit

For outcrops, measurements and discontinuities, a complete finite own latitude/longitude pair takes precedence; a missing pair can use the parent outcrop location. Out-of-range coordinates are excluded from point layers, not replaced by the parent to hide the error. coordinate_source records the distinction. Elevation comes from the same record or parent, not a new GPS fix. A measurement that copied the outcrop location retains that historical position when the parent moves.

Without valid coordinates, a saved record is omitted from point layers and listed in unlocated_records.csv, but remains in its CSV table and JSON backup. It is never fabricated at (0,0). Slope-assessment points use their own beginning coordinate. Ending coordinates are retained as attributes; no slope line is generated automatically.

Independent conversion example

> 1 ft=0.3048 m exactly; feet=metres/0.3048. Therefore 304.8 m=1,000 ft and 3.048 m accuracy=10 ft.

Recognized pre-feet elevation/accuracy and selected outcrop lengths convert once; ft-v1 records are not converted again. Legacy slope rainfall converts inches to feet in analytical tables; backup JSON retains originals. Unknown unit markers are rejected. Free text retains its recorded units. Manually changing coordinates or elevation clears the GPS capture time and inherited accuracy; an explicitly entered replacement accuracy remains a manual value.

Geolocation is device-reported [D-GPS]. It may be unavailable or unsuitable for survey control. The app does not transform to a state-plane CRS, apply a geoid, verify a vertical datum, or guarantee a surveyed elevation. Import GeoJSON as WGS84 geographic data, then choose any required projection through a documented GIS workflow [D-GEOJSON]. Preserve timestamps, source fields, north reference and corrections with measurements.

D9. Choose the right export and verify the file

Control	Scope	Use
Project / Outcrops / Structural sets / Measurements / Discontinuities CSV	Currently selected project	Queryable tables and external processing
All slope assessments & drafts CSV	All saved assessments plus separately marked drafts	Independent rating inventory
Project package JSON	Current project field records	Mergeable restore package; no independent slopes
Save full device backup	All local field records, slopes and recovery content	Primary portable recovery copy
Download GIS ZIP package	All local field records and independent slopes	Spatial layers + related CSVs + JSON backups

The GIS ZIP contains point layers for outcrops, structural measurements, discontinuities and saved slope assessments; base CSV tables; relationships.csv; data_dictionary.csv; unlocated_records.csv; manifest.json; field_backup.json and slope_assessments_backup.json. Repeated data becomes linked child tables, such as rebound readings, stress samples and attachment metadata. Join by the documented parent keys; item indices start at zero.

Each GIS property is scalar. Column names use snake_case, with double underscores between nested source paths. Known numeric fields export as numbers; unassessed values are null in GeoJSON or empty CSV cells. Identifiers and option codes remain text. Standalone CSVs use indexed columns for repeated values; the ZIP supplies normalized related tables instead. A conflicting normalized field name fails export instead of silently overwriting a column.

RMR totals and structural-set means are derived from saved inputs at export. Stored Hoek–Brown, Barton–Bandis and slope-rating results are retained as recorded, so distinguish a historical calculation from a newly recalculated value. Field/slope draft tables are unfinished work, not saved observations or map features. Raw source records are retained in JSON backups.

Binary photos are in JSON backup records, not scalar GIS properties; attachment names/captions remain queryable. References, chart assets, map-image caches and cloud-only records are not automatically folded into the field export. Download references/PNGs and restore or pull cloud records separately when needed.

On iPhone, use the displayed download link or Share / Save to Files; other browsers may begin downloading automatically. Confirm file presence before “I saved this file.” CSV formula-like text receives a leading apostrophe for spreadsheet safety, while numeric negatives and JSON/GeoJSON text are unchanged. Import IDs as text and consult the dictionary instead of trusting automatic CSV type inference.

D10. Restore, merge and recover without losing context

First download a full device backup. In Data → Recover from a device backup (merge only), or Desktop → Files & recovery → Choose JSON backup (advanced merge/replace), select a recognized current or legacy backup and review its counts. The import limit is 256 MiB per file (UI: MB). Invalid content, versions or unit markers can stop import. Legacy unlinked observations are preserved under an UNASSIGNED outcrop.

2. Understand the two import choices

Mode	Result	Important consequence
Merge by record ID	Identical IDs/content deduplicate; differing project content becomes a recovered project copy	Parent-child links are remapped together
Replace local field data	Replaces the field tables after confirmation	Removed saved records can queue cloud deletions when backup is enabled
Project package JSON	Merge only	Cannot replace all projects
Full device backup with slopes	Field mode as chosen; slope records/drafts merge separately	Existing independent slopes are preserved

A conflicting imported project is copied as a complete graph with a recovered-copy name, rather than accepting a mixed set of unrelated parent/child revisions. The prior local snapshot is retained as recovery metadata, but an independent exported file is still needed. Full-device recovery metadata is preserved in the imported recovery content; it is not a claim that every analytical session reopens automatically.

3. Restore independent assessments or cloud records

Slope rating → Download assessment backup saves the slope-only JSON; Restore assessment backup (merges by ID) merges its saved records and keeps unfinished drafts separately. Refresh saved list retains the open form. On a new device, sign in and select Restore cloud records: active cloud field data and slopes merge, conflicts become recovered copies, and local drafts remain.

The GIS ZIP contains two restore files: merge field_backup.json through Data → Recover from a device backup, and slope_assessments_backup.json with slope restore. Analytical CSVs/GeoJSON are not database restore files. CSV/paste importing into the stereonet analysis workspace is a separate workflow; it does not infer an entire field project from a GIS table.

Reopen a representative outcrop, its child set/measurement, a discontinuity, an attachment and a saved slope assessment. Compare counts, coordinates/units and key values with the export. Check cloud data verifies cloud readback; it is not a restore rehearsal. Full-device restore uses separate field and slope stores, so a partial error must be read and resolved before claiming the entire package restored.

D11. Local saves, drafts and offline readiness

WillItMap saves field records on this browser/device before optional upload. A local Save success, a retained draft, an upload queue and a verified cloud copy are four different states. A form change is not a committed observation until the appropriate Save button succeeds. Inspect the save badge and any error before closing the app.

Unfinished work and recovery

Project, outcrop, manual-measurement and discontinuity forms keep local drafts. Restore a recoverable draft to its original context, inspect it, then Save to commit. Restoring transfers the draft into the current form and removes its redundant recovery prompt; it does not upload it. Discard removes only that unfinished draft. If its parent was deleted, restore the parent first. Concurrent saved-record revisions are checked, so stale forms are retained rather than overwriting a newer record.

Slope assessments and desktop table edits have their own draft/recovery controls. Save assessment creates or updates the independent saved assessment; Recover draft is still local unfinished work. A concurrently edited assessment may be retained as a separate copy. Desktop drafts are staged until Review & save edits. None of these unfinished drafts are cloud-backed automatically.

Prepare before losing signal

Open the app online in the browser or installed home-screen app you will actually use. Wait for Data to show that the app shell is installed for offline access. Open the necessary tools and preload any geology references/images, then test reopening in airplane mode on that device. Offline shell availability is not the same as cached map coverage; new maps, sign-in links and cloud requests still need internet.

Request durable storage asks the browser to protect the origin’s storage from routine eviction [D-STORAGE]. A grant reduces that eviction risk; it does not prevent deletion by the user, device loss, profile removal, disk failure or all software faults. The browser may deny or omit this control. Use a normal browser profile rather than a temporary/private session for field work.

End-of-day control

Data > Field checks & deletion recovery lists outcrops missing location or rock type, unfinished drafts and field changes after the acknowledged snapshot time. These are completeness reminders, not a full engineering QA check. Save intended drafts, choose Save full device backup and inspect that exact file in Files/Downloads; only then select I saved this file on its prepared-file card. The separate exact-snapshot count compares saved-record hashes, including slopes, rather than confirmation time. When online, wait for queued changes and use Check cloud data. Keep a separate exported copy even when cloud readback matches.

Local storage belongs to the browser profile and website origin. Another browser, a new phone or a changed domain can have a separate empty store. App updates ordinarily retain records, but clearing browser site data removes local information. Cloud sign-out does not erase locally accessible records.

D12. Accounts and online backup: operating sequence

In Data → Online backup, enter your email, complete the sign-in security check and select Send sign-in link. Open the newest email link for the website, then return to the backup controls. The same flow requests account creation for a new email. Delivery, signup policy, abuse controls and rate limits depend on the deployed service; this manual does not certify current account settings.

2. Explicitly enroll this browser's records

Select Enable backup of this device's records and review the named account. This associates existing local field records and saved independent slope assessments with that owner. It also enables later saves/deletions to queue for that account. Sign-in alone and accepting Terms of Use do not confirm enrollment or upload. A cloud restore also establishes ownership to prevent later reassignment to a different account.

Included in record backup	Not uploaded automatically	Consequence
Projects, outcrops, sets, measurements, discontinuities	Unfinished forms / desktop drafts	Press the corresponding Save
Saved independent slope assessments	Slope drafts	Save assessment before syncing
Photos embedded in saved outcrop records	External GIS photos / geology references / image caches	Keep separate source files
Saved edits and deletion markers	Local analysis-workspace sessions	Export analysis/session packages separately

3. Keep the app active while synchronizing

Saved changes trigger sync; the app retries on connection/focus and periodically while visible. Retry sync or desktop Sync now requests another cycle. Uploads preserve parent-child ordering and retain pending changes after timeouts, rate limits, stale revisions or quota errors. Browser suspension can interrupt network work: do not assume a closed phone app uploads continuously in the background.

4. Verify, rather than infer, the remote result

Check cloud data reads back the signed-in account's records without uploading, restoring or editing observations. It compares saved content and shows Verified match, Missing in cloud, Different in cloud and Cloud only. Expand project/independent-assessment groups to inspect individual IDs and cloud timestamps. The result describes the displayed check time; new edits invalidate it. An empty upload queue is not this readback check.

On another device, sign into the same account and use Restore cloud records or allow enrolled sync to pull changes. Reopen and inspect representative records. Another email/account does not gain access to this data merely by using the app. The checked-in database design restricts record/history rows by authenticated owner [D-RLS]; no project-sharing/team-permission interface is asserted here.

D13. Conflicts, account limits and retention

A conflict is a decision, not a failed Save

A cloud version changed since this device last knew it can conflict with a pending local edit or deletion. The app preserves the difference and pauses related project pulls. Expand Compare versions and keep an independent export. Choose Use this device's version as primary or Use the cloud version after review. The decision rechecks both revisions; if either changed again, review the newer conflict. Parent/child conflicts may require resolving related records first.

Accepted resolutions retain recovery information. Cloud Restore and JSON merge can preserve conflicting projects as separate recovered copies; slope assessments can likewise become copies. This is not automatic line-by-line merge, a permanent archive or a guarantee that another user's simultaneous interpretation can be reconciled without judgment.

Read the live meter; these are checked-in defaults

Limit	Default in reviewed code	Meaning
Account allowance	25 MiB = 26,214,400 bytes	Current records + deleted-record recovery + history
One cloud record	2 MiB = 2,097,152 bytes	Includes embedded photo data
Shared payload guard	200 MiB	Combined accounted records/history
Database-size guard	350 MiB	Additional shared service stop
Historical versions	Up to 10 per record; 30 days	Old versions pruned on subsequent writes

Account & storage reports the account's returned allowance and used current/history bytes. The UI labels binary MiB as MB. The meter warns at 80%; a quota failure leaves local records saved and queued, and pauses the cloud change. Contact the operator after exporting a backup. A 25 MiB default is not a promise of 500 MB storage; operators can change limits and actual server values must be checked.

The accounting model includes serialized record payload, identifier/type bytes and a per-row allowance, rather than only raw photo-file sizes. Repeated edits can add historical copies. Current records do not automatically expire under this migration; old history is pruned when another write occurs. Tombstones may retain full deleted record content and count against quota, so deleting an observation need not immediately free its cloud storage.

Local drafts, map caches, downloaded backups and analytical session storage are separate from the cloud meter. Neither browser storage capacity nor provider availability is guaranteed by the account quota. This review inspected source and migrations; it did not query live billing, server quotas, deployed policies, email permissions or real user data.

D14. Deletion choices and shared-device precautions

Action	What changes	What remains
Delete outcrop	Its sets, measurements, discontinuities and saved attachments are deleted; enrolled cloud deletion queues	Other outcrops; independent ratings
Delete project	Its complete field hierarchy is deleted; enrolled cloud deletion queues	Other projects; independent ratings
Delete saved assessment	That independent slope record is deleted and queues when enrolled	Field project data
Clear this device only	Local field/slopes/drafts/recovery/queue cleared; signs out	Cloud records and exported files
Delete from this device and cloud	Local saved records plus cloud-only active records targeted; field/slope drafts cleared	Recovery/desktop history, other-device/exported copies; account

For local-only clearing, export first and close other app tabs. Unsynced observations and pending deletions would be lost with their local queue. For combined deletion, internet, the correct sign-in and matching backup enrollment are required. Review the counts, confirm the requested action, keep the app open and retain the local queue until the final cloud readback confirms no active targets remain.

Combined deletion rechecks the cloud and local previews before it proceeds; if either changed, it asks for a new review. Parent deletion is withheld when active children remain. Independent field/slope stores commit separately, so a partial failure can leave queued work requiring retry. Do not use device-only clearing to hide an unfinished cloud deletion.

Undo last field deletion and Undo assessment deletion are limited local recovery tools; restoring can queue records online again. Combined deletion retains recovery content, including desktop drafts/history and analysis metadata. Cloud markers are not secure erasure from history, other devices or files, and do not delete the account. Desktop Delete selected previews dependents and requires typed DELETE; delete assessments in their own list.

Account isolation is not a local privacy lock

Signing out stops this browser’s active login but leaves its offline records. Use a separate browser profile for another account; avoid sharing unlocked devices or browser profiles. The app does not claim client-side encrypted record storage. OS protection and organizational rules still apply. Keep email links/private backups out of public shares and review the destination before enabling backup.

The implementation checks owners, revisions and relationships; server row policies restrict cloud access by owner [D-RLS]. Those controls do not classify the data, authorize restricted use or establish organizational security approval. This manual’s source review is separate from a penetration test or a live account-security assessment.

D15. Desktop workspace: review and edit saved data

Choose Desktop view beside the app name; choose Field to return to the compact collection forms. Geology workspace keeps scope selectors in a sidebar, with linked outcrop map and stereonet panels, the observation register and a record inspector. The tables cover projects, outcrops, structural sets, strike/dip, discontinuities and independent slope ratings. These are the same saved records; switching layout does not create another dataset. D15A identifies the review areas and count scopes.

Find the records to review

Search searches the active table. Filter column supports contains, equals, greater than, less than and is blank. Click a column heading to sort and reverse its direction. Previous/Next pages contain up to 50 rows. Selection is explicit; Clear selection removes it. Columns lets you show/hide, reorder and set widths from 80 to 600 pixels. These viewing settings are local preferences, not edited observations.

Stage, review and commit

Double-click an editable cell, or focus it and press Enter. Dropdowns constrain categorical fields; numeric ranges are checked. Enter finishes the cell; Escape returns it to the value present when editing began. Draft cells are staged, and all record changes wait for Review & save edits → Save reviewed edits. Discard draft edits abandons them. Recover desktop drafts retrieves a retained batch for the current account; review it against the latest records before saving.

Tab-separated paste starts at the focused cell, across displayed columns and existing filtered rows. It stages changes, not new rows. A block extending beyond those bounds or across a read-only column is rejected. Align the columns first and review the entire pasted batch.

Review shows changed values and detects saved records that changed while you were editing. It retains the draft instead of silently overwriting the newer data. If offered, Keep my draft values against these reviewed versions resets the comparison only after inspecting those versions. Save field edits and independent slope edits in separate batches. Save success means local commit and a queue when backup is enabled.

Derived fields are recalculated from edited inputs: orientation edits update dip direction/normal and correction metadata; RMR/Hoek–Brown and Barton–Bandis inputs reconcile their results; independent rating totals recalculate. Read-only derived cells must be changed through their source fields. Existing historical choice text is retained as an existing option rather than discarded.

Undo last edit checks saved versions before reversing the last batch. Edit history shows local batches and bounded cloud history. Copy rows uses selected matching rows when present, otherwise filtered rows, with visible columns and formula protections; it can include unsaved displayed draft values. File export is blocked until drafts are saved/discarded.

Unrelated edits can retain an older invalid HB or BB result with an explicit review status. Editing a material input must pass current domain checks; saving notes does not certify that older calculation.

Open in field tools on a selected field record provides its original form and context. Delete selected previews cascaded dependents and asks for typed DELETE. Use the independent Slope rating list for slope deletion. A table containing rows is evidence of local saved data, not evidence that every row was uploaded.

D15A. Read the desktop review areas and their scope

Geology workspace separates record scope, spatial review and editable values. The top actions include Stereonet analysis, Account & storage, Sync now and Open field tools. It changes where controls are presented, not the field observations or equations. Auto uses the available screen and input device; Field and Desktop remain explicit choices. On a phone, continue using Field for the compact collection workflow.

Area / control	Review purpose
Workspace scope	Choose Table, Project, Outcrop and Structural set before interpreting the visible rows. Independent slope ratings have their own scope.
Outcrop map	Inspect located records and published context. Background tiles require internet; their absence does not delete local rows.
Linked stereonet	Compare saved orientations in the current linked population; a pole is perpendicular to its measured plane.
Data records	Search/filter/sort the active table, choose columns, select rows and stage valid cell edits.
Record inspector	Read the selected saved record and its context before editing or opening field tools.
Draft review	Use Review & save edits and inspect changed values before Save reviewed edits. A staged value is not a completed record commit.
Stereonet analysis / exports	Save/discard table drafts before opening structural analysis or file export. Confirm selected/filtered/project scope separately.

Saved project totals, matching rows and selected rows answer different questions. The project summary counts the saved project scope, not an outcrop or search subset; table filters can reduce matching rows without changing those totals. Selection is a further subset. The labeled geological-section illustration is decorative, not a section calculated from those records. Neither a populated panel nor a displayed total proves that every record has reached online backup. Use the cloud readback procedure in D12.

In structural analysis the source/filter controls, stereonet and sets/statistics share the desktop width. Filters, Plot, Rows, Sets and Files & exports jump to their sections. Narrower windows stack these panels; screen position is not a change in analytical scope. Review included rows, north reference, exclusions and interpreted sets before clustering or engineering analysis. K1-K1A retain the separate CSV/paste import and original-versus-interpreted joint labels.

The field collection procedure, saved measurements, analysis export formats, solver equations and separate slope-hazard workflow are unchanged by this layout. Offline observations remain local as before; new external map tiles, account operations and guide downloads require their existing connectivity. Save both PDFs separately for offline reading.

D16. Desktop maps, mean bedding and scoped packages

Fit outcrops fits located saved outcrops in the current context. Toggle Topographic map and Geologic units; Opacity adjusts the geology overlay. Click an outcrop to filter/select its context; click a geologic polygon for unit/source details. Saved field points remain separate from the reference layers. New tiles require internet and send the viewed area to USGS/Macrostrat; offline backgrounds may be absent even while observations remain accessible.

The map accepts outcrop points within 85°S–85°N and valid longitude. A missing map marker need not mean a missing row: compare the located/total count and inspect coordinates. The same data may still export geographically at higher valid latitudes because GeoJSON itself is not the desktop Web Mercator display.

Bedding symbols are derived observations

At each outcrop, the app selects saved measurements whose feature type or set name contains “bedd” and obtains the axial mean of their plane normals. A conventional strike line/dip tick is rotated toward the mean dip direction; its label is mean dip rounded to the nearest degree. Nearly horizontal (<0.5°) and nearly vertical (>89.5°) means have special symbols. The symbol is placed at the outcrop coordinate, not at an independently averaged location.

The mean is withheld for mixed north references, invalid orientations or an ambiguous axial mean. A uniform unknown north reference can still yield a descriptive mean, so its map alignment is not certified true north. Saved duplicates and distinct bedding populations are all members of that selection; the symbol does not establish a single geological population. Inspect the table/set and stereonet, and use the structural-analysis chapter for the mean/statistical equations.

Export exactly the intended scope

Workspace scope	CSV	GIS ZIP
Filtered rows	Matching saved rows, all data columns	Those rows plus required parent tables
Selected rows	Selected rows within current matching rows	Same selection plus necessary parents
Whole project	Chosen project table (all projects if no project selected)	Full selected field-project graph

For the independent slope table, “Whole project” means all saved independent assessments, not a relationship to a selected field project. Workspace GIS exports contain a scope manifest with table, project context and record IDs. They may be partial and are not a complete account backup. Data → Download GIS ZIP package uses all locally saved field records and independent slopes instead.

Stereonet analysis has separate dataset/import and output controls; engineering reports preserve calculation assumptions and results. Keep analytical sessions/reports separately: the field GIS ZIP delivers observations, not a calculation package.

D17. Preserve survey, domain and trace evidence

Release v1.13.0 introduces backup schema 6 for geological domains, survey sessions, observation assignments and numeric trace evidence. Earlier supported schemas 1-5 remain readable without inventing those fields. A schema-6 backup requires this release or a later compatible reader; an older app may reject it.

Record / export	Preservation rule
Project domain catalogue	Domains retain project-scoped IDs, names, geological basis/boundaries and update metadata.
Outcrop surveys	Survey records retain their parent outcrop, method, orientation, dimensions, visibility threshold, coverage, notes and assigned domain/reach.
Structure / discontinuity rows	Their saved survey/domain/reach values are explicit observations of context. Exported names describe the linked catalogue records; default changes do not rewrite the stored assignments.
Discontinuity trace columns	Numeric length, basis, both endpoints, direction and evidence notes remain separate columns. Legacy free-text length/persistence remains available independently.
GIS package relationships	Separate domain and survey tables preserve catalogues, including entries without observations. Project/domain and outcrop/survey composite keys distinguish copied or recovered records.
Desktop edits	Trace cells are editable with validation. Domain/survey IDs are read-only as ordinary cells. Assign survey / domain stages explicit context changes for selected rows; Review & save edits performs the normal reviewed commit.

Use the full backup to preserve the native project hierarchy and the GIS/CSV package for querying. Check that observations and catalogue rows are present after export/restore; a plotted point alone does not establish that all evidence survived. Account backup continues to preserve these field records through the app's normal queued/conflict-aware process. A completed local save is not a confirmed online upload.

Desktop context assignment requires selected saved outcrop, measurement or discontinuity rows from one project. A named survey is available only for observations from one outcrop; across outcrops, survey assignments may be kept or cleared. Domain, survey and reach are independent batch choices. Selecting a survey here does not infer its domain/reach. Outcrop edits change future defaults, not saved observations. Keep/clear choices, staged review, discard and version-checked undo preserve explicit control (Field Protocol 2.0C).

These additions do not modify the independent slope-hazard workflow, existing orientation equations, strength laws, factor-of-safety calculations, or local-only engineering-case retention. They make the source population and survey limitations explicit. Updating a parent description can change its displayed wording; retain a dated exported package with an engineering decision if its historical wording matters.

S1. Basis and scope

USACE EM 1110-1-2908 describes shear-strength selection, sliding stability and cut-slope mechanisms in Slope section S4, 7 and 8. Its force-equilibrium framework is an engineering basis, not an endorsement of this application or a statement that every requirement of the manual is implemented. [R1]

The equations below are original derivations from statics, geometry and the cited constitutive laws. Implementation choices are identified separately. No jurisdictional load factors, material factors or mandatory acceptance FS are silently imposed.

Component	Calculated / boundary
Planar prism	Translation on one continuous basal surface; side faces are free releases. No overturning or automatic critical crack search.
Finite wedge	Explicit convex block and up to three compressive contacts. Translational motion only; no complete rotational equilibrium.
Isolated block	Separate sliding and toe-overturning onset ratios for one rectangular block. Not an interacting slope.
Interacting columns	A strength-reduction recurrence with prescribed forces and contact audits. No displacement-compatible opening/slip evolution.
Flexure	Local elastic-section audit and diagnostic recurrence only. Whole-slope FS is withheld.
Water / reinforcement	Prescribed pressures and qualified capacities. No seepage, anchor-product qualification or mobilization displacement calculation.
Uncertainty / benches	Conditional numerical scenarios and an explicit width rule. Neither site failure probability nor a rockfall runout model.

Numerical verification and physical validation answer different questions. Here the former asks whether the implemented equations match independently calculated answers. Physical validation would require suitable observations or experiments and an uncertainty-aware comparison. NISTIR 8298 discusses that distinction in a different application domain; it is used only for verification terminology. [R2]

S2. Conventions and dimensional control

Quantity	Convention
Position and length	Local east (E), north (N), up (U); ft. This frame is not an automatic GIS coordinate conversion.
Plane orientation	Dip α down from horizontal; dip direction θ clockwise from north. A single declared true or magnetic north reference is required.
Applied-force direction	Trend θ clockwise from north; plunge p positive downward. This describes the force on the block.
Loads and stresses	Force lbf; area ft^2; volume ft^3; unit weight lbf/ft^3; moment lbf·ft; joint stress psi.
Rock-mass interpretation	Hoek-Brown UCS and envelope stresses are explicitly MPa. They are not joint strengths.
Seismic convention	kh positive horizontally outward; kv positive upward, reducing vertical body-force magnitude.

Direction vectors

$$n = (\sin\alpha \sin\theta, \sin\alpha \cos\theta, \cos\alpha) \quad \text{(upward geological normal)}$$

$$u = (\cos p \sin\theta, \cos p \cos\theta, -\sin p) \quad \text{(force / line unit vector)}$$

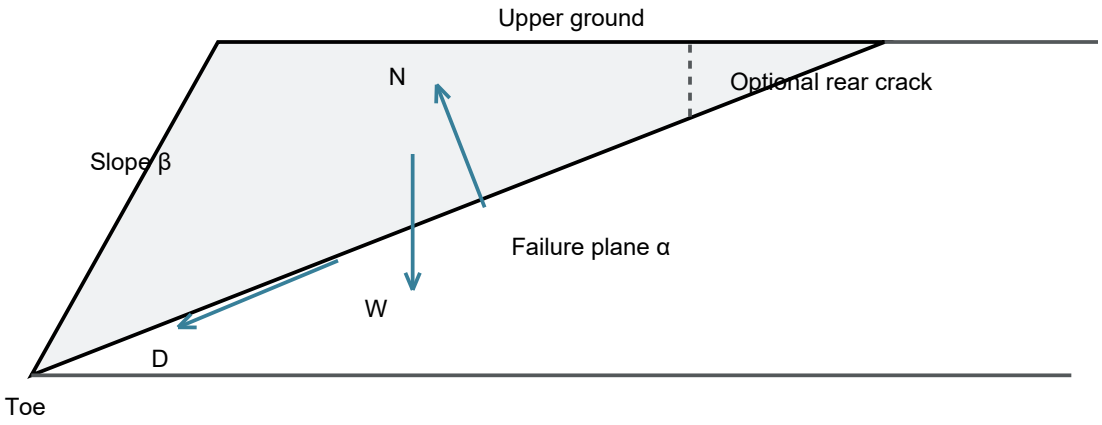
Each geometric face stores the inward normal selected by its retained halfspace. That normal can have the opposite sign from the upward geological normal. A rear crack is a release surface, not an extra frictional joint.

$$W = \gamma r V; \quad U = 144\, p\, A; \quad \sigma' = N' / (144\, A)$$

The factor 144 converts ft^2 to in^2 when multiplying psi by area. One foot is exactly 0.3048 m. Angles are converted to radians only for trigonometric evaluation. Independent tests include a dimensional conversion of power-law coefficients, whose units change with exponent.

A blank or unavailable value is not zero. A null FS accompanied by no-block, contact-loss, no-driving, search-limit or unresolved status is not a safe result. A support-only release ratio is distinguished from contact-maintained sliding.

S3. Planar geometry



Use a section with x horizontal into the hill and z upward. The toe is (0,0). Let H be the vertical slope height, β the face inclination, α the basal dip, δ the uphill upper-ground inclination and b the across-section width. All three surfaces lie in the same dip section; an oblique apparent-dip conversion is not inferred.

$$x_c = H \cot \beta; \quad z_{base} = x \tan \alpha; \quad z_{upper} = H + (x - x_c) \tan \delta$$

$$x_r = (H - x_c \tan \delta) / (\tan \alpha - \tan \delta); \quad z_r = x_r \tan \alpha$$

For no crack and horizontal upper ground, the area of the triangular section and basal contact length follow directly:

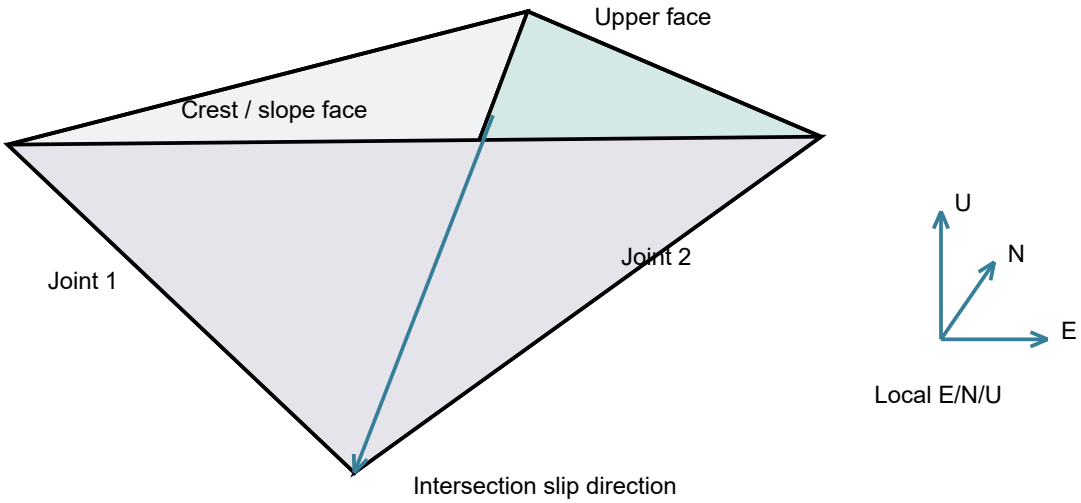
$$A_{section} = H^2(\cot \alpha - \cot \beta)/2; \quad V = b A_{section}; \quad L_{base} = H/\sin \alpha$$

For a rear crack, intersect its specified line with the upper and basal lines. Its horizontal location is measured behind the crest; 90° is vertical. The retained section must have positive area and finite intersections. The crack carries water pressure if requested, but zero joint shear strength.

$$A_{section} = |\Sigma(x_i z_{i+1} - x_{i+1} z_i)|/2; \quad V = b A_{section}$$

The polygon-centroid first moments and edge lengths give the block centroid and each face area. An extruded boundary face has area equal to section-edge length multiplied by b; each lateral release face has the section area. Parallel, unbounded, zero-volume and numerically unresolved sections are rejected. Geometry is checked separately from equilibrium.

S4. Wedge geometry and size



A finite wedge is the intersection of physical halfspaces $n_i \cdot x \geq d_i$. Candidate vertices solve three boundary equations. Retain vertices satisfying every halfspace; order each face around its normal and require a closed manifold. Artificial enclosure faces are never added to make an unbounded block finite.

$$x = [d_1(n_2 \times n_3) + d_2(n_3 \times n_1) + d_3(n_1 \times n_2)] / [n_1 \cdot (n_2 \times n_3)]$$

For a tetrahedron with vertices o,a,b,c, volume is $|(a-o)\cdot[(b-o)\times(c-o)]|/6$ and centroid is $(o+a+b+c)/4$. A convex polyhedron can be decomposed into tetrahedra from an interior point; volume-weighted centroids and triangular face areas preserve these identities.

For a two-joint tetrahedron, H1 is the vertical height at Joint 1 intersecting the slope/upper crest. Explicit basal geometry instead uses the crest height in the slope dip-direction reference section. Neither necessarily equals the maximum vertical span. Third/basal planes and rear cracks have explicit locations and retained sides; their worst locations are not automatically searched.

Similarity scale λ: length $\rightarrow \lambda L$; area $\rightarrow \lambda^2 A$; volume $\rightarrow \lambda^3 V$

Size and persistence limits restrict the specified geometry. Water, support and force geometry are then recomputed. Scaling a friction-only dry block leaves FS unchanged; fixed cohesion and fixed forces generally break that invariance. Joint occurrence, connectivity and rock bridges are not inferred from a length limit.

S5. Translational equilibrium

Let f be the sum of active applied force vectors: body force, inertia, prescribed loads, water and active support. In a one-plane section with inward normal n and unit downward-outward tangent s:

$$N' = -f \cdot n; \quad D = f \cdot s; \quad FS = R(N')/D$$

Require $N' > 0$ and $D > 0$. With gravity only, $N'=W \cos \alpha$ and $D=W \sin \alpha$. Mean basal pressure subtracts U from N′. A vertical water-filled rear crack pushes outward and changes both D and N′; subtracting it only as uplift would be incorrect.

For a vertical crack, with no additional prescribed force:

$$N' = W[(1-kv) \cos \alpha - kh \sin \alpha] - U - V_{crack} \sin \alpha$$

$$D = W[(1-kv) \sin \alpha + kh \cos \alpha] + V_{crack} \cos \alpha$$

Multiple contacts

Let N be the matrix of inward unit normals and r the nonnegative reaction vector. The translational contact selection is the following complementarity system. Here v is a force projection used to determine a motion direction; it is not a calculated physical velocity.

$$v = f + Nr; \quad r \geq 0; \quad N^T v \geq 0; \quad r_i(n_i \cdot v) = 0$$

It is equivalently the nonnegative least-squares minimization of $\frac{1}{2}\|f+Nr\|^2$. The app enumerates small contact sets; the independent verification uses a separate NNLS implementation and also checks the complementarity residuals. [R7]

$$s = v/\|v\|; \quad D = f \cdot s; \quad R = \Sigma\, 144\, A_i\, \tau_i(r_i / (144\, A_i))$$

For two maintained contacts, s is along their intersection. Released faces contribute no cohesion or friction. For a basal-only wedge, the centroid thrust must additionally intersect its finite footprint; that necessary test is not a full rotational analysis.

For nonlinear strength, each face uses its mean effective normal stress. In general, $A\,\tau(\text{mean } \sigma')$ differs from $\int \tau(\sigma')dA$. The app does not solve the contact-stress distribution needed for the latter. This approximation must be suitable for the case.

Worked planar case P01: construct the block

Use a calculator in degree mode and carry ten significant figures. Reuse original angles rather than rounded normals. The hand-check target is FS within 0.000002 and forces within 2 lbf of the program; these rounding allowances differ from the tighter automated tolerances. E/N/U means east/north/up; negligible roundoff components are shown as zero.

Step 1 — Enter the complete input

Input	Value	Units
Vertical height H; across-section width b	24; 8	ft
Slope dip β; basal dip α; friction φ	70; 35; 28	degrees
Slope/base dip directions; north reference	180; 180; true	degrees
Upper ground	Horizontal (dip 0)	—
Rock unit weight γr	160	lbf/ft^3

Cohesion, water pressure, kh, kv and support are zero. There is no crack or ponding; side faces release freely. In section, x is horizontally uphill (north here), z is up and the toe is (0,0). The block translates along its base; overturning is not calculated.

Step 2 — Intersect the three section lines

$$xc = H/\tan\beta = 24/\tan 70^\circ = 8.735285622 \text{ ft}$$

$$xr = H/\tan\alpha = 24/\tan 35^\circ = 34.275552162 \text{ ft}$$

The slope is $z=x\tan 70^\circ$, the base is $z=x\tan 35^\circ$, and the upper ground is $z=24$. The three section vertices are toe (0,0), crest (8.735285622,24) and rear intersection (34.275552162,24) ft. In 3D, place an identical triangle at E=−4 ft and E=+4 ft; north equals section x.

Step 3 — Calculate area, volume and basal area

$$A_{section} = \tfrac{1}{2}(24)(34.275552162-8.735285622) = 306.483198473 \text{ ft}^2$$

$$V = b\,A_{section} = 8(306.483198473) = 2{,}451.865588 \text{ ft}^3$$

$$L_{base} = 24/\sin 35^\circ = 41.842723095 \text{ ft};\quad A_{base} = 8L_{base} = 334.741784759 \text{ ft}^2$$

The section centroid is the average of its three vertices: $\bar{x}=(0+xc+xr)/3=14.336945928$ ft; $\bar{z}=16$ ft. The prism centroid is therefore (E,N,U)=(0,14.336945928,16) ft. Establish these geometry results before computing forces.

Worked planar case P01: resolve the forces

Step 4 — Define force directions

Use the block from the preceding page. A positive reaction must push into the block. For the south-dipping base, the inward normal n and outward/downward sliding unit vector s are:

$$n=(0,-\sin 35^\circ,\cos 35^\circ)=(0,-0.573576436351,0.819152044289)$$

$$s=(0,-\cos 35^\circ,-\sin 35^\circ)=(0,-0.819152044289,-0.573576436351)$$

Check $n\cdot s=0$ and $|n|=|s|=1$. A vector dot product is the sum of its three component products. Weight points vertically down, so $f=(0,0,-W)$.

Step 5 — Weight, compression and driving force

$$W=\gamma r V=160(2451.865587785)=392{,}298.494046 \text{ lbf}$$

$$N'=-f\cdot n=W\cos 35^\circ=321{,}352.113369 \text{ lbf}$$

$$D=f\cdot s=W\sin 35^\circ=225{,}013.172201 \text{ lbf}$$

N' is the effective compressive normal reaction and D is the positive force tending to move the block outward/downward. Both are positive, so this sliding calculation has a retained contact and a defined denominator.

Step 6 — Shear resistance and FS

$$\sigma'=N'/(144\,A_{base})=321352.113368881/(144\times 334.741784759)=6.666666667 \text{ psi}$$

$$\tau=c+\sigma'\tan\varphi=0+6.666666667\tan 28^\circ=3.544729544 \text{ psi}$$

$$R=144\,A_{base}\,\tau=N'\tan 28^\circ=170{,}865.949563 \text{ lbf}$$

$$FS=R/D=170865.949562583/225013.172200512=0.759359765$$

Cross-check	Hand value	Program, rounded
tan28°/tan35°	0.759359765	0.759359765
Effective reaction (lbf)	321,352.113369	321,352.113369

At the calculated strength-reduction factor, the force identity is $f+N'n-(R/FS)s=0$. It is a useful sign check: R/FS equals D. The physical available resistance R is smaller than D at the entered strengths, hence FS<1. Do not interpret this example as an acceptable design.

This translation model does not enforce global moment equilibrium or assess rotation. If $N'\le 0$ or $D\le 0$, report contact-loss/no-driving rather than dividing. No toe lever arm is needed for this translational ratio.

Worked planar case P06: combine every load

Retain the complete P01 geometry and γr=160 pcf, φ=28°. Change only cohesion to 2 psi, uniform mean basal water pressure to 1.2 psi, kh to +0.09 and kv to −0.04. Apply a 12,000 lbf horizontal force toward north (trend 0°, plunge 0°). There is no crack, ponding or other support.

Step 1 — Convert pressure to a force

U = 144 p Abase = 144(1.2)(334.741784759) = 57,843.380406 lbf

The 144 converts ft^2 to in^2. Water acts along n; do not also reduce the rock unit weight.

Step 2 — Sum actual E/N/U components

Load (lbf)	North component	Up component
Gravity	0.000000	-392,298.494046
Inertia: kh W outward; kv W upward	-35,306.864464	-15,691.939762
Basal water U n	-33,177.600000	47,382.523308
Prescribed inward force S	12,000.000000	0.000000
Total f (east component is zero)	-56,484.464464	-360,607.910499

Positive kh acts south, so fN is negative. Negative kv increases downward load. The inward support acts north. Apply these signs before summation.

Step 3 — Project onto the same n and s

N′ = −[(-56484.464464097)(−sin35°)+(-360607.910498854)cos35°]

N′ = 262,994.549235 lbf; D = −fN cos35°−fU sin35° = 253,105.564760 lbf

Step 4 — Add cohesion and friction once

Rc = 144(2)Abase = 96,405.634011 lbf

Rf = N′tan28° = 139,836.682304 lbf; R = 236,242.316315 lbf

FS = 236242.316314688/253105.564760263 = 0.933374644

The program gives FS=0.933374644 and σ′=5.455999578 psi. Do not subtract U again from N′. The entered support is an active resultant, not passive bolt capacity.

Worked wedge W01: solve its plane intersections

Use H1=20 ft; slope 75° toward 180°; horizontal upper ground; Joint 1 55° toward 130°; Joint 2 55° toward 230°. Both joints: φ=29°, c=0 psi. Rock weight: 160 pcf. Water, kh, kv and support are zero. No third plane, crack, sizing or persistence restriction is entered. Bearings use true north.

Step 1 — Convert dip α and direction θ to plane equations

$$n(\alpha,\theta)=(\sin\alpha \sin\theta, \sin\alpha \cos\theta, \cos\alpha)$$

Boundary	Inward unit normal (E,N,U)	Retained inequality
Joint 1	(0.627506871597, −0.526540784518, 0.573576436351)	n1·x ≥ 0
Joint 2	(−0.627506871597, −0.526540784518, 0.573576436351)	n2·x ≥ 0
Slope	(0, 0.965925826289, −0.258819045103)	ns·x ≥ 0
Upper	(0, 0, −1)	−U ≥ −20

The slope inward normal is the negative of its upward geological normal; using the geological sign there would retain the wrong side. Define $p=\sin55° \sin50°=0.627506871597$, $q=\sin55° \cos50°=0.526540784518$ and $k=\cos55°=0.573576436351$. Joint equations are $pE-qN+kU=0$ and $-pE-qN+kU=0$.

Step 2 — Solve each pair at upper elevation U=20 ft

At P, subtracting the two joint equations gives E=0; then N=20k/q. At Q and R, slope plus upper gives N=20cot75°. Substitute that N into Joint 1 for Q; reverse its E sign for R on Joint 2.

$$NP=20k/q=21.786591019;\ NQ=NR=20\cot75°=5.358983849$$

$$EQ=(qNQ-20k)/p=-13.784399118;\ ER=-EQ$$

Vertex / intersection	(E,N,U), ft
O: toe, joint/joint/slope	(0,0,0)
P: Joint 1 / Joint 2 / upper	(0,21.786591019,20)
Q: Joint 1 / slope / upper	(-13.784399118,5.358983849,20)
R: Joint 2 / slope / upper	(13.784399118,5.358983849,20)

Every vertex must satisfy all retained inequalities. H1 is the vertical toe-to-Q crest height. All upper vertices here have equal elevation because the upper ground is horizontal; inclined ground generally gives different elevations.

Worked wedge W01: areas, volume and weight

Step 3 — Calculate the upper triangular area

Use O, P, Q and R from the preceding page. Q and R have equal north coordinates, and P lies on E=0. The upper triangle PQR therefore has base QR=2|EQ| and perpendicular plan height NP−NQ.

$$QR=2(13.784399118)=27.568798235 \text{ ft}$$

$$NP-NQ=21.786591019-5.358983849=16.427607170 \text{ ft}$$

$$A_{upper}=\tfrac{1}{2}(QR)(NP-NQ)=226.444693781 \text{ ft}^2$$

Step 4 — Compute each joint area by side lengths

Joint 1 is triangle OPQ. For a pair of points a,b, distance is $\sqrt{[(Ea-Eb)^2+(Na-Nb)^2+(Ua-Ub)^2]}$. This gives the three side lengths below; Joint 2 is its mirror image.

Side	Substitution	Length (ft)
OP	$\sqrt{(21.786591019^2+20^2)}$	29.574576045
OQ	$\sqrt{[(-13.784399118)^2+5.358983849^2+20^2]}$	24.874251083
PQ	$\sqrt{[(-13.784399118)^2+(16.427607170)^2]}$	21.444718146

$$sH=(OP+OQ+PQ)/2=37.946772637 \text{ ft}$$

$$A_{joint}=\sqrt{[sH(sH-OP)(sH-OQ)(sH-PQ)]}=261.791669761 \text{ ft}^2$$

The symbol sH is the Heron semiperimeter, not the slip unit vector used later. Both joint areas are 261.791669761 ft^2. A useful extra area check is $A_{slope}=(QR/2)\sqrt{(NQ^2+20^2)}=285.413201355$ ft^2.

Step 5 — Volume, centroid and weight

$$V=A_{upper}(20)/3=1{,}509.631292 \text{ ft}^3$$

The factor one-third is the tetrahedron base-area × perpendicular-height formula. Here the toe-to-upper perpendicular height is exactly 20 ft. The centroid is the average of the four vertices:

$$\bar{x}=(O+P+Q+R)/4=(0,8.126139679,15) \text{ ft}$$

$$W=\gamma_r V=160(1509.631291875)=241{,}541.006700 \text{ lbf}$$

Program checkpoints: V=1509.631292 ft^3; each joint area=261.791670 ft^2; W=241541.006700 lbf. The hand-derived values above agree at the displayed precision.

Worked wedge W01: contacts, movement and FS

Step 6 — Solve the two normal reactions

Gravity is f=(0,0,−W). Use inward joint normals n1,n2 from the geometry page. First assume both contacts stay compressed; verify that assumption after solving. Let g=n1·n2 and fi=f·ni. Requiring the remaining force to be tangent to both planes gives N1+gN2=−f1 and gN1+N2=−f2.

$g=-p^2+q^2+k^2=0.212470252197$; f1=f2=−Wk=-138542.229856 lbf

$N1=(-f1+g\ f2)/(1-g^2)$; $N2=(-f2+g\ f1)/(1-g^2)$

N1=N2=−f1/(1+g)=114,264.436265 lbf > 0

Step 7 — Identify the unbalanced tangential force

v=f+N1n1+N2n2=(0,-120329.771827,-110462.230391) lbf

$D=|v|=\sqrt{(vN^2+vU^2)}=163,343.681638$ lbf

s=v/D=(0,-0.736666215804,-0.676256524178)

This is trend 180° and downward plunge 42.551802695°. Check n1·s=n2·s=0, sU<0, and that s points out through the slope face. The v symbol is a force projection, not a physical velocity; normal reactions must be positive for both assumed contacts.

Step 8 — Calculate contact strength, total resistance and FS

σ1′=σ2′=N1/(144Ajoint)=3.031047666 psi

R1=R2=N1tan29°=63,337.811281 lbf; R=126,675.622562 lbf

FS=R/D=126675.622561957/163343.681637503=0.775515902

The application gives FS=0.775515902, with both contacts retained. For an independent symmetry check, let ψ be the intersection plunge: tanψ=tan55° cos50°, so ψ=42.551802695°. Then FS=tan29° $\cos^2$ψ/(cos55° sinψ) gives the same value. Force closure at reduced strength is f+N1n1+N2n2−(R/FS)s=0.

If the assumed contact mode fails

A negative calculated Ni invalidates that two-contact assumption. Test the remaining compressed plane using Ni=−f·ni and v=f+Nini; its opened neighbor must satisfy nj·v≥0 (no penetration). Give a released or zero-compression joint no friction or cohesion. If no compressed contact remains, or movement is upward/into the slope, do not report an ordinary sliding FS. These checks still do not establish moment equilibrium, rock-bridge strength or compatible rotational motion.

S6. Joint shear-strength laws

Shear laws apply to a retained compressive discontinuity at effective normal stress σ′. They do not convert intact strength or a rock-mass classification into joint strength. Units in this section are psi unless expressly stated.

Law	Equation / parameter meaning
Mohr-Coulomb	$\tau = c + \sigma' \tan \varphi$. c is the shear intercept; φ is the selected contact friction angle.
Barton-Choubey form	$\tau = \sigma' \tan[\varphi r + JRC \log_{10}(JCS/\sigma')]$. JCS and σ′ have the same units. JRC and JCS must represent the surface and scale. [R3]
Power curve	$\tau = c + a(\sigma' + d)^b$. The coefficient a has stress$^{(1-b)}$ units; b is dimensionless. This is a declared fitted law, not an automatic calibration.
Additional waviness (advanced)	Additional stress $\Delta\tau = \sigma' \tan w$. Default w = 0. This adds resistance, not angles; it is not the Patton angle-addition law. See S6A-S6B before using a nonzero value.

Domain and interpretation

At exactly zero effective compression, WillItMap releases the face and credits zero shear, including cohesion. This is a no-tension contact convention; it is not the value of the mathematical Mohr-Coulomb intercept on a still-bonded surface.

For Barton-type contact calculations the program enforces σ′ ≤ JCS and a base peak angle of 0–70°. This is an explicit computational applicability guard, not a universal material standard. An inadmissible value is rejected rather than clipped. The advanced additional-waviness term must not duplicate roughness in JRC, the friction angle or fitted test envelope. Zero is the recommended starting choice, not universal proof of conservative behavior.

$$a_{psi} = a_{MPa}\, k^{1-b}, \quad k = 145.03773773020923 \text{ psi/MPa}$$

For a selected field scale ratio r=Ln/L0≥1, with Ln≥L0>0: $JRCn = JRC0\, r^{-0.02\, JRC0}$; $JCSn = JCS0\, r^{-0.03\, JRC0}$. These empirical corrections use the original JRC0 in both exponents. The slope solver expects field-scale parameters and does not repeat the correction. [R11]

Log10(JCS)−log10(σ′) avoids an overflowing ratio. Thick infill, stress history, dilation and scale selection require independent engineering evidence.

S6A. Choose joint strength from evidence

In Slope stability > Materials, open Choose a strength law from the evidence. Choose the contact model for the relevant surface, shear direction, moisture, scale and stress range. No model is selected automatically from a rock name, roughness dropdown or RMR/GSI classification.

Model	Evidence and interpretation
Mohr-Coulomb	A supported linear envelope over the relevant effective-stress interval. State whether friction/intercept represent peak, residual or another condition; measured rough-joint friction may already include roughness. Do not add a peak roughness contribution again.
Barton-Bandis	The implemented Barton-Choubey shear criterion needs applicable rock contact and direction/scale-specific JRC, JCS and residual friction. The slope solver expects field-scale JRC/JCS. The separate field calculator can apply the documented length correction; do not repeat it. Thick weak infill requires its own applicable strength evidence.
Power curve	Use coefficients fitted to representative shear data over a known stress interval in consistent units. The fitted envelope can already include surface roughness. The app does not infer a fit range, remove roughness from the fit or calibrate the coefficients for you.

Recommended starting choice: no additional waviness

Additional waviness offers No additional waviness (recommended) or Additional term (advanced). New or missing values use w = 0 degrees. Choose zero when tests, a fitted envelope or JRC already represent the roughness being considered. This is an explicit modeling recommendation, not a universally conservative material parameter or evidence that the base model is correct.

Advanced exposes Additional waviness angle (degrees). Its contribution is the separately implemented stress term in S6B. Use a nonzero value only with a documented reason that the base law omits that contribution and that this additive convention is suitable. Record feature/test IDs, shear direction, represented scale, stress range, moisture and rationale in Geometry, strength, water and load evidence. The app does not enforce the adequacy of those notes.

Existing nonzero saved/imported values open the advanced controls unchanged; switching strength laws retains them. Selecting No additional waviness deliberately sets the draft value to zero. Review and save the case to retain that change. An advanced zero is numerically equivalent to no additional term. No silent saved-case migration or formula substitution occurs.

Barton and Choubey [F8] establish an empirical JRC-JCS-friction formulation and report scale dependence; they do not validate an arbitrary extra additive angle term. Descriptive waviness remains valuable field evidence even when the additional analysis value is zero. Keep contact loss and other S6 domain guards.

S6B. Additional waviness: reproduce the distinction

For a retained compressive contact, WillItMap evaluates the selected base law first, then adds the separately specified contribution below. Stress is psi and the trigonometric argument is degrees. This documents existing arithmetic; this release changes guidance and controls, not numerical mechanics.

$$\Delta\tau = \sigma' \tan w;\ \tau_{total} = \tau_{base} + \Delta\tau$$

Illustrative Mohr-Coulomb calculation

Take effective normal stress $\sigma' = 100$ psi, cohesion $c = 0$ psi, friction $\varphi = 30$ degrees. First use the recommended zero additional term; then explicitly examine an illustrative $w = 10$ degrees. This is an arithmetic comparison, not a field recommendation for 10 degrees.

$$\tau_{base} = 0 + 100 \tan(30°) = 57.73502691896 \text{ psi}$$

$w = 0°$: $\Delta\tau = 0$; $\tau_{total} = 57.73502691896$ psi

$w = 10°$: $\Delta\tau = 100 \tan(10°) = 17.63269807085$ psi

$$\tau_{total} = 57.73502691896 + 17.63269807085 = 75.36772498981 \text{ psi}$$

Angle addition is a different model

USBR Chapter 5, printed p. 108 [W1], describes putting large-scale undulations inside the friction-angle tangent. A Patton-type angle-addition illustration for the same numerical angles gives:

$$\tau_{angle} = c + \sigma' \tan(\varphi + i) = 100 \tan(30° + 10°) = 83.90996311773 \text{ psi}$$

The 8.54223812792 psi difference is not a numerical error between two implementations of one equation. The equations are different. WillItMap does not implement this Patton angle-addition option or its transitions between asperity sliding and shearing. Do not enter i as w and assume that model has been selected.

At these inputs the additional-term result is lower, but this example establishes neither universal conservatism nor the physically correct resistance. Actual applicability depends on contact morphology, stress, scale and shear mechanism. Never use a model comparison alone to justify greater resistance.

For a contact area A in ft^2, the resulting force contribution is $\Delta R = 144 A \Delta\tau$ in lbf. The implemented zero-effective-compression convention releases the contact and credits no shear. Do not apply this positive-compression example at a released contact.

Worked example: joint shear resistance

Compare two alternative joint laws on the same uniformly loaded contact, with waviness w = 0 for both. Total compressive normal force N = 36.0 kip, water resultant U = 7.2 kip, and contact area A = 2.0 ft^2. Use degrees for trigonometry, base-10 logarithms for joint roughness, and unrounded intermediate values.

1. Convert force and area to effective normal stress

$N' = N - U = 36.0 - 7.2 = 28.8$ kip $= 28{,}800$ lbf

$A = 2.0 \times 144 = 288$ in^2; $\sigma' = N'/A = 28{,}800/288 = 100$ psi

Water is subtracted once. The constitutive law receives σ'; it must not subtract U again. To recover resistance in kip, multiply shear stress in psi by area in in^2 and divide by 1,000.

2. Mohr–Coulomb: c = 7.5 psi and φ = 35°

$\tau = c + \sigma' \tan \varphi = 7.5 + 100(0.700207538210) = 77.520753821$ psi

$R = \tau A/1{,}000 = 77.520753821 \times 288/1{,}000 = 22.325977100$ kip

3. Barton–Choubey with a field scale correction

Set residual friction φ_r = 30°, profile-scale $JRC_0 = 10$ and $JCS_0 = 1{,}000$ psi. Let profile length $L_0 = 0.3280839895$ ft and assessment length $L_n = 3.280839895$ ft, so $r = L_n/L_0 = 10$. Apply the empirical correction only to profile-scale values.

$JRC_n = JRC_0\, r^{(-0.02JRC_0)} = 10 \times 10^{(-0.2)} = 6.309573444802$

$JCS_n = JCS_0\, r^{(-0.03JRC_0)} = 1{,}000 \times 10^{(-0.3)} = 501.187233627$ psi

$\log_{10}(JCS_n/\sigma') = \log_{10}(501.187233627/100) = 0.700000000000$

$\theta = \varphi_r + JRC_n \log_{10}(JCS_n/\sigma') = 34.416701411361°$

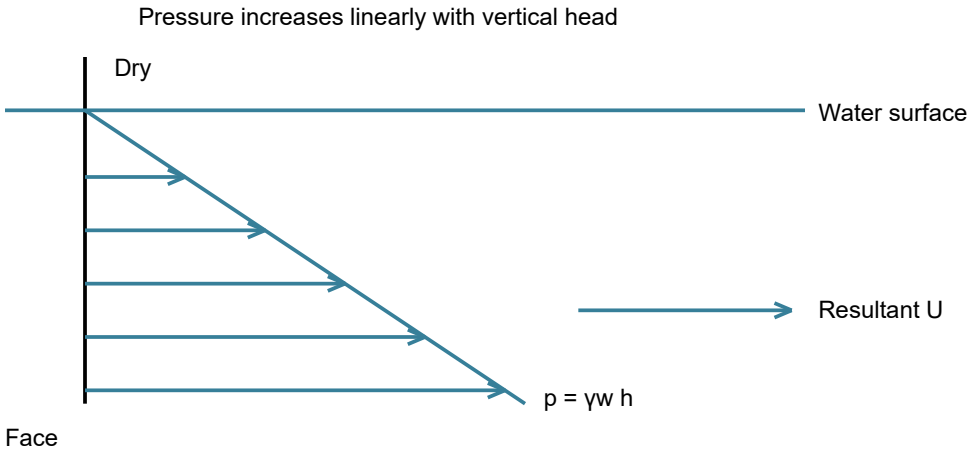
$\tau = 100 \tan \theta = 68.514253293$ psi; $R = \tau \times 288/1{,}000 = 19.732104948$ kip

Check: omitting scaling gives θ = 40°, τ = 83.909963118 psi and R = 24.166069378 kip. Scaling therefore changes the assigned joint properties; it is not a unit conversion. Never scale properties already estimated at the assessment scale.

Limits: this example has positive contact stress, $\sigma' \le JCS_n$ and θ ≤ 70°, satisfying the app's declared Barton domain. Released contact receives zero shear resistance, including cohesion. Optional waviness adds $\sigma' \tan(w)$ separately; it does not replace φ by φ + w. This calculation supplies resistance, not a factor of safety or a displacement-dependent joint model.

Basis: Barton–Choubey (1977); Barton–Bandis (1990), scale equations 9–10. Numerical anchors: MC-100-35-0, BC-10-100-0 and FIELD-BB-scale-10; force conversion is shown explicitly above.

S7. Water forces and moments



Prescribe a water elevation zw(E,N), optionally affine in plan. The vertical pressure head is h=zw−z. Groundwater multiplier Hu scales the pressure; external ponding uses a separate horizontal surface with Hu=1. Neither input is a seepage solution.

$$p_{psf}(x) = \gamma w\ Hu\ \max(h(x),0); \quad Fw = n \int p\ dA$$

$$Mw = \int[(x-xo) \times n]\ p\ dA$$

Clip a convex planar face at h=0, triangulate the wetted polygon, and integrate affine head exactly. For a triangle of area A with vertex heads hi and relative vertex coordinates ri:

$$\int h\ dA = A(h1+h2+h3)/3$$

$$\int r\ h\ dA = A[(\Sigma ri)(\Sigma hi) + \Sigma(ri\ hi)]/12$$

With ri=xi−xo, the absolute pressure center is xo+∫r h dA/∫h dA. The integrated moment is available for the relevant moment audit; the planar/wedge translation solver does not enforce global moment equilibrium. A vertical rectangle of wetted height h and width b has U=γw b h^2/2 acting h/3 above its base.

The planar crack-head option separately prescribes hydrostatic crack loading and a linear decline of basal pressure toward a drained toe. Mean-pressure and prescribed-head definitions cannot be added indiscriminately. The selected wet faces, elevations, Hu, pressure units and moment origin are part of the case record.

Worked groundwater case P22: integrate the wet base

Return to P01: H=24 ft, β=70°, α=35°, b=8 ft, γr=160 pcf, φ=28°, with zero cohesion, seismic coefficients and support. Use a horizontal groundwater surface at U=7 ft above the toe; γw=62.4 pcf and Hu=1. Select only the basal face. Mean-pressure input is zero, no crack is present and external ponding is disabled.

Step 1 — Find the wetted length and pressure diagram

Lwet = 7/sin35° = 12.204127569 ft; Awet = 8Lwet = 97.633020555 ft^2

pmax = γw h = 62.4(7)=436.8 lbf/ft^2 = 3.033333333 psi

Pressure is maximum at the toe and decreases linearly to zero at elevation 7 ft. It is zero above that elevation. Thus the pressure diagram along the base is triangular: its average over the wet area is half its maximum.

Step 2 — Pressure resultant and its location

U = ½ pmax Awet = ½(436.8)(97.633020555) = 21,323.051689 lbf

lCP = Lwet/3 = 4.068042523 ft uphill from toe along base

xCP=(0,lCP cos35°,lCP sin35°)=(0,3.332345349,2.333333333) ft

The one-third rule is measured from the large-pressure end, not from the water surface. Symmetry puts the center at E=0. As an audit about the toe, rCP is perpendicular to the pressure normal, so the lever arm is lCP and the moment is positive about east:

ME = U lCP = 86,743.080994 lbf·ft; MN=MU=0

Step 3 — Reuse the unchanged rock weight

N′ = W cos35°−U = 300,029.061680 lbf; D = W sin35° = 225,013.172201 lbf

FS = N′tan28°/D = 0.708973081

Check	Hand calculation	Program, rounded
Water force (lbf)	21,323.051689	21,323.051689
Full-face equivalent mean (psi)	0.442361111	0.442361111
FS	0.708973081	0.708973081

The equivalent full-face mean is U/(144 Abase), including the dry portion; it differs from the wet-area mean. The force solver uses the integrated U once. The reported pressure moment is an audit only: this planar method does not perform an overturning check or solve seepage.

Worked face H01: calculate a water-force lever arm

H01 is a vertical rectangle with corners (E,N,U)=(0,0,0), (0,7,0), (0,7,9), (0,0,9) ft. Pressure acts east: n=(1,0,0). Water surface U=4 ft; γw=62.4 pcf; Hu=1. The moment origin is xo=(2,−3,1) ft. This face calculation has no stability FS.

Step 1 — Separate wet geometry from whole-face geometry

$A_{face}=7\times9=63$ ft^2; $A_{wet}=7\times4=28$ ft^2

$p_{max}=62.4\times4=249.6$ lbf/ft^2; p=0 at U=4 ft

The area is a wet rectangle, but its pressure varies triangularly with elevation. Its pressure force is width × area under that triangular pressure diagram:

U = 7×½×4×249.6 = 3,494.400000 lbf

Step 2 — Locate the pressure center, not the area center

NCP=7/2=3.5 ft; UCP=4/3=1.333333333 ft; ECP=0

Uniform pressure across width makes NCP the midpoint. The triangle centroid is one-third of the wetted height above its bottom. The wetted-area centroid is U=2 ft; using that instead would give the wrong water-force moment.

Step 3 — Form the lever arm from the chosen moment origin

r=xCP−xo=(0−2, 3.5−(−3), 4/3−1)=(−2,6.5,1/3) ft

F=(3494.4,0,0) lbf

For any vectors r and F, the cross product components are ME=rN FU−rU FN, MN=rU FE−rE FU and MU=rE FN−rN FE. Substitute the actual components, retaining the signs:

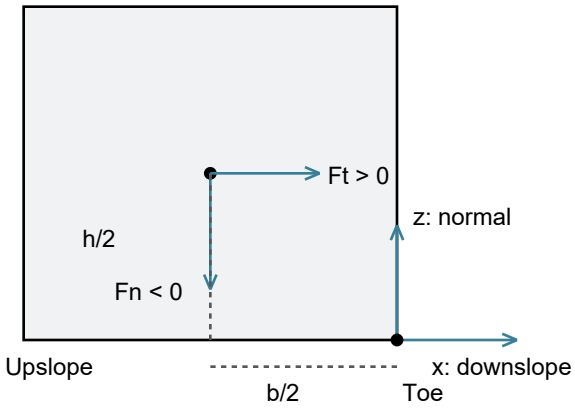
ME=0; MN=(1/3)(3494.4)=1164.8 lbf·ft

MU=−6.5(3494.4)=−22713.6 lbf·ft

Quantity	Hand answer	Program, rounded
Force vector (lbf)	(3494.4, 0, 0)	(3494.4, 0, 0)
Pressure center (ft)	(0, 3.5, 1.333333333)	(0, 3.5, 1.333333333)
Moment (lbf·ft)	(0, 1164.8, −22713.6)	(0, 1164.8, −22713.6)

The −2 ft east offset lies along F and produces no moment. About the toe (0,0,0), M instead equals (0,4659.2,−12230.4) lbf·ft. Always state the force, application point and moment origin; all inputs here match fixture H01.

S8. Isolated-block forces and moments



Axes shown rotated with the base

Centroid: x = −b/2, z = h/2

Ft positive downslope

Fn positive outward from base

Restoring-positive M = x Fn − z Ft

Use separate component moments

Use x positive downslope along the base and z normal into the block. The toe is (0,0), centroid (−b/2,h/2), base-water resultant (−b/2,0), and support (−b/2,ηh). Width b is along the base, height h normal to it, d is cross-slope depth and η the support-height fraction.

1. Resolve the applied forces

In horizontal-outward / vertical-up coordinates, a force is (Fx,Fz). With base dip α, its local components are:

$$F_t = F_x \cos\alpha - F_z \sin\alpha; \quad F_n = F_x \sin\alpha + F_z \cos\alpha$$

Combine gravity and seismic inertia into one effective body force at the centroid before resolving it. Keep water and support as separate loads at their own locations. Compression is $N' = -\Sigma F_n$; downslope demand is $D = \Sigma F_t$.

2. Calculate and classify each component moment

$$M_{normal} = x F_n; \quad M_{tangent} = -z F_t; \quad M_{net} = x F_n - z F_t$$

Positive component moments restore; negative ones overturn about the toe. The app sums their positive and negative parts separately. Do not first combine the normal and tangential moments of gravity into one net moment: that would change the ratio's denominator.

$$M_{rest} = \Sigma\max(M_{component}, 0); \quad M_{drive} = \Sigma\max(-M_{component}, 0)$$

3. Form the two checks and locate the basal resultant

$$\sigma' = N'/(144bd); \quad R_{slide} = 144bd\,\tau(\sigma'); \quad FS_{slide} = R_{slide}/D$$

For Mohr–Coulomb with zero waviness, $R_{slide} = 144cbd + N'\tan\varphi$. Use Slope section S6 for the other selected shear laws. $FS_{overturn} = M_{rest}/M_{drive}$.

$$a_R = (M_{rest} - M_{drive})/N' \quad \text{[ft upslope from the toe]}$$

Within numerical tolerance: $N' \le 0$ withholds both factors; $D < 0$ or $a_R > b$ is outside this downslope model. A zero driving denominator gives no ratio for that check. A negative a_R indicates downslope overturning onset and can give $FS < 1$. No tensile overturning capacity is credited. The governing onset factor is the smaller available ratio.

Worked B1. Dry isolated block

Original fixture B01-dry. Intermediate values carry about ten significant digits; calculations retain full precision. Ratios are dimensionless.

Input	Value	Meaning
b; h; d	5; 8; 2 ft	Base width; normal height; depth
γ; α; φ	155 pcf; 25°; 32°	Unit weight; base dip; friction
Direction; c; p	0°; 0 psi; 0 psi	Base dips north; no cohesion/water
k_h; k_v; support	0; 0; 0 lbf	No inertia or applied support

1. Set the axes and force point

Origin O is the downslope toe. Local x is positive downslope along the base; z is positive normal away from it. In north/up coordinates t=(cos25°, −sin25°), n=(sin25°, cos25°). The centroid is (x,z)=(−b/2,h/2)=(−2.5,4) ft. Gravity acts there; no other applied force is present.

$V = b\,h\,d = 5 \times 8 \times 2 = 80\ \text{ft}^3$; $W = 155 \times 80 = 12{,}400$ lbf.

$F_t = W \sin 25° = +5{,}240.466446$ lbf; $F_n = -W \cos 25° = -11{,}238.21656$ lbf.

2–3. Resolve forces and compute toe moments

Positive moment restores about O: $M = xF_n - zF_t$. Classify the base-normal and base-tangential components separately before summing restoring/driving magnitudes. Do not classify gravity only by its net moment; that would erase the driving denominator of this defined onset ratio.

$M_{normal} = (-2.5)(-11{,}238.21656) = +28{,}095.5414$ lbf·ft.

$M_{tangent} = -(4)(5{,}240.466446) = -20{,}961.86578$ lbf·ft.

4. Calculate ratios and required basal reaction position

$FS_{slide} = N \tan\varphi / D = 11{,}238.21656 \tan 32° / 5{,}240.466446 = 1.340037$.

$FS_{overturn} = 28{,}095.5414 / 20{,}961.86578 = 1.340317$.

$M_{net} = 28{,}095.5414 - 20{,}961.86578 = 7{,}133.675616$ lbf·ft; $e = M_{net}/N = 0.6347693674$ ft.

Here $0 \le e \le 5$ ft and $N > 0$. Production returns FS_{slide}=1.340037 and $FS_{overturn}$=1.340317; sliding narrowly governs. e is measured upslope from O, so its signed local coordinate is x=−e. These are separate onset ratios, not equilibrium after motion starts.

Worked B2. Support force and its moment

Original fixture B06-applied-support-low. Retain B1 exactly: b=5 ft, h=8 ft, d=2 ft, γ=155 pcf, α=25°, φ=32°, northward base dip, c=p=k_h=k_v=0. Add one already applied 700 lbf horizontal uphill force; trend 180°, plunge 0°. Its height fraction η=0.1 gives z_s=0.8 ft. This is a specified force, not a bolt-capacity calculation.

1. Locate and resolve the support

$r_s = (x_s,z_s) = (-b/2,\eta h) = (-2.5,0.8)$ ft.

$S_t = -700 \cos 25° = -634.4154509$ lbf; $S_n = -700 \sin 25° = -295.8327832$ lbf.

Both components are negative: the tangential component acts upslope, and the normal component pushes into the base. The base reaction must balance that extra compression. The force point is halfway across the base width, not on the block front face.

2. Apply the cross product, with signed lever arms

$M_{s,n} = x_s S_n = (-2.5)(-295.8327832) = +739.581958$ lbf·ft.

$M_{s,t} = -z_s S_t = -(0.8)(-634.4154509) = +507.5323607$ lbf·ft.

$M_s = 739.581958 + 507.5323607 = 1,247.114319$ lbf·ft.

Independent global check: its vertical height above O is Z_s=(b/2)sinα+$z_s$cosα=1.781591884 ft. A horizontal force has that perpendicular lever arm, so 700×Z_s=1,247.114319 lbf·ft, agreeing with the two-component cross product.

3. Recompute forces and ratios

$N' = 11,238.21656 - (-295.8327832) = 11,534.04934$ lbf; $D' = 5,240.466446 + (-634.4154509) = 4,606.050995$ lbf.

$R = N' \tan 32° = 7,207.273938$ lbf; $FS_{slide} = 7,207.273938/4,606.050995 = 1.564740$.

$M_{rest} = 28,095.5414 + 1,247.114319 = 29,342.65572$ lbf·ft.

$FS_{overturn} = 29,342.65572/20,961.86578 = 1.399811$; $e = 8,380.789935/11,534.04934 = 0.7266129774$ ft.

The unchanged driving moment is 20,961.86578 lbf·ft. Both support contributions restore. Production matches 1.564740 sliding and 1.399811 overturning; overturning now governs. Total applied net restoring moment is 8,380.789935 lbf·ft, balanced by the compressive basal reaction at e.

Worked B3. Change only support height

Original fixture B07-applied-support-high. All geometry, strength and loading remain B2 values, including the 700 lbf horizontal uphill force. Change only η from 0.1 to 0.9: z_s=0.9×8=7.2 ft. The force vector remains identical; its moment changes because its application point changes.

1. Recompute the signed point and lever arms

r_s = (−2.5,7.2) ft; S_t = −634.415451 lbf; S_n = −295.832783 lbf.

$M_{s,n}$ = (−2.5)(-295.8327832) = +739.581958 lbf·ft.

$M_{s,t}$ = −(7.2)(-634.4154509) = +4,567.791247 lbf·ft.

M_s = 739.581958 + 4,567.791247 = 5,307.373205 lbf·ft.

The north/up point is (Y,Z)=(0.7770820169,7.581961721) ft from O. Thus the independent horizontal-force check is 700×7.581961721=5,307.373205 lbf·ft. Do not use 7.2 ft as the horizontal force's global perpendicular arm: 7.2 ft is measured normal to the inclined base.

2. Sum components and check the base resultant

M_{rest} = 28,095.5414 + 5,307.373205 = 33,402.9146 lbf·ft.

M_{drive} = 20,961.86578 lbf·ft; M_{net} = 12,441.04882 lbf·ft.

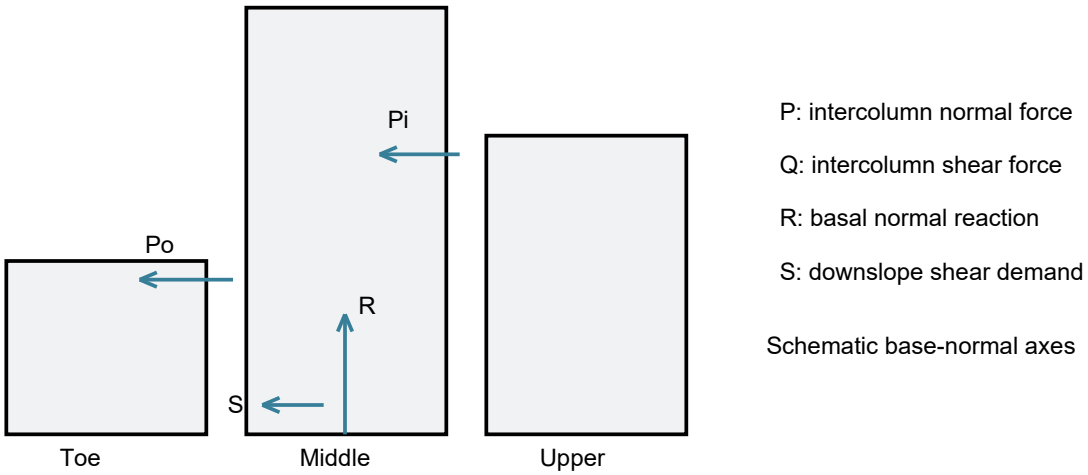
$FS_{overturn}$ = 33,402.9146/20,961.86578 = 1.593509; e = 12,441.04882/11,534.04934 = 1.078636691 ft.

Force equilibrium still gives N′=11,534.049342 lbf and D′=4,606.050995 lbf. Therefore sliding resistance and FS do not change. The required base resultant remains inside the 5 ft base.

Result	η=0.1: B2	η=0.9: B3
FS sliding, hand / app	1.564740 / 1.564740	1.564740 / 1.564740
FS overturn, hand / app	1.399811 / 1.399811	1.593509 / 1.593509
Governing onset	Overturning	Sliding

The transfer from overturning to sliding control follows the changed lever arm. Neither ratio proves dynamic rocking behavior or the capacity/anchorage of a real installed bolt. Changing a force location without changing its moment would be an implementation error; these paired cases explicitly detect it.

S9. Interacting-column recurrence



Pi and Po arrows show transmitted loads. The reaction of Po on the middle column acts in the opposite direction.

Use rectangular columns ordered toe to uphill. The model descends from the upper column. At trial strength-reduction factor F, basal cohesion and friction tangent are divided by F; intercolumn friction is fully mobilized at tan φj/F. Goodman and Bray provide the conceptual column-equilibrium basis. [R4]

The block recurrence requires zero intercolumn cohesion and zero basal/intercolumn tensile strength; basal shear cohesion c may be nonzero. Cohesive/tensile block-flexure uses a separate diagnostic branch and receives no accepted whole-slope factor.

For one column, let D,N be tangential/compressive forces; Pi,Qi incoming and Po,Qo outgoing contact forces; w the base width; ℓ the outgoing arm. Here moments are positive overturning (opposite Slope section S8): M0=D h/2−N w/2+Mext for centroid body forces. A is basal area in ft^2 and c is psi.

$$R = N + Qi - Qo; \quad S = D + Pi - Po; \quad Qo = \mu j\, Po$$

$$M = M0 + Pi\, \ell i - Qi\, w - Po\, \ell; \quad \mu j = \tan \varphi j/F; \; \mu b = \tan \varphi b/F$$

$$Ptopple = (M0 + Pi\, \ell i - Qi\, w)/\ell$$

$$Pslide = [D + Pi - \mu b(N+Qi) - 144\, cA/F] \,/\, (1-\mu b\, \mu j)$$

For the basic frictional column branch, select nonnegative support sufficient for both modes, and transmit it at the declared point. The sliding denominator can be negative; then it defines an upper bound, not an ordinary lower-bound division. No negative or tensile reaction may be accepted to force a desired ratio.

Every reported critical state checks R>0, |S|≤144 cA/F+μbR and the admissible basal moment/resultant range. Fully mobilized contact shear and prescribed heights remain assumptions; passing them does not establish compatible displacement or progressive opening.

Worked T1. Three columns: body forces

Original fixtures T04 and T05. Use explicit columns ordered toe→uphill, width w=2 ft, depth d=1 ft, normal heights [2,6,4] ft and base offsets [0,0,0] ft. γ=160 pcf; base friction φ_b=35°; intercolumn friction φ_j=20°; all cohesion, tension, water, inertia and applied loads are zero.

Replay geometry fields are H=20 ft, face 60°, upper −5°, overall base 25°, and into-slope joint dip 70°. Explicit column heights/offsets override that descriptive envelope; the joint dip sets the actual individual base angle α=90°−70°=20°. This distinction prevents inadvertently generating a different set of columns.

1. Fix signs and locations before transferring forces

Here x is uphill along the base and z is normal outward; each column's local toe is x=0. Its centroid is (w/2,h/2). D is a positive downhill force magnitude, N positive compression. M_o=Dh/2−Nw/2 is positive **overturning**, opposite the restoring sign used in B1–B3. Incoming P acts downhill at the upper joint; incoming Q acts into the base. Outgoing P acts uphill at the lower joint; outgoing Q acts away from the base.

2. Compute the three independent body free bodies

$W_i = \gamma\, w\, h_i d$; $D_i = W_i \sin 20°$; $N_i = W_i \cos 20°$.

Column / quantity	Force	Body toe moment
1: h=2 ft; W=640 lbf	D_1=218.8928917 lbf N_1=601.4032773 lbf	(218.8928917)(1)−(601.4032773)(1) =-382.5103856 lbf·ft
2: h=6 ft; W=1,920 lbf	D_2=656.6786752 lbf N_2=1,804.209832 lbf	(656.6786752)(3)−(1,804.209832)(1) =165.8261936 lbf·ft
3: h=4 ft; W=1,280 lbf	D_3=437.7857835 lbf N_3=1,202.806555 lbf	(437.7857835)(2)−(1,202.806555)(1) =-327.2349877 lbf·ft

3. Start uphill and compute the first transferred thrust

Column 3 has no incoming force, negative overturning moment and adequate basal friction near the solution; it needs no outgoing thrust. Column 2 receives zero P and Q from 3. Its contact against the 2 ft high toe column has a 2 ft thrust arm. Outgoing Q acts at column 2's downslope toe, so it contributes no moment about that toe.

$P_2 = M_{o,2}/2 = 165.8261936/2 = 82.91309682$ lbf; $Q_2 = P_2 \tan 20°/F$.

P_2 is an equal-and-opposite contact pair: uphill on column 2 and downhill on column 1. Q_2 is outward on 2 and compressive on 1. On the toe column, Q_2 has a 2 ft lever arm measured along the inclined base. Fully mobilized intercolumn friction and the declared thrust point are assumptions of this restricted model.

Worked T2. Transfer, audit and solve F

4. Audit an admissible trial at F=1.4

μ_b = tan35°/1.4 = 0.5001482416; μ_j = tan20°/1.4 = 0.2599787388; Q_2 = 82.91309682μ_j = 21.55564234 lbf.

Use $R=N+Q_{in}-Q_{out}$, $S=D+P_{in}-P_{out}$, and positive-overturning $M=M_o+P_{in}\ell_{in}-Q_{in}w-P_{out}\ell_{out}$. Cohesion is zero. Required basal position is $e=-M/R$, measured uphill from the local toe.

Column 2: R_2=1,804.209832−21.55564234=1,782.65419 lbf; S_2=656.6786752−82.91309682=573.7655784 lbf; M_2=165.8261936−82.91309682×2=0.

Column 1: R_1=601.4032773+21.55564234=622.9589196 lbf; S_1=218.8928917+82.91309682=301.8059886 lbf.

M_1=-382.5103856+82.91309682×2−21.55564234×2=-259.7954766 lbf·ft; e_1=259.7954766/622.9589196=0.4170346847 ft.

Column	Demand S / capacity μbR	Base resultant e
1	301.8059886 / 311.5718082 lbf	0.4170346847 ft
2	573.7655784 / 891.5913583 lbf	0 ft
3	437.7857835 / 601.5815832 lbf	0.2720595315 ft

All R are positive, $|S|\le\mu_b R$, and $0\le e\le 2$ ft. The toe requires zero outside thrust. T05 independently reproduces these forces and positions; each agrees with the app within the recorded absolute and relative tolerances.

5. Solve the toe's limiting sliding equation

$D_1+P_2 = [N_1+P_2\tan20°/F]\tan35°/F$.

$AF^2-BF-C=0$; $A=D_1+P_2$=301.8059886 lbf; $B=N_1\tan35°$=421.1071083 lbf; $C=P_2\tan20°\tan35°$=21.13079256 lbf.

$F = [B+\sqrt{(B^2+4AC)}]/(2A)$ = 1.443784.

At this root Q_2=20.901942 lbf. Toe R_1=622.305219 lbf, S_1=301.805989 lbf equals $\mu_b R_1$, and e_1=0.415372 ft. Columns 2 and 3 still pass basal shear/moment checks. App T04 returns 1.443784; difference=1.56e-09, below 2e-8. The small positive app toe-force tolerance explains the last digits.

This proves the stated three-column branch, not general motion compatibility or whole-slope flexure. Here F reduces both friction tangents; it is not the isolated-block restoring/driving moment ratio.

S10. Search, contact checks and flexure

The column solver samples F from 0.01 to 100 at 161 logarithmically spaced values. A single resolved stable-to-unstable transition is refined by 65 bisections. The contact audit is applied to the critical trial. Multiple transitions, unresolved stronger states, inadmissible reactions and missing brackets withhold an accepted FS.

Finite sampling cannot prove absence of every narrow disconnected stability interval. The manual therefore describes a bracketed recurrence threshold, not a mathematical global minimization over all possible failure mechanisms. Force tolerances scale with total weight; they are numerical thresholds, not design margins.

Local rectangular elastic section

$A = d\,w$; $I_{centroid} = d\,w^3/12$; $Z = I/(w/2) = d\,w^2/6$

$\sigma_{edges} = (N/A \pm M/Z)/144$ [psi, using ft and lbf]

An intact-section audit compares tensile edge stress with the specified reduced tensile capacity. Its axis, section geometry, applied moment and axial force must be the same quantities used in equilibrium. A coefficient selected to match another program would not establish this identity.

The alternating jointed/intact recurrence is diagnostic. Pure branches must satisfy force and moment conditions at their own declared thrust heights; unresolved branches stop propagation. Even a passing local section and bracket do not establish a whole-slope flexure solution. The app returns **fs = null** for every full-slope flexure case.

What remains to establish a flexure method

A justified coupled formulation must specify opening/contact transfer, compatible motions, intact bending constitutive behavior, tension and shear interaction, boundary conditions and a selection rule for combined modes. Independent small-system solutions, mesh/column convergence and physical or independently reviewed benchmark evidence are then required. That work is not replaced by the current diagnostic calculation.

S10A. Local bending calculation, step by step

Original reference T08: local elastic section only. An intact rectangular column is 10 ft high, 2 ft wide and 1 ft deep, with a horizontal base. Rock unit weight is 100 lbf/ft^3; kh=0.10, kv=0; tensile strength is 10 psi. There is no water, support or neighboring-column force.

1. Calculate the section properties and body load

$A = dw = 1\times2 = 2\ ft^2$; $V = dwh = 1\times2\times10 = 20\ ft^3$

$I = dw^3/12 = 1\times2^3/12 = 0.6666666667\ ft^4$

$Z = I/(w/2) = 0.6666666667/(2/2) = 0.6666666667\ ft^3$

$W = \gamma V = 100\times20 = 2{,}000$ lbf; $H = khW = 0.10\times2{,}000 = 200$ lbf

2. Take the moment about the base center

Weight acts through the section center and has zero moment about that center. The horizontal inertia acts at half-height: its perpendicular lever arm is h/2=5 ft. Thus N=2,000 lbf and M=200×5=1,000 lbf·ft.

3. Calculate the edge stresses

$N/A = 2{,}000/2 = 1{,}000\ lbf/ft^2$

$M/Z = 1{,}000/0.6666666667 = 1{,}500\ lbf/ft^2$

$\sigma compression = (1{,}000+1{,}500)/144 = 17.36111111$ psi

$\sigma opposite = (1{,}000-1{,}500)/144 = -3.472222222$ psi

Compression is positive. The negative edge stress is 3.472222222 psi tension. The 144 divisor converts lbf/ft^2 to lbf/in^2.

4. Compare against the reduced tensile capacity

$10/F = 3.472222222$; $Flocal = 10/3.472222222 = 2.88$

The original reference and app agree on the 3.472222222 psi tensile stress and 2.88 local diagnostic threshold. This is one elastic section. It does not establish contact transfer, compatible movement or an accepted whole-slope flexural-toppling factor. The full-slope result remains **fs=null**.

S11. Reinforcement and FS definitions

Active support is a prescribed preload. Passive support is available capacity mobilized by movement. FHWA distinguishes tensioned anchors from untensioned dowels and emphasizes bond and geological controls. Its guidance does not itself establish the numerical convention used here. [R5]

For a simple planar contact, let D0,N0 be active loads before support. Let T be the opposing tangential support component and C its added compression. With zero cohesion for clarity:

$$FS_{active} = (N0+C) \tan \varphi / (D0-T)$$

$$FS_{passive} = [(N0+C) \tan \varphi + T] / D0$$

These definitions satisfy the same force balance at FS=1 but generally differ away from one. A reference that puts all anchor contribution in resistance uses the second arrangement. Merely calling both values “FS” does not make them interchangeable.

Check	Meaning
Geometric engagement	The installed line intersects the finite block and has required embedment beyond the failure surface. Pattern members are checked individually.
Capacity	Axial force is bounded by steel, plate, anchor and bond limits. The entered bond transfer q is lbf/ft and capacity uses qL; a qualified bond stress × perimeter can establish q independently.
Orientation	Selected tensile efficiency or declared local linear convention changes available force. Shear mode substitutes its qualified capacity; it is not added to full tensile capacity.
Shotcrete	Shear capacity acts along slope-face traces; attached weight enters body forces. Adhesion, punching, bending, durability and installation design remain separate.

The wedge support wrapper retains several branch candidates and a beneficial-support selection convention. It does not solve a general coupled displacement-compatible supported wedge. All candidate ratios and contact status must be inspected; a support-only lift ratio is not a sliding FS. The verification manual states the independently tested subset.

$$B = A + P + \Sigma N'_i n_i; \quad B - (B \cdot s)s = 0$$

The supported contact reactions must be compressive and balance every component transverse to the active-selected movement s. A one-contact wedge has a second tangential direction: support along it cannot simply be projected away. An unresolved residual withholds the factor and requires a coupled contact/movement solution. Detached support additionally requires P + Flift A = 0; an opposing scalar projection alone is insufficient.

The checks above apply only to the selected support definition. A force-only resultant without an independent service limit remains externally qualified and unchecked by the software. Geometry/component checks do not establish the complete anchor system, and a legacy capacity copied from the same force is not independent evidence. E23-E25 explain the additional service limit, steel-stage screen and preserved historical cases.

Worked S1. Support case: geometry and forces

S01-active/passive have identical geometry and capacity. This translation model does not check overturning.

Input	Value	Definition
H; β; α	12 ft; 65°; 30°	Face height; face dip; failure dip
d; γ	6 ft; 150 pcf	Across-slope width; rock unit weight
φ; c	28°; 0.5 psi	Joint friction and cohesion
Directions and upper ground	Face/plane 0°; upper 0° dip	Common northward dip section; horizontal top
Water; kh; kv	0 psi; 0; 0	Dry, static; no rear crack
Support P; count	3,000 lbf; 1	Horizontal uphill, trend 180°, plunge 0°
Application / evidence	Specified force; efficiency off	Externally qualified resultant; no extra prescribed force

1. Reconstruct the finite prism

For geometry only, take X horizontal uphill and Z vertical up from the toe. The face reaches the crest at $X_c=H\cot\beta$; the basal plane reaches the horizontal top at $X_r=H\cot\alpha$. The triangular rock section lies between those lines. d extrudes the section.

$X_c=12\cot65°=5.595691898$ ft; $X_r=12\cot30°=20.78460969$ ft.

$A_{section}=\frac{1}{2}H(X_r-X_c)=\frac{1}{2}\times12\times(20.78460969-5.595691898)=91.13350676$ ft^2.

$V=91.13350676\times6=546.8010405$ ft^3; $W=546.8010405\times150=82{,}020.15608$ lbf.

$L=12/\sin30°=24$ ft; $A=Ld=24\times6=144$ ft^2.

Return to local t positive downhill and n outward normal. Gravity acts at the prism centroid. The force-only support is also treated as a resultant at the centroid; no eccentric-moment resistance is inferred.

$D_0=W\sin30°=41{,}010.07804$ lbf; $N_0=W\cos30°=71{,}031.53879$ lbf.

$S_t=-3{,}000\cos30°=-2{,}598.076211$ lbf; $S_n=-3{,}000\sin30°=-1{,}500$ lbf.

Thus T=2,598.076211 lbf is the positive opposing tangential magnitude, and C=1,500 lbf is added compression. Retain these signs and the 0.5 psi cohesion in the next page; forgetting 144 in cA would be a unit error.

Worked S2. Active and passive are different ratios

3. Evaluate the same fully supported contact strength

$N' = N_0 + C = 71{,}031.53879 + 1{,}500 = 72{,}531.53879$ lbf.

$\sigma' = N'/(144A) = 72{,}531.53879/(144 \times 144) = 3.497855844$ psi.

$R_{cohesion} = 144cA = 144 \times 0.5 \times 144 = 10{,}368$ lbf.

$R_{friction} = N' \tan 28° = 72{,}531.53879 \tan 28° = 38{,}565.70327$ lbf;
$R_{joint} = 10{,}368 + 38{,}565.70327 = 48{,}933.70327$ lbf.

4. Active: the force is already applied

The applied preload changes both contact compression and the net driving load. The entered 3,000 lbf must already be justified; its capacity is not divided by the displayed sliding ratio.

$D_{active} = D_0 - T = 41{,}010.07804 - 2{,}598.076211 = 38{,}412.00183$ lbf.

$FS_{active} = R_{joint}/D_{active} = 48{,}933.70327/38{,}412.00183 = 1.273917$.

5. Passive: the force is available resisting capacity

The force has not selected or reduced the active-load driving denominator. Under this declared limit-equilibrium convention, its mobilized normal component contributes to N′ and its opposing tangential capacity is added to resistance. Required mobilization displacement is not computed.

$R_{total} = R_{joint} + T = 48{,}933.70327 + 2{,}598.076211 = 51{,}531.77948$ lbf.

$FS_{passive} = R_{total}/D_0 = 51{,}531.77948/41{,}010.07804 = 1.256564$.

Comparison	Independent hand calculation	Production output
S01-active	1.273917	1.273917
S01-passive	1.256564	1.256564

At FS=1 both definitions reduce to $R_{joint} + T = D_0$. Away from 1 they are numerically different; neither may be substituted for the other to meet a design criterion. Force equilibrium, geometry, stress conversion and the declared conventions agree with the independent fixtures. Anchorage, installation, stiffness, displacement compatibility and the admissibility of the selected capacity require separate evidence.

These are specified-force fixtures. An actual checked bolt must also cross the finite block, have sufficient bonded length and meet its individual steel/plate/anchor/bond limits. A shear-capacity option replaces the same bolt's axial contribution; it does not justify adding both capacities.

S12. Rock-mass interpretation

Generalized Hoek-Brown uses intact compressive strength σci, intact constant mi, observed GSI and disturbance D. The author formulation supplies these rock-mass parameters and compression envelope. [R6]

$$mb = mi \exp[(GSI-100)/(28-14D)]$$

$$s = \exp[(GSI-100)/(9-3D)]$$

$$a = 1/2 + [\exp(-GSI/15)-\exp(-20/3)]/6$$

$$\sigma'1 = \sigma'3 + \sigma ci(mb\ \sigma'3/\sigma ci + s)^{a};\quad \sigma c = \sigma ci\ s^{a}$$

σc is the zero-confinement rock-mass UCS. It is not the different overall rock-mass strength denoted σcm elsewhere in the source paper.

The calculation retains MPa for stresses. The generalized rock-mass envelope is separate from discontinuity shear resistance. A single weak bedding plane, fault or persistent joint can control a block even when the surrounding mass has a high rock-mass strength.

Outcrop evidence and manual values

Each parameter can have a manual basis, a selected outcrop or an explicitly selected set of outcrops. Means use available values and report their sample counts, missing values and ranges. GSI remains an observation; neither RMR nor the presence of other measured fields manufactures a GSI value.

Averaging inputs then applying nonlinear equations is different from averaging resulting strengths. In general, f(mean inputs) ≠ mean f(inputs). The app stores the selected aggregation and source snapshot so that this interpretation remains reviewable. It does not establish whether outcrops belong to one homogeneous engineering domain.

Geological parameters are not validated by arithmetic

Drop-down charts support field selection, but cannot prove intact UCS, in-situ stress, discontinuity persistence or hydraulic connectivity. Parameter basis, scale, disturbance and applicability require engineering judgment, test data where appropriate, and sensitivity assessment.

Worked example: Hoek–Brown material

This empirical rock-mass calculation uses observed GSI and intact-rock properties. Assume a sufficiently jointed rock mass without a dominant weakness plane controlling failure. Compression is positive; σ'_1 and σ'_3 are major and minor effective principal stresses. All stresses in this example are MPa.

Input	Value	Meaning / source needed
GSI	45	Observed rock-mass structure and surface condition
σ_ci	50 MPa	Intact UCS; document test or estimate
m_i	10	Intact-rock constant; document test or reference
D	0	Undisturbed baseline; document affected zone

1. Calculate the dimensionless parameters

$m_b = m_i \exp[(GSI - 100)/(28 - 14D)] = 10 \exp(-55/28) = 1.402560337260$

$s = \exp[(GSI - 100)/(9 - 3D)] = \exp(-55/9) = 0.00221808490432$

$a = 0.5 + [\exp(-GSI/15) - \exp(-20/3)]/6$

$a = 0.5 + (0.049787068368 - 0.00127263380134)/6 = 0.508085739094$

2. Find one failure-envelope point at $\sigma'_3 = 1.0$ MPa

$\sigma'_1 = \sigma'_3 + \sigma_{ci} [m_b \sigma'_3/\sigma_{ci} + s]^a$

Bracket = $1.402560337260(1/50) + 0.00221808490432 = 0.0302692916495$

Bracket^a = 0.169129322633; $\sigma'_1 = 1 + 50(0.169129322633) = 9.456466132$ MPa

Thus, at 1 MPa effective confinement, the calculated major effective principal stress on the failure envelope is 9.456466132 MPa. It is not shear strength on a mapped bedding plane and is not a slope factor of safety.

3. Set confinement to zero to obtain rock-mass UCS

$\sigma_c = \sigma_{ci} s^a = 50 \times 0.0448259347864 = 2.241296739$ MPa

σ_c is zero-confinement rock-mass UCS (2002 equation 6), distinct from intact σ_ci and the paper's overall rock-mass strength σ_cm. The app requires $0 \le GSI \le 100$, $0 \le D \le 1$, positive σ_ci and m_i, parameter evidence, and confirmed applicability. GSI remains an observation; averaging outcrop inputs does not produce the average of their nonlinear strengths. No equivalent cohesion/friction fit is implied.

Basis: Hoek, Carranza-Torres and Corkum (2002), equations 2–6. Numerical anchors: HB-45-0 and HB-envelope-45-0 (envelope index 10). Retain at least 12 significant digits in m_b, s and a for the displayed answers.

S13. Uncertainty and descriptive statistics

A deterministic case is rerun with selected scalar distributions or spherical plane perturbations. Uniform, normal, triangular, lognormal, beta, gamma and exponential variables use explicit parameters and inverse-CDF sampling. For truncation to [L,U]:

$$x = F^{-1}[F(L) + u(F(U)-F(L))], \quad 0 < u < 1$$

Monte Carlo draws each u. Latin hypercube sampling assigns one probability stratum per marginal and shuffles pairings. Selected correlation pairs use either joint untruncated normals or a Gaussian copula; rank and ordinary Pearson correlation are distinct. Achieved dependence is recorded. [R8, R12]

$$\text{For Gaussian-copula Spearman target } \rho s: \quad \rho latent = 2 \sin(\pi \rho s/6)$$

Fisher perturbations sample directed poles on the sphere and fold antipodal normals into the selected hemisphere for planes. Folding changes the directed distribution; a broad plane population cannot be interpreted as an unmodified directed Fisher sample. [R9]

$$\text{Conditional fraction} = \text{count(accepted FS} < 1) / \text{count(accepted FS)}$$

$$\beta normal = (\text{mean FS} - 1)/\text{sample SD}; \quad \beta log = \text{mean ln FS} / \text{sample SD ln FS}$$

Only status=ok factors enter factor summaries, percentiles, histograms, fitted distributions and factor-axis regression. Support-only lift ratios remain in the raw rows with their status and a separate exclusion count; they are not pooled with sliding factors. Sensitivity lines break at excluded samples. Invalid geometry, lost contacts, unresolved mechanisms and no-block cases likewise remain separate. The legacy unresolvedCount counts every sample without an accepted factor, including lift. Neither undefined FS nor exclusion silently becomes safe. The empirical reliability index is $-\Phi^{-1}$(conditional fraction); boundary and zero-variance results remain undefined.

Descriptive CDF distance and regression are summaries of the specified scenario population. They do not establish fitted-distribution adequacy, statistical independence, hazard probability, a formal goodness-of-fit p-value or field validation. Repeated field readings and interpreted set means need a geological sampling rationale.

Worked example: uncertainty bookkeeping

Given five numerical FS and two unresolved outcomes, n = 5, u = 2 and total T = 7. This arithmetic audit illustrates statistical definitions; it does not establish a site failure probability.

FS = x	$(x - 1.2)^2$	ln(x)
0.5	0.49	−0.693147180560
0.8	0.16	−0.223143551314
1.1	0.01	0.0953101798043
1.4	0.04	0.336472236621
2.2	1.00	0.788457360364

Mean = 6.0/5 = 1.2; $\Sigma(x - \text{mean})^2 = 0.49 + 0.16 + 0.01 + 0.04 + 1.00 = 1.70$

Sample variance = 1.70/(5 − 1) = 0.425; sample SD = $\sqrt{0.425} = 0.651920240520$

2. Show the denominator and the unresolved bounds

Two numerical outcomes satisfy FS strictly below 1. Conditional fraction = 2/5 = 0.4. Over all seven outcomes, allocating both unresolved above the threshold gives 2/7 = 0.285714286; allocating both below gives 4/7 = 0.571428571. These are allocation bounds, not confidence limits. Neither unresolved outcome is declared safe.

3. Reproduce the three descriptive indices

$\beta_{normal} = (\text{mean} - 1)/SD = 0.2/0.651920240520 = 0.306785995539$

For y = ln(FS), all five FS must be positive. The table gives $\Sigma y = 0.303949044916$, mean(y) = 0.0607898089831 and $\Sigma[y - \text{mean}(y)]^2 = 1.255731659534$. Therefore sample SD(y) = $\sqrt{(1.255731659534/4)} = 0.560297166585$.

$\beta_{log} = 0.0607898089831/0.560297166585 = 0.108495656606$

$\beta_{empirical} = -\Phi^{-1}(0.4) = -(-0.253347103136) = 0.253347103136$

Φ is the standard normal CDF; a normal table gives $\Phi(-0.253347103136) = 0.4$. All three indices condition on numerical outcomes. Zero sample spread makes the corresponding ratio undefined; empirical fractions of 0 or 1 have no finite empirical index. No index is supplied when every outcome is unresolved.

Quantiles: a continuous distribution uses $Q(p) = F^{-1}(p)$. For finite sorted observations $x_{(1)} \ldots x_{(n)}$, the bench rule uses one-based rank $k = \max(1, \text{ceil}(np))$, $Q(p) = x_{(k)}$, without interpolation. Sorting [20,1,8,2,4] gives [1,2,4,8,20]: Q(0.5) = x_(3) = 4 and Q(0.95) = x_(5) = 20. The p = 0 endpoint is defined as the minimum.

Basis: NIST normal CDF; app conventions for sample SD, unresolved outcomes and nearest-rank quantiles. Fixtures: STAT-reliability-unresolved, STAT-moments and BENCH-quantile-*.

S14. Bench scenarios and numerical limits

Each selected planar, restricted finite-wedge or generated dry block-toppling scenario is rerun for each selected face angle. Specified wedge persistence governs whether that wedge can form; E19-E20 give the added planar/toppling geometry and limits. The implemented bench rule combines separate nearest-rank quantiles of backbreak and estimated debris spill with a selected usable-width allowance.

$$Qq(x) = \text{sorted}(x)[\max(1,\text{ceil}(qn))] \quad \text{[one-based index]}$$

$$Breq = Qq(\text{backbreak}) + Qq(\text{spill}) + Ballow$$

$$\text{For fixed inter-ramp angle } i: \quad Bavailable = H(\cot i - \cot \beta)$$

For WEDGE scenarios only, use in-place failed volume V, swelling K (debris volume KV), crest length L and repose φr in these retained cone/pyramidal estimates. E19 uses a different uniform-prism coefficient for planar/toppling:

$$Bcone = [6KV(\cot \varphi r - \cot \beta)/\pi]^{1/3}$$

$$Bpyramid = [6KV(\cot \varphi r - \cot \beta)/L]^{1/2}; \quad Bspill = \min(Bcone, Bpyramid)$$

The equations require $\beta > \varphi r$. These are accumulation-width estimates, not trajectories, bounce or fragmentation. The legacy data key windrowFt denotes the pyramidal expression, not a uniform prismatic windrow. This edition verifies arithmetic and similarity, not site performance. [R10]

Finite computational limits

The solver uses float64 arithmetic. Geometric tolerances scale with local dimensions and machine roundoff, not arbitrary map-origin distance. Near-parallel, degenerate and unbounded geometry is rejected. A revised coordinate-tolerance check is documented in the Verification Manual.

Trials, contact sets and sample counts are finite. Increasing a sample count cannot cure an incorrect physical model. A final review must consider alternative kinematics, spatial persistence, parameter variability, groundwater, load combinations, anchorage and construction conditions. A “meets scenario width” label applies only to that width rule and the evaluated cases.

Worked example: catch-bench arithmetic

1. Debris accumulation geometry: a 70° face example

Let in-place failed rock volume V = 100 ft^3, crest length L = 20 ft, swelling factor K = 1.2, face angle α = 70° and repose angle φ = 35°. Bulk debris volume is KV = 120 ft^3: do not bulk V twice. Cotangent means 1/tan, using degrees.

$$f = \cot \varphi - \cot \alpha = 1.428148006742 - 0.363970234266 = 1.064177772476$$

$$6KVf = 6 \times 1.2 \times 100 \times 1.064177772476 = 766.207996183\ ft^3$$

$$R_{cone} = (6KVf/\pi)^{(1/3)} = (243.891580058\ ft^3)^{(1/3)} = 6.247874093\ ft$$

$$R_{pyramid} = \sqrt{(6KVf/L)} = \sqrt{(38.310399809\ ft^2)} = 6.189539547\ ft$$

Selected spill = min(R_cone, R_pyramid) = 6.189539547 ft. The geometric construction requires L > 0 and α > φ. It estimates accumulation width, not bounce, fragmentation, impact or trajectory runout.

2. Separate synthetic scenario comparison: a 60° face

The following independent bookkeeping example uses supplied backbreak/spill outputs; these are not the 70° result above. Set bench height H = 30 ft, inter-ramp angle β = 45°, design FS = 1.2, quantile p = 0.5 and additional usable-width allowance C = 2 ft.

Scenario	Result	Backbreak / spill used (ft)
A	FS = 0.8	3 / 5; below design FS
B	FS = 1.1	7 / 9; below design FS
C	FS = 1.8	Excluded from width quantiles
D	No block	Excluded from width quantiles

$$B_{available} = H(\cot \beta - \cot \alpha) = 30[1 - 0.577350269190] = 12.679491924\ ft$$

Use only A and B for width quantiles: sorted backbreak [3,7], sorted spill [5,9]. Each has n = 2, so one-based rank ceil(np) = ceil(2 × 0.5) = 1. Thus Q_backbreak = 3 ft and Q_spill = 5 ft, without interpolation.

$$B_{required} = Q_{backbreak} + Q_{spill} + C = 3 + 5 + 2 = 10\ ft$$

$$Margin = B_{available} - B_{required} = 12.679491924 - 10 = 2.679491924\ ft$$

This candidate meets the selected scenario-width rule. The below-design scenario fraction is 2/4 = 0.5, not 2/3 and not a failure probability. Replacing D with an unresolved result withholds the recommendation. Separate marginal quantiles are not generally a quantile of summed widths or a joint exceedance target.

Basis: Gibson, de Bruyn and Walker (2006), §2.3.2; app scenario convention. Fixtures: BENCH-spill-100, BENCH-scenario-summary and BENCH-unresolved-withholds. Width comparisons retain unrounded values.

S15. Source register and traceability

The register separates public engineering guidance, published constitutive models and mathematical references. It is not a declaration of compliance with every provision of any standard. Equations and original synthetic examples in these manuals are not copied from commercial verification tables.

[R1] U.S. Army Corps of Engineers (1994). *Rock Foundations*, EM 1110-1-2908, 30 November. Slope section S4 Eq. 4-2; §§7-4 to 7-6 and Slope section S8. Public-release primary document, accessed through ASDSO mirror: document. Agency guidance; not a product certification.

[R2] Yeo, D. (2020). NISTIR 8298, *A Summary of Industrial Verification, Validation, and Uncertainty Quantification Procedures in Computational Fluid Dynamics*, §3. doi:10.6028/NIST.IR.8298. Terminology only; its CFD application is distinct.

[R3] Barton, N. and Choubey, V. (1977). The shear strength of rock joints in theory and practice. *Rock Mechanics* 10, 1-54. doi:10.1007/BF01261801. Published empirical joint law.

[R4] Goodman, R.E. and Bray, J.W. (1976). Toppling of rock slopes. ASCE Specialty Conference on Rock Engineering for Foundations and Slopes, Boulder, vol. 2, pp. 201-234. Original paper consulted locally; classical rectangular-column equilibrium basis. No claim of a complete general toppling solution.

[R5] FHWA (2011). *Context Sensitive Rock Slope Design Solutions*, FHWA-CFL/TD-11-002, §5 Reinforcement Systems. FHWA primary guidance. Active/passive anchors and geological/bond controls.

[R6] Hoek, E., Carranza-Torres, C. and Corkum, B. (2002). Hoek-Brown failure criterion - 2002 edition. NARMS-TAC, pp.267-273, Eqs.2-6. Author-hosted source. Generalized rock-mass criterion.

[R7] Lawson, C. and Hanson, R. (1995). *Solving Least Squares Problems*, SIAM. Independent oracle: SciPy NNLS documentation; convex nonnegative least squares/KKT conditions.

[R8] NIST/SEMATECH *e-Handbook of Statistical Methods*, probability distributions and distribution functions, §1.3.6.6. NIST distribution reference. Independent quantile checks use SciPy and high-precision mpmath.

[R9] Fisher, R. (1953). Dispersion on a Sphere. *Proceedings of the Royal Society A* 217, 295-305. doi:10.1098/rspa.1953.0064. Directed spherical distribution; app axial folding is separately declared.

[R10] Gibson, W.H., de Bruyn, I.A. and Walker, D.J.H. (2006). Considerations in the optimisation of bench face angle and berm width geometries for open pit mines. SAIMM International Symposium, pp.557-578, §2.3.2 (author manuscript pp.12-14). Cone/pyramidal deposit equations. Author-uploaded original.

[R11] Barton, N. and Bandis, S. (1990). Review of predictive capabilities of JRC-JCS model in engineering practice. In *Rock Joints*, Balkema, p.606, Eqs.9-10. Author-uploaded original. Empirical size corrections; not a universal standard.

[R12] SciPy LatinHypercube and Statsmodels GaussianCopula, official project documentation. Definitions of strata and marginal/copula construction. Separate from NIST scalar-distribution guidance.

Implementation map

Subject	Source modules (js/)
Geometry / translation	slope-planar, slope-wedge, slope-polyhedron, slope-wedge-basal, slope-wedge-crack, slope-wedge-size
Constitutive laws / water	slope-strength, barton-bandis, hoek-brown, slope-material, slope-hydrostatic, slope-hydraulics
Blocks / reinforcement	slope-block, slope-toppling, slope-toppling-forces, slope-toppling-flexure, slope-reinforcement, slope-bolt-capacity, slope-support
Studies / reporting	slope-sampling, slope-statistics, slope-bench, slope-stability, slope-report-calculations

E1. Build a reviewable slope case

The slope workspace is a separate engineering interpretation of selected field evidence. Describe the slope and select the mechanism/north reference, then follow Geometry, Materials, Water & loads, Reinforcement and Review setup. I6-I9 explain live geometry, the separate definition sketch, copied property profiles, readiness and preservation. A cloud backup or populated field form does not establish a complete engineering model.

Step	What to enter or inspect
1 · Model	Planar translation, finite wedge, isolated block, or interacting columns. A kinematic flag helps select a candidate; it does not create dimensions, loads or strengths.
2 · Geometry	Vertical slope height and face orientation; upper ground; release-plane orientations; section width where required. Isolated-block height is normal to its base. Column width is perpendicular to the toppling joints.
3 · Strength / material	Choose supported inputs for each contact, optionally by copying a named property profile and reviewing local overrides. Hoek-Brown rock-mass parameters do not automatically become joint friction/cohesion.
4 · Water / loads	Choose one contact-water definition. Add external ponding, seismic coefficients, point/face loads and support only where supported by that model. Record the basis.
5 · Calculate / inspect	Use Review to resolve linked setup issues and inspect the explicit assumptions. Calculate, then read geometry, forces, contacts, governing mode and limitations. A completed setup is not an accepted FS.
6 · Save / reproduce	Save the case and source snapshots. Export the calculation package with the inputs, result and version; rerun after changing inputs.

Planar, wedge and isolated-block geometry use local east/north/up feet; columns use uphill/across/up feet (E8). Neither is longitude/latitude or an automatic terrain reconstruction. The model view may be rotated and zoomed without changing the calculation; changing geometry values does change the model.

“No block,” “persistence excluded,” contact loss and unresolved mechanisms are separate outcomes. A missing or withheld FS is not infinity, zero, or a safe result. The S chapters retain the detailed equilibrium derivations and worked examples.

E2. Geometry options and wedge sizing

The planar section and finite wedge are convex bodies bounded by explicit planes. Each inward face normal ni and point pi define $n_i \cdot (x - p_i) \geq 0$. Solve each nonparallel triple of boundary planes for a vertex, keep vertices satisfying every halfspace, order face vertices, and calculate area/volume before weight.

For three boundaries: $[n1^T; n2^T; n3^T]\ x = [n1 \cdot p1; n2 \cdot p2; n3 \cdot p3]$

A tension crack adds a rear release boundary and may remove rock volume; it is not assumed to contribute friction/cohesion. A basal joint adds a third potential contact, requiring its own orientation, location and strength. The rear cut has a physical offset/depth; drawing an infinite plane alone does not locate a finite wedge. Planar and two-joint wedge crack geometry is entered under Geometry; its pressure/head controls are under Water & loads. The explicit basal-wedge crack remains with its positioned geometry. Moving controls does not change the single stored definition.

1. Apply a stated physical size limit

$\lambda = \min[1, Llimit/L0, (Vlimit/V0)^{1/3}, (Wlimit/W0)^{1/3}, \ldots]$

$xnew = crest + \lambda(xold - crest);\ Anew = \lambda^2 A0;\ Vnew = \lambda^3 V0$

Each available limit contributes its ratio: length parallel to the actual crest, backbreak, joint trace or within-face persistence use power 1; rock volume and weight use power 3. Only supplied limits are used. Example: V0=800 ft^3 and Vlimit=100 ft^3 give λ=(100/800)^(1/3)=0.5; a 20-ft length becomes 10 ft and a 60-ft^2 face becomes 15 ft^2.

2. Distinguish size scaling from persistence selection

Small/ubiquitous-spacing mode finds a geometrically similar candidate limited by available lengths. Large-spacing mode first places the explicitly chosen height-fraction candidate, then tests its lengths: an oversized candidate is excluded, not silently moved to a new joint location. Persistence mode is limited to the simple two-joint tetrahedron without a crack or basal plane.

Joint persistence is the greatest within-face vertex separation. Trace is the larger exposed joint edge on the slope or upper face. Backbreak is extent perpendicular to the crest within the upper-ground plane. These dimensions are not interchangeable. Similarity moves joint boundaries about the crest; recalculate loads and bolt engagement. Fixed support positions do not scale automatically.

E3. Water definitions and external loads

S7 and its worked cases derive pressure integration. This page explains the choices feeding that calculation. Groundwater and ponding are independent inputs; ponded water does not automatically raise the internal water surface.

Choice	Calculation / consequence
Mean contact pressure	Enter psi on each contact; resultant U=144 pmean A. Planar crack-head mode instead defines a pressure distribution. Do not add both definitions to the same face.
Horizontal water elevation	Head h=max(0, zwater−z). Calculate pressure only on selected internal faces. Unselected internal faces are set dry in this mode.
Affine water surface	zwater=z0+gE(E−E0)+gN(N−N0). Gradients are ft/ft. Integrate vertical head over each clipped wetted polygon.
Hu multiplier	p=Hu γw h in lbf/ft^2. Hu is explicitly chosen, from 0 to 1; no seepage or groundwater-flow equation is solved.
External ponding	Integrate water on the slope and upper free faces as separate inward forces; these faces are treated as impervious in this coupling.
Point / face loads	Point resultant P times its direction vector; uniform face pressure gives 144 p A times inward normal. Translation uses the resultants, not an overturning check.

Example: evaluate head before integrating

z0=8 ft; E0=N0=0; gE=0.10; gN=−0.20; (E,N,z)=(2,3,4) ft

zwater=8+0.10(2)−0.20(3)=7.6 ft; h=7.6−4=3.6 ft

Hu=1; γw=62.4 lbf/ft^3; p=62.4(3.6)/144=1.56 psi

Evaluate head at every polygon vertex, clip where head is zero, then integrate; using one sampled head for a partially wetted face is wrong. Reported hydraulic pressure centers and moments are audit quantities. Planar/wedge translation does not enforce their rotational equilibrium.

E4. A bolt: position, crossing and embedment

A checked bolt has an installed head, a head-to-anchor axis, total length and required embedment beyond the modeled release plane. Its tensile force acts toward the anchor. Trend is clockwise from north; plunge is positive downward.

$$b = (\sin t \cos p, \cos t \cos p, -\sin p); \quad x(s)=\text{head}+s\,b$$

For every inward face normal ni, let $m_i=n_i\cdot(\text{head}-p_i)$ and $d_i=n_i\cdot b$. The bolt ray must satisfy $m_i+sd_i\geq 0$. For $d_i<0$, the exit candidate is $s_i=-m_i/d_i$; the smallest positive exit across all faces is the block crossing.

Original rectangular geometry control

Use a block $0\leq E\leq 4$ ft, $0\leq N\leq 6$ ft, $0\leq U\leq 10$ ft. The installation face is $N=0$ and the release plane is $N=6$; all other faces bound the rock domain. Head=(2,0,5) ft; trend=0°, plunge=0°, L=12 ft; required embedment=3 ft.

$$b=(0,1,0);\ \text{release condition: } 6-s\geq 0 \text{ implies } s_{exit}=6 \text{ ft}$$

Exit=(2,6,5) ft; tip=(2,12,5) ft; Lembedded=12−6=6 ft

The head is inside the installation-face edges, the axis enters the block, the only exit is the release plane, and the tip stays behind all free-face planes. Thus $6\geq 3$ ft satisfies the geometric requirement. This is a geometry test, not a complete slope-stability example.

Guard	Why capacity may not be credited
Head on an edge / outside face	Bearing face or load path is ambiguous.
Tip within block or at the joint	No positive length is anchored beyond the release boundary.
Exit through another free face	The segment is not anchored into the modeled stable-rock domain.
Short embedment	Required length is not achieved, even if steel capacity is high.

A group count at one checked head assumes equivalent geometry for each represented bolt. Use a generated pattern when actual individual head locations matter. Geometry does not prove rock-cone strength, bond, installation quality or stable-rock extent.

E5. Available axial force along the bolt

Let L be total bolt length, x the joint distance from the head, Lb the bonded length measured back from the tip, q the qualified bond transfer in lbf/ft, T steel capacity and P plate capacity, both lbf. Bond transfer is force per length, not pressure. A bond stress can be converted by multiplying the appropriate bonded perimeter.

$s0=L-Lb$; $Lin=\max(0,x-s0)$; $Lout=\min(Lb,L-x)$

$Csteel=T$; $Cpullout=q\ Lout$; $Cstripping=P+q\ Lin$

$Cavailable=\min(Csteel,Cpullout,Cstripping)$

Continue the E4 geometry control

At L=12 ft and x=6 ft, select Lb=8 ft, q=1,000 lbf/ft, T=10,000 lbf and P=2,000 lbf. These are stated synthetic capacities, not recommended design values.

$s0=12-8=4$ ft; $Lin=6-4=2$ ft; $Lout=\min(8,12-6)=6$ ft

$Csteel=10{,}000$; $Cpullout=1{,}000(6)=6{,}000$ lbf

$Cstripping=2{,}000+1{,}000(2)=4{,}000$ lbf implies $Cavailable=4{,}000$ lbf

Selected model	Capacity rule
Specified	Use the entered qualified axial capacity. Geometry is still a separate gate.
Mechanical anchor	Minimum of steel, plate and anchor capacities.
Partially / fully grouted	Use the bonded-interval rule above.
Cable / friction sleeves	The selected model requires full-length bond; use Lb=L. Inputs still need qualification.
User force diagram	Piecewise-linear interpolation between ordered distance/capacity points spanning 0 through L; no extrapolation.

The displayed force diagram is an available-capacity envelope, not the mobilized axial stress distribution. With no lower independent service limit, an active pretension of 3,000 lbf passes the 4,000-lbf envelope; 5,000 lbf is rejected. The applied force remains 3,000 lbf, not the 4,000-lbf reserve. A lower qualified service limit is an additional constraint. E23-E25 distinguish that limit, historical unchecked inputs and the separate optional steel-stage screen.

E6. Passive orientation and tension/shear choice

Let b be the unit head-to-anchor axis and s the unit movement vector. Extension is positive when movement separates the head from the anchor. Normalize both vectors before applying an efficiency.

$$f=-b\cdot s;\ g=\sqrt{(1-f^2)}$$

Convention	Efficiency η
Cosine	max(0,f); tension is credited only for extension.
Full capacity when extending	1 when f>0; otherwise 0.
Efficiency off including compression	1 for all orientations; this is an explicit empirical force option, not a tensile displacement prediction.
Declared local linear	f/(f+g) when f>0; otherwise 0. The transverse direction lies in the bolt/movement plane.

Continue E5 with a stated movement

$$b=(0,1,0);\ s=(0.8,-0.6,0);\ f=0.6;\ g=0.8$$

$$\eta\text{cosine}=0.6;\ \eta\text{linear}=0.6/(0.6+0.8)=0.4285714286$$

Cosine passive force, with no lower service limit = 0.6×4,000 = 2,400 lbf

Resolve that force into contact compression and opposing movement components. Apply the passive FS definition in S11; do not treat it as an active preload. Conversely, active pretension is already applied and is not reduced using this passive efficiency.

Shear is a separate capacity mode

For every crossed joint, calculate gap rate nj·s. Negative gap means penetration and is invalid; zero is sliding; positive is opening. When shear capacity is enabled and all crossed contacts slide, the entered qualified shear force acts opposite movement and replaces tensile capacity. At an opening contact use tension. Mixed opening/sliding crossings with shear selected are unresolved, so the same bolt is not counted in both capacities.

At numerical boundaries, $f\le10^{-12}$ is treated as no extension except in the explicit all-orientations option. Joint gap below -10^{-8} is penetration, above $+10^{-8}$ is opening, and the intervening interval is sliding.

An isolated rotating block uses an explicit resultant and application height; the anchored-bolt geometry wrapper is not a rotational anchor solution. Interacting columns use their own prescribed per-column forces. FHWA distinguishes tensioned anchors from untensioned dowels [R5]; the numerical capacity and efficiency conventions here are explicitly stated app assumptions.

E7. Patterns and shotcrete arithmetic

1. Place a geometric pattern on the finite face

Form horizontal unit h=(vertical×nin)/|vertical×nin| and upward face unit v=nin×h. For a horizontal installation face use east/north. Project every face vertex onto h,v; the grid origin is the minimum projected rectangle corner. At integer column i and row j:

$$\text{Head}_{ij} = \text{origin} + (o_h + i\, s_h)h + (o_v + j\, s_v)v$$

Here sh is horizontal spacing, sv true distance up the face, and oh,ov the offsets. Retain heads inside the polygon with the required edge clearance. Each head receives its own ray, embedment and capacity check. A pattern has count 1; a second group multiplier double-counts bolts. Bounds are 20,000 candidates per pattern and 2,000 accepted bolts across all patterns.

2. Calculate the implemented shotcrete contribution

For the planar base or the two primary wedge joints, find each intersection trace on the slope face and sum lengths Lt. The current wrapper does not include an additional basal-joint trace. With thickness ts, qualified shear strength τs and unit weight γs:

$$C_{\text{shotcrete}} = 144\, \tau_s\, t_s\, L_t;\quad W_{\text{shotcrete}} = \gamma_s\, t_s\, A_{\text{slope}}$$

Use the dry P01 geometry from S5: slope height 24 ft, slope inclination 70°, section width 8 ft. The one failure-plane/slope intersection is an 8-ft toe trace. Select ts=0.25 ft, τs=100 psi and γs=145 lbf/ft^3.

$$A_{\text{slope}} = 8(24/\sin 70°) = 204.322132315\ \text{ft}^2$$

$$C_{\text{shotcrete}} = 144(100)(0.25)(8) = 28{,}800\ \text{lbf}$$

$$W_{\text{shotcrete}} = 145(0.25)(204.322132315) = 7406.677296432\ \text{lbf}$$

The implementation applies this qualified resistance along the inward slope normal using the passive-force wrapper. Attached weight enters gravity and seismic inertia. It does not solve adhesion, punching, flexural concrete response, thickness design, durability or load sharing. Such checks require a separate design basis.

E8. Locate loads on interacting columns

The column recurrence in S9 is fed by a two-dimensional upslope-positive horizontal x and upward-positive z frame. This differs from the downslope-positive tangent used for an isolated block. State the selected column and the actual force location; a force without its lever arm is incomplete.

For a column base point B, unit base direction e and normal n:

$$r = B + a\,w\,e + \eta\,h\,n;\ 0 \le a \le 1;\ 0 \le \eta \le 1$$

The application-point fractions are measured along the base and normal height. With origin at the downslope toe, use the 2D cross product to obtain the overturning-positive external moment. Resolve the same force into tangential driving and normal compression before adding it to the recurrence.

Horizontal-base force example

A 10-ft-wide, 2-ft-high column has an applied force $F_x = -1{,}000$ lbf (downslope) and $F_z = -500$ lbf. Choose $a = 0.8$, $\eta = 0.6$. From the downslope toe the application point is $r = (8, 1.2)$ ft.

$$M_{ext} = x\,F_z - z\,F_x = 8(-500) - 1.2(-1{,}000) = -2{,}800 \text{ lbf·ft}$$

Thus the external contribution restores 2,800 lbf·ft while adding 1,000 lbf of downslope force and 500 lbf of compression. Do not infer the moment from the force magnitude alone.

Water and contact transfers

For a horizontal 10×2-ft base under 1 ft of head at $\gamma_w = 62.4$ lbf/ft^3 and $H_u = 1$, uplift $U = 62.4(1)(20) = 1{,}248$ lbf. Its resultant acts 5 ft from the toe, giving +6,240 lbf·ft about that toe. An inclined or partly wet face must instead use the integrated pressure centroid.

Selected joint-water faces are clipped to their actual overlap. Equal and opposite forces on two adjacent column faces must both appear; a fixed riser does not receive an invented neighboring-column reaction. Water is external loading, not reduced shear strength. Cohesion/friction are reduced by trial F as stated in S9.

Column pressure and force moment audits do not remove the unresolved whole-slope flexure limitation. No accepted flexural FS is claimed merely because one local bending section passes.

E9. Scalar distributions used in studies

A scalar draw transforms a probability u using inverse cumulative distribution Q(u). Normally 0<u<1; the legacy untruncated-uniform Monte Carlo path retains 0≤u<1. Other scalar paths and LHS use open-bin midpoints. These are selected input distributions, not established field uncertainty. Angles retain degree units.

Family / parameters	Inverse or defining calculation
Uniform a,b	$Q(u)=a+(b-a)u$.
Normal μ,σ	$Q(u)=\mu+\sigma\Phi^{-1}(u)$; Φ is the standard-normal CDF.
Triangular a,m,b	Let $c=(m-a)/(b-a)$. If $u<c$: $a+\sqrt{[u(b-a)(m-a)]}$; otherwise $b-\sqrt{[(1-u)(b-a)(b-m)]}$.
Lognormal μlog,σlog	$Q(u)=\exp[\mu\log+\sigma\log\Phi^{-1}(u)]$. Inputs describe natural logs, not ordinary arithmetic mean/SD.
Beta α,β,a,b	$Q(u)=a+(b-a)I^{-1}u(\alpha,\beta)$; invert the regularized beta CDF on [0,1].
Gamma shape k, scale θ	$Q(u)=\theta\ P^{-1}(k,u)$, where P is the regularized lower incomplete-gamma CDF. Scale is not rate.
Exponential rate λ	$Q(u)=-\ln(1-u)/\lambda$. Mean is 1/λ.

Normal, beta and gamma quantiles are numerical inverse-CDF calculations; a hand check can use a statistical table or independently evaluated special function. The automated numerical tolerance is distinct from displayed rounding. References R8 and R12 give distribution and numerical-library definitions.

Truncation is conditioning, not clamping

$$p=F(L)+u[F(U)-F(L)];\ x=Q(p)$$

A missing bound uses CDF 0 or 1. The implementation rejects retained probability mass below 10^{-10} and unresolvable/infinite quantiles. It does not silently clamp draws to engineering input limits or resample an invalid slope geometry. Those outcomes remain classified in the study.

E10. Work one draw from each distribution

Use the same deliberately prescribed probability u=0.25 for every row. This checks the distribution transform independently of the pseudorandom generator. It is not one complete Monte Carlo run.

Inputs	Substitution / result
Uniform a=20,b=40	20+(40−20)(0.25)=25.000000000
Normal μ=30,σ=5	$\Phi^{-1}(0.25)=-0.6744897502$; Q=26.627551249
Triangular a=20,m=30,b=50	c=1/3; Q=20+√(0.25×30×10)=28.660254038
Lognormal μlog=ln30,σlog=0.2	Q=30 exp(0.2×−0.6744897502)=26.214152367
Beta α=β=2,a=20,b=40	Solve $3t^2-2t^3=0.25$: t=0.3263518223; Q=26.527036447
Gamma k=1,θ=10	For k=1, Q=−10 ln(0.75)=2.876820725
Exponential λ=0.1	Q=−ln(0.75)/0.1=2.876820725

Normal distribution truncated to 25 through 35

$F(25)=\Phi(-1)=0.1586552539$; $F(35)=\Phi(1)=0.8413447461$

$p=0.1586552539+0.25(0.8413447461-0.1586552539)=0.3293276270$

$x=30+5\Phi^{-1}(p)=27.791147267$

Simply clipping the untruncated result to [25,35] would leave 26.627551249 unchanged and would not reproduce the conditional draw above. Record the bounds, family, parameters and sampler settings in the report.

E11. Sampling, correlations and scenario meaning

1. Choose how probability points are generated

Monte Carlo generates a probability per variable and row. Latin hypercube sampling (LHS) partitions each marginal CDF into n equal strata, independently permutes stratum order, and puts one jittered point into each stratum: $u=(j+r)/n$. Seed, sampler version, variable order, sample count and method identify the run; a seed alone is insufficient.

2. State dependence rather than assuming it

Correlation accepts disjoint variable pairs. Pearson mode is for two untruncated normal distributions. For a standard-normal pair, generate $z2=\rho z1+\sqrt{(1-\rho^2)}e$ with independent standard-normal e; then transform each component by its marginal inverse CDF. Spearman mode maps target rank correlation ρs to latent normal correlation:

$$\rho latent=2\sin(\pi\rho s/6)$$

LHS retains the original marginal draws and reorders their ranks using latent-normal pairs. Achieved Pearson and Spearman values are reported; finite samples need not equal the targets. Distinct pairs and directional populations are independent of one another. These controls are not a general multivariate correlation matrix.

3. Sample planes on a sphere

Fisher perturbation uses a mean geological pole, concentration κ, azimuth $2\pi v$, and axial cosine c. For $\kappa>0$:

$$c=1+\ln[u+(1-u)\exp(-2\kappa)]/\kappa;\ \kappa=0 \text{ gives } c=2u-1$$

$$m=(\sin d\sin a,\sin d\cos a,\cos d);\ e1=(\cos a,-\sin a,0);\ e2=m\times e1$$

Here d,a are mean dip and dip direction. Form $c\,m+\sqrt{(1-c^2)}[\cos(2\pi v)e1+\sin(2\pi v)e2]$. Fold antipodal normals to the upper hemisphere and convert to a plane. This specific tangent basis reproduces the same prescribed u,v draw; arbitrary tangents preserve the distribution but change individual draws.

Use 10–10,000 draws, up to 20 scalar variables, seven Fisher planes and ten disjoint correlation pairs; at least one scalar or Fisher variable is required. Every draw still passes the model's geometry/input checks. Broad hemisphere folding changes directed statistics. S13 explains unresolved counts and reliability summaries.

E12. Sensitivity, combinations and report packages

Tool	Procedure and interpretation
One-variable sensitivity	Select a supported scalar, bounds and steps. Recalculate the model for each stated value while other inputs remain at the baseline. Retain invalid/withheld outcomes. This is not optimization over mechanisms.
Discrete joint combinations	Choose measurements or explicit set means with a common north reference. All-pairs mode evaluates n(n−1)/2 pairs; disjoint cross pools evaluate nA nB pairs. Each pair receives the selected geometry, strengths, loads and support.
Parameter source snapshots	Record selected outcrop IDs, missing values, dates, selected mean/manual mode and basis. Refresh sources deliberately; saved observations are not silently replaced by current field edits.
Bench scenarios	Rerun each candidate face angle and explicit scenario; combine backbreak and debris-width quantiles as stated in S14. This is not rockfall trajectory simulation.
Report / calculation package	Save the case, calculate, then export. The package records the case snapshot, results, units, source selections, explanatory steps, force/geometry tables, study rows, and model/version identifiers. Open the printable report and use Print/Save as PDF.

Discrete combinations have computational bounds: 200 selected sources, 10,000 source members, 5,000 pairs, 50,000 work units and a 4 MiB source snapshot. A pair of joint-set means is one interpreted pair; it does not have the same sampling meaning as every original observation pair.

Hand-check the study bookkeeping

Five selected sources implies 5×4/2=10 all-pairs cases

Cross pools with 3 and 4 sources implies 3×4=12 cases

If only eight of ten cases return accepted FS, a count of three below one means a conditional fraction 3/8, not 3/10. Support-only lift ratios do not join the sliding-factor population: keep their values and counts separate, along with unresolved cases. Factor histograms, fits, percentiles and factor-axis regression exclude these ratios. Confirm why every case was omitted, excluded or unresolved before comparing scenarios.

An export preserves a calculation record; it is not independent checking, peer approval or a guarantee of a physically complete mechanism. Detailed steps must agree with the saved results. Do not use an old report as evidence for subsequently edited inputs.

E13. Fitted distributions and CDF distance

The distribution-fit tool summarizes numerical outcomes using candidate moment fits and a CDF-distance statistic. It does not automatically establish the true population distribution or calculate a valid goodness-of-fit significance level. It requires at least five nonconstant values; unavailable families are reported separately.

Population moment $v=\Sigma(xi-\bar{x})^2/n$; sample variance $s^2=\Sigma(xi-\bar{x})^2/(n-1)$

Candidate	Estimated parameters
Normal	$\mu=\bar{x}$; $\sigma=\sqrt{v}$.
Uniform	a=min(x); b=max(x).
Lognormal	$\mu log=mean(\ln x)$; $\sigma log=\sqrt{[\Sigma(\ln xi-\mu log)^2/n]}$. Requires all x>0.
Gamma	Shape $k=\bar{x}^2/v$; scale $\theta=v/\bar{x}$. Requires all x>0.
Exponential	Rate $\lambda=1/\bar{x}$. Requires all x>0.
Beta	a=min(x), b=max(x), $m=(\bar{x}-a)/(b-a)$, $v^*=v/(b-a)^2$, $k=m(1-m)/v^*-1$; $\alpha=mk$, $\beta=(1-m)k$. Reject unsupported/nonpositive shapes.
Triangular	a=min(x), b=max(x), mode=$3\bar{x}-a-b$. Exclude if mode is outside [a,b].

For sorted observations x(i), evaluate each fitted CDF G at every observation and compare the left and right empirical steps:

D=max over i of {|G(x(i))−(i−1)/n|, |i/n−G(x(i))|}

Rank candidates by increasing D. A lower D is a descriptive match among these candidates, not a p-value or acceptance test: the same observations were used to estimate the parameters. Sample extrema do not establish physical bounds, and fitted tails are not validated by this ranking. The tool does not automatically adopt the selected fit as an engineering input.

Hand example using the S13 values (0.5,0.8,1.1,1.4,2.2): $\bar{x}=1.2$ and v=0.34. Normal $\sigma=\sqrt{0.34}=0.5830951895$; gamma k=1.44/0.34=4.235294118 and θ=0.34/1.2=0.2833333333; exponential rate=1/1.2=0.8333333333.

For the uniform fit a=0.5,b=2.2, the largest CDF step difference occurs at x(4)=1.4: G=(1.4−0.5)/(2.2−0.5)=0.5294117647 versus empirical right step 4/5=0.8; D=0.2705882353.

E14. Regression and rank correlation

Trend summaries operate on the selected paired numerical values. They do not change the individual slope calculations. Report the filtered population, units and missing-value handling with the coefficients.

A regression does not change any slope calculation

$$b=\Sigma(x_i-\bar{x})(y_i-\bar{y})/\Sigma(x_i-\bar{x})^2;\ a=\bar{y}-b\,\bar{x}$$

Take three paired observations x=(1,2,3), y=(2,4,5). Then $\bar{x}=2$, $\bar{y}=11/3$, Sxx=2, Sxy=3, Syy=14/3.

$$b=3/2=1.5;\ a=11/3-1.5(2)=2/3$$

$$r=Sxy/\sqrt{(Sxx\ Syy)}=3/\sqrt{(2\times14/3)}=0.9819805061$$

Both rank sequences are (1,2,3), so Spearman rank correlation is 1, despite Pearson being slightly smaller. Tied ranks use their mean rank. Zero x variation makes the regression slope undefined; zero variance makes correlation undefined. A three-point example proves arithmetic only, not an engineering trend.

The numerical examples E4–E7 and E10/E13/E14 were independently calculated with interval geometry, elementary arithmetic and SciPy quantiles, then compared with application outputs. Their component checks supplement the original S-chapter verification; they are not whole-app or field-performance certification.

E15. Explicit design factors: calculation order

Design factors are an optional transformation of a preserved characteristic-input case. Enter a named set, its project/reference basis and every factor; classify applied loads as permanent or variable. The app supplies no governing-code preset or automatic favorable/unfavorable load combination. An enabled result is a **design-value equilibrium ratio**; 1 is its equilibrium boundary, not a conventional unfactored FS.

Entered factor	Exact implementation
Friction tangent Mphi; ground resistance Rg	tan(phi_d) = tan(phi_k)/(Mphi Rg). Take atan to recover degrees. A Mohr-Coulomb waviness angle, if present, receives the same tangent transformation independently.
Cohesion/strength Mc; Rg	c_d = c_k/(Mc Rg); an explicit tensile-strength input receives the same divisor. Rg is applied here, not divided into the final ratio again.
Self-weight Gw	gamma_d = Gw gamma_k, including shotcrete unit weight. Recalculate weight and inertia; seismic coefficients and geometry remain unchanged.
Water multiplier U	Multiply entered contact/crack pressures or selected water unit weight by U. Hydraulic heads and wetted geometry do not change. Do not multiply the resulting pressure again.
Permanent G; variable Q	Multiply each classified point/face load or prescribed column force by its category factor. Directions, locations and areas remain unchanged. Missing/stale classifications are rejected.
Support divisor Ms	Divide entered support resultants, active pretension, passive shear, axial-capacity components/diagrams and independent service capacity by Ms; shotcrete shear strength also divides by Ms. Validate original loads first, then rerun engagement, capacity and force equilibrium. Saved steel-certificate data and its stage screen remain unfactored (E25).

The original case is cloned, factors are applied once, design inputs are validated, then the selected solver runs. Reports retain characteristic values, each multiplier/tangent divisor, design values and the factor basis. Applying a factor to active pretension changes that applied load; justify the choice independently of passive capacity.

Non-unit material/ground divisors require Mohr-Coulomb contacts; nonlinear joint laws are not silently converted. Non-unit self-weight with a wedge weight-size limit is rejected: use a physical volume limit derived from characteristic weight/density. The app does not infer characteristic values or certify a standard. Partial-factor concepts and tangent reduction are described in [N1]; the table above defines this implementation.

E16. Work a design-value ratio by hand

Synthetic planar case: vertical H=10 ft, face beta=60 degrees, basal alpha=30 degrees, flat upper ground, release width B=2 ft, unit weight gamma=165 lbf/ft^3, phi=45 degrees, c=0. All bearings share 180 degrees; water, seismic and support are zero. This is an arithmetic check, not a project design or recommended factor set.

1. Geometry and characteristic forces

$V = (H^2/2)(\cot \alpha - \cot \beta)B = 115.470053837925\ ft^3$

$W = \gamma V = 19{,}052.5588832577\ lbf$

$T = W \sin \alpha = 9{,}526.27944162883\ lbf$; $N = W \cos \alpha = 16{,}500\ lbf$

$FS_k = N \tan(45°)/T = 1.73205080756888$

2. Transform strength; recalculate resistance

Enable Mphi=1.25 and Rg=1.10, with every other factor 1. The product is 1.375. Divide the friction tangent, not the angle in degrees.

$\tan(\phi_d) = 1/1.375$; $\phi_d = 36.0273733851036°$

$R_d = 16{,}500/1.375 = 12{,}000\ lbf$; ratio $= R_d/T = 1.25967331459555$

3. Check cohesion, pressure units and changed weight

For a separate check, restore Mphi=Rg=1; set c_k=10 psi, Mc=2 and Gw=1.35. Then W_d=25,720.9544923978 lbf, c_d=5 psi and basal area $A = B\,H/\sin(\alpha) = 40\ ft^2$. With ϕ_d=45 degrees:

$R_d = W_d \cos 30° + (5\ psi)(144\ in^2/ft^2)(40\ ft^2)$

ratio $= R_d/(W_d \sin 30°) = 3.97147003351652$

The 144 multiplier converts pressure-area units, not a design factor. Separately, a 100-lbf variable load with Q=1.5 becomes 150 lbf; 2-psi mean water pressure with U=1.5 becomes 3 psi; 100-lbf entered active support with Ms=2 becomes 50 lbf. Verify the transformed-value audit before interpreting the recalculated result.

E17. Search geometric bolt spacing

Under Reinforcement, fully define one Geometric bolt pattern, then use Find bolt spacing for a target FS. The search fixes capacity law, active/passive behavior, length, minimum embedment, direction, face, offsets and edge clearance. It changes only horizontal strike spacing sh and true spacing up the face sv; sv is not a vertical-elevation increment.

Step	Reproducible operation
1. Define the search	Select current/saved finite planar or wedge cases. Enter each spacing minimum, maximum and increment, target FS/design ratio and the target/range basis.
2. Enumerate	For each axis use min + k*increment within max, then include exact max if necessary. Test every Cartesian-product pair. Finer spacing is not assumed to improve FS.
3. Preserve and replace	Clone each case. Remove ALL geometric patterns and add the common template at trial spacings. Retain individual checked bolts, specified-force groups, loads and other inputs. Also evaluate a no-geometric-pattern baseline.
4. Check each head	Regenerate the grid on each case's finite face; exclude edge/outside heads. Check joint crossings, embedment and capacity individually using E4-E7. Each case uses its own face-bounds origin.
5. Require every case	Only status ok with finite ratio at least the target qualifies. Unknown, absent-block, contact-loss, lift-only and unsupported outcomes block qualification. All cases need the same north reference and named factor values/basis.
6. Rank and apply	Maximize tested sh*sv. Ties prefer fewer summed heads, then higher minimum FS, then larger sh. Apply explicitly to the current included draft; Calculate and Save. Saved cases remain unchanged.

If every baseline case meets the target, the selected cases need no additional geometric pattern under these assumptions; other reinforcement remains. Incomplete, cancelled or stale studies issue no recommendation. Export result-row CSV and full-input JSON. A change to any selected case/template invalidates the old recommendation.

Limits: 121 spacing pairs, 20 cases, 1,000 analyses including baseline, 2 MB of inputs, 12 MB of result rows; existing limits also cap each pattern at 20,000 candidate positions and 2,000 actual heads. This discrete search is not a common surveyed layout, global optimum, cost estimate or construction quantity. Toppling and isolated-block checked-bolt optimization are excluded. Stiffness sharing, rock-cone interaction, tolerances and unselected failures are not inferred.

E18. Check the bolt-spacing recommendation

Synthetic dry planar prism: H=30 ft, face beta=60 degrees, basal alpha=30 degrees, common dip direction 0 degrees, flat upper ground, width B=10 ft, gamma=165 lbf/ft^3, phi=30 degrees, c=0, seismic/support/water zero and design factors off.

The common pattern has passive shear capacity Q=10,000 lbf per engaged bolt and qualified axial capacity 10,000 lbf; length 40 ft, minimum embedment 1 ft, fixed trend 180 degrees, plunge 0 degrees, cosine efficiency, slope-face installation, offsets 2.5 ft horizontally and 5 ft up face, edge clearance 0. For this sliding-contact case shear replaces tension; it is not added to tension. All listed heads engage.

$$V = (30^2/2)(\cot 30° - \cot 60°)(10) = 5{,}196.15242270663 \text{ ft}^3$$

$$W = 857{,}365.149746594 \text{ lbf}; \quad T = W \sin 30° = 428{,}682.574873297 \text{ lbf}$$

$$N = W \cos 30° = 742{,}500 \text{ lbf}; \quad R = N \tan 30° = T; \text{ baseline } FS = 1$$

Face length H/sin60°=34.6410161514 ft. Horizontal sh=5 gives head coordinates 2.5 and 7.5 ft; sh=10 gives only 2.5 ft. Along-face sv=10 gives rows at 5,15,25 ft; sv=20 gives 5,25 ft. These are interior positions measured from the face-bounds origin.

$$FS(n) = (R + nQ)/T; \quad n \text{ needed} = \text{ceil}[(1.08T - R)/Q] = 4$$

sh (ft)	sv (ft)	Heads n	Calculated FS	Target 1.08
5	10	6	1.13996370162173	Pass
5	20	4	1.09330913441449	Pass
10	10	3	1.06998185081086	Below
10	20	2	1.04665456720724	Below

The largest qualifying tested cell is 5 x 20 ft = 100 ft^2. Equal area alone does not determine the result: 10 x 10 ft generates fewer heads and fails this target. Summed heads over repeated case faces are not a bill of materials.

A second otherwise-identical case at gamma=330 pcf controls a target 1.05: 5 x 10 gives FS=1+60,000/(2T)=1.06998185081086, while 5 x 20 is below 1.05. Both cases must pass. With common Mphi=1.25 and Ms=2 instead, the first-case baseline ratio is 0.8 and each increment is nQ/(2T); target 0.86 selects 5 x 10. These synthetic capacities and factors are not design recommendations.

E19. Bench geometry beyond finite wedges

Bench comparison reruns selected cases at each face angle, with one vertical height H and flat upper ground. Cases are alternative scenarios, not volumes to add as simultaneous failures. The common factor basis must match: enabled state, set name, reference and numerical factors; individual load classifications may differ. Crest loss and debris retention need both geometry and failure interpretation [N2].

Model	Geometry and scope
Planar	Continuous basal plane, finite release width L and free side releases; an explicit rear crack is allowed. Without crack: crest xc=H cot(beta), rear intersection xr=H cot(alpha), backbreak B=xr-xc, area A=HB/2, V=AL. With crack use the polygon area; B is the exposed upper-ground edge, not underground extent.
Finite wedge	S14 cone/pyramid formulas remain wedge-specific. Non-overhanging two-joint geometry, explicit finite persistence/spacing; no third basal contact, tension crack or separate size limiter combined with persistence.
Block toppling	Generated dry columns only; no explicit column list or prescribed column forces. Angle changes cannot silently remap force/ water attachment IDs. Critical sliding/toppling columns and stable-side columns at the force/moment tolerance boundary contribute scenario volume; stable columns away from a limiting condition do not. Flexure stays excluded.

Toppling crest loss and potential volume

For zero-based column j with width w, height h, base offset b and depth L, volume is w h L. Sum critical sliding/toppling columns and stable-side columns at the incipient force/moment tolerance boundary defined in E30; exclude stable columns away from those limits. With a=90 degrees minus joint dip, transform upper corners from u=jw or (j+1)w, n=b+h using X=u cos(a)-n sin(a). Surface B=max[0,max(Xupper)-H cot(beta)]. Bottom corners are not crest loss; midpoint column geometry needs spacing sensitivity.

Uniform triangular-prism deposit: planar/toppling only

$$C = \cot(\phi_{repose}) - \cot(\beta) > 0;\ S = h_{pile}\, C$$

$$K\,V = L\left(S\,\frac{h_{pile}}{2}\right) = L\,\frac{S^2}{2C};\ S = \sqrt{\frac{2\,K\,V\,C}{L}}$$

Require beta > repose and h_pile=S/C <= H. Otherwise spill width is unresolved. K is loose/solid volume. This derives a fully fragmented, uniformly spread deposit against the finite face. It predicts no bounce, intact-block rotation, fragmentation process, dynamic runout or catch efficiency. Do not replace S14's wedge coefficient 6 with this prism coefficient 2.

E20. Work a bench-width scenario

Synthetic planar case: H=30 ft, alpha=50 degrees, beta=70 degrees, flat upper ground, L=20 ft, phi=20 degrees, c=0, gamma=363.84 pcf, dry, no support/seismic or design factors. Use K=1.5, repose=38 degrees, target FS=2, nearest-rank quantile q=0.95, usable allowance 5 ft and available width 100 ft. Angles share one interpreted section.

Calculation	Result
B = 30(cot50 - cot70)	14.2538819073323 ft
A = 30B/2; V = A(20)	213.808228609985 ft^2; 4,276.16457219970 ft^3
FS = tan20/tan50 (below target 2)	0.305407289332279
C = cot38 - cot70	0.915971397926877
S = sqrt[2(1.5)V C/20]	24.2389493613991 ft
h_pile = S/C < H	26.4625614034011 ft: in domain
Required = B + S + 5	43.4928312687315 ft
Margin = 100 - required	56.5071687312685 ft

For multiple cases below the chosen target, sort B and S separately. Each quantile uses one-based index max[1,ceil(qn)]. Required width is Qq(B)+Qq(S)+allowance. These separate quantiles need not come from the same case and are not a joint failure probability. For a fixed inter-ramp angle i, available width is H(cot i-cot beta); for fixed width Wb, i=atan[H/(H cot beta+Wb)].

A numerical FS can still leave the catch-bench result unresolved

The retained dry toppling example uses H=9.85/0.3048 ft, face=58.65 degrees, upper=0, stepped base=30 degrees, joints=64 degrees into slope, column width=1.75/0.3048 ft, depth=1/0.3048 ft, basal/intercolumn friction=31 degrees, c=0, gamma=25(6.365880354) pcf, kh=kv=0. The recurrence gives FS=0.912016044906 and critical sliding/toppling and incipient toe column IDs 1-8.

Their potential volume is 1,651.69944304900 ft^3 and upper-corner backbreak 15.0410293703792 ft. K=1.5 and repose=38 degrees require pile height 47.4523523918982 ft, exceeding H=32.3162729658793 ft. Preserve the FS/geometry but withhold spill width and the bench recommendation. Do not alter repose simply to force a result. Unknown contacts, absent dimensions or other unresolved scenarios also withhold the study recommendation.

E21. Compound filters preserve the full study

In sensitivity/uncertainty or joint combinations, create a named Compound result filter. Choose AND (all conditions) or OR (any), add rules or nested groups, then Save and apply. The saved name is a **view definition, not a result record**. Show all rows clears the compound filter; existing combination basic filters may still apply. Delete removes the definition only. Portable filter-library JSON is separate from complete study JSON.

Rules compare accepted FS/design ratio, block volume in ft^3, exact status/mode text or result class. Numbers use <, <=, =, !=, >=, >, is-missing or is-present; text equality is case-sensitive. A missing value fails every ordinary comparison, including !=. Accepted factors require a finite value and status ok (or legacy absent status). A numerical lift-only ratio is not an accepted sliding FS. Classes accepted, no-block, support-only-lift and unresolved remain distinct; none means safe.

Reproduce a filtered view and its unchanged denominator

Row	Status	FS / raw ratio	V (ft^3)	Class
a	ok / both	0.8	100	accepted
b	ok / joint1	1.6	500	accepted
c	ok / both	2.0	900	accepted
d	invalid	missing	missing	unresolved
e	no-block	missing	0	no-block
f	support-only-lift	0.1 raw	300	support-only-lift
g	contact-loss	missing	200	unresolved

((FS < 1 AND V >= 100) OR class = unresolved) selects a, d, g: 3 of 7

The full accepted population remains a,b,c: count 3, with 1 below unity; the conditional fraction remains 1/3. FS != 0 selects only a,b,c. Accepted-FS is-missing selects d,e,f,g. Filtering does not rerun the solver, replace missing values with zero or turn the shown fraction into a physical failure probability.

Tables/plots identify the filter and visible/original counts. Histograms show visible accepted numbers; full-study reliability and fitted summaries keep the original population and denominator. Sensitivity lines break at hidden or nonnumerical rows. Full JSON/CSV retain all results; explicitly filtered exports carry view name, expression and original counts. Local named definitions can be reloaded/imported; invalid edits/imports preserve the active valid filter.

Bounds: 20 saved names, 64 expression nodes, 4 nested group levels, 12 children/group, 128 KiB imported library and 50,000 result rows. Filters use validated data predicates, not executable expressions. Applying a filter never changes field observations, engineering inputs, raw results or a governing acceptance criterion.

E22. Anchor direction: from the head into the slope

The bolt axis points from its head toward its anchored end. Trend t is clockwise from north; plunge p is positive downward from horizontal. Thus b=(sin t cos p, cos t cos p, -sin p) in east, north, up coordinates. A downslope face bearing is not the inward bolt bearing.

1. A geometric starting orientation, not an optimum

For conventional face dip β: t=(face bearing+180°) mod 360°; p=90°-β

For a 70° face dipping toward 270°, t=90° and p=20°. The vector is (0.939692621, 0, -0.342020143): east into the slope, descending toward the tip. These numbers orient a line; they provide no bolt length, bond, force or capacity. For steep 60-90° faces this face-normal construction gives plunges of 30-0°.

New planar/wedge bolt entries use that inward face normal only when the face bearing and conventional dip are known. Unknown or overhanging geometry leaves unsupported direction components blank. For the isolated-block editor, the starting direction is uphill along the base bearing and horizontal; its prescribed force/moment model still requires its separate support-height assumption. These are starting values, not an automatic design.

2. Edit deliberately and verify the crossing

Existing support rows do not rotate when slope inputs change. Point into slope, keep plunge changes the trend deliberately while retaining the entered plunge; Use face-normal direction deliberately replaces the orientation with the eligible face normal. Review the resulting head-to-tip line, release-plane crossing and required competent embedment (E4). The admissible geometry is more important than merely falling within a typical angle range.

Optional below-normal offset δ: p=(90°-β)+δ; β=70°, δ=15° → p=35° down

The angle dropdown distinguishes perpendicular and 5°, 10° or 15° below perpendicular from absolute 0°, 15° or 30° downward plunges. The 15° below-normal option is not the default and is not the same as 15° below horizontal. Custom / manual input retains arbitrary valid values. Direction/layout figures explain the convention; Calculate separately checks the actual crossing.

3. Keep reference scopes separate

FP-24 §260.08(a) specifies face-normal rock bolts/dowels or 0-5° downward from that normal unless the plans specify otherwise [A-FP24]. GEC 4 §5.3.6 describes general ground anchors: 10-45° construction inclinations, commonly 15-30° below horizontal; inclinations below 10° can need special grouting [A-GEC4]. The latter is not a universal rock-bolt optimum. Apply the project specification, geological release surfaces and installation constraints.

E23. Independent service resistance and applied support force

An active bolt has a specified retained pretension, Tactive. A passive bolt has an available resistance that is credited according to the selected mobilization assumption; the app does not predict the movement needed to develop it. Count multiplies the applicable per-bolt contribution. Applied force is not evidence that the system can sustain that force.

1. Establish each independent limit

The qualified service limit S is a finite nonnegative force per bolt in lbf with a documented basis. Establish the controlling usable system resistance from the relevant steel, head/plate, anchorage, bond, rock/ground and installation evidence. The geometric/component diagram capacity C is evaluated at the release-plane crossing as in E5. A saved ultimate steel check alone does not establish S.

Checked passive: $A=\min(C,S)$ when S is supplied; otherwise $A=C$. Axial credit$=A\eta$.

Active: Tactive must be $\le C$ where checked and $\le S$ where supplied. Axial credit=Tactive.

An active load above an applicable limit is rejected, not silently reduced. A force-only passive input above its stated service limit is also rejected; it is not a displacement-mobilization calculation. A separately entered passive shear contribution is checked against the applicable service limit. Shear-only and axial modes retain their existing exclusive behavior.

2. Reproduce the passive cap before efficiency

Retain E5 geometry: L=12 ft, crossing x=6 ft, bonded length 8 ft, q=1,000 lbf/ft, steel 10,000 lbf and plate 2,000 lbf. Inner bond=2 ft, outer bond=6 ft; the existing diagram gives C=4,000 lbf. Independently qualify S=3,000 lbf and retain E6 cosine efficiency $\eta=0.6$.

$A=\min(4{,}000,3{,}000)=3{,}000$ lbf; $T_{passive}=3{,}000\times0.6=1{,}800$ lbf per bolt

Without the lower service limit the same diagram/efficiency gives 2,400 lbf. For an active load of 2,500 lbf, both $2{,}500\le4{,}000$ and $2{,}500\le3{,}000$ pass, and only 2,500 lbf is applied. An active load of 3,500 lbf passes C but fails S and must not be calculated. Orientation efficiency remains a passive assumption, not a way to reduce an active demand until it passes.

Historical cases without an independent service limit preserve their established calculation and are visibly unchecked where appropriate. A legacy capacity copied from the same entered force remains marked legacy-force; supplying the number again is not independent qualification. The UI requires deliberate documented confirmation after replacing/reviewing that capacity. Export the input and result audit, including the limit, basis, crossing and controlling status.

E24. Steel design, lock-off and proof loads: a separate screen

The optional FHWA screen uses certified specified minimum ultimate tensile load Tu, or an imported certified area A and specified minimum ultimate stress fpu with Tu=A fpu. Do not substitute an observed break-test load. These routes are mutually exclusive. The basis and maximum-test/design multiplier m are retained. This is an ultimate prestressing-steel screen [A-GEC4], not a universal yield-stress rule for every rock bolt.

Design steel ceiling=0.60Tu; lock-off ceiling=0.70Tu; maximum test ceiling=0.80Tu

Governing design ceiling=min(0.60Tu, 0.80Tu/m); associated test load=m×design ceiling

1. Follow one original example by hand

For an illustrative certificate specified minimum Tu=100,000 lbf and m=1.33, the steel ceilings are 60,000 / 70,000 / 80,000 lbf for design / lock-off / maximum test. The test-based design ceiling is 80,000/1.33=60,150.375940 lbf. Therefore the governing design ceiling is min(60,000,60,150.375940)=60,000 lbf and its test load is 79,800 lbf.

Changing m to 1.5 gives test-based design 53,333.333333 lbf, which governs over 60,000 lbf. That example explains why the chosen proof/performance test can restrict design. This separate certified-ultimate helper does not copy its ceilings into force or service capacity. The published-product workflow in E26-E27 can fill only the steel component of a grouted/mechanical capacity model; neither route establishes the ground, plate or bond capacity.

For a separate published scale example, GEC 4 Table 9 lists a Grade 150 nominal 1-inch bar with area 0.85 in^2 and specified minimum stress 150,000 psi: Tu=127,500 lbf, giving 76,500 / 89,250 / 102,000 lbf at 60/70/80%. The table rounds lock-off to 89.3 kip. This is not a suggested product or pretension; use the actual certified area and project-qualified system resistance.

2. Do not substitute one load stage for another

Design load is the selected working/design demand; lock-off is the retained load transferred after stressing; proof is a controlled acceptance-test stage. FP-24 §260.09(b) uses proof 1.33 times design and lock-off at design after acceptance [A-FP24]. GEC 4 §7.5 gives different context-specific lock-off considerations and losses [A-GEC4]. There is no universal pretension in lbf and no app-inferred loss allowance.

An active input with a saved steel screen is rejected above 0.70Tu. The lock-off gate is not 0.60Tu: a 65,000-lbf retained load in this example passes the steel lock-off ceiling, although it exceeds the 60,000-lbf design ceiling and still needs a justified design/load-stage basis and all independent system checks. Passive resistance is not a lock-off load and is not subjected to that active-only gate.

E25. Preserve qualification evidence and inspect the audit

1. Commit or discard a pending steel edit

Open Check tendon steel and load stages, enter the certified specified minimum ultimate load, maximum-test/design multiplier and certificate/design basis. Unfinished helper edits are preserved as pending draft values when other controls rerender or the local draft is reopened; they do not replace an accepted steel check. Calculate is blocked until Save FHWA steel check validates and commits the draft, or Discard steel-check edits restores the prior accepted check. Remove FHWA steel check removes both saved and pending steel information. A helper edit invalidates the previous result.

2. Inspect load stages and system capacity separately

Save and export the case with support type, active/passive basis, per-bolt values, capacity law and provenance, independent service limit, certified steel screen and test multiplier. The calculation report retains the audit. Pattern heads share their parent steel/service evidence by identifier, while engagement, crossing and effective contribution are evaluated for the actual generated heads. A non-engaged head is not credited merely because its certificate is valid.

A published-product selection additionally preserves its catalog version, source, original properties, explicit overrides and their basis. Pending product edits must be applied or discarded before calculation, separately from pending edits to the certified-ultimate helper. Reports retain the distinction between published and overridden values (E27).

3. Apply a project factor without rewriting a certificate

The enabled design-factor set first validates the original support demands. Its support divisor Ms then divides applicable entered forces, diagram components and the independent service limit together. Certificate values and the saved steel-stage screen remain characteristic and unchanged. The resulting ratio belongs to the named factor set (E15), not to an automatic code combination.

Example: T=100 lbf, S=125 lbf, Ms=2 → Tdesign=50 lbf, Sdesign=62.5 lbf

Utilization=100/125=50/62.5=0.8; a certified Tu=200 lbf remains 200 lbf

4. Understand the remaining boundary

An in-range steel fraction and a finite service limit do not prove a stable bonded zone, rock-cone resistance, corrosion protection, installation quality, tested anchorage, compatible displacement or accepted long-term losses. The user must establish those. Saved legacy-force evidence is explicitly not an independent capacity. Local single-bolt/finite-block calculations remain bounded by their stated mechanical models; whole-slope block-flexure FS is still withheld.

E26. Published bolt materials: selection is not system design

Step 2, Select the bar and steel properties, offers four published threaded-bar presets or Custom product / manual steel capacity. The small catalog uses manufacturer minimum net threaded areas and minimum material stresses [A-W75, A-W150]. It is not a comprehensive product list, current procurement recommendation or project material certificate.

Published preset	A (in^2)	fy / fu (psi)	Ty / Tu (lbf)
Grade 75 #8; R61-08	0.79	75,000 / 100,000	59,250 / 79,000
Grade 75 #10; R61-10	1.27	75,000 / 100,000	95,250 / 127,000
Grade 150 1 in; R71-08	0.85	120,000 / 150,000	102,000 / 127,500
Grade 150 1-1/4 in; R71-10	1.25	120,000 / 150,000	150,000 / 187,500

Ty=A fy; Tu=A fu; area (ft^2)=A/144; nominal diameter (ft)=diameter (in)/12

The app retains unrounded products. For the Grade 150 1-inch preset, 0.85×150,000=127,500 lbf, even when a manufacturer table displays a rounded 128 kip. Never infer the net threaded area from $\pi d^2/4$ using nominal diameter. The custom editor labels its product designation and certified/custom area in inches and square inches; the normal display also supplies feet and square feet. Stresses remain psi, loads lbf.

1. Select a procedure within its scope

FHWA FP-24 §260 addresses rock bolts/dowels and its steel design/test limits; §722.03 identifies applicable bars [A-FP24]. GEC 4 provides prestressed ground-anchor stages [A-GEC4]. The catalog permits the latter procedure only for its prestressing-bar class. No strand or generic friction-bolt material preset is inferred from incomplete source data.

2. Preserve all the other load-path decisions

Selecting a product fills the steel design component only for grouted or mechanical bar capacity models. A specified/system or other capacity model retains the product for reference and uses its separately entered resistance. The product supplies no plate, nut, coupler, grout/rock bond, corrosion allowance, pretension or qualified system service limit. Step 4 must establish anchorage; Step 5 must establish the load and check the result.

E27. Calculate a steel limit and preserve edited product data

Let A be the accepted net area, fy the minimum yield stress and fu the specified minimum ultimate stress. Calculate Ty=A fy and Tu=A fu. For the catalog, the app adds an explicitly conservative yield guard to the published ultimate-fraction stages. It does not change the separate certified-ultimate-only helper in E24.

D0=min(0.60Tu,Ty); Qmax=min(0.80Tu,Ty)

If test/design ratio m is supplied: D=min(D0,Qmax/m); otherwise D=D0

Prestressed procedure only: lock-off ceiling=min(0.70Tu,Ty)

1. Reproduce the initial Grade 75 #8 selection

A=0.79 in^2, fy=75,000 psi and fu=100,000 psi give Ty=59,250 lbf and Tu=79,000 lbf. D0=min(47,400,59,250)=47,400 lbf. Qmax=min(63,200,59,250)=59,250 lbf, controlled by the additional yield guard. The UI starts a new product selection at the FP-24 test/design ratio m=1.33; the underlying saved format can explicitly omit that ratio.

D=min(47,400,59,250/1.33)=44,548.8721804511 lbf

For a grouted/mechanical capacity model, that D initializes its Steel tensile capacity. A lower supported project value may be entered. The product-derived limit does not become bond, service resistance or applied force. FP-24 selection supplies no separate lock-off output. For the Grade 150 1-inch prestressed example, Ty=102,000 and Tu=127,500 lbf give design 76,500, lock-off 89,250 and test 102,000 lbf; m=1.5 reduces design to 68,000 lbf.

2. Edit with traceable evidence, then apply

Custom material properties and design basis exposes diameter, area, yield, minimum ultimate, procedure and test ratio. Record Material override evidence for changed source properties. Raw edits are saved as a pending draft and block calculation and a stale capacity preview. Apply bolt-product edits validates and commits the selection and updates an eligible steel component; Discard bolt-product edits restores the accepted selection. Existing manually entered bolt values are not revised merely by a catalog update.

The case keeps the original source snapshot and separate overrides, catalog version, procedure and ratio. The report/JSON audit preserves them. A published table is not relabeled as a supplied certificate. A later catalog revision does not silently refresh an existing saved case.

E28. Trial length, geometric embedment and bonded resistance

A new planar/wedge checked entry starts as one passive grouted trial dowel: 20 ft total length, full bonded-length mode, zero plate resistance credited, an eligible face-center head and inward face-normal direction. Required geometric embedment, site bond resistance and capacity basis remain blank. These starting values describe a trial installation; they do not complete or approve it. Existing support rows preserve their values.

FHWA rock-slope guidance describes 20 ft as a typical anchor length [A-ROCK]. The menu also offers 10, 15, 25, 30 and 40 ft with Custom / manual input. Minimum embedment and spacing choices are entry shortcuts only. Their suitability depends on the release surfaces, competent anchorage, load path and installation, not on the menu choice.

1. Separate the three lengths

Total axis length L; crossing distance x from head; geometric length beyond crossing e=L-x

Minimum geometric embedment requires adequate modeled length beyond the controlling release surface; it is not a bond-capacity calculation or proof that rock is competent. A specified bonded length Lb occupies the interval from L-Lb to the tip. Full mode uses Lb=L and follows explicit edits to total length. The backend rejects a stale full-mode mismatch. Partial mode preserves a tip-bonded interval and must match the intended construction.

2. Evaluate the actual bonded segments

For an internal crossing $0 < x < L$, use inner bonded length $l_i=\max(0,x-(L-L_b))$ and outer bonded length $l_o=\min(L-x,L_b)$. The retained grouted model evaluates $C=\min(T_{steel},P+q\,l_i,q\,l_o)$, with plate capacity P and qualified bond transfer q in lbf/ft (E5). It is a simplified capacity envelope, not a computed bond-stress distribution.

Example: L=20, Lb=20, x=8 ft; P=0, q=1,000 lbf/ft, Tsteel=44,548.8721804511 lbf

li=8 ft; lo=12 ft; C=min(44,548.8721804511,8,000,12,000)=8,000 lbf

This independent teaching example assumes a qualified uniform q; the app does not obtain that value from the bar catalog. Check both relevant bonded interfaces and site conditions. The lower independent service limit, where supplied, further caps checked passive resistance before orientation efficiency (E23). For active anchors, the free-stressing length and stable bond zone during installation must also be established; a final fully grouted state alone does not demonstrate a workable stressing sequence.

E29. Read bolts and patterns on the current model geometry

Finite planar/wedge models display current checked heads and shafts. Specified forces supply no shaft geometry; isolated-block/toppling support retains its separate scope. Show bolts and Transparent block start on; Bolt labels starts off. Display choices change no inputs or calculations.

1. Read the actual axis and crossing

Head H=(E,N,U); unit axis b=(sin t cos p,cos t cos p,-sin p); tip=H+L b

Entered trend, plunge and length construct the shaft. A circle marks the head; a ring marks a known release-plane crossing on the shaft. View fit includes full heads and tips: long bolts may shrink the apparent block. Read numeric feet; scale changes across edits.

Appearance	Interpretation
Green shaft	Geometric engagement passes; usable capacity and credited force are not established.
Red shaft	Known geometry is drawn, but engagement fails. Inspect the reason and crossing.
Dashed amber shaft	Required embedment is missing or unchecked. Resolve it; amber is not a safe result.
No shaft, with reason	Missing/invalid head, direction or length, or an off-face head, prevents drawing. Old-result shafts never substitute.

2. Distinguish one equivalent group from a pattern

Count greater than one at one checked head shows one shaft and an equivalent-count note, not invented locations. Patterns use the actual generator. At most 200 shafts display, with total/omission counts; labels cover the first 12 and details the first 30. These limits do not change the analysis population.

3. Use geometry to inspect, then calculate

Edits replace current shafts without using stale result geometry. Surface picking still identifies faces; bolts are not edit handles. Revise supports through Reinforcement, then Calculate. Colors establish no steel/bond/service resistance, capacity, FS or construction acceptance. Read the separately calculated support audit.

K25. Query, include and remove individual observations

In Stereonet analysis, Click poles selects and queries the closest visible measurement pole. The detail shows the original plane dip and dip direction, observed set, feature, outcrop, north reference and stable ID. These are plane angles, not the pole trend/plunge. Shift-click adds to selection; circle/freehand and table checkboxes support multiple selection. Coincident observations need row/ID review. Engineering kinematic and stereonet-tool plots, phone Kinematics and the live field stereonet also expose pole queries.

Clicking empty net space in Stereonet analysis, Engineering or phone Kinematics shows a Cursor plane, explicitly not a saved observation. With center(160,160), net radius140 and ρ=distance/radius, inverse equal-area plane dip=2asin(ρ/√2); inverse equal-angle dip=2atanρ. Convert radians to degrees. Pole trend=atan2(x−160,160−y); plane dip direction=wrap(pole trend+180°). At center dip=0° and direction is undefined; clicks outside the net have no plane query. Existing pole hits display recorded values, not pixel-rounded inverse values.

Selecting a point does not automatically restrict Engineering. Its default Engineering input scope is All plotted measurements; Selected plotted measurements is explicit. Filters/exclusions define plotted scope first. All pairs is a hypothetical orientation screen: no set assignment or common outcrop is needed, but this does not establish joint persistence, coexistence, connectivity or actual block geometry.

Action	What changes
Exclude selected from analysis	Reversible interpretation exclusion; saved observations remain.
Delete selected measurements…	Lists exact stable IDs, origins and orientations for review; type DELETE and submit.
Delete a saved field measurement	Removes that record locally and queues its normal account-scoped cloud tombstone. Parent outcrop/set definitions and separately saved discontinuities remain; historical source links are retained.
Delete imported / portable snapshot rows	Removes rows and their current assignments/reference overrides from this local analysis only.
Undo analysis edit	Restores the preceding interpretation/import rows, not deleted field records.
Field view > Data > Field checks & deletion recovery	Undo last field deletion restores the last saved field deletion, then queues return to backup. Keep an independent file for earlier history.

The reviewed field deletion and saved-analysis update commit in one IndexedDB transaction. Account/backup owner, field snapshot and analysis revision are checked again; stale review fails before writing. Only the selected record identities are removed. Cloud completion needs the usual sync/readback and may be paused offline. This is not secure erasure, an account deletion or deletion of external photos.

K26. Large kinematic runs and complete exports

candidate pairs = N(N − 1)/2; tested = candidates − scope-excluded − parallel

The equations, friction/daylight boundaries and denominator definitions in K11-K18 are unchanged. Every candidate is visited; display markers and first-example lists remain bounded samples. Batching changes storage, not the classification or population. Known homogeneous true or magnetic reference is read from the included records. The slope bearing must use that same frame; unknown/mixed observations are never silently corrected.

Independent regression population	Exact expected count
900 unassigned planes: 450 at 60°/150°, 450 at 60°/210°	404,550 candidates = 900(899)/2
Pairs within the two identical populations	202,050 parallel = 2 × 450(449)/2
Cross-population intersections	202,500 tested = 450 × 450; all qualify for the stated wedge screen
Slope 60°/180°, friction 30°, lateral 20°	Complete critical rows: 202,500; one union row per qualifying plane/pair, not one row per flag
2,100 identical planes	2,203,950 candidates, all parallel; no qualifying pairs
Two-step sweep of the 2,100-plane control	4,407,900 candidate-pair visits; no former aggregate ceiling

The temporary result database is separate from saved field/analysis records. Each successful batch is awaited before proceeding; completion checks its exact count. Complete analysis JSON reconstructs the full critical array; complete critical CSV uses one consistent header and retains source context for each endpoint. Missing/incomplete batches block export and request a rerun; no truncated file is offered as complete. Closing, cancellation and input invalidation remove the associated temporary run. Confirmed Clear this device only also clears the temporary result stores; a stale clearing preview changes nothing.

The plotted sample and readable summary are not the complete pair archive. Download complete JSON/CSV while the result is current. Very large populations are quadratic in time and export size; browser storage quota, memory needed for a downloadable Blob, device power and existing import/backup size limits still apply. Abrupt browser/process termination can leave temporary batches; these are not field observations and are not cloud-backed engineering records.

S17A. Overhanging block-toppling section geometry

The interacting rectangular-column model extends the published Goodman-Bray block-toppling recurrence [R4] to a physical face inclination θ at or above vertical. This is an independently implemented geometry extension of the same force/moment model, not a new empirical strength rule. FHWA Rock Slopes Reference Manual [R2] and USACE rock-slope guidance [R1] supply the broader engineering framework; neither certifies this implementation. Retained S/E toppling chapters define contact forces, reduction and admissibility.

$$\alpha = 90^\circ - \psi;\ e = (\cos\alpha, \sin\alpha);\ q = (-\sin\alpha, \cos\alpha)$$

Use uphill horizontal X and vertical Z, toe (0,0), H vertical crest height, ψ joint dip into slope, β overall stepped-base inclination and w column width along the local base. A physical face θ=90° is vertical; θ>90° puts crest X=H cotθ negative, toward the exposed side. This is a section inclination, not a geological dip direction or kinematic slope angle. Enter θ directly in Slope face inclination. Upper ground angle μ is signed uphill.

$$C = (H\cot\theta, H);\ t_i = (i + 1/2)w;\ b_i = i\, w \tan(\beta - \alpha)$$

$$n_{face}(t) = t \tan(\theta - \alpha)$$

$$m = \tan(\mu - \alpha);\ \text{intercept} = [H - H\cot\theta \tan\mu] / [\cos\alpha + \sin\alpha \tan\mu]$$

$$n_{roof}(t) = \text{intercept} + m\, t;\ h_i = \min[n_{face}(t_i), n_{roof}(t_i)] - b_i$$

At θ−α=90°, the face is parallel to q: its n limit is unbounded and the roof governs. Do not evaluate a floating tan90° and use its arbitrary sign. Columns are rectangles sampled at joint-spacing midpoints, with base origin iw e + b_i q, height h_i, centroid t_i e + (b_i+h_i/2)q, area wh_i and volume wh_i d. Stop at the first nonpositive height; retain the existing finite-column and angle checks. This is the declared midpoint idealization, not the exact volume of the whole triangular exposure.

Generated toe-supported geometry requires θ ≤ 180°−ψ (equivalently θ−α≤90°). Beyond it, the front envelope would produce an unsupported partial nose which this generator cannot model; the case is rejected instead of dropping that mass. Also require θ>β≥α and −ψ<μ<β. The physical-face range is 0.001°–179.9°, but these geometric relationships further constrain it. Explicit column inputs still require their own supported geometry/contact review; they do not automatically model an arbitrary undercut.

S17B. Hand calculation for a supported overhang

Synthetic single-column control: H=10 ft, θ=100°, μ=0°, β=45°, ψ=60°, w=20 ft, d=3 ft, γ=160 lbf/ft^3. Base φ=35°, c=0 psi; intercolumn φ=25°, c=0. No water, support, seismic or applied loads, no design factors. Here α=30° and θ−α=70°; the 120° maximum is satisfied. One column is formed and the roof controls its midpoint height.

C = (10 cot100°, 10) = (−1.7632698071, 10) ft; t_0 = 10 ft; b_0 = 0

h_0 = [10 − 10 sin30°] / cos30° = 5.7735026919 ft

A = 20h_0 = 115.4700538379 ft^2; V = Ad = 346.4101615138 ft^3

W = γV = 55,425.6258422041 lbf

N = W cos30° = 48,000 lbf; D = W sin30° = 27,712.8129211020 lbf

For this isolated dry sliding control there are no intercolumn forces. At reduction factor F, tanφ_m=tan35°/F; basal resistance N tanφ_m equals D at critical equilibrium. Thus the recurrence has a directly checkable independent solution:

FS = tan35° / tan30° = 1.2127950320219434

The stable-side numerical bracket returns 1.212795032210658 for this control, a difference of 1.89×10^-10. Both display as 1.2128. A toe thrust of about 5.54×10^-6 lbf is within the force tolerance; it is not a separate physical load. Retained recurrence chapters specify the iteration/contact tolerances. Compare full-precision independent arithmetic within those tolerances, rather than demanding exact binary equality.

x_R = w/2 − (h_0/2)tan30° = 8.3333333333 ft from the toe

The base normal acts at x_R. Because 0<x_R<w, the basal resultant lies within the column base; force/moment residuals and unilateral contact checks pass. In a multicolumn case use the retained recurrence, each column geometry and exact source/replay appendix; do not apply this isolated sliding expression to a column receiving neighboring thrust, water or reinforcement.

Regression controls independently solve ray/line intersections with determinants for multicolumn faces 95°,105°,115° and120°. Isolated faces 89.9°,90°,100°,110°,119.999° and120° with base φ15°,25°,35° match tanφ/tan30°. A125° face with ψ60° is rejected for unsupported partial columns, with links to both input fields. These bounded controls establish this geometry and equilibrium, not every physical overhang or commercial-software equivalence.

Flexural-toppling screening remains geometric possibility. Whole-slope block-flexure remains diagnostic and supplies no accepted FS. Overhang support does not resolve its bending-inertia/model-basis limitation; it must not be described as a validated whole-slope flexural design.

S17C. Independently solve a five-column overhang

Keep the S17B inputs except β=30° (linear base) and w=4 ft. The same 100° physical face now produces five columns. Using S17A, midpoint heights are 5.4949548389,8.0829037687,5.7735026919,3.4641016151 and 1.1547005384 ft; volume 287.6419614357 ft^3. The front limits column 1; the flat roof limits columns 2-5. There are no loads, water, support or design factors.

Columns 3-5 are too squat to overturn under gravity: h/w < cot30°. Their basal sliding demand is also below the reduced capacity at the root below, so they send no thrust downhill. Column 2 is slender enough to topple and receives no uphill thrust. Write its equilibrium about its downhill toe, with normal force P2 from the lower neighbor acting at shared contact height h1; its shear Q2 acts at the toe and adds no moment.

W1 = (4)(h1)(3)(160) = 10,550.3132907057 lbf; W2 = 15,519.1752358171 lbf

P2 = [W2 sinα (h2/2) − W2 cosα (w/2)]/h1 = 815.2933247563 lbf

Q2(F) = P2 tan25°/F; N1(F) = W1 cos30° + Q2(F); D1 = W1 sin30° + P2

The equal/opposite contact shear increases compression on column 1 and reduces compression on column2. At the toe sliding boundary, D1=N1 tan35°/F. Multiply by F^2 and collect terms; do not reduce the angle itself or omit the dependence of Q2 on F.

$A F^2 - B F - C = 0$

A = D1 = 6,090.4499701092 lbf; B = W1 cos30° tan35° = 6,397.6837726215 lbf

C = P2 tan25° tan35° = 266.2031660456 lbf

$F = [B + \sqrt{(B^2 + 4AC)}]/(2A) = 1.0905252111600992$

The coupled solver returns 1.0905252117367175 (difference 5.77×10^-10); both display 1.0905. At the independent root Q2=348.6187362620 lbf, N1=9,485.4580638978 lbf. Column 2 has N2=13,091.3812637380 lbf and D2=6,944.2942931523 lbf, below N2 tan35°/F. Its basal resultant is at the toe. Column1 has resultant 0.0732468404 ft from its toe, within the 4 ft base; the remaining columns have no outgoing thrust. These checks verify that the assumed branch is actually admissible. A quadratic derived from a wrong branch is not a general toppling solution.

Other angles/properties can switch branches, break contacts or leave no accepted FS. Use the retained full recurrence and per-column audit then. The independent regression checks this exact coupled factor, thrust, normal/shear balances and branch conditions; it does not accept every overhanging section.

I22. Manual contact inputs and scope feedback

Field data and named property profiles are optional sources for Slope stability. Orientation source starts in Manual orientation — enter the contact angles, with the numeric case inputs authoritative. For toppling, Geometry contains Overall stepped-base inclination, Toppling joint dip into slope and spacing; Materials has separate Block-base and Intercolumn joint strength groups. Enter the interpreted friction and cohesion directly. An isolated block has its separate basal contact. No field set or saved outcrop parameter is required to supply these values.

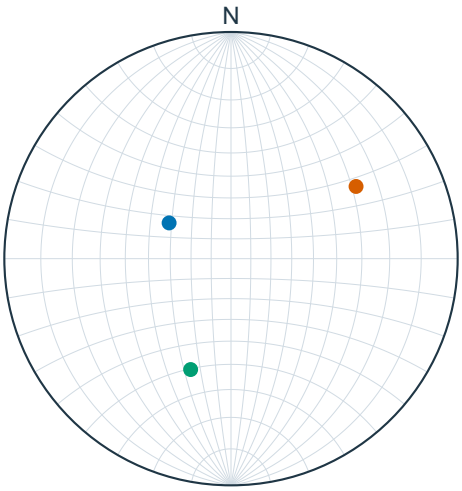
Enter [contact] manually removes that contact’s assigned profile link while retaining numerical values for review and focuses the existing authoritative field. It creates no duplicate input and does not infer material properties. Applying a profile or observed orientation is still an explicit copy, with provenance; later changes to field data/library do not rewrite the saved case. Use the existing references/figures to justify section angles, strength and water/load assumptions.

Live Geometry uses the same generated columns as the solver, including negative-X overhanging crest context. Recalculate explicitly after any change. Invalid geometry clears the current result; Review setup/Calculate links recognized unsupported-overhang errors to both face inclination and joint dip. Reports preserve the full case, column geometry, forces, contact audit, warnings and exact calculation source. Save/reload and exports retain the entered face inclination.

K27. Equal-angle stereonet: construction, grid and hand checks

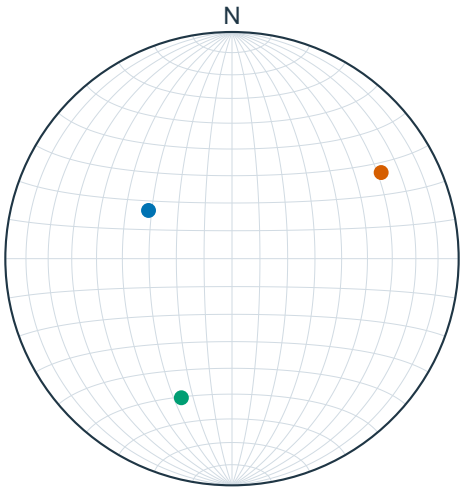
The opening default is a lower-hemisphere equal-angle Wulff net, with meridians and parallels at 10° spacing. Equal area (Schmidt/Lambert) remains a deliberate display choice. These are projections of the same orientations, not two competing mechanical models. Equal angle is conformal: infinitesimal angles are preserved. Screen distances between distant points are not spherical angular separation; calculate the latter from the unit-vector dot product.

Equal angle / Wulff



Same three planes; different display radii

Equal area / Schmidt



Same three planes; different display radii

Step 1. Form a unit lower-hemisphere direction. For trend T clockwise from north and plunge P positive downward, E=sinT cosP, N=cosT cosP, D=sinP. For a plane, first use pole T=wrap(dip direction+180°), P=90°−dip. $E^2+N^2+D^2=1$ and D≥0.

Step 2. Project from the upper pole. Put the upper projection point at S=(0,0,−1). The line S+t[(E,N,D)−S] reaches the equatorial plane D=0 when −1+t(1+D)=0. Therefore t=1/(1+D). Its normalized equatorial coordinates are E/(1+D), N/(1+D).

$$x=160+140E/(1+D);\ y=160-140N/(1+D)$$

$$\rho=\cos P/(1+\sin P)=\tan[(90°-P)/2]$$

At P=90°, ρ=0; at P=0°, ρ=1. Pole dip α gives ρ=tan(α/2). For α=60° toward 90°, pole T=270°, so ρ=tan30°=0.5773502691896 and x=79.1709623135, y=160. The equal-area alternative uses $\rho=\sqrt{(1-\sin P)}=\sqrt{2}\sin[(90°-P)/2]$, giving x=61.0050506339 for the same plane.

K27A. Inverse query, 10-degree grid and projection consistency

Step 3. Invert a clicked empty point. Normalize screen east e=(x−160)/140 and north n=(160−y)/140; $q=e^2+n^2$. Reject q>1 outside the rim. The stereographic sphere point is (2e/(1+q),2n/(1+q),(1−q)/(1+q)). Thus P=90°−2atan√q and plane dip α=2atan√q. Pole trend=atan2(e,n); plane direction=wrap(trend+180°). Convert radians to degrees. At the center, a horizontal plane has no unique direction. An actual pole hit returns its stored observation instead of inverse pixel-rounded values.

Step 4. Build the reference grid. For each φ=10°,20°,…,170°, meridian points are (sin u cosφ, cos u, sin u sinφ), with u=0°…180°. For each λ at the same 10° spacing, parallel points are (sinλ cos v, cosλ, sinλ sin v), with v=0°…180°. Each point is unit length and lies on the lower hemisphere. Project with Step 2. The implementation uses 2° steps: 91 points per curve, 34 curves. Thirty-degree curves are slightly darker; the rim has 10° bearing ticks. This grid is a display aid, not a new angular measurement.

Step 5. Use one transform for every layer. Poles, mean/observed great circles, cones, slope/friction curves, critical-zone cells and intersection markers share the selected projection. Great-circle lines retain the spherical trace in K3. Density first inverts each screen-grid cell through that projection, then evaluates the existing spherical kernel/count; the grid-normalized peak and interpolated contour pixels can differ after a switch. No spherical observation, cluster membership, Fisher statistic or kinematic count changes.

Step 6. Preserve the display convention. Analysis views and portable files retain their explicit projection, as do SVG/PNG figure captions. A legacy view/file without a projection retains its original equal-area convention on explicit load. Ordinary Stereonet analysis opening starts at equal angle and Observed set, without removing saved scopes, interpretations or views. Phone live/Kinematics and Engineering offer the alternative selector; the compact Desktop linked net uses equal angle. Rose plots are azimuth histograms and do not acquire the stereonet grid.

Independent control	Expected result
Horizontal plane	Pole at (160,160); cursor direction undefined
Vertical plane	Pole on radius 140; great circle is a full diameter
Same plane, both displays	60°/90° query retained; different radial coordinates as above
Changing projection during density	Old worker response cannot replace the current projection grid
Underlying engineering result	Same candidate population, pair counts, classifications and statistics

Primary projection reference: Snyder, J.P. (1987), Map Projections - A Working Manual, USGS Professional Paper 1395, stereographic and Lambert azimuthal equal-area chapters. USGS report. The hemisphere normalization, grid and hand checks above are independently derived. Regression controls use the Cartesian ray construction, not a renamed call to the implementation. This display verification does not calibrate field bearings.

I23. Locate controls without changing the analysis basis

Controls are grouped by purpose, retaining their inputs, units, equations, identities, populations and review/save contracts. Opening remains equal angle (Wulff), colored by Observed set; explicit Schmidt display and saved-view choices remain available.

Work area	Actions and population
Data & filters	On desktop, Source & filters opens import, source, project, feature and outcrop controls; Reload field data stays visible in the source strip. Phone Data & filters retains its original actions. Active view & action scopes identifies the current population. North-reference correction and Undo analysis edit remain separate actions.
Stereonet	Projection and Color by are beside Plot layers. The legend uses the same color and circle/square/triangle/diamond/cross/plus marker as its group in the plot, with name and count. Symbols identify displayed groups, not geotechnical quality or probability.
Measurement selection	Click/query, circle/freehand and row selections use the existing IDs. Selection & review actions groups include, exclude, duplicates and reviewed deletion. Exclude retains the source; deletion has its own review and recovery contract.
Follow-up analysis	Engineering input scope independently chooses all or selected plotted rows. Its default is all. Slope stability continues using selected plotted rows when a selection exists, otherwise all plotted rows. Moving buttons does not equate these two scopes.
Sets & statistics	Assignments, observed-set copying and statistical warnings retain their meanings. Suggest joint sets, angular-outlier review and field adoption are disclosed separately. Changing cluster settings still invalidates old suggestions.
Files & exports	Analysis JSON backs up the session/provenance/views and required field snapshots. The two CSV actions obey Rows and statistics scope. Figures use all plotted accepted interpretation even when CSV uses selection. A pending suggestion is not silently accepted.

The plot opens in view; Filters, Rows, Sets and Files & exports navigate the groups. Narrow windows put the plot first. Icons retain text labels and keyboard focus. Disclosures do not change an input or selection.

Slope control group	Preserved behavior
Case settings & actions	One shared Case name, Common north reference, New blank case, Load example case, Restore previous inputs and Save as new case remain accessible in every setup step. A correction link opens this group and focuses a missing field. Geometry still owns the analysis-model selector.
Workflow and live model	Six setup steps, Back/Next, input diagrams, live model visibility/focus, readiness, surface feedback and result warnings remain distinct. The model and calculations use unchanged case geometry.

Slope control group	Preserved behavior
Reports	One shared menu retains Calculation report and Detailed calculation report. Both use a fresh current-case snapshot at generation. Standard packages and full discrete/source walkthroughs have different detail. Result JSON, OBJ, model-view SVG, audit CSV, draft JSON, saved-case files, property libraries and optional studies keep their separate scopes.

I24. Numerical agreement in portable report replay

A detailed package discloses exact inputs, full recorded results and the computational source. Run node reproduce.mjs after extraction with Node.js 22 or later. Source-file hashes are checked before recalculation. This is repeatability of the stated implementation, not independent engineering approval.

Comparison	Required agreement
Record structure	The same object keys, array lengths, data types, nulls, statuses, text and other non-numeric values. Missing, changed or relabeled fields fail.
Finite numeric leaves	For each actual a and recorded b, require abs(a-b) <= 32 x Number.EPSILON x max(1, abs(a), abs(b)). Number.EPSILON = 2.220446049250313e-16. Each numerical leaf is compared separately.
Reported roundoff	The script prints the number of differing numeric leaves, largest absolute difference, and largest difference divided by its allowed bound. Larger differences fail with the precise result path.

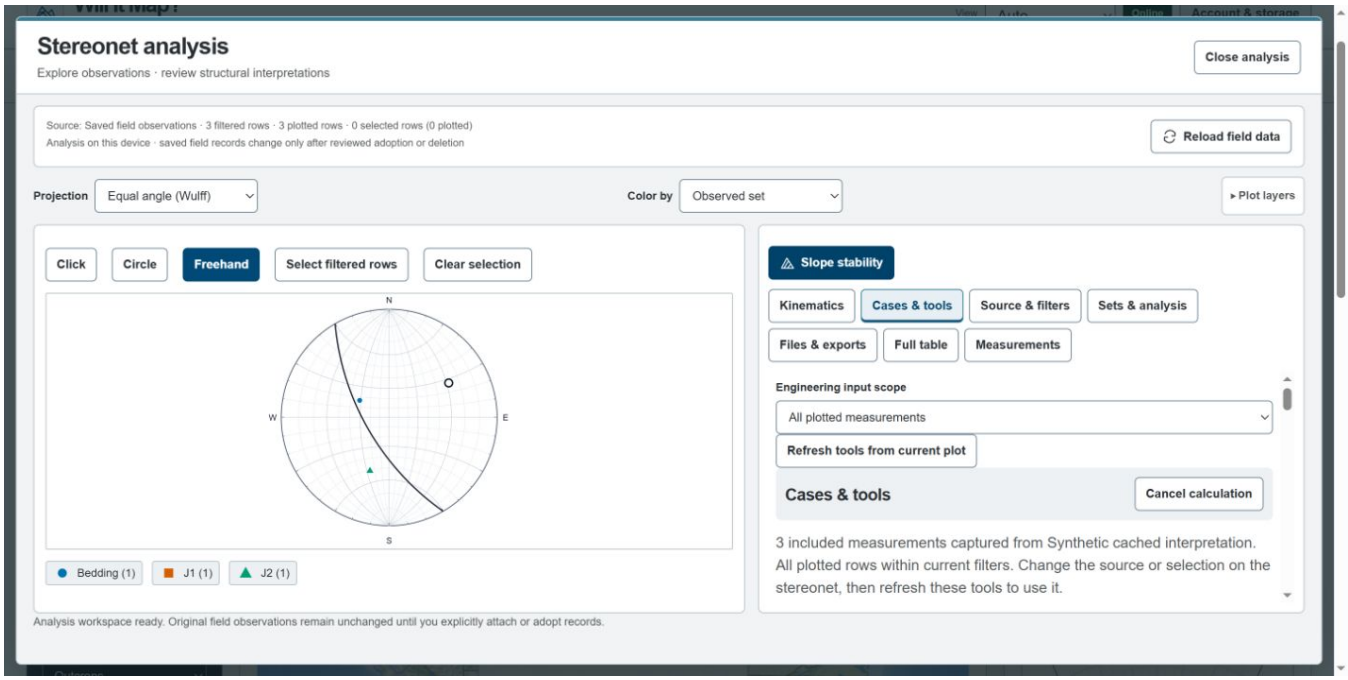
This is an implementation comparison convention for last-bit differences between JavaScript engines. It does not change inputs, stored results, formulas, solver stopping rules, engineering tolerances, field uncertainty or displayed factors of safety.

A browser/Node control returned an intermediate equivalent friction angle of 20 versus 19.999999999999996 degrees: abs difference 3.552713678800501e-15 degrees, compared with an allowed 1.4210854715202004e-13 degrees. Both retained FS 0.3639702342662023. The independent dry, cohesion-free planar control is tan20 / tan45. This bounded example is not evidence for every geometry.

Regression controls accept this last-bit variation and reject an FS change of 1e-8, changed mechanism text, omitted result fields, null/text substitution for a number and changed vertex-array length. Preserve a failed package unchanged; investigate the reported path instead of rounding the saved file or increasing the allowance.

I25. Keep the plot, population and interpretation in view

Desktop retains one main stereonet with Kinematics, Cases & tools, Source & filters, Sets & analysis, Files & exports, Full table and Measurements in a scrollable right-hand panel. Slope stability remains a separate factor-of-safety workflow. Narrow screens stack the same controls. Expand stereonet hides surrounding panels; Restore workspace brings them back. Selection stays available above the plot. Layout and camera changes remain view-only.



Actual synthetic interface: three observed sets on the main net, persistent Click / Circle / Freehand / Clear selection, and Cases & tools beside it. Select a pole or draw around a group; Shift adds to selection. Clear selection removes only the selection, not observations. Measurements holds Find in this list, 50-row pages and selected-pole details. List search does not change the plotted population.

Cases & tools contains Cases & sensitivity, Stereonet tools, Traverses & core, and Report & exports. This replaces the former separate engineering dialog. Numerical methods, source observations and saved-case signatures are unchanged. I33 describes source refresh and the distinct live-screen versus named-case input bases.

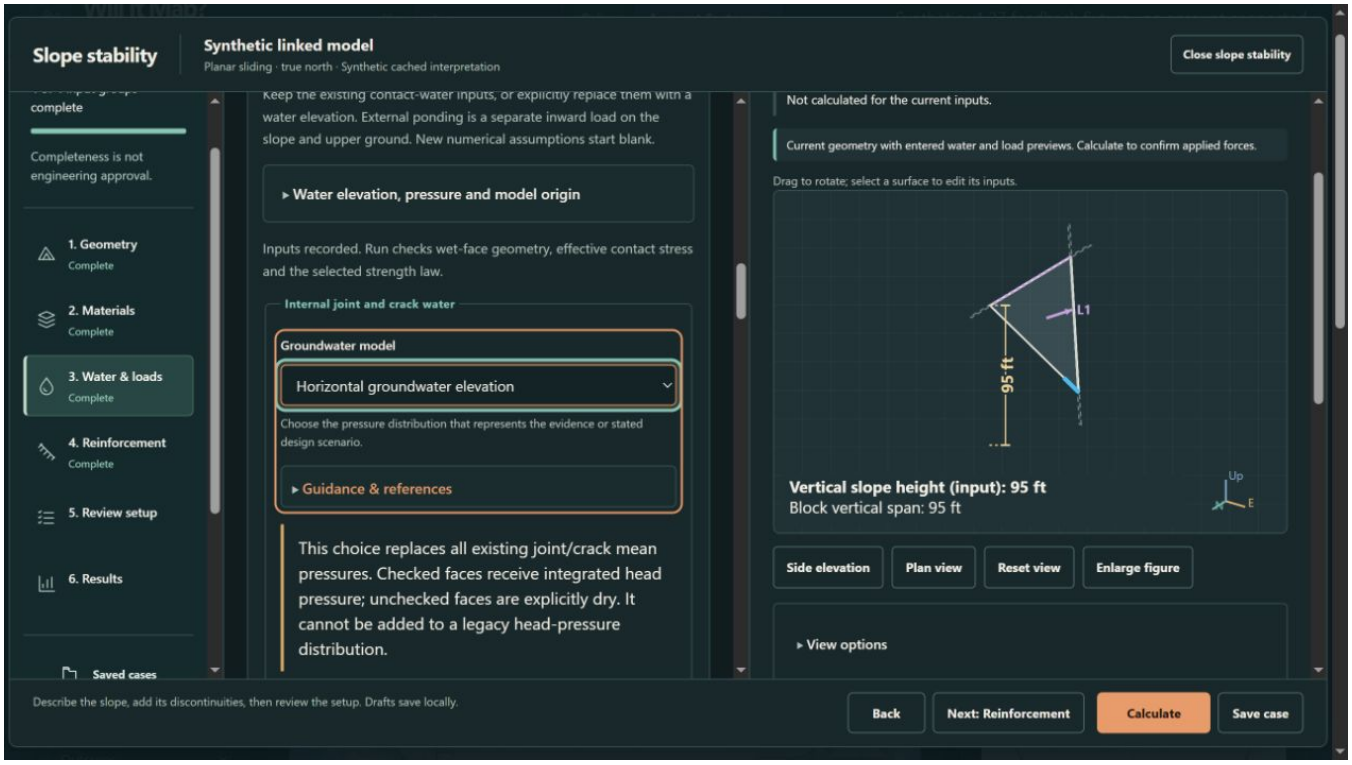
I26. Inspect the slope model without assigning an assumption

The current block precedes the longer surface and stage details. The adjacent context identifies case, mechanism, common north, source-analysis name, available-measurement count and local draft status. Available measurements are the case-opening context, not the number of block boundaries, selected contacts or applied statistical means. Draft saved on this device is distinct from Save case, a case file, a report package or a field cloud backup.

Visible object / current step	Inspection and meaning
Materials	Select a contact face to focus its friction input or selected strength-law controls. Rock body · unit weight focuses whole-block unit weight. Contact colors locate boundary properties; no interior geology is inferred.
Water & loads	Select a blue wet-face area to inspect its corresponding active water input. Under an elevation model, an inactive derived mean is not enabled; inspect Groundwater model instead. Purple pressure areas and named point-load arrows select the load by stable ID.
Reinforcement	Select a shaft or Current-stage inputs entry to open that same reinforcement definition and its layout inputs. Gold selection rings indicate inspection, while engagement/capacity qualifications retain their own labels. Prescribed force without a geometric layout has no invented shaft.
Both directions	Focusing a corresponding input highlights its face/object. Native labeled buttons give the same inspection path without precise pointing. A click inspects; an actual drag only rotates/pans. Cancelled gestures do not assign inputs.

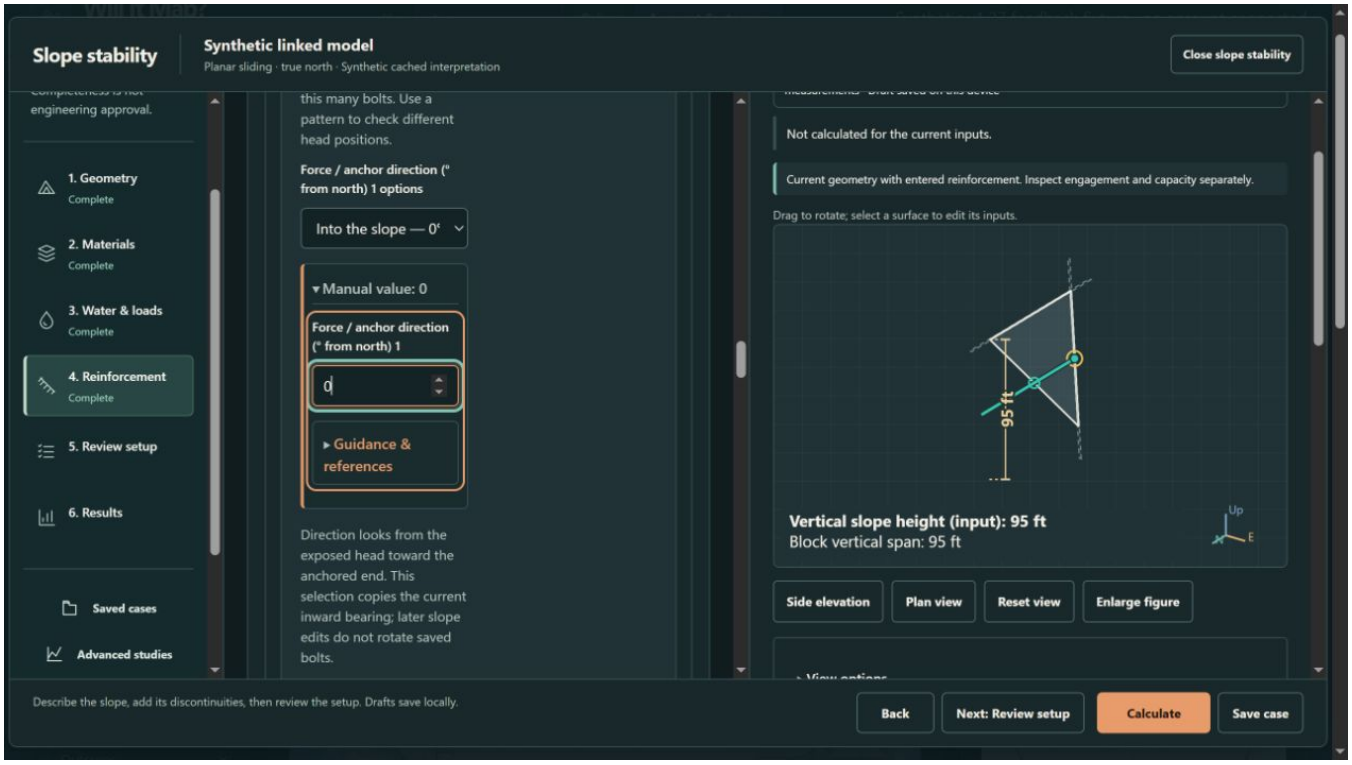
Links change view/focus only. They do not enable seismic loading, choose a water law, replace material values, rotate a saved bolt, adopt field means or start a calculation. A deleted load/support is reported as absent rather than falling back to another definition. Supported field/model validation and meaningful blank inputs remain unchanged.

I26A. Inspect the water-area preview and its active input



Actual synthetic water-input inspection: the blue area is an entered head-pressure preview on the finite failure plane. Clicking it focuses Groundwater model. Purple L1 is the entered point-load direction; upper-face pressure is a separate load. Neither the water area nor a direction arrow establishes calculated equilibrium. See the hydraulic and load chapters for integration equations and location limits.

I26B. Inspect reinforcement without assigning a design value



Actual synthetic reinforcement inspection: the shaft selects Trial bolt A by identity, opening its direction under the layout step. This 100 ft teaching shaft isolates the UI connection; it is not a typical length or installation recommendation. Geometric engagement is separate from steel, bond, plate and service-load qualification.

I27. Mode relevance, stale calculations and phone boundaries

State	Required interpretation
View hiding / inspection	Collapse, focus, model layers and input-reference disclosure preserve case/session values. Only mode-relevant fields are displayed; blank required values remain incomplete. Short meanings reuse the same sourced guidance. Full definitions, examples and citations remain in Guidance & references.
Physical mode changes	While editing, inactive load components remain in the raw draft, so switching a point load to pressure and back restores its entered magnitude/trend/plunge. A pressure mode with blank pressure fails readiness. Canonical saved cases validate the chosen physical model; irrelevant inactive raw-draft fields are not all retained. Assessed inactive Mohr-Coulomb entries are retained for strength-law round trips (I29); only the selected law supplies resistance. Deliberately removing an assumption follows its existing explicit rules.
Out-of-date calculation	Changing a numerical input clears the old result and overlay. If a result existed, Result out of date and the existing Recalculate action appear. Run Recalculate to produce a current result; camera/inspection alone never makes it current. Current calculation describes input freshness, not acceptable FS or engineering approval.
Phone workflow	Field/Structure/Data retain capture, review, full device backup, recovery and explicit online-backup state. Advanced tools remain available. Local SVG feedback adds no remote graphic dependency. Save matching manuals separately for offline reading.

Scoped checks preserve a linked case before/after inspection, point-load draft values and missing-pressure requiredness. Actual Chromium manual-save, exact full-backup download/acknowledgement and field-note recovery passed. The iPhone keyboard report remains unverified: a short Chromium viewport and the bounded focus-clearance adapter are not a physical iOS keyboard test. No speculative resize-scroll hook was added. These checks do not certify physical sensors, all devices, cloud recovery, complete accessibility or engineering designs.

I28. Clear actions and field keyboard affordances

Area	Preserved basis and clearer presentation
Slope stability	Prescribed Geometry, Materials, Water & loads, Reinforcement, Review setup and Results sequence; original scrolling and current case/model context. Calculate/Recalculate is the primary calculation; Save case has a separate outlined treatment. Guidance, diagrams, sources, physical assumptions and critical warnings remain accessible.
Data	Full device backup and safe merge recovery remain direct local actions. Online status and last cloud-check result remain visible. More backup actions & recovery retains restore, account, diagnostics and conflicts. Errors/conflicts/paused deletion open its details. Offline cache & browser storage is technical information. Delete or clear data retains the two distinct device-only and device-and-cloud scopes, warnings and confirmations.
Field forms	Existing record-required inputs are visibly marked required; no requiredness is changed. Blank optional observations remain unassessed. Latitude/longitude labels identify decimal degrees; physical distance/elevation units remain feet and scientific pressure/strength units retain their definitions.
Keyboard	Single-line field inputs offer Next. Enter advances to the next visible editable input in the same existing card, skipping hidden/read-only/disabled controls. The last visible single-line field uses a Done hint; it never saves automatically. Textarea Enter remains a newline; modified/composing keys are not intercepted. Nonnegative numbers suggest a decimal keyboard; signed coordinates/declination/elevation use a text-keyboard hint rather than a decimal-only hint; browser/device behavior still needs checking. No value, unit or save behavior is changed.

Source/record engines, calculations, scoring, method domains, requiredness and source populations are unchanged. Existing RMR, Barton-Bandis, visual GSI/Hoek-Brown and independent slope-hazard protocols remain complete. A required record ID is not evidence that every optional observation needed for design was collected. Calculation completeness remains separate from engineering approval.

Scoped synthetic Chromium checks cover list/plot selection, secondary panels, normal/short/narrow layouts, field order and keyboard focus, Data file recovery and the slope setup-to-results/save/export path. The current synthetic dry cohesion-free planar control with dip 45 degrees and friction 20 degrees returns FS 0.3639702342662025, matching tan20/tan45. The reported physical iPhone keyboard jump was not reproduced on an iPhone; no speculative viewport/scroll workaround was added. These checks are not hardware calibration, live-cloud recovery, formal accessibility acceptance or universal design validation.

I29. Strength-law round trips and location completeness

O-03: saving validates a canonical case without replacing the live editor inputs. Save case and Save as new retain the device draft, including incomplete inactive entries. Assessed finite in-range Mohr-Coulomb friction and cohesion are also retained in saved cases when Barton-Bandis or a power curve is selected. Unassessed inactive MC entries are saved as null rather than manufactured zeros; raw draft input remains available separately. Calculation copies use their required unused placeholders, including for a third wedge contact, without converting those saved nulls into observations. Only the selected law contributes resistance. Changing back activates the displayed values; an incomplete reactivated input blocks calculation, including after saved-case reload.

Synthetic hand control: the planar 95 ft / 85-degree slope with a 45-degree plane, unit weight 363.84 pcf, friction 20 degrees and cohesion 10 psi returns FS 0.5465910029867309. Temporarily selecting JRC 0, JCS 1000 psi and residual friction 20 degrees, saving, then returning to Mohr-Coulomb reproduces that same value without re-entering the height. The geometry, normal/driving forces and MC equation in S remain unchanged. Reports capture and recalculate the current case; their normalized snapshot, result and visible active inputs must agree.

O-02: location completeness requires both numeric coordinate axes to be present, finite and within latitude +/-90 and longitude +/-180 degrees. Empty or whitespace strings, null and undefined are missing; numeric 0/0 is a complete pair. The notebook incomplete filter, labels and end-of-day count use that rule. Maps and GIS do not manufacture a point from a missing axis. Supported backups retain the original entries for review; this change does not infer or move observations.

S17D. Exact-factor and conditioning audits for toppling

The retained rectangular-column forces, strength reduction, contact inequalities and moment equations in S17A-S17C are unchanged. After the existing scan isolates one stable-to-unstable recurrence transition, 65 bisections retain lower (stable-side) and upper bounds. The reported candidate factor is the exact lower-bound factor f, and the complete column audit is evaluated at f itself. An audit at a different floating-point value cannot qualify f.

An isolated recurrence transition need not be an admissible contact-maintained equilibrium. For ordinary interacting-block toppling, repeat the existing force/contact/moment audits at factors f(1+delta), where delta is -1e-8, -1e-12, 0, +1e-12 and +1e-8. Every trial must pass its existing contact audits; the stronger-side trials must also retain recurrence stability. This is a conservative implementation acceptance check, not a change to friction, cohesion or force tolerances, and not a published universal engineering tolerance. The small perturbations test whether the result is an isolated numerical spike. Root convergence alone cannot prove contact admissibility.

thresholdAudit retains the final bracket, returned factor, exact probe factors, contact status, recurrence status and column issues. Results → Threshold conditioning checks shows the trial factors and issues, including when the exact-factor column table passes but its neighbors fail. If the exact or nearby checks fail, status is contact-unresolved and fs is null. A retained recurrenceThreshold is diagnostic only and must not be used as an accepted FS or a study recommendation. Full-slope block-flexure remains diagnostic under its separate restrictions.

O-04 synthetic control: H 36.4484775532037 ft, face 94.09536342309488 degrees, overall base 15.988807060290128 degrees, into-slope joint 80.90625886176713 degrees, column width 4.905610596002177 ft, depth 10.527105968352407 ft, gamma 121.15733916405588 pcf, base phi 14.595270303543657 degrees/c 9.538903285283595 psi, bedding phi 24.547112181782722 degrees/c 0, kh 0.46510783159174024 and kv -0.0407841014675796. Scale H, width, depth and base cohesion together by 0.1 through 10. A recurrence threshold about 0.01272869 persists, but neighboring contacts lose compression or violate inequalities; all tested scales withhold FS. This low threshold is not evidence of a false-safe design.

Passing control: one column, H 10 ft, face 60 degrees, overall base 30 degrees, joint into slope 70 degrees, width 20 ft, depth 3 ft, gamma 160 pcf, zero water/cohesion/seismic/support, basal phi 35 degrees. Its sliding control is tan(35 degrees)/tan(20 degrees) = 1.9238044001630872. The exact-factor audit and nearby contacts pass. Phi 15/25/35 degrees at length scales 0.1/1/10 reproduce the analytic control within the recorded numerical tolerance.

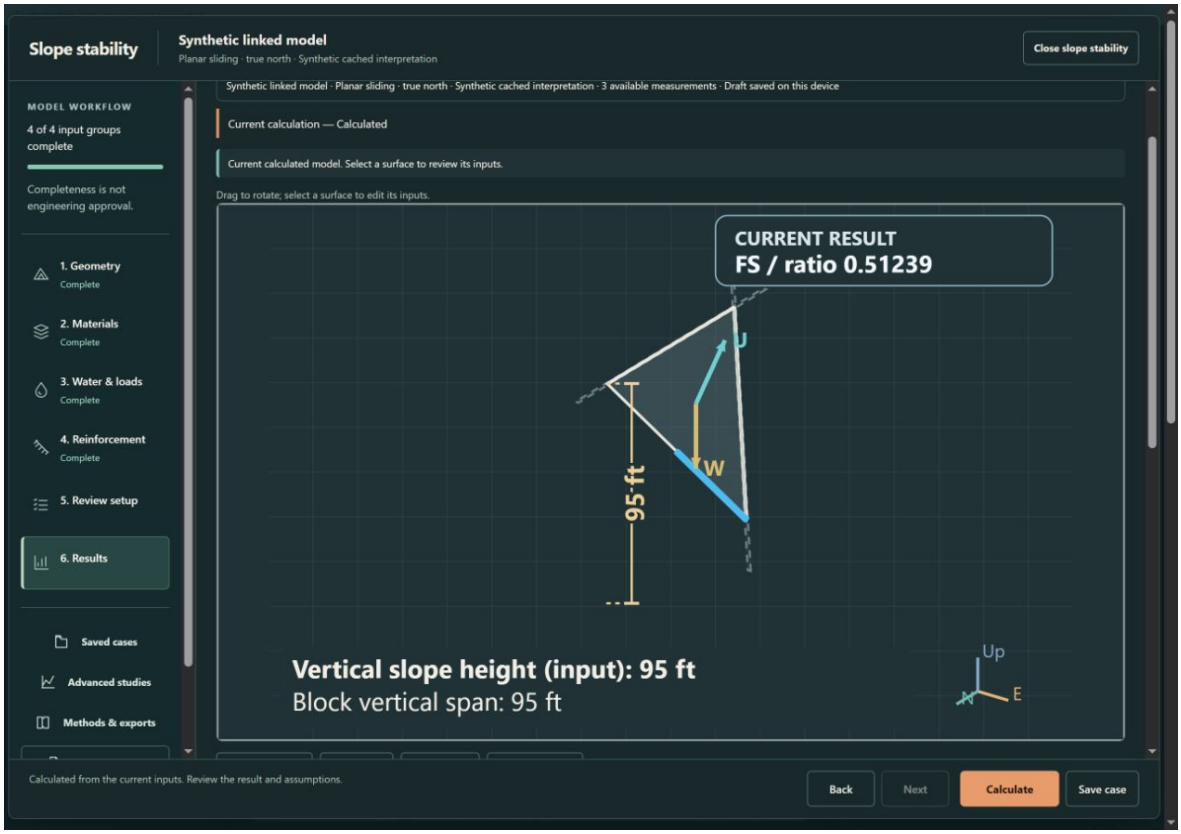
Numerical background: bracketing methods assume an appropriate function and convergence tolerance; converging a scalar root is not an equilibrium audit. See SciPy brentq documentation and its Brent reference. This app retains its own bisection/recurrence algorithm; it does not use or claim to implement SciPy.

I30. Wet footprints for planar head-water modes

O-01: the blue area represents the wet contact prescribed by the selected distribution, not a generic water table inferred from mean pressure. Existing water-force equations in S are unchanged. For mid-height and toe modes without a rear crack and with horizontal upper ground, f = percentFilled/100, wet vertical height = H f and wetted basal length = H f / sin(alpha). The footprint is the actual basal face clipped at that vertical height above the toe. Partial and full footprints therefore have area ratios f and 1; 0 percent is dry.

For crack-head and crack-only modes, clip the actual crack face at zbase + vertical water depth. Its wet inclined length is depth/sin(crack dip), and pressure increases linearly to gamma-water times depth at the base. A positive crack-head depth also prescribes pressure over the entire basal face with a drained toe; crack-only leaves the base dry. Depth zero produces no wet area; above-crack overflow is rejected. These footprint geometries follow the chosen pressure model and do not solve seepage.

Loading, review, results and the exported current model SVG retain these footprints. Invalid or incomplete assumptions produce an explicit incomplete-preview issue instead of claiming a dry valid model. Force arrows/results still come from the solver. A calculated pressure tooltip identifies the whole-face mean: force divided by 144 times the entire contact area, including any dry part. It is not the mean over only the blue wetted area. Before calculation, the head-mode preview supplies wet extent without an invented mean pressure. A whole-face mean-pressure input remains its own descriptive full-face assumption; no head extent is reverse-engineered from its average.



Actual synthetic v1.29 Results / Focus model: H 95 ft, face 85 degrees, plane 45 degrees, width 1 ft, gamma 363.84 pcf, MC friction 20 degrees/cohesion 10 psi; toe-head mode with water 62.4 pcf and 50 percent filled. The blue lower half is prescribed wet extent; U is the calculated water resultant direction. This case returns FS 0.5123874083589143. Directions and wet areas are different information; neither is a site groundwater observation.

K28. Live kinematics on the analysis stereonet

The desktop analysis workspace retains one stereonet at the left and moves controls, tables, interpretation, selection actions, comparisons and exports to the scrollable right panel. Switching a tool does not change the plotted source, selection or orientation values. Slope stability remains a separate finite-block workspace with a persistent shortcut. On narrower screens, the original vertical order returns, with the live kinematics panel in the plot section.

Show live kinematics starts enabled. A new analysis has no assumed slope dip, slope direction or friction angle: enter all three. The visible lateral-limit starting value is 20 degrees and is editable. Valid inputs trigger a debounced worker calculation after 300 ms without another dialog or a set-selection requirement. All plotted measurements is the initial population; Selected plotted measurements is explicit. Same-outcrop, survey, domain/reach, different interpreted sets and hypothetical all-pair association use K19-K20 predicates.

The worker uses exactly the K kinematic classifiers and their endpoint conventions. It tests every eligible pair and streams complete critical rows to temporary local storage. The nine summary counts use plane count for plane screens and tested nonparallel intersection count for pair screens. Bounded markers are for display only. Choose Highlight mechanism to show its screening region, black slope great circle, orange limiting boundaries, red critical pole rings or red critical intersection diamonds on the original plot. Gray diamonds show sampled background intersections. Observation colors and pole selection remain available; a red mark means a candidate, not an FS, probability, persistent plane or connected block.

North reference is inferred from the current population; unknown or mixed reference prevents calculation. The slope direction must be entered in that same frame. Blank, invalid, changed or canceled inputs clear previous results immediately. Obsolete worker replies cannot restore them. Population changes rerun the calculation; projection and highlight changes redraw its valid result. The CSV exports complete critical rows with orientation/context provenance, configuration and method version. Figure SVG/PNG includes current overlay and basis text. Settings are saved with the analysis; temporary results are recalculated, not restored as authoritative results.

Synthetic reproduction: true-north planes dip/direction 35/120, 65/240 and 55/20; slope 60/120; friction 30; lateral 20; hypothetical all pairs. There are 3 planes and 3 nonparallel pairs. Counts are planar 1, flexural 0, wedge 1, wedge-single 2, wedge-either 2, direct-toppling 1, oblique-direct 0, primary-base 1 and oblique-base 0. Reproduce the vector predicates in K on these same raw planes. No equilibrium or persistence check is added by the live interface.

I31. Predictable model rotation and pointer ownership

Live Geometry rotates around a fixed world-space center of the displayed model bounds, including the chosen contextual surfaces, dimension endpoints and visible bolts. Changing view cannot change any geometry input, volume, contact, load or calculated force. Automatic fit is held constant while dragging so an asymmetric projected outline does not repeatedly rescale.

Drag rotates the screen-facing side with the pointer. Horizontal drag changes view azimuth with the negative screen-x increment; downward drag increases the view elevation. Elevation remains bounded from -10 to 90 degrees. At plan view, azimuth acts as in-plane rotation; use Pan to translate the whole drawing without rotating it. Arrow keys follow the corresponding screen direction; Shift plus arrows pan. View-angle sliders remain explicit angle controls.

A gesture belongs to the pointer that started it. Further pointer presses, moves or releases cannot replace that gesture. Cancellation or lost capture ends it without selecting an input surface. The drag threshold still distinguishes a click from a rotation; ordinary surface inspection, Reset view, Plan view, Side elevation and zoom remain available. The corrected guards are tested with synthetic pointer sequences; a reported intermittent physical-device event is not proof that every possible device interaction has been reproduced.

I32. Retained survey geometry and reproducible case settings

Changing a mapping group from Window or Scanline to reconnaissance or selected critical joints retains entered geometry. If either face dip/direction or scanline trend/plunge is entered, both controls remain visible under retained geometry. Validation still requires a complete pair or neither value. Error handling opens the containing sections and reveals the requested control before focus. Complete the missing companion, including a legitimate zero, or deliberately clear both; the method, survey identity and original values are not silently replaced.

Cases & tools restores its valid saved Orientation population and Pair scope along with slope, direction, friction and lateral limit. Absent legacy choices use all included measurements and all pairs; the interface states those defaults. Invalid saved choices are rejected for review. Each run recomputes planes and compatible pair associations from current source rows. Named-case loading continues to compare the saved source signature; changed source data cannot silently reuse the old case.

Hand-check population control: four true-north planes at dip/direction 45/150 and 50/155 in set A/outcrop 1, and 45/210 and 50/205 in set B/outcrop 2. Interpreted means produces two planes. Same outcrop excludes their only cross-outcrop pair: zero tested intersections and one scope exclusion. Leaving, reopening and running the unchanged settings must retain those denominators. Raw measurements with hypothetical all pairs would instead produce six pairs; these populations are not interchangeable.

Live stereonet screening stores its own nested settings and cannot overwrite the separate Cases & tools population, association or named cases. Its first configuration may inherit the saved angles and association; its raw-measurement population remains explicit. Later edits are independent. No kinematic predicate, equilibrium equation, unit conversion or source observation changes.

Slope-case names are trimmed and limited to 120 characters. Overlength values are rejected before persistence; the same exact canonical name is used for lookup and storage. Re-saving one unique name updates that case. Historical duplicate labels remain intact and are numbered in the chooser; automatic overwrite is blocked. Load and review each entry, then deliberately remove only unwanted copies or save a distinct name. Existing source signatures and the 50-case limit remain in effect.

I33. Embedded tools and selection lifecycle

Click queries the nearest pole or an empty-net orientation. Circle selects poles within a dragged radius; Freehand closes the traced polygon for point-in-polygon inclusion. Shift adds members; Clear selection changes only selected IDs. These controls remain above the main plot across right-panel changes and expanded plot mode. Projections still use the inverse and forward transforms in K27; selection does not rewrite orientation measurements.

Opening Cases & tools captures the chosen All plotted measurements or Selected plotted measurements source. The four tool pages retain named cases, interpreted-set means, sensitivity, density/rose and construction tools, traverses/core/scanline workflows, and complete reports. Switching pages preserves in-progress tool inputs. Tools are initialized only when opened; worker calculations and offline assets remain local.

A source or selected-scope population change invalidates pending work and case results. Calculation, save, conversion and export actions refuse the obsolete snapshot. Refresh tools from current plot requires deliberate confirmation before replacing unsaved tool inputs/results. Named saved cases remain. Refresh with no eligible rows fails without discarding the existing form. Named-case loading still checks source signatures.

The Kinematics panel remains the quick live raw-measurement screen. Cases & sensitivity has its own explicitly displayed angles, population and pair scope for named studies and reports; its report uses that case, not an unrelated live overlay. Their settings remain separate and neither save replaces the other. Case/plot previews belong to the labeled tool; they do not silently redefine the main plotted observations. Existing equations, quantities, unit conventions, north validation and source provenance are unchanged.

I34. Interface appearance and engineering meaning

The current interface uses Arial with blue controls, charcoal navigation and neutral work surfaces. Daylight and Dark modes retain their existing settings and responsive layouts. No corporate logo is included. Selected controls retain text, pressed states and visible focus; color alone is not the selection instruction.

Observed/interpreted set colors, critical kinematic symbols, water and material overlays, and validation warnings retain their existing engineering meanings. This appearance update changes no equations, defaults, source identities, storage, exports or field measurement procedures. Older method screenshots illustrate their named calculation workflow; I25 shows the current visual shell.

I35. Accessible controls and enlarged text

The interface applies the supplied HDR internal-app accessibility baseline: readable text contrast, visible keyboard focus, native labeled controls, at least 24 CSS-pixel controls and linked field instructions. This public app does not treat internal-policy exclusions as a waiver, and these changes are not a complete WCAG certification.

Settings offers 200% text. Relative text sizes also respect browser text preferences. Enlarged analysis and slope workspaces use scrolling content rather than squeezing plots beneath fixed-height controls. Browser zoom is also available. Tables retain horizontal scrolling for their two-dimensional records.

Use Tab and Shift+Tab, Enter or Space on controls, and Escape to dismiss ordinary dialogs. Focus returns to the launching workflow. Skip to content passes repeated navigation. Select observations with table checkboxes or measurement-list controls rather than requiring a drawn selection. In the slope model, arrow keys rotate, Shift+arrows pan, plus/minus zoom, and Home resets; named surface buttons provide another way to inspect inputs.

Live kinematics identifies invalid numerical fields programmatically and links the status and visible hint to them. Correcting a value clears its invalid state. Input bounds, geometry, north-reference validation, calculations and data storage are unchanged. Optional sensors and dragging do not replace manual numerical entry and controls. Reduced-motion preferences suppress interface animation.

Evaluation uses synthetic browser data, keyboard actions, contrast/target measurements and enlarged layouts. Physical devices, screen-reader combinations and externally controlled authentication require separate acceptance testing. The PDF guides retain navigable contents and readable formulas; they are not claimed as PDF/UA-certified documents.

Expanded Field sections include bottom spacing around their final control. Project setup separates Geological domains, Save project and Manage this project so creation and management controls remain visually distinct. Rock type, color and texture pickers restore the field view when a choice or Cancel closes them. The phone sensor panel groups strike, dip and dip direction with the capture control, keeping north reference and current quality visible. Position instructions and historical-reading guidance remain expandable below. Sensor capture confirms success or failure inline without moving focus or opening an app popup. Save-induced layout changes retain the capture position unless the user navigates or scrolls. Poor-quality capture requires an inline acknowledgement for each saved reading. Recovery merges copies whose contents and context match despite differing timestamps, preserves genuinely different drafts, rejects stale list updates, and takes the logger to the recovered input. These corrections do not change numerical inputs, defaults, equations, saving or deletion confirmation.

I36. Discontinuity averages and embedded field references

Default to average is an explicit choice below Enter independently. It uses only the active Structure set in the active project and outcrop. The same axial-normal averaging method described in F6 supplies strike, dip and dip direction; it is not an arithmetic average of bearings. Incompatible north references or invalid members withhold the option.

A control pair with RHR strike 0 degrees and dips 30 and 50 degrees in one north-reference frame gives mean strike 0 degrees, dip 40 degrees and dip direction 90 degrees. Another outcrop or set is outside that population. The selected mean is an interpretation, not another independent field measurement.

The discontinuity stores orientationMean with set identity, count, mean orientation, north reference, angular scatter and source measurement IDs/revisions. measurementId remains blank because a mean is not one measured row. Opening a saved record preserves its snapshot; Refresh from active set explicitly recomputes it. Manual orientation edits mark the retained source mean as modified. Ordinary backups retain this optional provenance object.

Every Barton-Bandis input has an embedded procedure table. Local diagrams illustrate aperture, profile length/direction, hammer orientation, smooth-surface tilt testing and effective normal stress. These are original measurement diagrams; the profile sketch is explicitly not a numerical JRC template. They cannot supply a universal rebound-strength calibration or basic/residual friction angle. Keep the referenced procedure and site-specific test evidence.

Local guide assets are included in the offline shell and full-screen image viewer. Source links remain available for further reading. Field Use Guide Protocols 2.3, 4.1 and 7.2N describe the working sequence. Browser/device acceptance for this debugging batch remains pending; source, synthetic regression and artifact checks do not establish physical-phone accuracy.

I37. Read the detailed calculation worksheets

The detailed report groups related calculations in their original order. Each group explains its purpose. Each numbered step separates the governing equation, the substituted values and the result with units. Step IDs link the reading copy to discrete_calculations.csv and discrete_calculations.json; the step IDs identify the rows in this generated package; branch-specific rows follow the accepted result.

Reading aid	How to use it
Group index	Jump to geometry, loads, contact strength, equilibrium or the named trial.
Common symbols and units	Check the meanings of V, A, unit weight, weight, driving force, normal reaction and resistance. Coordinate order follows the equation and model.
Use these values	Read the rounded substitution beside the governing equation. Full precision is used internally.
Result	Up to six significant digits, with thousands separators. Scientific notation retains small nonzero values. Unavailable never means zero.
Exact arithmetic and source	Expand to read the original substitution, result digits, source basis, implementation module and any recorded reconstruction difference.
Exact appendices and companion files	Retain the full inputs, results, worksheet CSV/JSON, computational source and offline replay.

For example, the reading copy may show 123,457 lbf while its exact arithmetic retains 123456.789 lbf. This is display rounding, not an altered input or force. Carry the exact operands from the expanded arithmetic or companion files when independently reproducing a result.

An intermediate reconstructed ratio does not establish an accepted factor of safety. Read the governing result status and model limits. The report retains contact loss, unsupported branches, diagnostic flexure and other withheld outcomes. Mechanical equations, numerical tolerances, records and cloud schema are unchanged. Physical-phone acceptance and professional engineering review remain separate.

I38. Contact branches, support geometry and recoverable edits

The detailed worksheet uses the support point recorded by the accepted isolated-block solution. Its height above the base is the normal projection of support point minus toe. With a 10 ft block, an active support at height fraction 0.25 acts 2.5 ft above the base. In the synthetic 1,000 lbf horizontal-support example, its signed tangential moment is 2,349.231551964771 lbf-ft. The report no longer substitutes an inactive legacy height fraction. Active groups must satisfy the existing common-height rules; the solver and its factor of safety are unchanged.

A released wedge contact has applied effective normal stress, shear stress and resistance all equal to zero. The report states that branch before evaluating any strength equation. It does not compute log10(0) for Barton-Bandis or apply the fitted power-law intercept at an unloaded contact. Loaded contacts retain their actual law and recorded effective stress; a zero-contact row is not a laboratory extrapolation.

A copied discontinuity mean retains its original source snapshot. Changing its physical plane or north reference in either phone or Desktop marks the orientation independently edited and hides Refresh from active set. Comment-only edits, no-op values, equivalent 0/360 bearings and equivalent entry modes retain the snapshot link. Enter independently deliberately detaches it; choosing Default to average again creates an explicit new snapshot. Dips 30 and 50 degrees at strike 0 give mean dip 40 degrees; changing the saved dip to 65 degrees retains the 40-degree provenance as independently edited.

When the stereonet source changes, Cases & tools keeps every panel available for reviewing entered values. Navigation, Cancel calculation and closing the dialog remain available. Calculating, converting, saving and exporting still require refreshed source data. Moving among panels does not clear the stale-source warning or refresh the captured population.

Restore and Discard compare the exact displayed draft revision in an atomic local-storage transaction. A changed or removed draft refreshes the list and leaves the editable form and active context unchanged. Restore accepts a durable copy before changing the screen, preserves displaced unfinished work, and keeps any later source revision separately recoverable. User typing during context persistence is not repainted by late completion. Recovering a draft does not save a field record; review it and use the record Save action.

This correction changes report reconstruction and workflow safeguards. Mechanical equations, prescribed engineering inputs, units, field collection order, strength laws and cloud schema remain unchanged. Synthetic adapters and local browser tests do not establish physical-phone calibration, live cloud recovery or engineering acceptance.

I39. Resolve orientation evidence before analysis

A quadrant attached to dip is directional evidence. When converting a legacy axial strike, the app selects the perpendicular dip direction that agrees with that quadrant, then derives RHR strike. N70W / 60 SW becomes RHR strike 110 degrees, dip 60 degrees and dip direction 200 degrees. The same strike with 60 NE becomes RHR 290 and dip direction 20. N20E / 45 NW becomes RHR 200 and dip direction 290; with 45 SE it becomes RHR 20 and dip direction 110. Both RHR and dip-direction entry use this check. A conflicting explicit direction or incompatible quadrant blocks conversion. A failed conversion preserves the legacy strike and entry mode for review.

Imported or historical measurements can contain disagreeing strike, dip direction or normal vectors. The review flag compares those representations without selecting one as authoritative or rewriting the record. A comment-only edit, no-op orientation edit or unchanged north correction preserves all original orientation fields. Review the actual observation and make a deliberate orientation correction when justified. Conflicting measurements are withheld from a set mean and marked unresolved in analysis rather than silently giving different planes to different consumers. Exports and backups retain the original evidence.

Copied set means are shown with six significant digits in editable fields. Saving an untouched display retains the full-precision source snapshot and exact orientation. Deliberate orientation edits detach the mean link while retaining its provenance. Single-reading and mean copy actions fill blank or previously auto-filled feature/tool fields; manually entered classifications and tools survive. In particular, Unspecified can clear an earlier auto-filled classification, but cannot erase a manual choice. This supersedes the earlier unconditional-clear description.

Use live reading retains full numerical precision. Poor-quality acknowledgement belongs to the current project, outcrop, set and reference context and resets after use or a context change. A previous acknowledgement cannot authorize a later capture in another context. These checks do not establish physical sensor calibration or resolve an unknown north basis.

I40. Reviewable field actions and backup comparisons

Restoring a legacy draft configures its text/number input type before assigning a cardinal bearing. The restored form therefore retains N70W rather than letting browser number-input sanitization blank it. Interrupted restores release a redundant claim only when another equivalent durable copy remains; a unique recoverable copy is retained. Restore still does not save an observation.

Saving an untouched discontinuity asks for explicit inline confirmation. Partial observations remain valid evidence and do not require a completed strength calculation. The compact sticky manual Save row and focus scrolling keep the next reading accessible. Status messages sit in the context header and clear on tab change. App dialogs provide explicit Confirm/Cancel and Escape for rename, exact-value edits and destructive actions. Larger phone labels and the cloud-status target improve legibility and touch use.

Acknowledged backup comparison hashes canonical record content: object keys are sorted and revision-only metadata is excluded. The exact downloaded-file hash remains byte-specific. Acknowledgements from the former comparison format are retained as backup evidence but ask for a new acknowledged file before presenting the new content comparison. No original observation, export field or backup schema is removed.

The field interface uses Collect, Map, Analyse and Data. Collect opens the notebook and outcrop hub; Readings opens capture and manual entry; Joints opens discontinuity observations. Existing scientific equations, units and physical field protocols remain. Native desktop-browser synthetic checks are distinct from physical iPhone, Safari, live-cloud recovery and independent field acceptance.

I41. Field navigation without changing engineering evidence

The phone interface uses Collect, Map, Analyse and Data. Start with a project name; optional project details, including magnetic declination, remain available in Project details & north-reference correction. Collect contains the notebook and outcrop hub. Readings opens the sensor/manual sequence; Joints opens the discontinuity form; Rock mass and Photos bring the original outcrop fields into view. Analyse opens the separate kinematics, set-statistics, geology and independent slope-hazard workflows. Desktop scientific tools retain their existing methods.

Notebook coverage counts four recorded categories: readings, joints, a complete basic RMR, and photos. A count is not investigation completeness, representative sampling, field readiness or engineering adequacy. The Map uses saved coordinates, with an accessible list of outcrops. Basemap tiles need internet; a missing basemap is not a missing saved observation.

Live north and the saved active-set north basis are separate. A true-north live reading does not establish that every saved record uses true north. Mixed and unknown references remain explicit. The live stereonet pole is an unsaved marker using the selected Wulff/Schmidt projection. Compare only compatible references. There is no new sensor accuracy estimate, automatic capture, or arbitrary outlier rejection.

Sunlight and night themes change presentation. Fonts are stored with the offline app. Saved device theme choices are retained; only an unset preference follows the operating-system theme. Local saved status and cloud-backup status remain distinct.

I42. Orientation authority, drafts and repeat observations

Manual Readings supports RHR strike/dip and dip direction/dip, using the existing orientation conversion. The saved measurement still contains RHR strike, dip, dip direction and its explicit north reference. Joint entry retains legacy text when needed. A new explicitly RHR strike of 290 degrees with dip 60 SW conflicts and is rejected; it is never silently rotated to 110. An existing legacy N70W/60 SW may convert to RHR 110 and direction 200 because its axial strike was not yet assigned an RHR meaning.

Deleting a primary bearing leaves it empty and clears the derived secondary. A missing primary is reconstructed only on an explicit entry-mode conversion. Recovery retains unresolved cardinal text without allowing a numeric input to erase it. Secondary-only imported orientations remain unresolved; notes-only saves retain their evidence. Resolve the original legacy or secondary-only record before Duplicate last. Check the displayed authority and physical dip side before saving.

A reviewed CSV convention selects the authoritative raw bearing; original cells remain unchanged. A deliberately changed imported direction updates derived strike/normal; unchanged or metadata-only edits cannot repair a contradiction, and a dip-only edit cannot choose between conflicting bearings. Retained analysis correction notes and applied-rotation fields describe prior interpretation. A later manual bearing or north-reference edit does not become certified by that history; select the actual reference of the current entered number.

Keep pins initially retain the same seven fields as earlier releases: plane type, tool, separation, roughness, infilling, weathering and water. Keep for next joint pins selected observational fields on this device. Context station, slope ID and rock type continue to carry forward. Angles, mean snapshots, trace lengths and strength-test inputs are not pinned. Review each carried value for the new surface. Partial observations remain saveable; an untouched-default record asks for explicit confirmation.

The rebound keypad appends to the original raw joint-wall or fresh-reference readings. Existing statistics show count, mean, minimum and maximum. Undo reverses only the exact latest keypad edit and never overwrites subsequent manual typing. No readings are discarded and no strength is inferred. Exact aperture remains in feet; a numeric entry is also displayed as millimetres using 304.8 mm/ft. Descriptive text is retained without a numeric conversion.

I43. Supported classification and interpretation limits

This release keeps the existing RMR89 category method and its input withholding rules. It does not round a Table E detailed condition score to 30/25/20/10/0, automatically infer joint condition from logged joints, or reuse a strength/RQD/spacing override reason as a new condition override. Select the supported condition category from the documented observations.

Visible trace length still records each endpoint separately, along with the exact measured length and lower-bound basis. Hidden-end evidence is retained. No class-only trace/aperture value, I-IX roughness mapping or new infill hardness/thickness classification is introduced. A visual prototype is not authority to add engineering categories to storage.

The existing cited JRC references, numeric JRC and method fields remain. Generated decorative roughness paths are not calibrated Barton-Choubey profiles. RMR, Hoek-Brown and Barton-Bandis use their existing equations, units, applicability restrictions and missing-data behavior. Rebound statistics are observations; JCS, friction and scale inputs require their own defensible basis.

Testing covers synthetic desktop-browser flows and numerical regressions. It does not establish physical-phone calibration, Safari acceptance, live-cloud recovery, or professional approval. The exact published build and independent review status are recorded separately in release evidence.

I44. Automatic phone declination: model and provenance

Phone sensor capture uses an east-positive correction exactly once: true bearing = wrap360(magnetic bearing + declination). An explicit project override, including zero, wins. Otherwise the bundled WMM2025 uses the device date and a phone GPS fix no more than 30 minutes old, falling back to saved outcrop coordinates. Transient GPS timeouts do not erase a usable fix. The calculation is offline; it sends no coordinates to a declination service. Location permission remains the browser operating-system choice.

WMM2025 is limited here to 1 January 2025 through 31 December 2029 and field altitudes from -1 to 10 km. Phone altitude is device-reported, nominally WGS84 ellipsoid metres; saved outcrop elevation has no mandatory vertical datum and is not substituted. Missing altitude uses an explicitly recorded 0 m ellipsoid assumption. The applied angle is rounded to 0.01 degree; the unrounded model value is also retained. This resolution is not a sensor accuracy claim.

Horizontal model field below 2000 nT withholds automatic correction (polar blackout); 2000 to below 6000 nT triggers caution. A reported position accuracy worse than 1 km triggers location review; this is an app review guard, not a WMM accuracy threshold. Missing position, expired model date or unusable correction leaves the phone magnetic and requires explicit poor-quality acknowledgement. Prefer waiting for correction before adding to a true-north set; mixed references cannot produce a valid common-reference mean.

A change in applied correction, source, day or outcrop context requires fresh sensor samples. Fix timestamps and accuracy metadata alone do not reset the buffer. A capture retains applied correction, model evaluation time, model value, position, fix timestamp/accuracy and altitude assumption. Its magneticHeading is the last sample top-edge heading, not an averaged magnetic strike. Recover the corresponding magnetic plane by subtracting the saved correction from the saved true strike/dip direction; dip is unchanged.

Live-to-joint copy retains an original sensor snapshot separately from editable observation fields. Later tool or orientation edits do not rewrite that historical snapshot; it does not certify the current edited values. Duplicate last clears the phone snapshot. A manually chosen conflicting tool blocks live copy until the operator explicitly selects Phone sensor. Imported/manual orientations retain their declared reference and are never silently re-corrected.

The regional model does not remove local magnetic interference, crustal anomalies, phone calibration errors or extreme geomagnetic-storm effects. Compare with a control instrument away from metal. Browser iPhone compass heading is magnetic; a native Compass app setting does not establish the web sensor reference. Device-specific acceptance remains outstanding.

Sources: NOAA/NCEI WMM2025 model and official test values; NOAA accuracy, polar zones and limitations; Apple webkitCompassHeading; W3C Device Orientation. The pinned Apache-2.0 implementation includes local UTC leap-year and official validity-window corrections. All 12 NOAA reference rows match their published rounding; this is computational evidence, not field calibration.

I45. Switch layouts while keeping unfinished work

Choose Desktop view beside the app name to open the desktop workspace. In Desktop, the same button reads Field view and returns to the field interface. The switch is outside the collapsed badges and More menu, so it is visible in both layouts. The existing View selector in Desktop still offers Auto, Field and Desktop; choosing the direct button sets an explicit view.

Switching changes presentation without reloading the page, submitting a field form, saving a desktop edit, or discarding work. Unfinished project/outcrop notes, manual readings and joint observations remain in their forms. Desktop cell edits remain drafts, including text being typed when the switch is pressed. The selected field context and desktop scope remain distinct and retained.

Return to the same form or desktop table and review its unfinished values. Use the normal Save action for a field observation, or Review & save edits for desktop changes. A layout switch is not a save, a verified cloud backup or protection from browser storage clearing. Before closing or updating the app, save work and keep an independent device backup using the existing procedure.

Verification used an isolated desktop browser with synthetic records: repeated round trips, active cell typing, unchanged stored records, keyboard Enter/Space, 320/390/740/1280-pixel widths and 200% text. These checks do not establish physical-phone, Safari or assistive-technology acceptance. No measurement equations, units, categories, north correction or record schema changed.

I46. Current audit: save, recovery and observation identity

This edition accompanies local candidate v1.35.4, Theory v49 and Field v47. Publication remains on hold. The overnight audit used isolated synthetic records, native Edge controls, mathematical references and simulated failures. Repairs do not establish physical-device calibration, production cloud delivery or universal engineering acceptance.

Save commits the values selected at the click. New typing remains unfinished and is linked to the same newly saved record, so the next Save does not create an accidental duplicate or use its own obsolete revision. This applies to project, outcrop and joint forms and queued independent-slope saves. Creating a structural set preserves newer typed names and a changed context; repeated Enter shares the pending-action guard.

Before replacing field forms, the app checks that unfinished input is stored. If a draft write fails, keep the page open and export a full device backup or resolve storage before retrying. A successful Save of another form cannot discard that unfinished input. Restoring one draft restores only that editor’s identity and revision; unrelated forms keep the freshly loaded saved revisions. A genuinely stale restored observation still requires review.

Deletion compares the confirmed record and its dependent records with current storage. Newer edits or newly added children require fresh review. Undo of an older deletion preserves a newer deletion’s recovery record. These protections cover field records and independent slope assessments; they do not authorize deletion without user review.

Device imports and cloud restore cross separate field and slope stores. They are not one atomic transaction. Incoming device recovery information is archived before records import; an archive failure stops the record import. A later slope-store failure explicitly reports that field records committed and slopes remain incomplete. Counts refresh, unfinished forms remain available, and the original file must be retained. Retry after resolving the error and review recovered copies before deleting anything. Repeating a conflicting import can create another recovered project copy.

Cloud restore results remain in a separate visible outcome message rather than being replaced by periodic queue status. Files & recovery displays import/export failures inside its open dialog. Neither a completed download nor an empty upload queue proves recipient/cloud readback. Offline readiness checks the active release’s complete cached shell; a controller alone is insufficient. Missing cache or failed installation is reported explicitly. Browser eviction remains possible; keep backups and verify offline reopening before travel.

I47. Current audit: numerical corrections and worked checks

Fisher mean confidence uses the finite-sample concentrated-population approximation, with the existing minimum N, common north, shape and concentration checks. These eligibility checks do not prove independent sampling or Fisher fit. Confidence in a mean is distinct from variability of individual orientations.

cos(alpha95) = 1 - (N-R)/R x [20^(1/(N-1)) - 1]

Fisher (1953), printed pp.303-304, supplies the finite-sample expression and a nine-direction worked result. Transcribing its angles gives R=8.771981493912264 and alpha95=8.813187311624041 degrees, consistent with the published rounded 8.8 degrees. The former large-N expression gave 8.00079681 degrees. The eight-pole 10-degree circle in K6 now gives mean confidence 7.3602742425 degrees; estimated variability remains 18.5608027961 degrees.

Shifted beta CDFs evaluate the upper tail using the direct upper-end distance (max-x)/(max-min) and exchanged shape parameters, rather than subtracting a rounded lower-distance fraction from one. Eight difficult retained cases agree with independent 60-digit integration within 1.70e-13. This correction does not eliminate binary64 endpoint/quantile resolution limits.

The secondary wedge region excludes equality at the friction-angle plane using a strict positive dot-product tolerance. A horizontal intersection at zero friction therefore cannot change single-plane candidate counts merely because observations are reordered or all azimuths rotate. This is a geometric screen, not force equilibrium or evidence of physical connectivity.

Toppling force checks now use 1e-10 times total column weight, without the former absolute 1e-7 lbf floor. For a dry squat single column on a horizontal base, sliding threshold F=tan(phi)/kh. With phi=30 degrees and kh=0.585, F=0.9869235371 independent of length scale; the 0.002 by 0.01 by 0.002 ft example agrees with its larger companion. The retained 112 homogeneous scaling cases agree within their stated checks. Whole-slope block flexure remains diagnostic and receives no accepted FS.

Groundwater reporting separates equivalent full-face pressure application from the physical wet extent. For the 95 ft, 45-degree planar section with water elevation 20 ft and width 1 ft, the full base is 134.3502884254 ft; integrated wet length is 20/sin45=28.2842712475 ft. FS remains 0.3579064391. Mean pressure alone does not determine wet extent. Legacy wetted-length result keys in mean mode are explicitly qualified as equivalent application lengths.

Wedge reports use the actual geometry result’s height definition. The through-toe two-joint model uses Joint 1 / slope-crest height. Explicit basal geometry uses vertical crest height at the slope dip-direction reference section with signed joint offsets. Neither necessarily equals the clipped block’s complete vertical span. Print table headers stay with the initial data row.

I48. Current audit: inputs, source freshness and limits

A reproducible uncertainty seed must be explicitly entered as an integer; zero is valid, blank is not zero. Invalid imported cases are reported at file import without marking a valid active case field invalid. Invalid study settings stay with Advanced studies. Invalid observations are preserved for review rather than silently rewritten.

Scanline rows require unique, nonempty observation IDs so spacing from/to references identify actual records. Coordinates in independent slope assessment must be within latitude +/-90 and longitude +/-180 degrees. Explicit negative lengths, widths, traffic, speed or rainfall are rejected; valid incomplete drafts remain allowed. Project declination override is limited to +/-180 degrees, with blank meaning Auto and explicit zero retained.

Opening Field Kinematics or changing its source records refreshes the outcrop choices and invalidates obsolete results/exports. Select all and None update the selected population before describing its north reference. Recalculate the current population; source freshness does not establish common north, physical association or engineering suitability.

Keyboard Next skips collapsed groups. Larger text enlarges help, navigation and actions consistently; the direct Field/Desktop switch wraps rather than covering the subtitle. Intermediate-width engineering tools use the full available content row. Project-map fits stop prior movement and update without zoom animation so the previous project cannot override the new extent.

The explicit audit inventory distinguishes tested native controls, simulated storage/network/device branches, unlinked controls and physical-device limitations. Automated tests cannot close physical iPhone/Safari sensor checks, live account/cloud roundtrips, the original USMP workbook gap, arbitrary site model validity or unresolved whole-slope flexural force transfer.

I49. Geology access from the Field Map

The Field Map restores direct access to the existing geology layer and reference tools. This is a navigation change: coordinates, vector-tile decoding, source interpretation, engineering equations, saved observations and exports retain their existing basis.

Control or state	Meaning
Geologic units	Explicit online overlay request; off by default on a fresh load.
Geology opacity	Display transparency only; it does not weight a geological interpretation.
Selected geologic units	Published attributes and original map source for the tapped polygon.
Geology references	The existing selected-outcrop descriptions and downloadable static-image workflow.

Open Map in Field view. Geologic units and Geology references are directly above the project map. Geologic units starts off on a fresh app load; switch it on to request the published polygon overlay. Adjust Geology opacity to compare it with the topographic background.

Tap a colored polygon to read its formation, lithology, age and original map source in Selected geologic units below the map. Descriptions are published interpretations, not surveyed contacts or automatically adopted field observations. Turning the layer off clears the selected-unit panel.

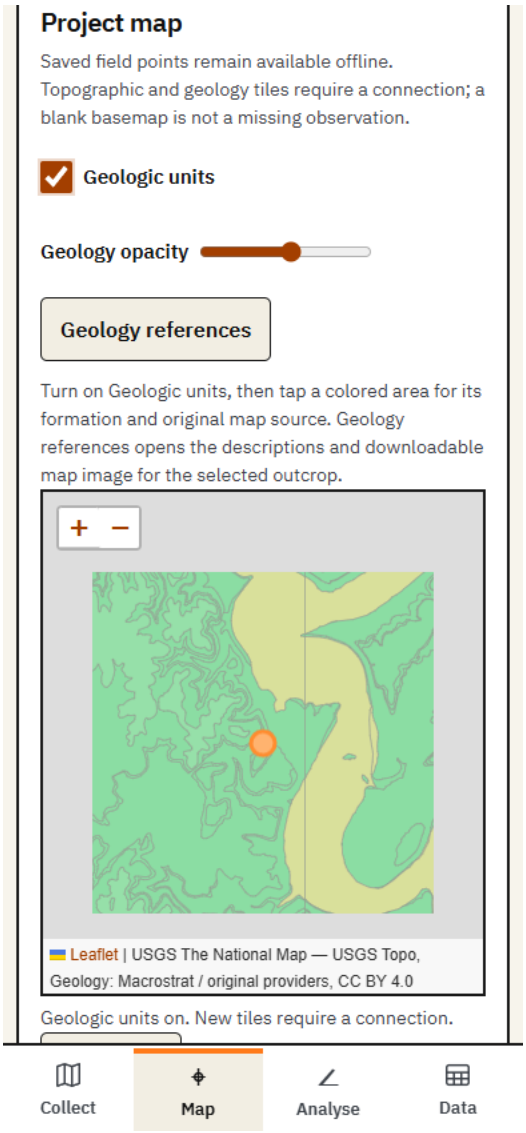
Choose Geology references to open the existing formation descriptions and Create / refresh image workflow for the selected outcrop. Confirm the displayed location. Use Map to return. Analyse also retains its Geology references entry.

Map controls retain their settings while navigating tabs and switching Field/Desktop during this app session. Desktop has its own Geologic units switch. A fresh reload resets these display choices; they are not geological observations or cloud-backed settings.

New tiles need internet and send the displayed area to USGS / Macrostrat. A missing basemap or geology tile does not mean the outcrop was deleted or that a unit is absent. If a request fails, check connectivity and switch Geologic units off and on to retry. Saved outcrop markers remain usable.

Keep raw observations separate from map interpretation. Map navigation does not save an unfinished field form: use its normal Save action. Keep a downloaded image and reference CSV for offline reference; they remain separate from field-record and GIS backups.

I49A. Field Map control example



Example interface with a synthetic outcrop and one recorded public geology tile. The gray background represents unavailable topographic tiles. This illustrates the controls, not a new site investigation or complete mapped coverage.

Checks used an isolated desktop browser at phone-sized widths, native controls, the recorded vector tile, simulated service failures and unchanged saved-record comparisons. Physical-phone behavior and current service coverage require separate evidence.

I50. Mobile appearance and input readability

In Data, choose Display settings. Choose Sunlight / Daylight or Dark, and a comfortable text size. After a successful save, the same appearance and text size are applied before the app starts on refresh or reopening. The browser toolbar follows the Field appearance.

An older installation may have its choice only in the local database. On its first opening after this update, a neutral light shell waits for that saved choice. If startup fails or takes more than eight seconds, the shell is released so recovery notices and controls are not permanently hidden. Restricted browser storage may require this neutral start on each opening.

Phone layouts keep editable input, selector and note text at least 16 CSS pixels before focus. Larger text settings remain available. Pinch-to-zoom stays enabled; the application does not restrict browser magnification. The keyboard may still move a field into view as part of normal phone behavior.

If a display setting cannot be saved, the app reports the storage error. Its immediate on-screen appearance may differ from the last successfully saved choice. A later reload restores the saved choice. Display preferences do not alter geological observations, units, calculations, record exports or cloud-backed project data.

Browser checks cover delayed startup, preference changes, refresh, close/reopen, legacy and restricted storage, computed input sizes and record preservation using synthetic data. Physical iPhone keyboard, toolbar and focus-zoom behavior still require a device check. Keep a backup of field records before any browser-storage maintenance.

I51. Choose the geology image area by panning

Open Field Map, choose Geology references, then Choose area on map under Geology image. Pan and zoom the square topographic preview to frame the desired area. The outer edge is the generated image boundary. On a keyboard, focus the map and use arrow keys to pan and + / - to zoom.

Read the Image center and approximate width beneath the preview. Panning chooses an image center; it does not move the saved outcrop, GPS preview or formation-description lookup. A preset image width changes the size around the chosen center. Return to selected location restores the outcrop or GPS-preview center.

Choose Create / refresh image. The raster background and geologic polygons use the same square Web Mercator extent. Widths from 200 to 528,000 feet are supported; the width and scale bar describe approximate ground distance at the center latitude. Areas crossing a projection limit or the date line are rejected. Pan to one side or zoom in before retrying.

The output red target marks the image center, which may differ from the outcrop. Review the image, unit legend, original source citations and retrieval date. Preview and output may contain different source detail; a blank tile is not evidence that geology is absent. The preview uses USGS topography; the generated PNG adds the published geology polygons.

Moving the frame while generation is in progress cancels that request so its old extent cannot replace the new selection. Resizing the map changes its view; recheck the center and width before generating. Map tiles and new images require internet.

Download the PNG for a separate copy. A successfully cached custom image reopens for the same selected source location on this device. Unsaved panning is a session choice; the last generated area is retained with its cached image. The bounded image cache can evict older images, is separate from field/cloud/GIS backups, and is cleared by the existing device-data deletion controls.

Validation used real pointer drag, keyboard pan/zoom, recorded geology tiles and simulated raster responses; tests checked matching raster/vector extents, stale-request rejection, download, reload, reset, responsive layout and unchanged synthetic field records. Independent projected-coordinate checks support the extent calculation. Physical-phone gestures and live external-service coverage remain separate checks.

Additional sources · 1

[F1] W3C Geolocation Recommendation, coordinates and accuracy semantics Primary source.

[F2] W3C Device Orientation and Motion, Candidate Recommendation Draft 12 February 2025 Primary source.

[F3] USBR Engineering Geology Field Manual, volume I, chapter 4: Classification and description of rocks Primary source.

[F4] USBR Engineering Geology Field Manual, volume I, chapter 7: Discontinuity surveys Primary source.

[F5] FHWA-NHI-16-072, GEC 5: Geotechnical Site Characterization (2016), printed pp.9-34–9-35, Tables9-5 and9-6 Primary source.

[F6] Marinos and Hoek (2000), GSI: A Geologically Friendly Tool for Rock Mass Strength Estimation, GeoEng2000, pp.1422–1446, Tables1–3

[F7] Hoek, Carranza-Torres and Corkum (2002), Hoek–Brown failure criterion—2002 edition, author-hosted paper Primary source.

[F8] Barton and Choubey (1977), The shear strength of rock joints in theory and practice Primary source.

[F9] Barton and Bandis (1990), Review of predictive capabilities of JRC–JCS model in engineering practice, author copy Primary source.

[F10] Apple Developer: webkitCompassHeading, headingAccuracy and headingOrientation Primary source.

[F11] WebKit source: WebCoreMotionManager.mm, sendMotionData:withHeading: Primary source.

[ST-REF-01] Snyder, J.P. (1987). Map projections—A working manual. USGS Professional Paper 1395. Primary source.

[ST-REF-02] Fisher, R.A. (1953). Dispersion on a Sphere. Proceedings of the Royal Society A 217, 295–305. Primary source.

[ST-REF-03] Terzaghi, R.D. (1965). Sources of Error in Joint Surveys. Géotechnique 15(3), 287–304. Primary source.

[ST-REF-04] Bezdek, J.C., Ehrlich, R. and Full, W. (1984). FCM: The fuzzy c-means clustering algorithm. Computers & Geosciences 10(2–3), 191–203. Primary source.

[ST-REF-05] USACE (1994). EM 1110-1-2908, Rock Foundations, Chapter 8: Rock Slope Stability. Primary source.

[D-USMP] FHWA-FLH-19-002, Unstable Slope Management Program for Federal Land Management Agencies (January 2019) Appendices A/B; Table 23; equations 1–7; field form Rev 1.09. App uses the separately supplied USMP_RATING_SHT 2.xlsx worksheet variant; differences are explicit. Primary source.

[D-MACRO] Macrostrat data services and original geologic-map sources Map-unit API v2, source/lithology definitions and multiscale cartographic tiles; retain original map citations. Original provider: https://macrostrat.org/ Primary source.

[D-TOPO] USGS The National Map — USGS Topo service Service description, spatial reference and export/tile endpoints. Primary source.

[D-GPS] W3C Geolocation specification Sections 1.1, 7 and 9: WGS84 coordinates, accuracy, altitude and acquisition options. Primary source.

[D-GEOJSON] IETF RFC 7946, The GeoJSON Format Sections 3.1.1, 4 and 6: positions, longitude/latitude and geographic CRS. Primary source.

[D-STORAGE] WHATWG Storage Standard Storage buckets, persistent storage and StorageManager persist/persisted/estimate. Primary source.

Additional sources · 2

[D-RLS] Supabase Row Level Security documentation Ownership predicates, grants and policies. Used to interpret checked-in migrations, not evidence of live configuration. Primary source.

[FC1] USBR Engineering Geology Field Manual, Volume I, Chapter 5: Terminology and descriptions for discontinuities. Printed pp. 101-103: trace direction, length, exposure size and visible endpoints; pp. 106-109: roughness and waviness descriptions. Primary source.

[FC2] USBR Engineering Geology Field Manual, Volume I, Chapter 7: Discontinuity surveys. Printed pp. 205-208: purpose, scanline geometry and directional sampling limitations. Primary source.

[W1] USBR, Engineering Geology Field Manual, Volume I, Chapter 5: Terminology and descriptions for discontinuities Printed pp. 106-109, especially p. 108: roughness/waviness descriptions and angle-addition expression. This is a contrasting model, not validation of WillItMap's additional term. Primary source.

[E-R1] FHWA, Context Sensitive Rock Slope Design, Chapter 5: rock reinforcement, anchors and dowels. Used for physical distinction; numerical force conventions are stated separately. Primary source.

[E-R2] NIST/SEMATECH e-Handbook of Statistical Methods: distribution definitions and parameter conventions. Primary source.

[N1] Bond, A.J., Schuppener, B., Scarpelli, G. and Orr, T.L.L. (eds.), Eurocode 7: Geotechnical Design - Worked examples (2013), European Commission Joint Research Centre. Chapter 6, especially section 6.2.3.1 (printed pp.61-62): partial-factor and global-factor distinction. Cited for general principles only; WillItMap does not implement an automatic Eurocode design approach or national annex. Primary source.

[N2] Spirin, V., de Bruyn, I., Mylvaganam, J. and Lium, D. (2025), Considerations for optimal assessment of bench-berm stability and design in competent, fractured rock masses. SSIM 2025, Australian Centre for Geomechanics, section 3.2: finite failure dimensions, crest loss and retention concepts. The E19 prism equation is an explicit volume-conservation derivation, not a claim that this source verifies the app's toppling collapse scenario. Primary source.

[A-FP24] FHWA. Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects, FP-24 (2024). Rock bolts and dowels: §260.06, printed pp.195-196; installation §260.08(a), p.196; proof testing/lock-off §260.09(b), p.199. This specification applies within its contract context. Primary source.

[A-GEC4] FHWA. Ground Anchors and Anchored Systems, Geotechnical Engineering Circular No.4, FHWA-IF-99-015 (1999). §5.3.6, p.70 (inclination); §5.3.8 and Tables 9-10, pp.77-78 (prestressing steel); §7.5, p.154 (lock-off). Ground-anchor examples are not universal rock-bolt design values. Primary source.

[A-ROCK] FHWA. Context Sensitive Rock Slope Design Solutions (2011), Chapter 5, rock reinforcement, tensioned/untensioned anchors and Figs 41-43. Geometry, water, anchor length and bond must be established for the actual slope. Primary source.

[A-W75] Williams Form Engineering. Grade 75 & Grade 80 All-Thread Rebar, product rows #8/R61-08 and #10/R61-10 plus Structural Properties. Undated; accessed 10 October 2026. Only the Grade 75 properties are included in this catalog. Primary source.

[A-W150] Williams Form Engineering. 150 KSI All-Thread-Bar, nominal 1-inch/R71-08 and 1-1/4-inch/R71-10 rows plus Structural Properties. Undated; accessed 10 October 2026. Published values are not project certificates. Primary source.