Overview of LANDSLIDE MITIGATION TECHNIQUES

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for

Slope Stability & Landslides Course

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Engineering Professional Development
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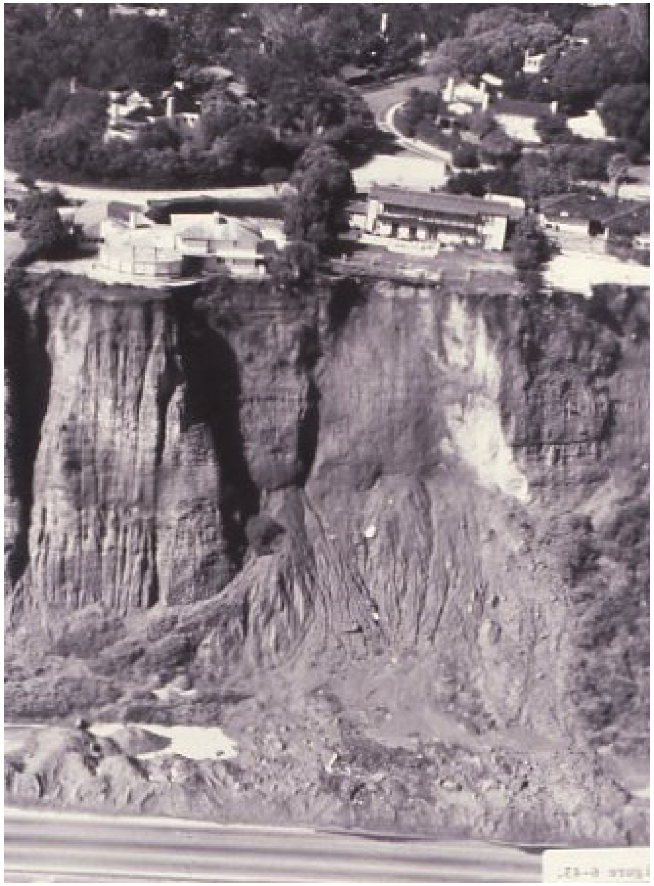
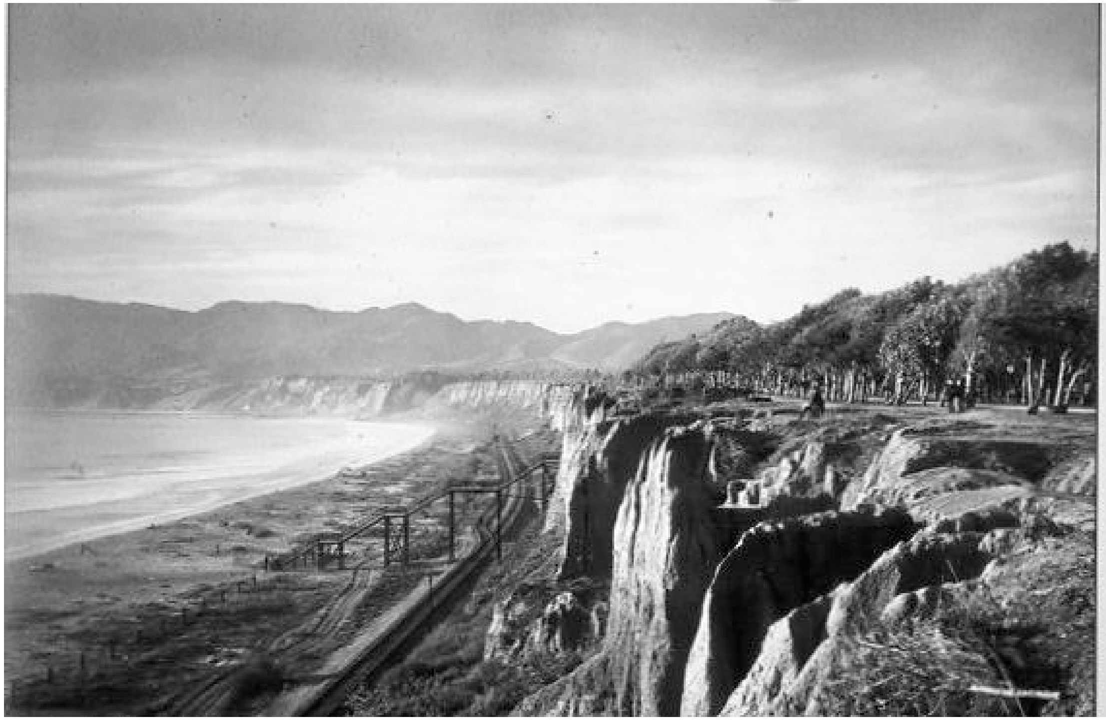
Part 1

BACKGROUND ON LANDSLIDE REPAIR TECHNIQUES

Oversteepened Slopes Erode and Regress

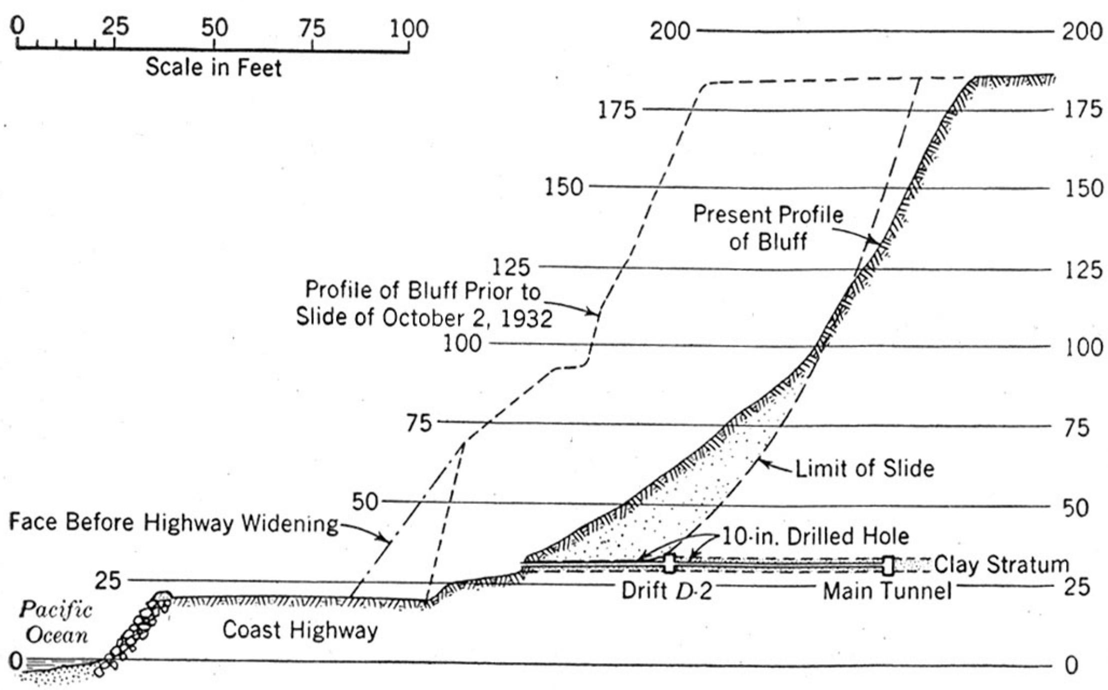




- **Natural slopes stand at the steepest inclinations possible, given the environmental conditions to which they are subjected. Natural slopes don't exhibit factors of safety of 1.5; closer to 1.15**

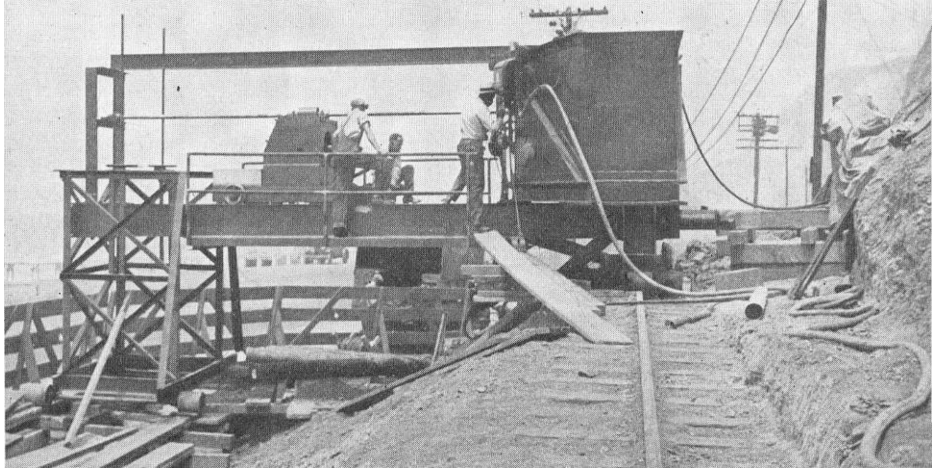


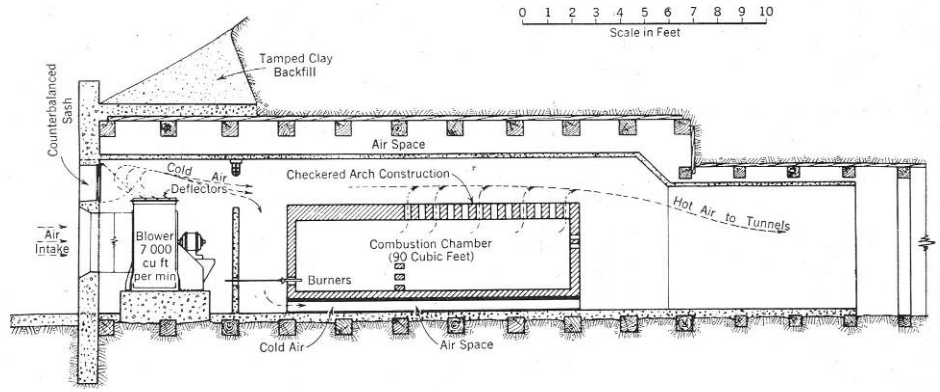
The advent of mechanized earth moving equipment between 1920-50 revolutionized society's ability to construct improvements in hilly areas.

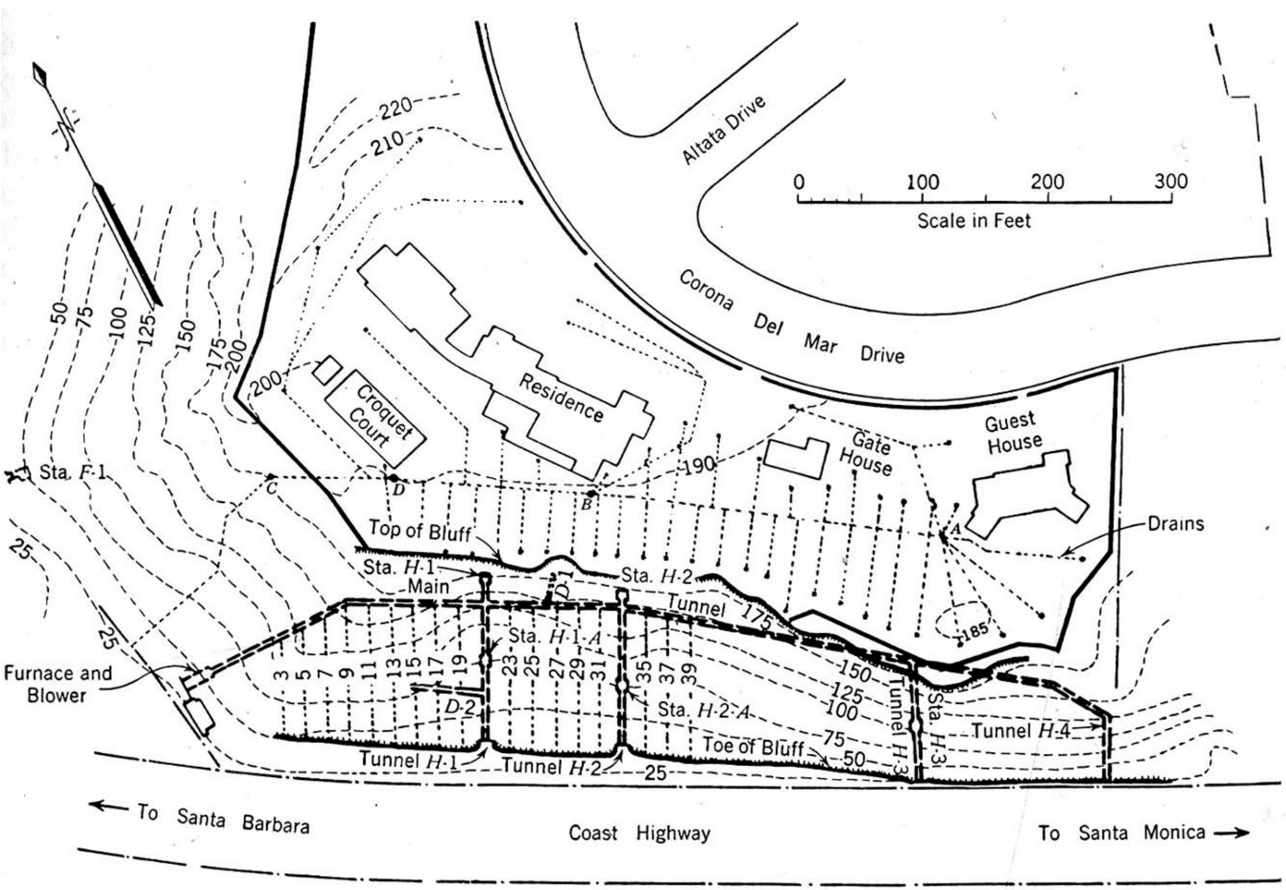


1932 Quelinda Estate Landslide

- **The Quelinda Estate slide shut down Pacific Coast Highway in 1932.**
- **Los Angeles engineer Robert A. Hill attacked the clay seam at the base of the cliffs using hot air to desiccate the clay**



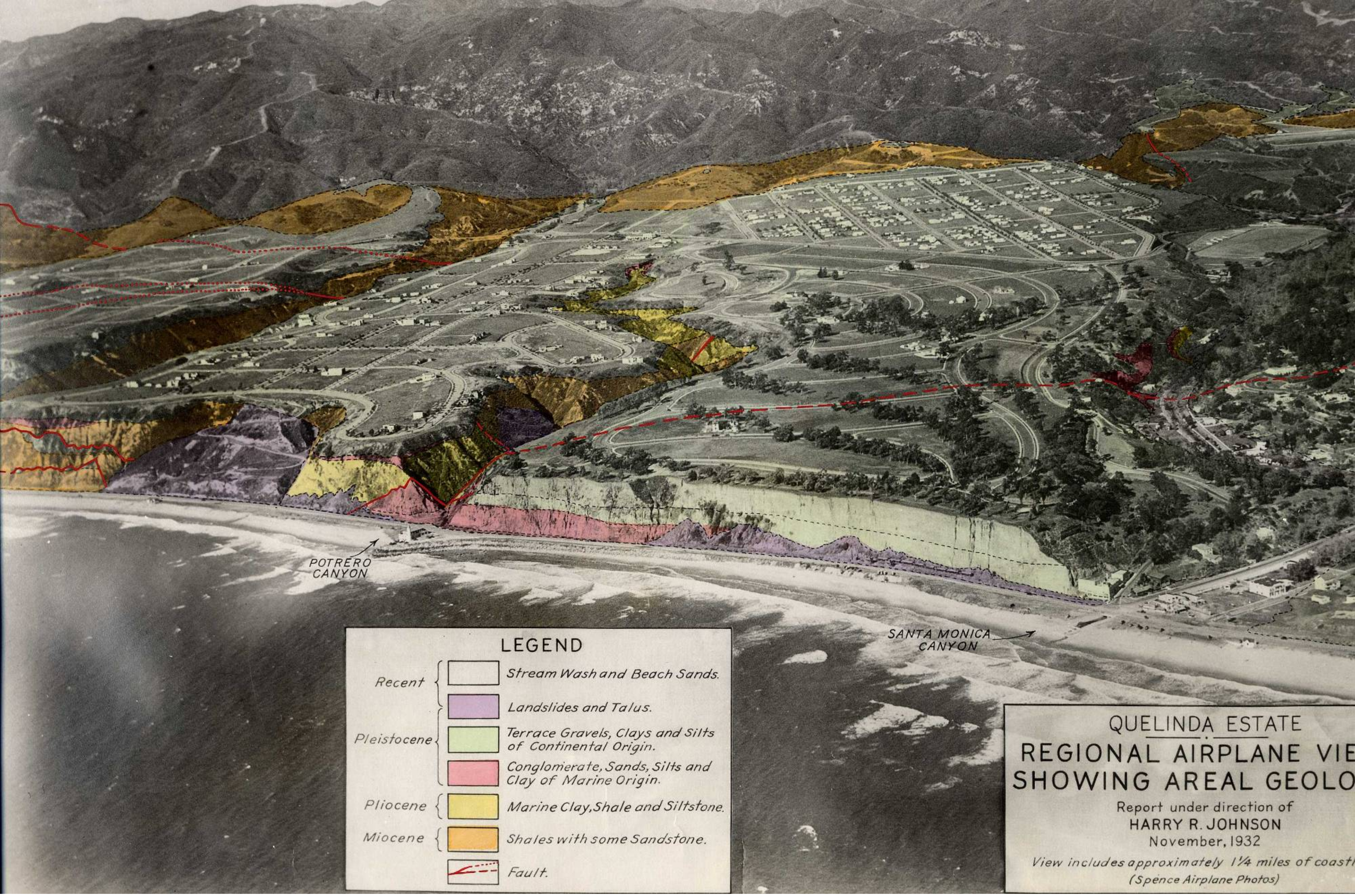




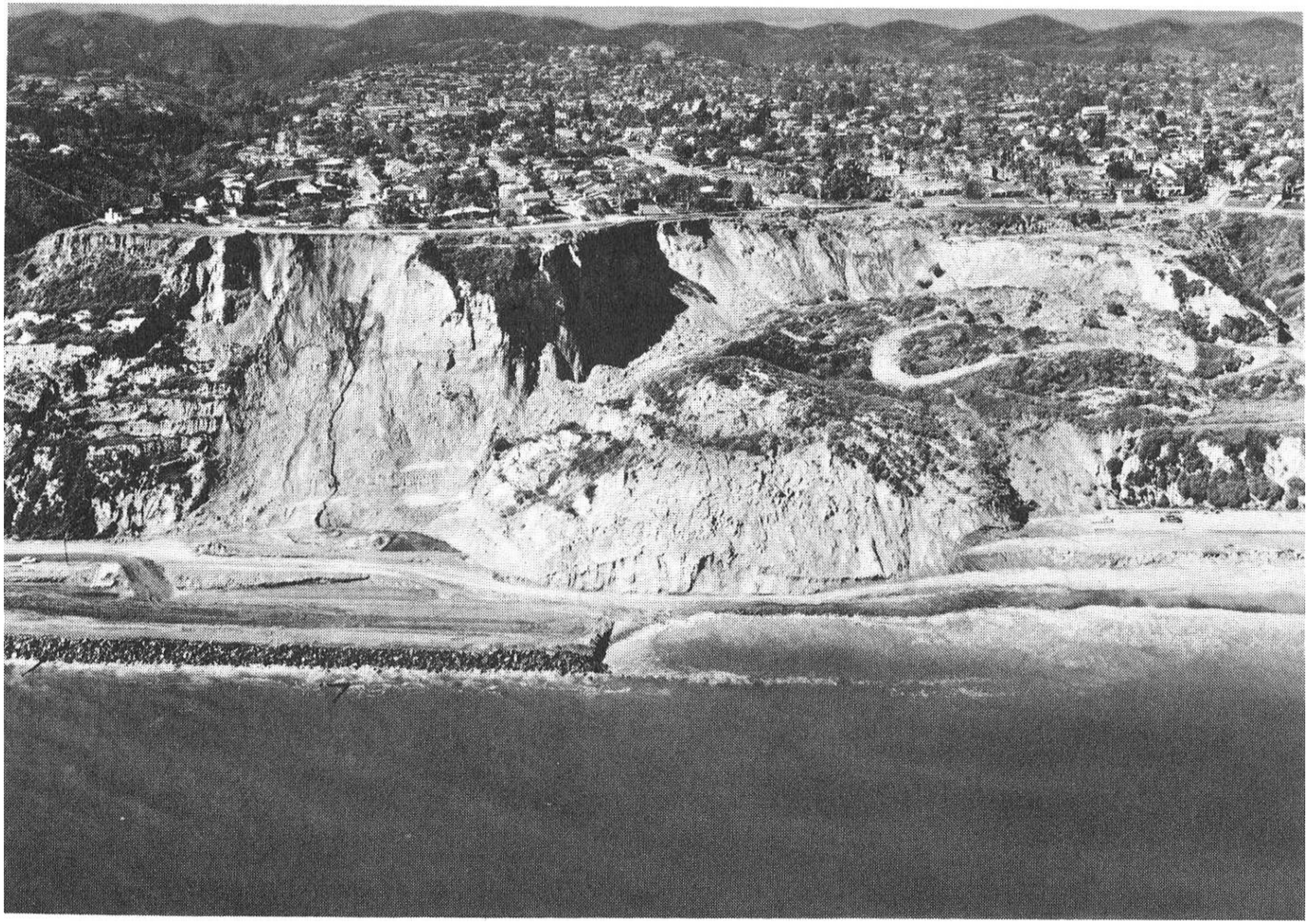
- **An ingenious system of tunnels were excavated and hot air was circulated through these to hasten desiccation of the low strength clay layer.**

How many years does it take to forget about past problems?

The Quelinda Slide repair soldiered on successfully for about 15 years. At that juncture, the problem seemed solved because the site hadn't experienced any additional sliding, so the decision was made to shut down the furnace and the blowers.

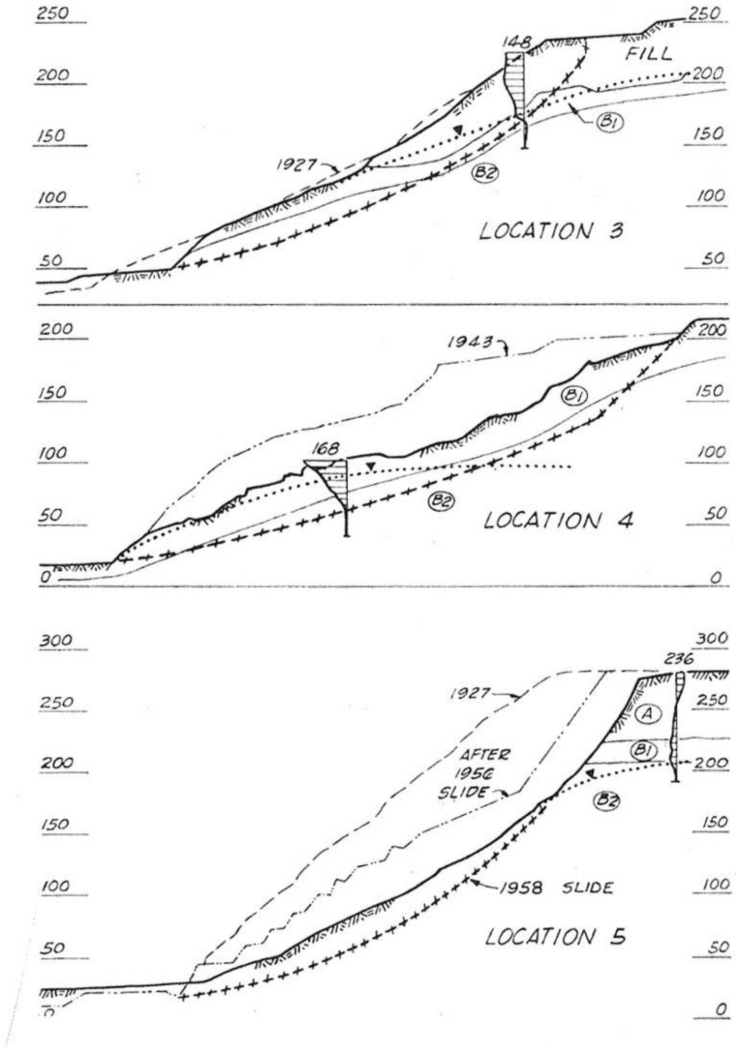


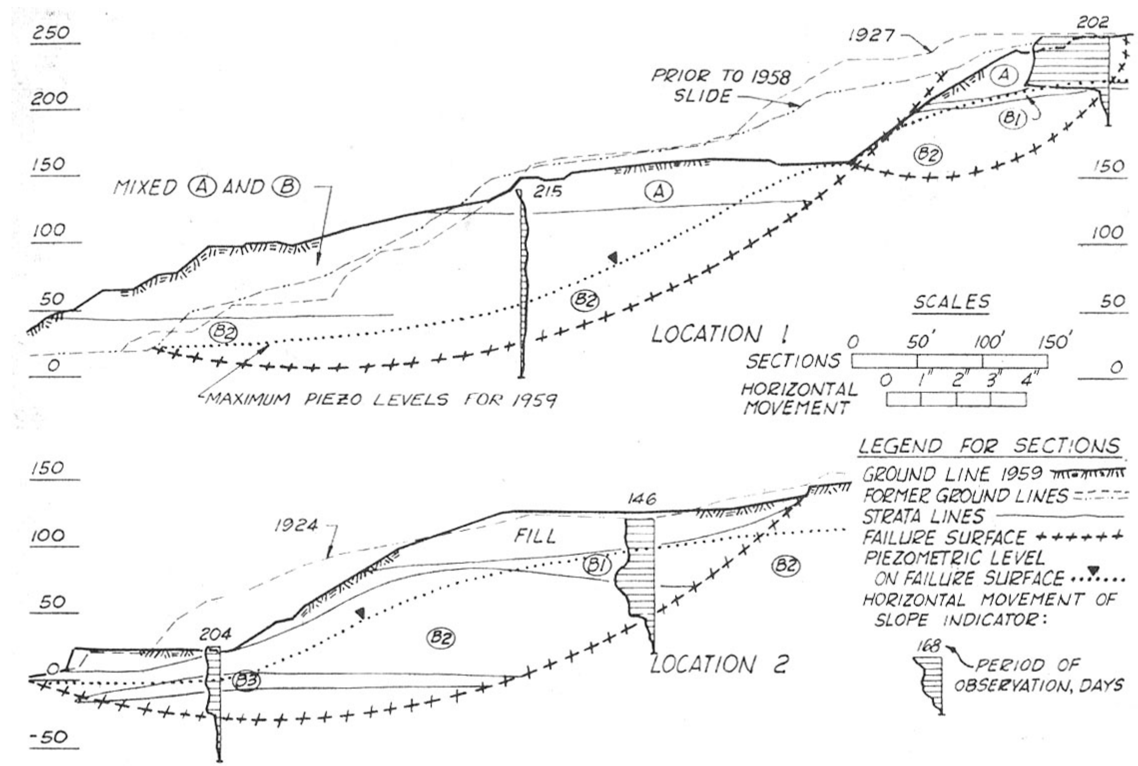
- Consulting geologist Harry R. Johnson used aerial photo overlays to illustrate the geologic conditions along 1-3/4 miles of coastline, shown here.



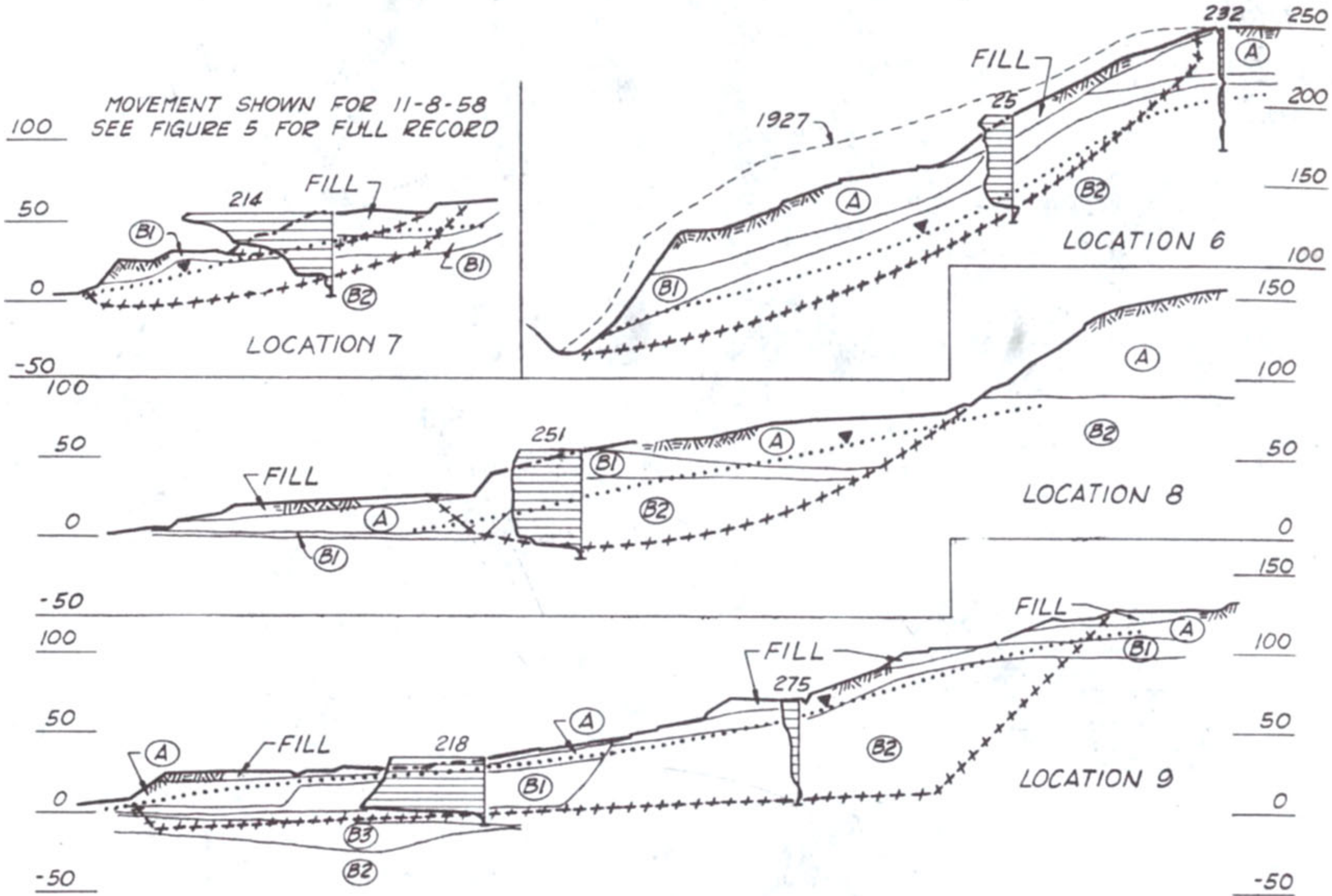
- The 1958 Via de Las Olas Landslide in Pacific Palisades closed Pacific Coast Highway and drew the City of Los Angeles into costly litigation.
- The City hired Mueser-Rutledge of New York City to make a comprehensive two-year study, which included mapping slides along 15 miles of coastline.

Via de Las Olas slope stability studies





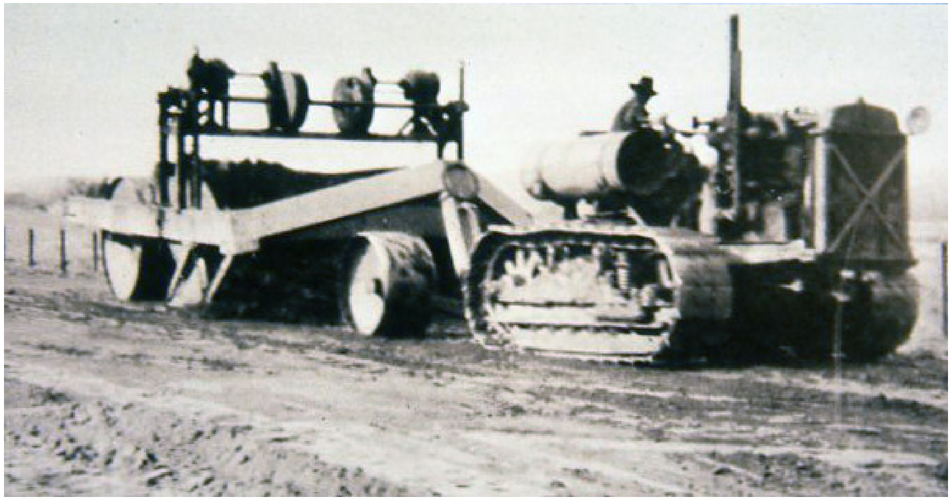
- **Jim Gould headed up the team at Mueser-Rutledge that back-analyzed the Pacific Palisades slope failures. These studies were published by ASCE in 1960 and formed the basis for most subsequent assessments in southern California.**



- Mueser-Rutledge examined various mitigation options.
- Recompacted buttress fills became the standard mass grading technique in southern California and the Via de Las Olas slide became a city park.

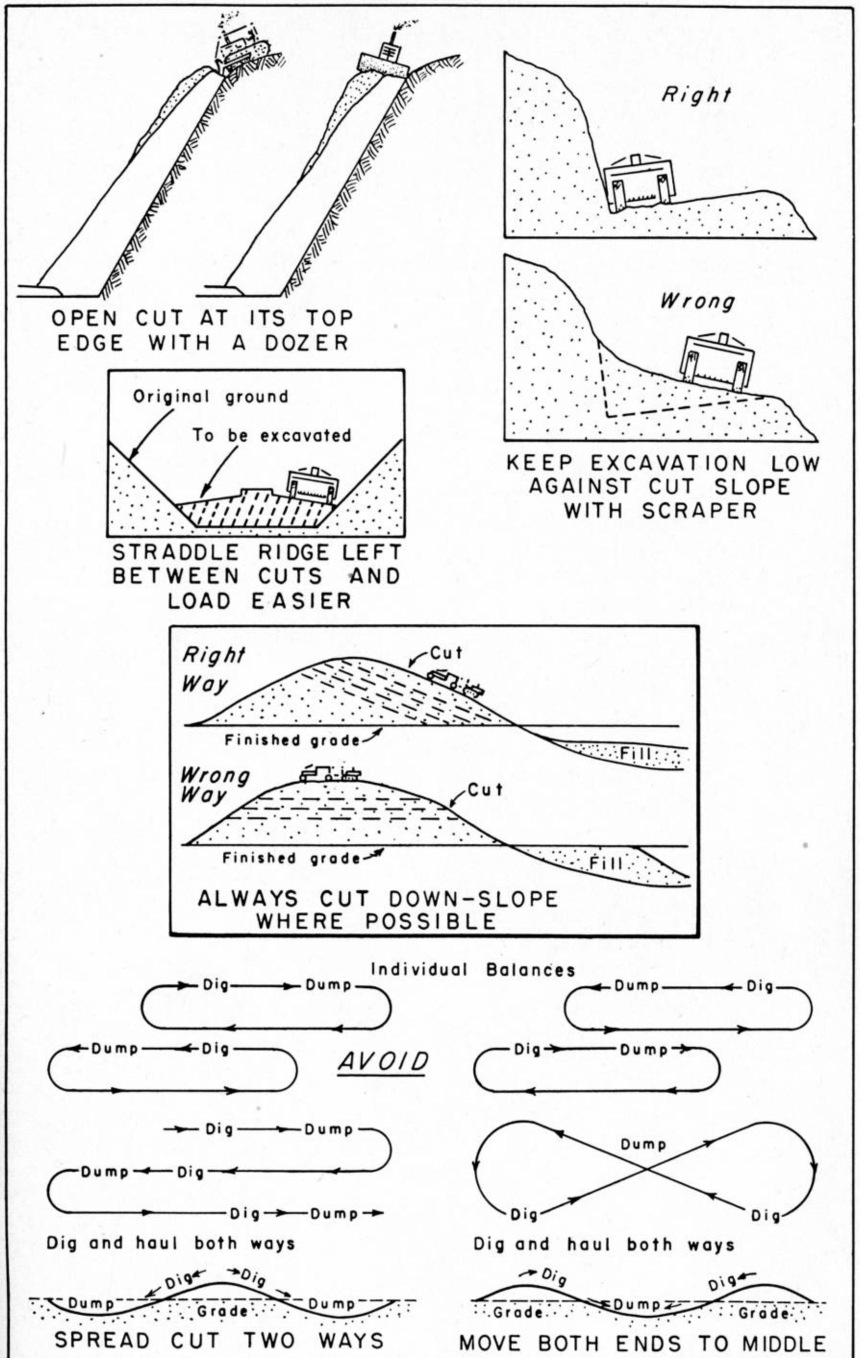
Part 2

RECOMPACTED BUTTRESS FILLS



R. G. Letourneau’s introduction of scrappers with pneumatic tires in 1931 and the articulated Tournapull scrapper n 1937 (below right), served to revolutionize earth moving technology.

Sequencing earthwork

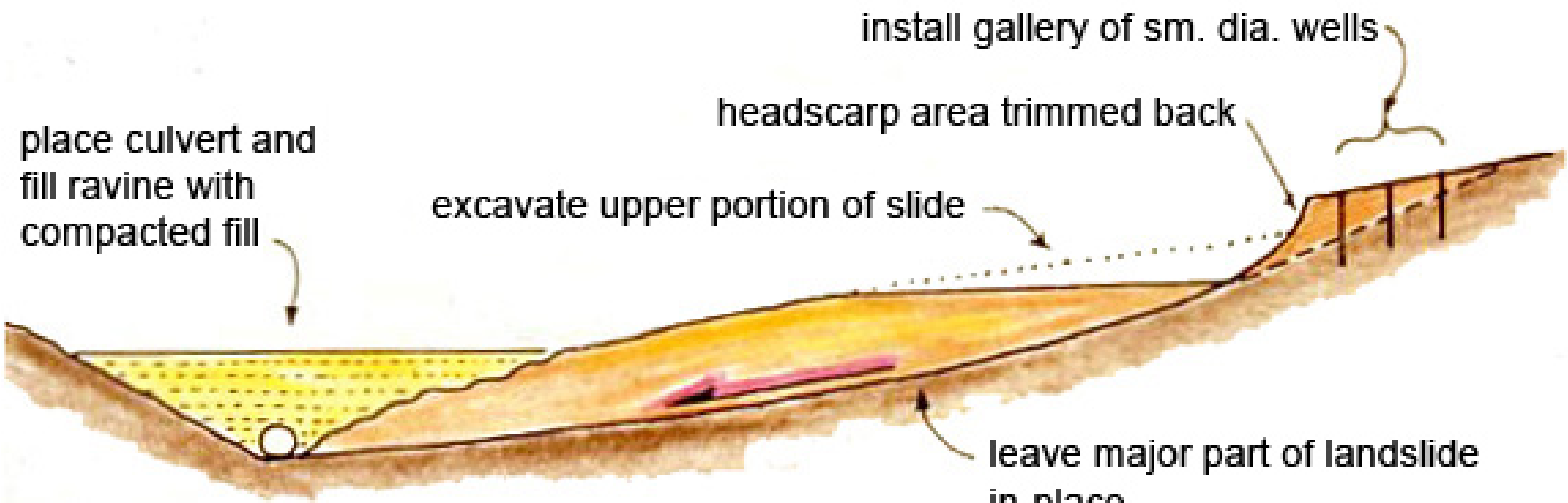


(After Park, 1942.)

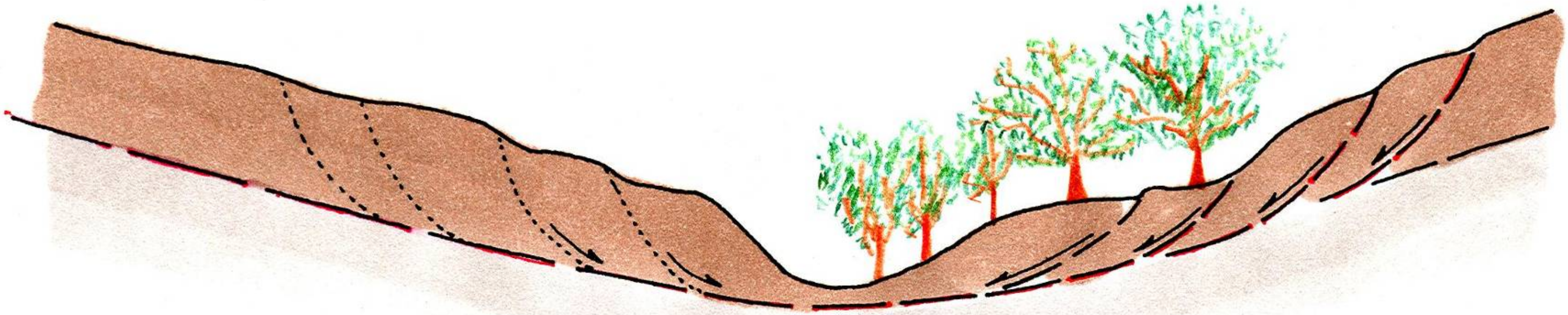
FIGURE 7. Some principles of excavation using a dozer and scraper.

- **Unit costs for moving earth depend on material volume and haulage distances. Unit prices typically range between \$1 and \$10/yd^3**
- **Beware of "double-dumping," shown below**

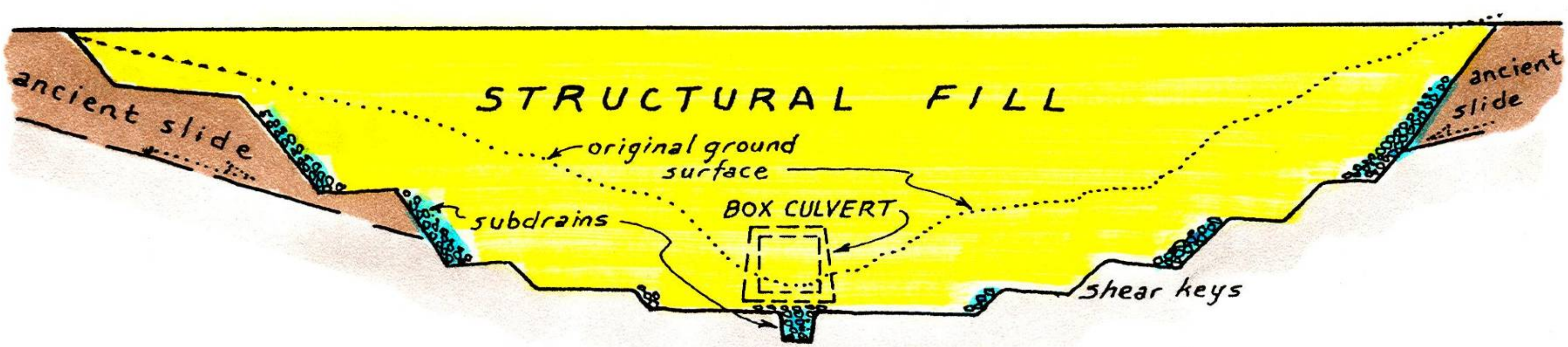
Toe Buttresses

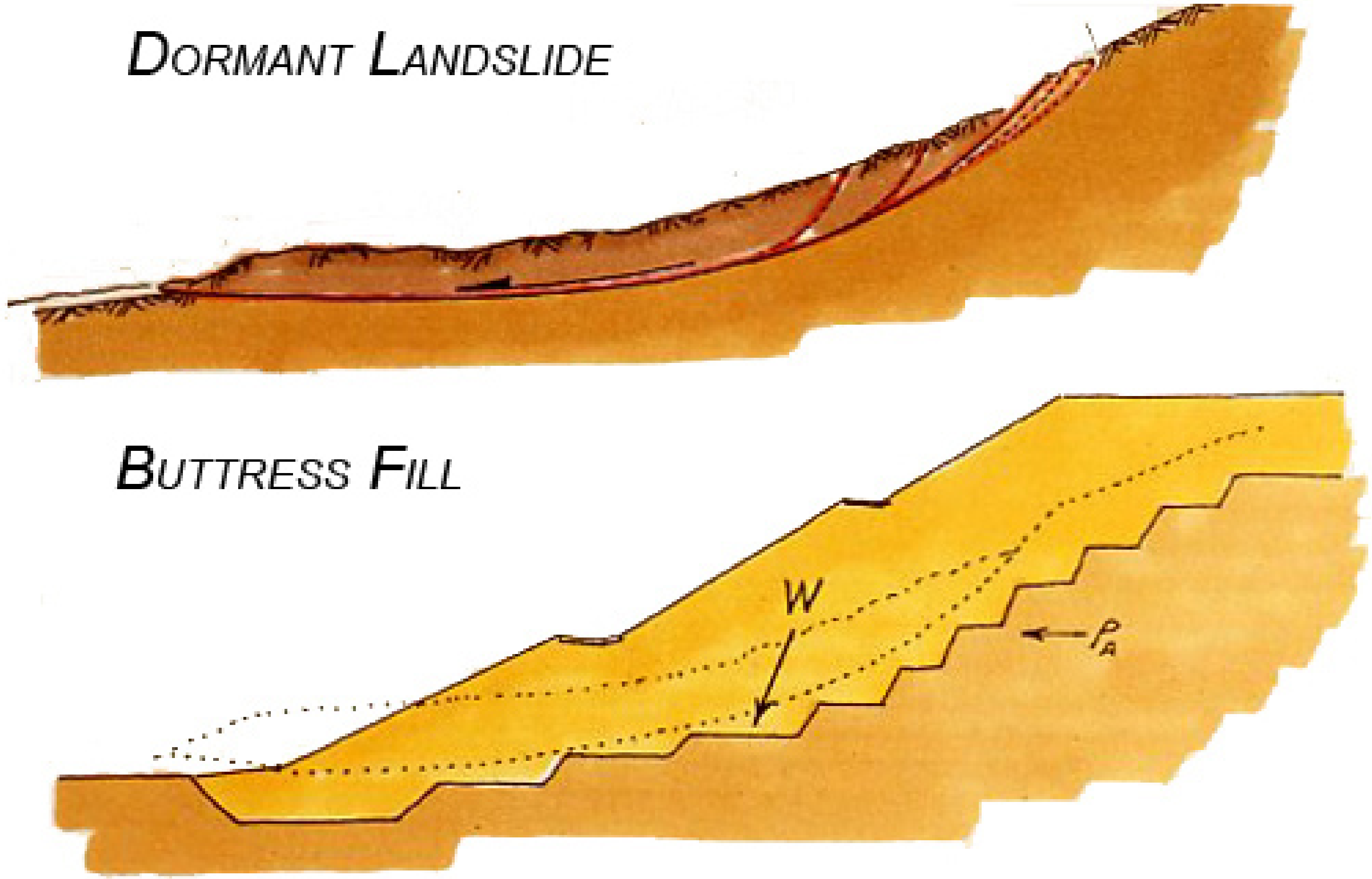


- **Toe buttresses have been employed since the mid-1930s to mitigate large landslides sliding into creek channels.**



Valley fills have been used in situations where active slides encroach both sides of a channel. These require concrete box culverts, subdrainage, and a permit from the governing agency that oversees aquatic life in natural channels.

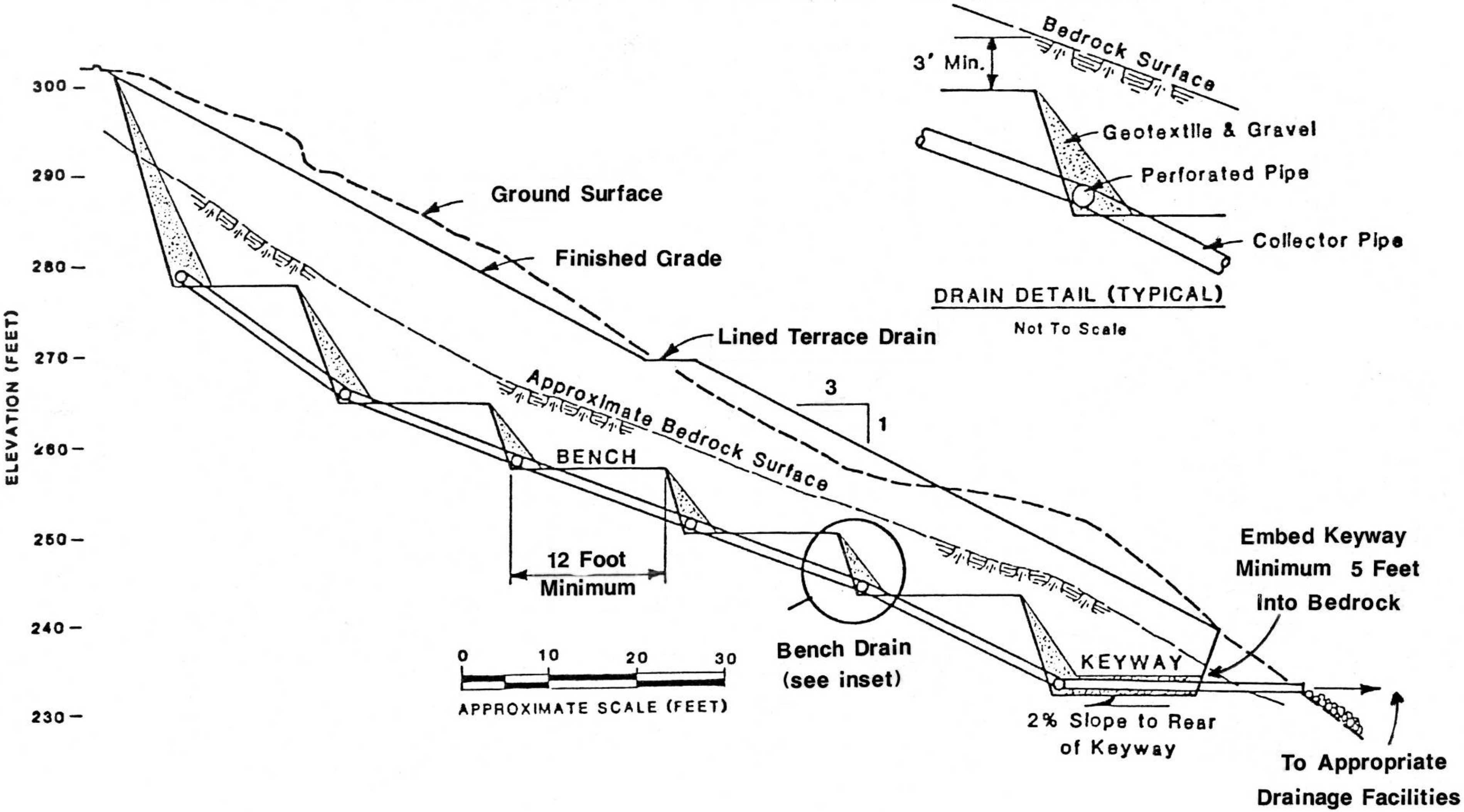




DEAD WEIGHT OF FILL, W, RESISTS LATERAL PRESSURE OF THE ADJACENT SLOPE, P_A

- **During the 1950s-60s recompacted buttress fills became the preferred alternative in repairing landslides, whenever economically feasible.**

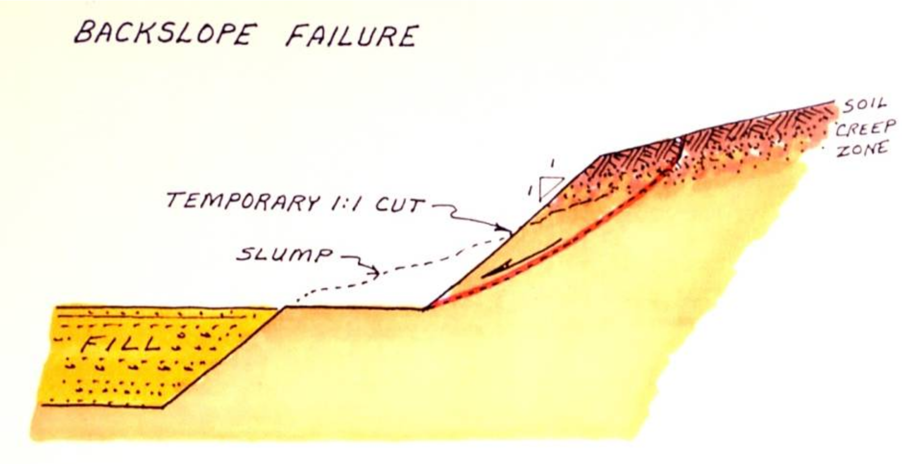
TYPICAL LANDSLIDE REPAIR SECTION

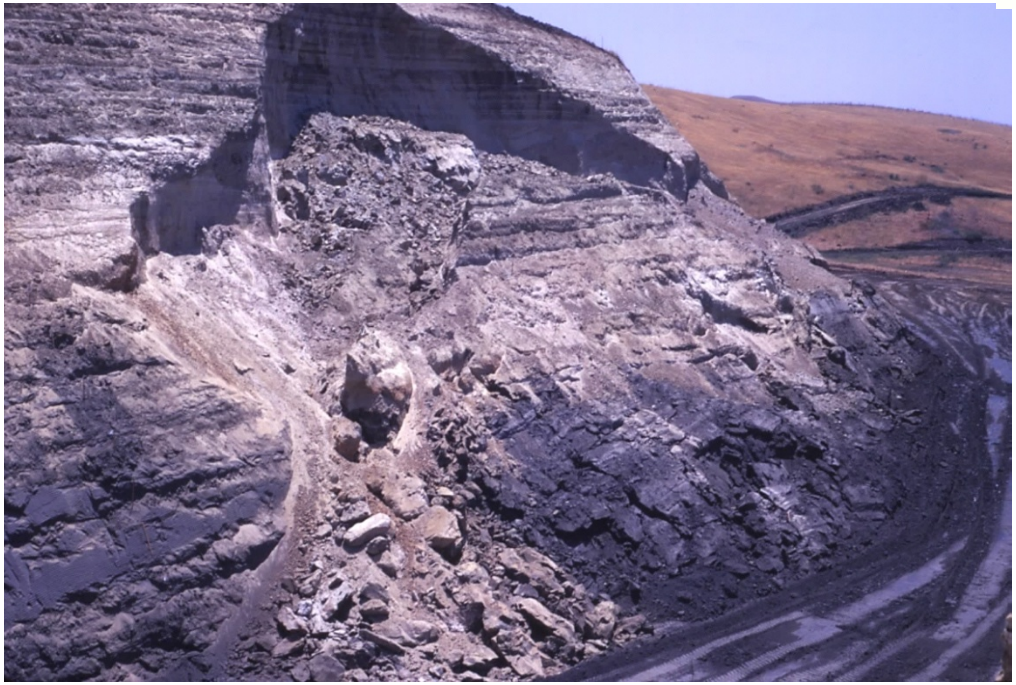


- **Standard scheme for recompacted buttress fill repair of landslides using mass grading, adopted by City of Los Angeles in 1967.**

- **The viability of earthwork schemes to repair landslides usually turns on site access and stockpile area. If ample space is available, earthwork repairs are usually more feasible/economic. In rare occasions police powers can be exercised to gain site access.**

Backslope Failures

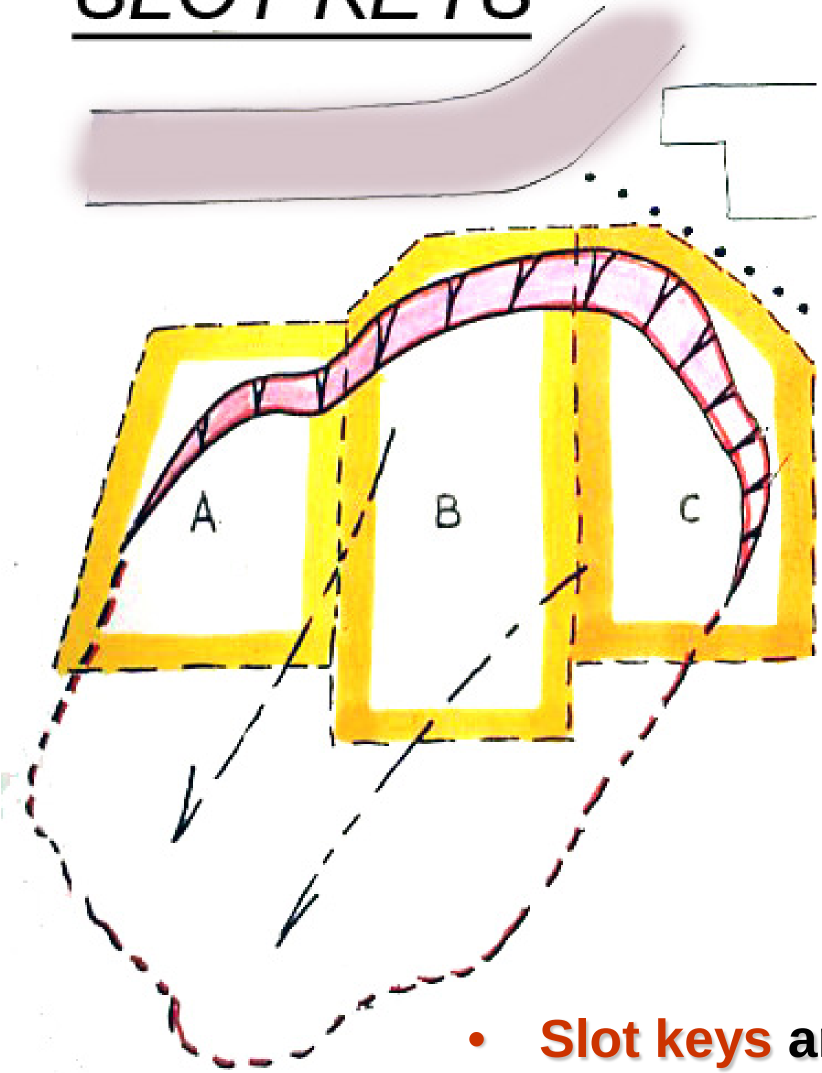




Backslope failures are common on slide repairs. These materials should be over-excavated as the fill buttress is brought upward, disaggregating the failed material and compacting it in the fill.

Do not leave the failed mass in-place; it will become a gigantic tension crack.

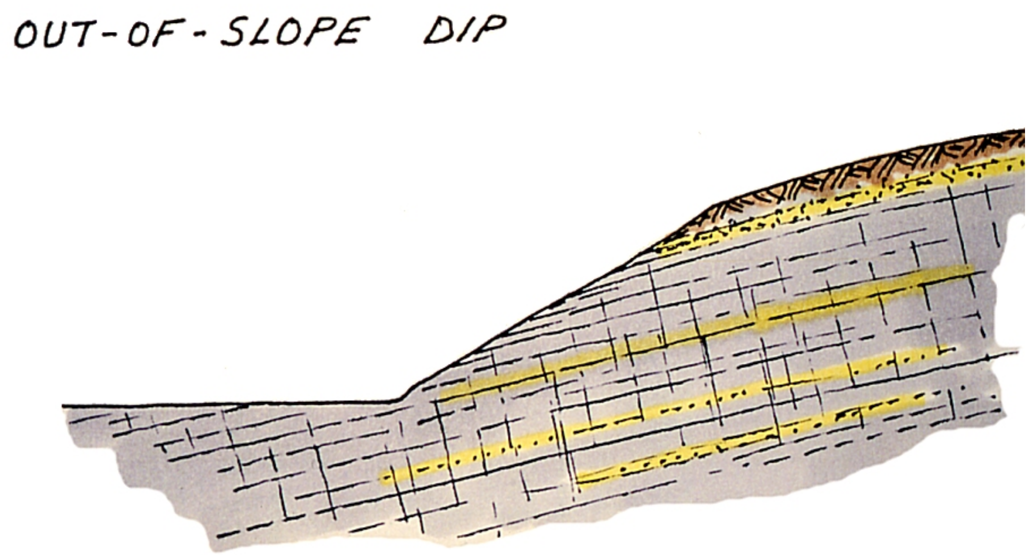
SLOT KEYS

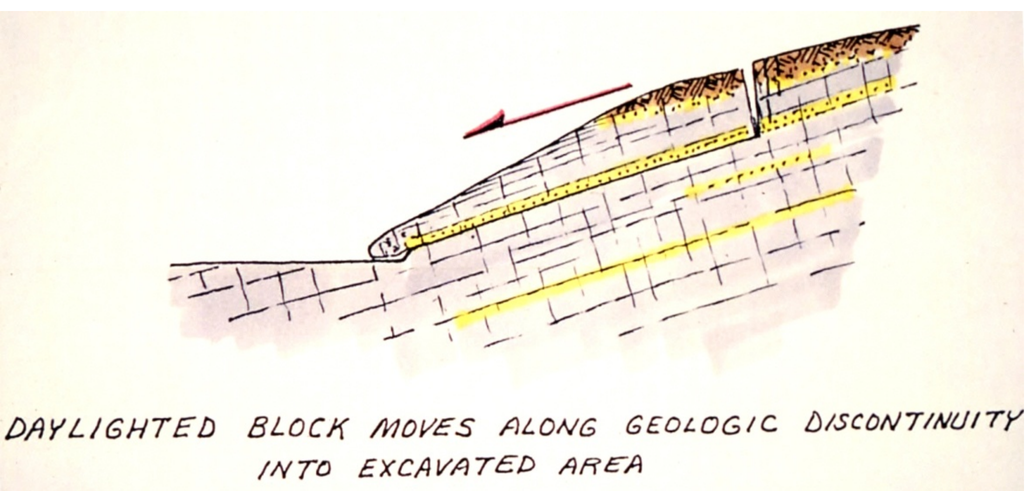


- **Slot keys** and **pin piles** are two options that can always be used to effect earthwork repairs in tight access situations, but the unit costs will be double or triple what they otherwise might be.

The special case of DIP SLOPES

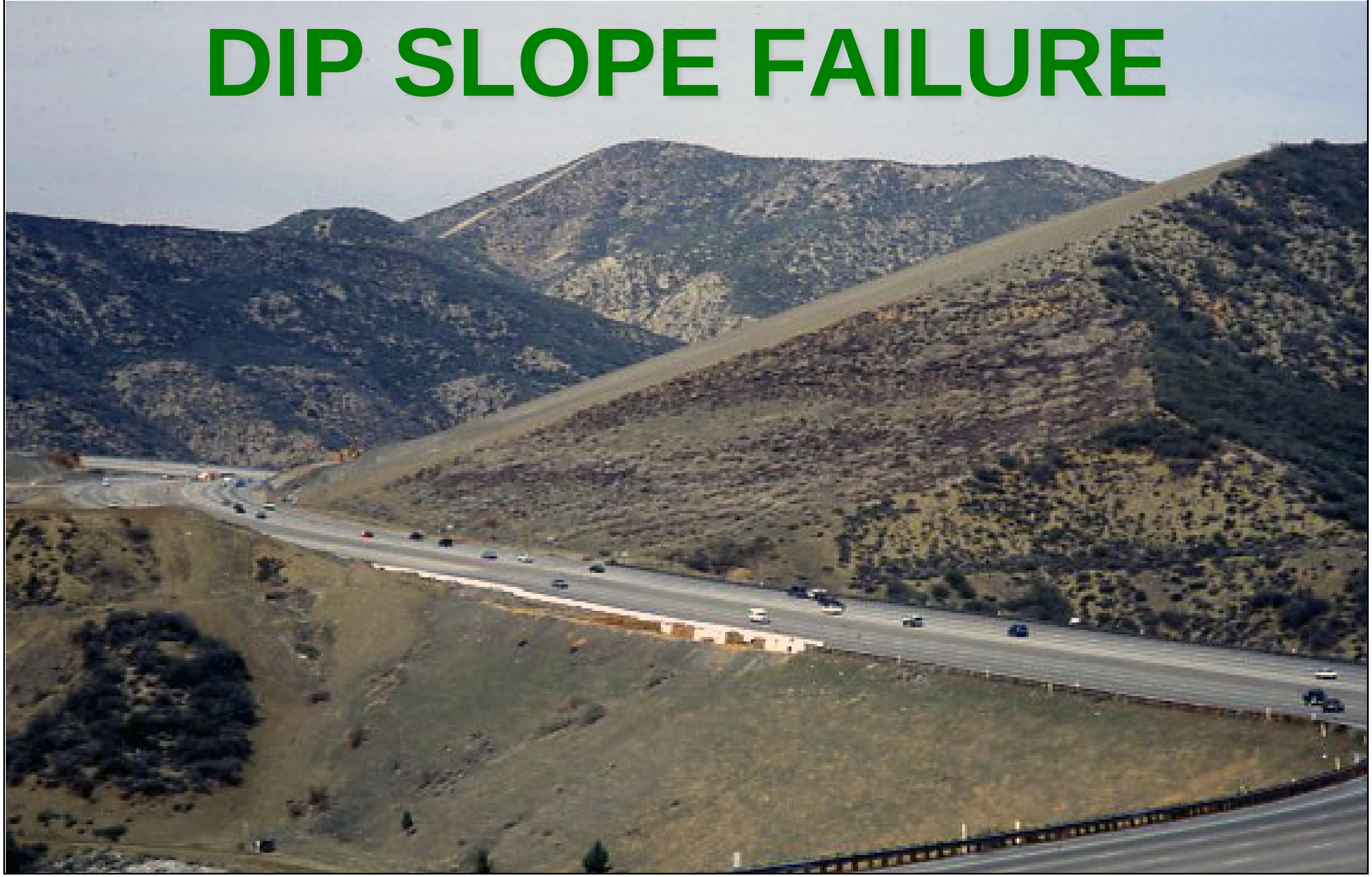
DAYLIGHTED CUT SLOPES



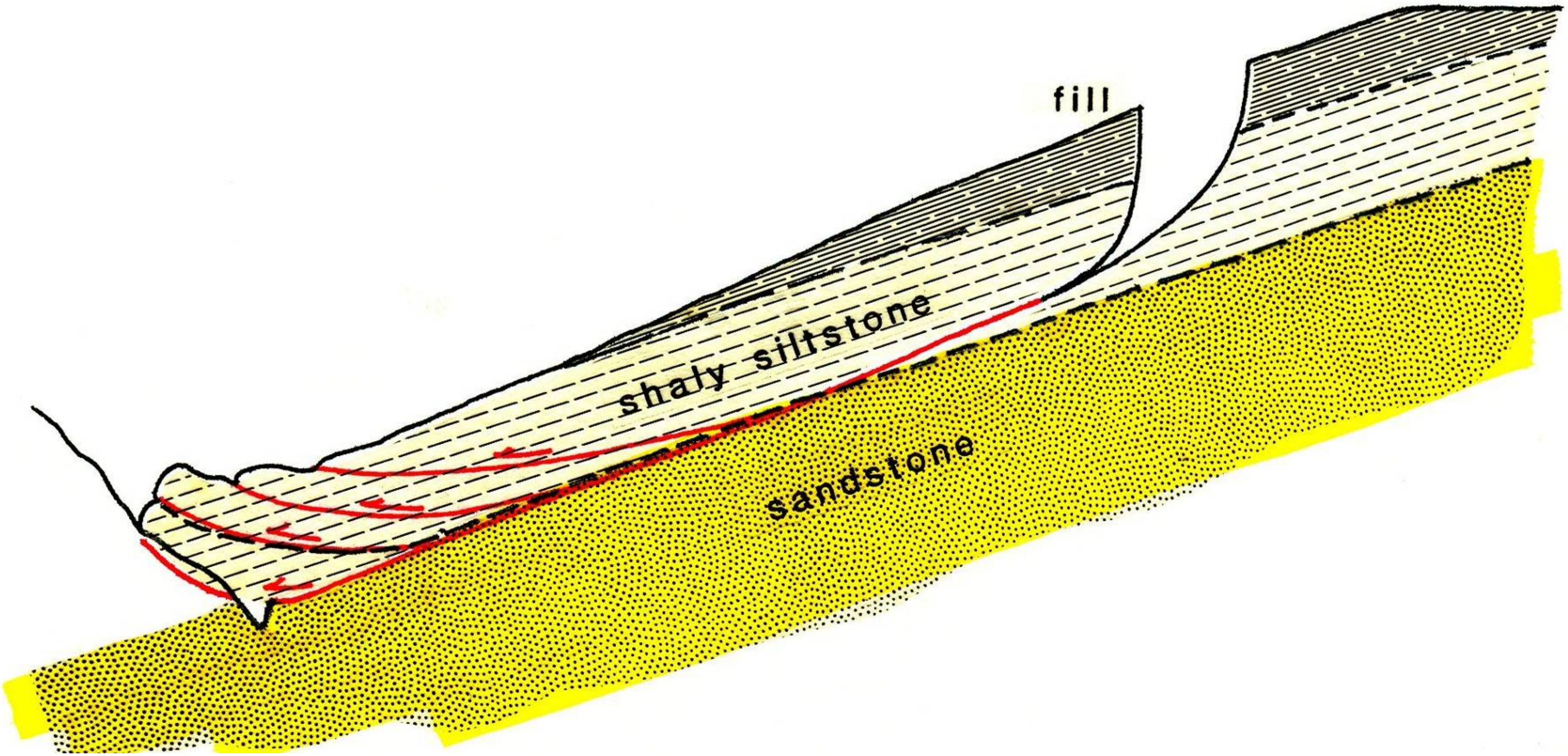


- **When excavations are made into dip slopes or slopes with upward inclined strata, potential planes of weakness are truncated and exposed. These are called out-of-dip, or daylighted cut slopes**

DIP SLOPE FAILURE

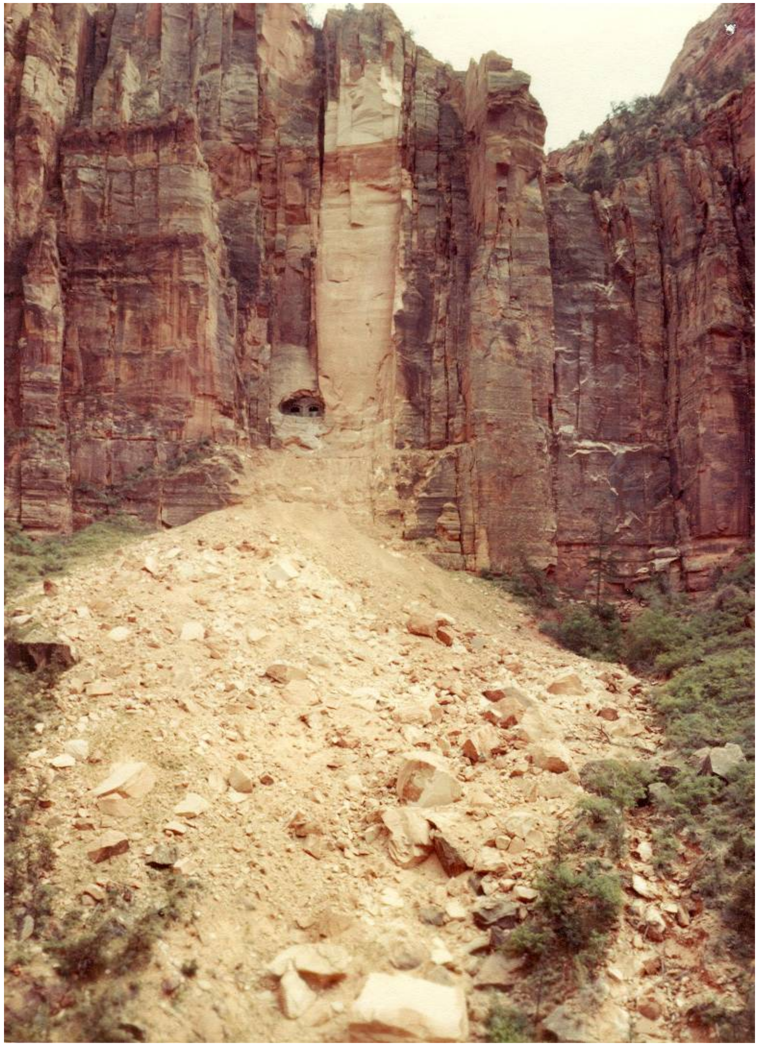


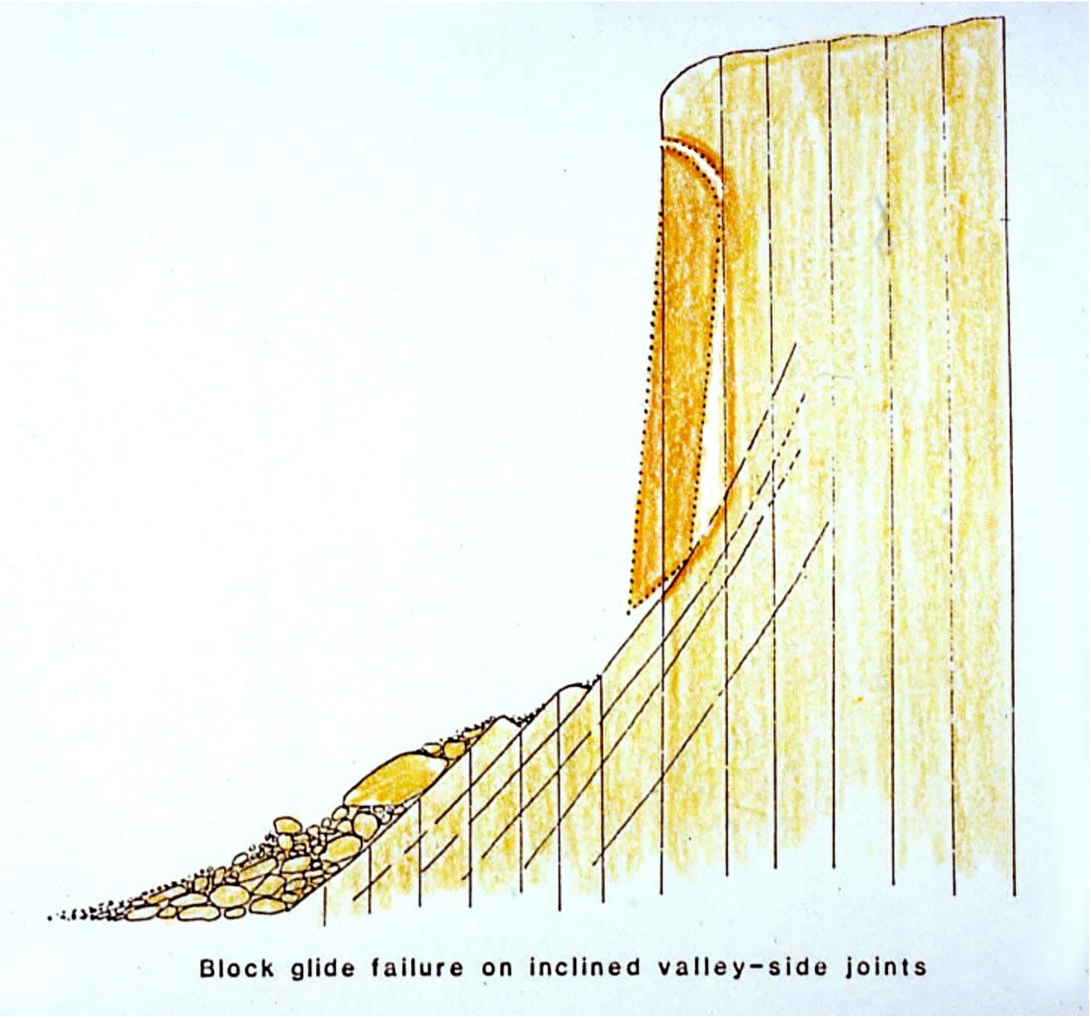
- **Mitigation of a major dip slope failure along Interstate 5 on the Ridge Route (Grapevine Pass) through the Tehachapi Mountains in California. What had originally been a 1:1 cut, had to be laid back to its apparent dip of 30 degrees.**



- **Many dip slope failures are ascribable to strain incompatability between materials of contrasting permeability or stiffness, such as sandstone and shale.**

- Dip slope conditions are also created by inclined discontinuities, such as systematic or secondary valley-side joints; especially in strongly foliated rocks, such as schist.

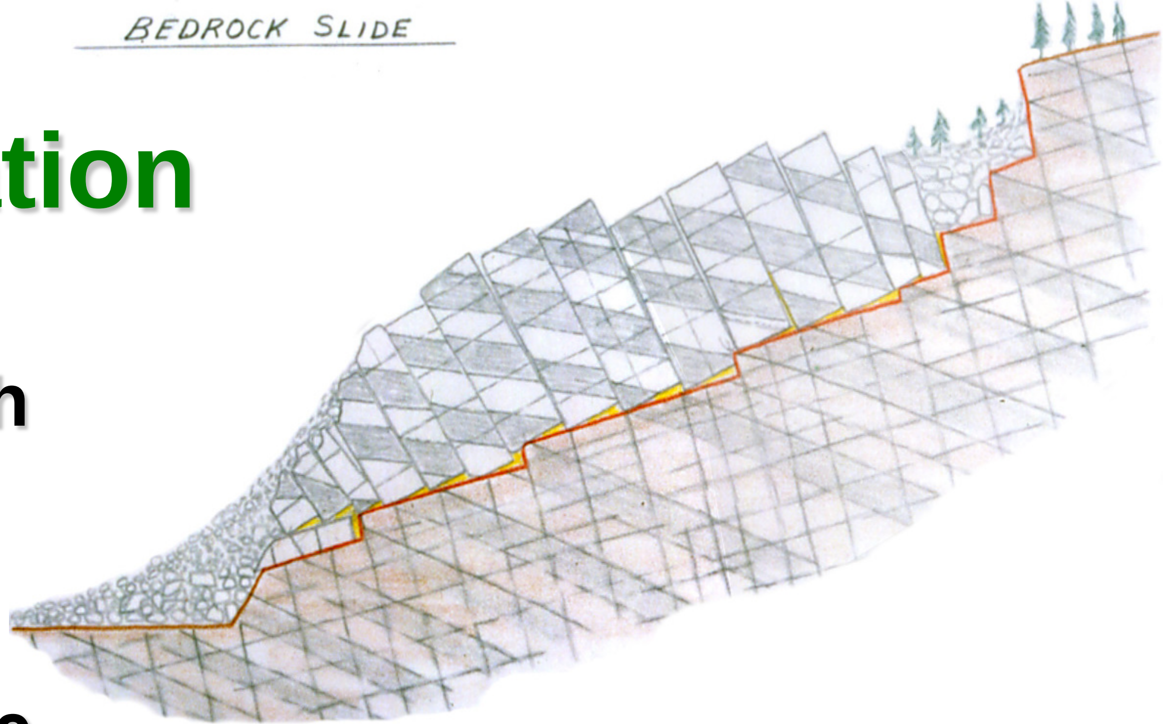




- **Inclined valley-side joints span most rock falls along steeply inclined escarpments, as sketched here.**

Planes of foliation

- Carmel Valley Landslide of March 1983, in massive biotite gneiss
- 45 degree cut slope made in 1940
- Foliation dipping back into slope
- Massive **toppling failure** along inclined joints

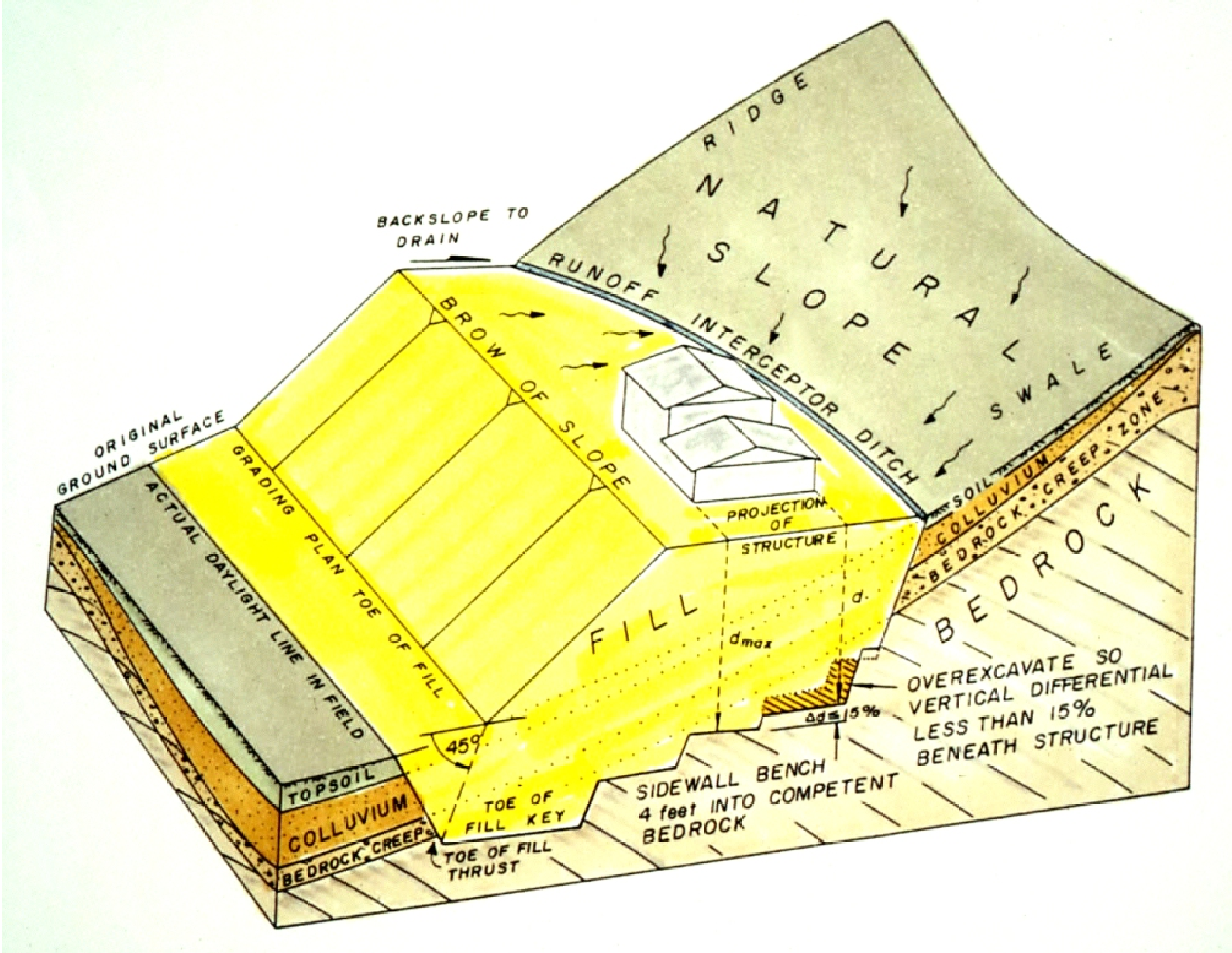


DIP SLOPE FAILURE

- Dip slope failure caused by surcharging slope with unkeyed fill and excavating toe of slope for development. Failure occurred along inclined bedding plane.

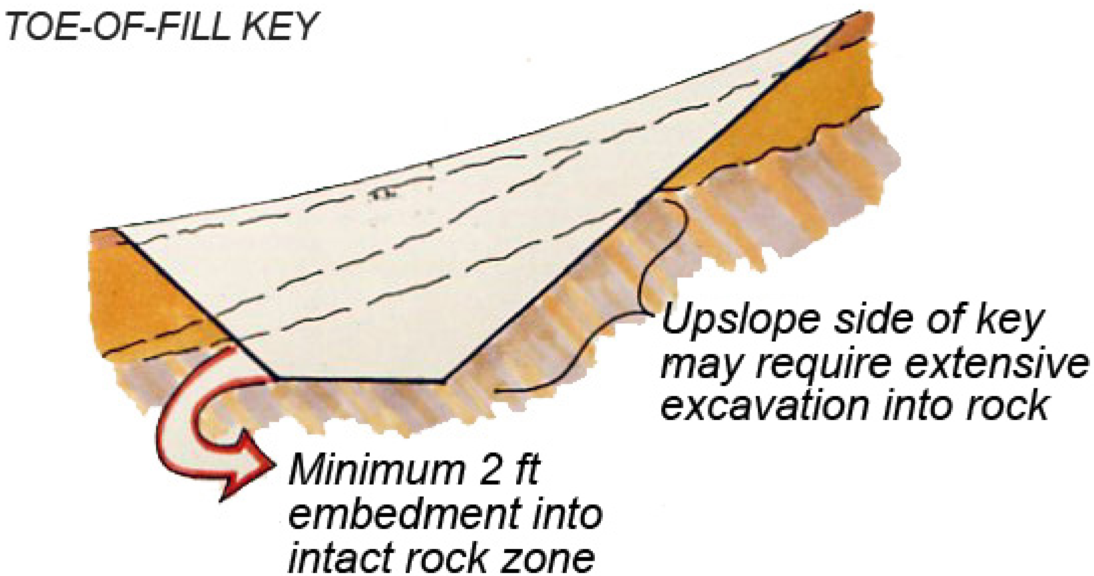
Part 3

HOW DEEP SHOULD WE DIG WHEN EFFECTING A SLIDE REPAIR?



- **Proper keying and benching of engineered fill requires overexcavation and on-site engineering geologic observation.**

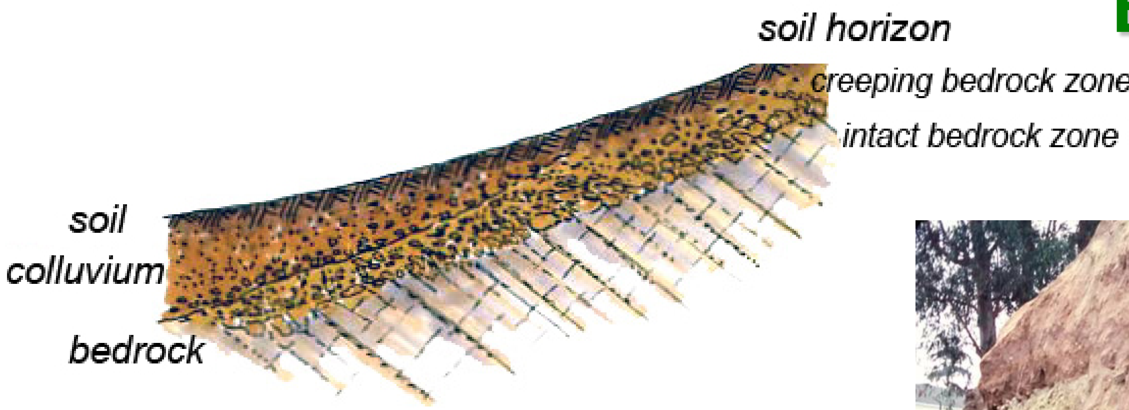
- The <u>toe-of-fill keyway</u> is the most important part of an embankment. It bears the overall thrust of the slope and usually contains the lowest subdrainage

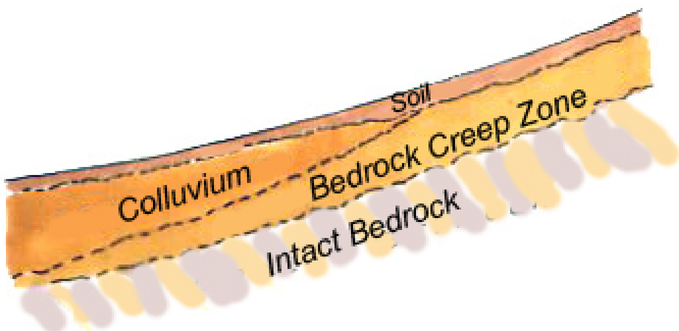


Keyways

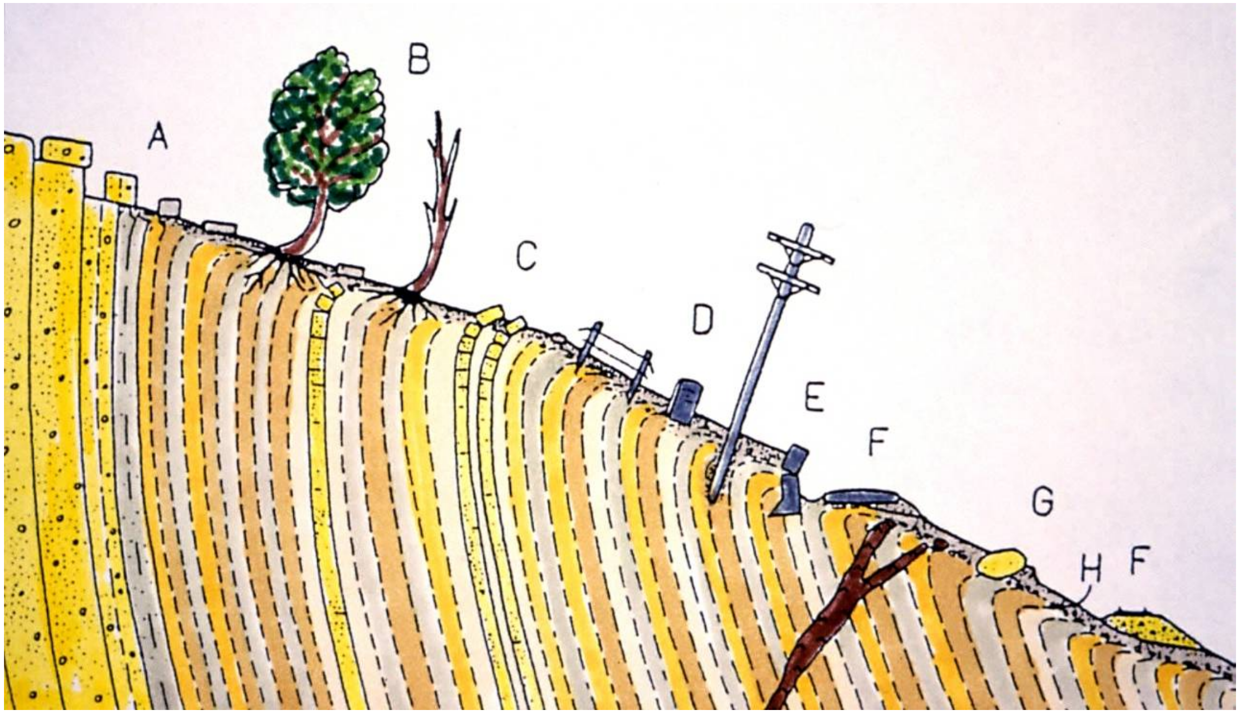
- **Shear keys and toe-of-fill keys need to extend beneath zones of past movement, such as the bedrock creep zone or zones of past and/or ancient landslippage**

Engineering geologic inspection needed





- **Many buttress slide repairs have failed because the keyways were not extended to sufficient depth to intercept older slip surfaces. Keyways need to be observed by competent engineering geologists.**

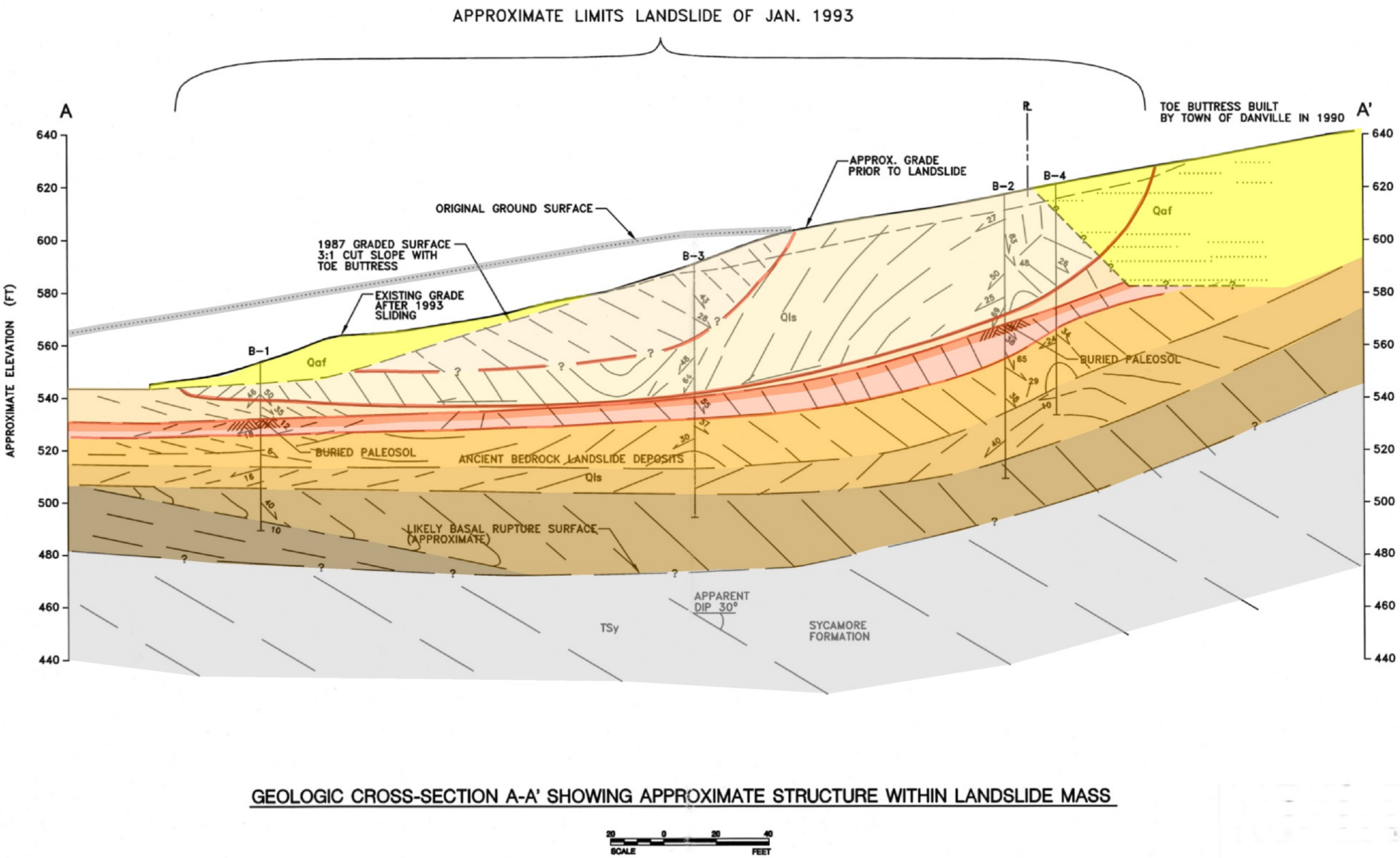


Bedrock Creep Zone

- A bedrock creep zone always exists on sloping ground; you just have to look for it. Water percolates through this zone. So it is of critical import.

Finding slip surfaces

- **Some slip surfaces are easy to see; many older, deeper surfaces are not easily recognized.**
- **The engineering geologist should also search diligently for *old slip surfaces*, which are often buried beneath active surfaces.**



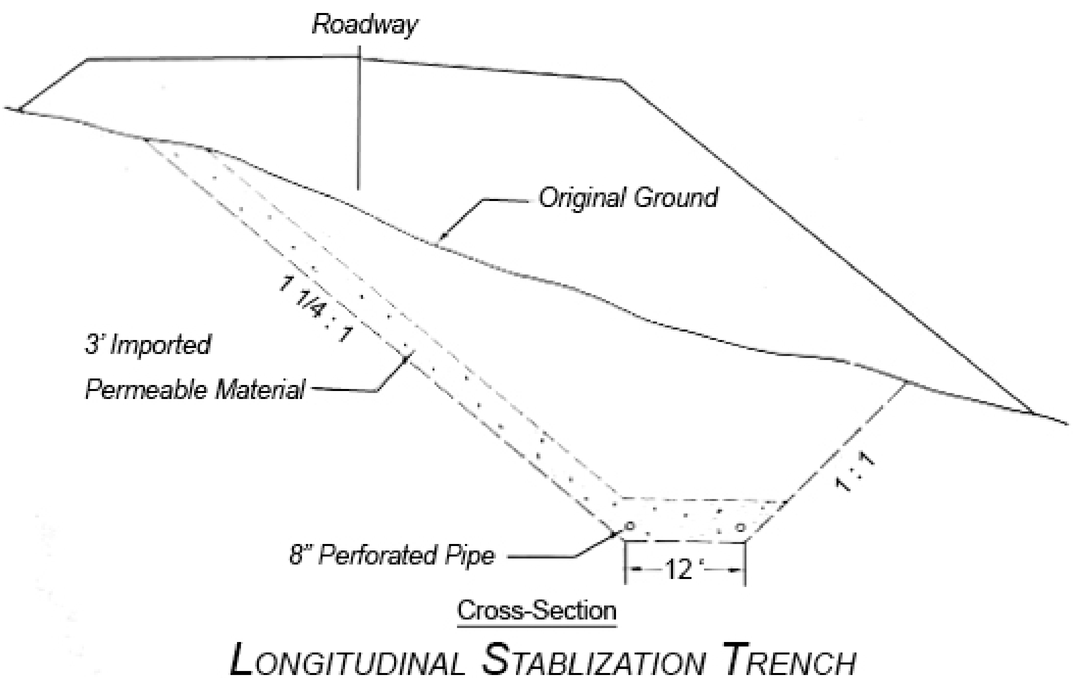
GEOLOGIC CROSS-SECTION A-A' SHOWING APPROXIMATE STRUCTURE WITHIN LANDSLIDE MASS

- **Multiple slip surfaces** are common in large, deep-seated landslides. Downhole logging often required to assess such the presence of such features.

Part 4

Some Notes on SUBDRAINAGE FOR SLOPE REPAIRS

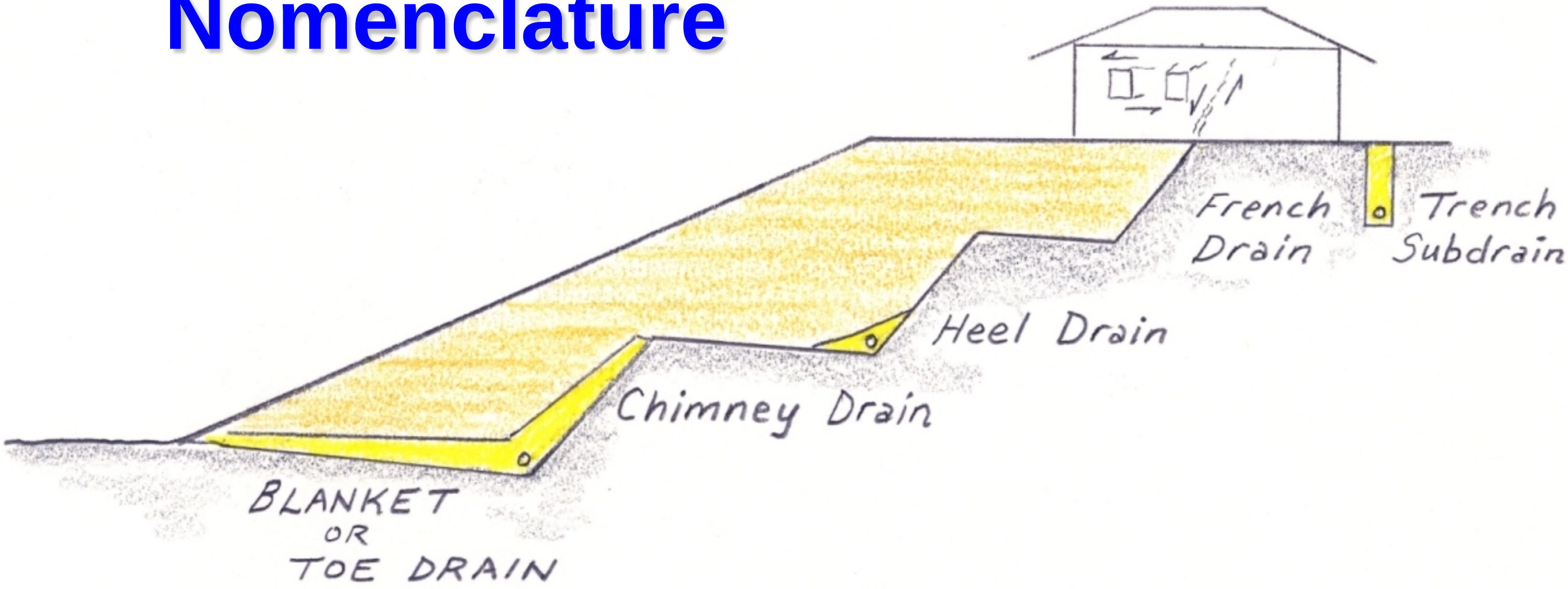
Subdrains within embankments



- In 1938 the Cal Div Hwys began using drained embankments where slope stability problems were being experienced.

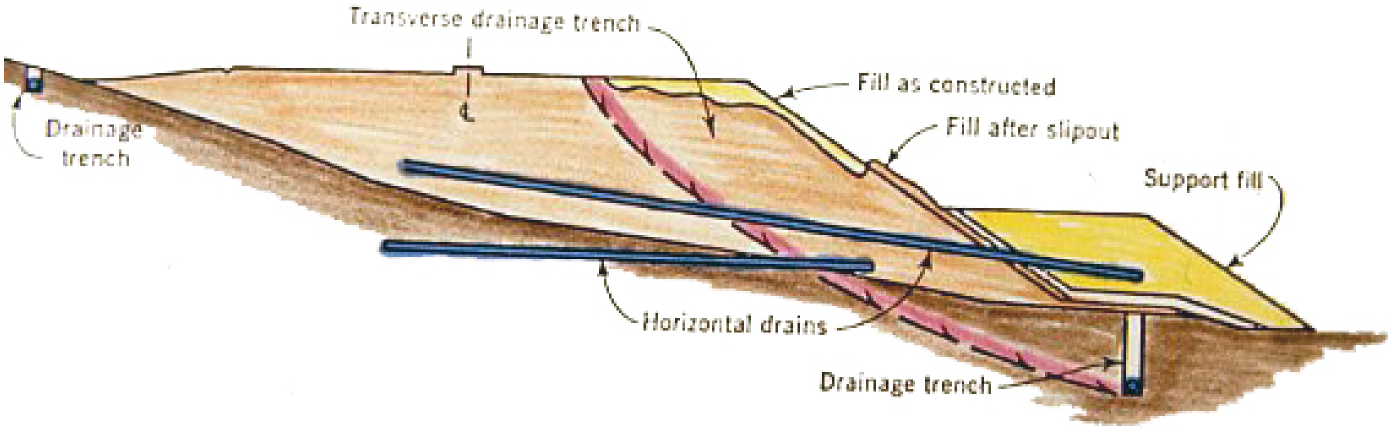
  This shows subdrain trenches for embankment along the new Los Gatos-Santa Cruz Hwy

Colloquial Subdrain Nomenclature



- Colloquial names applied to various kinds subdrains that are commonly used in and adjacent to sidehill embankments.
- The ubiquitous "French Drain" is named after Henry F. French, author of the text "*Farm Drainage*," published in 1859.

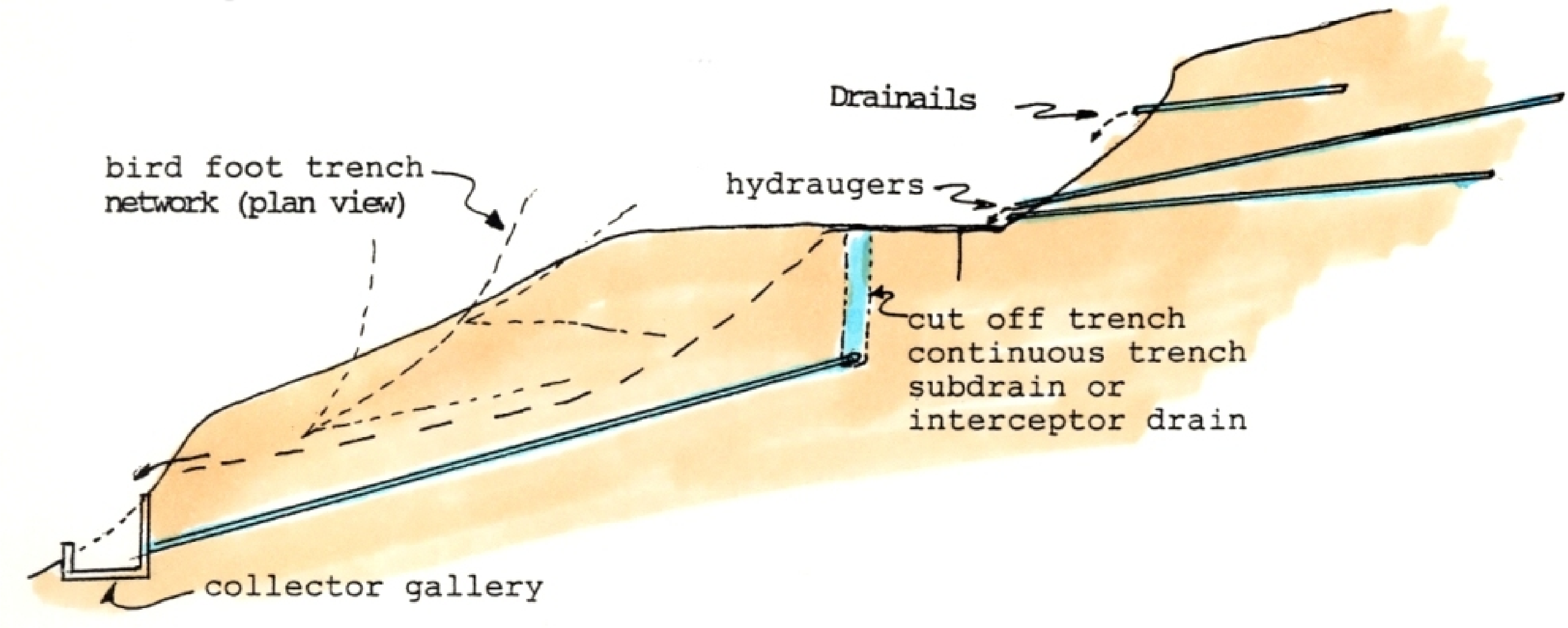
- **Temporary backcuts should be inspected carefully, looking for physical evidence of active seeps, such as those shown above, along the contact between the weathered band unweathered zones. Evidence of past seepage, such as carbonate (caliche) is also valuable.**



Slipout Treatment by a Combination of Methods

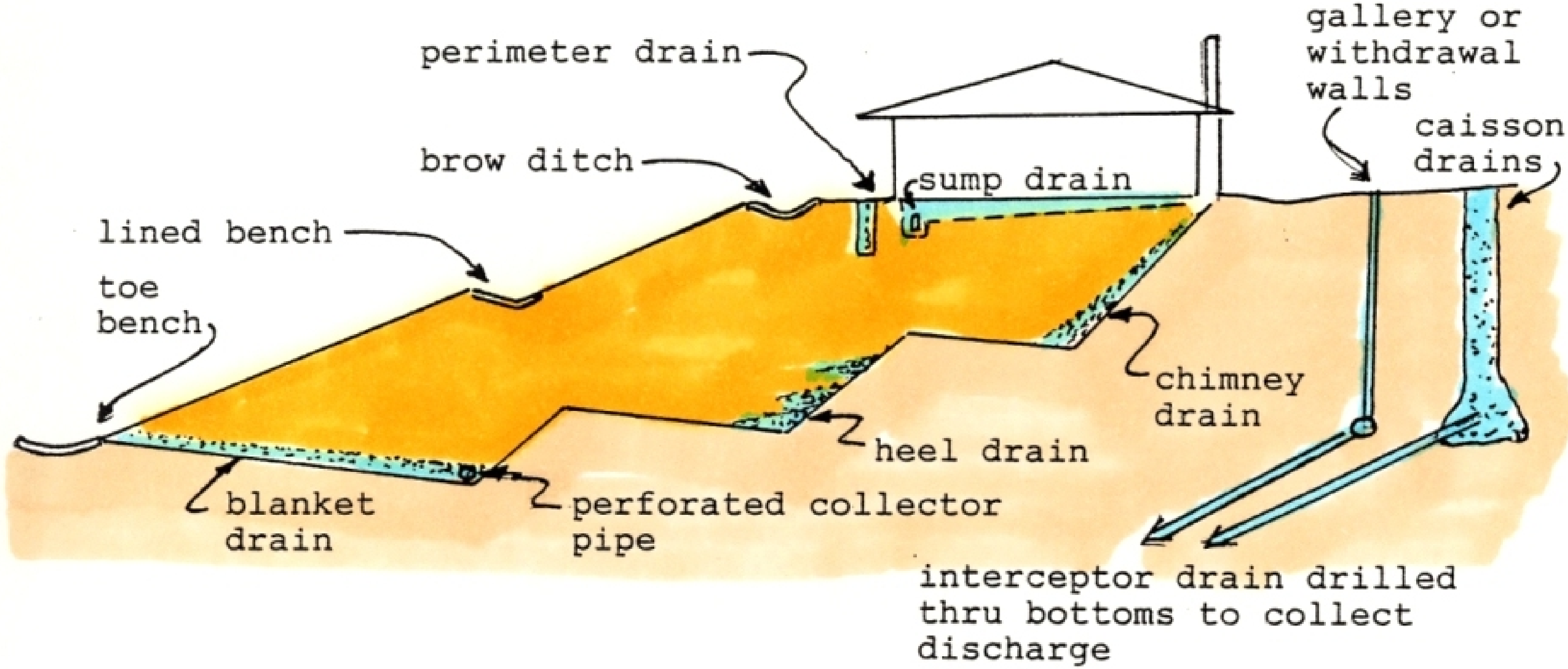
- **Combination systems utilizing subdrainage have been routinely employed since the early 1940s, as sketched here.**
- **This shows a toe buttress used in combination with several hydraugers.**
- **Note the drainage trench extending to maximum depth of sliding.**

Hydraugers allow gravity drainage when other options unavailable

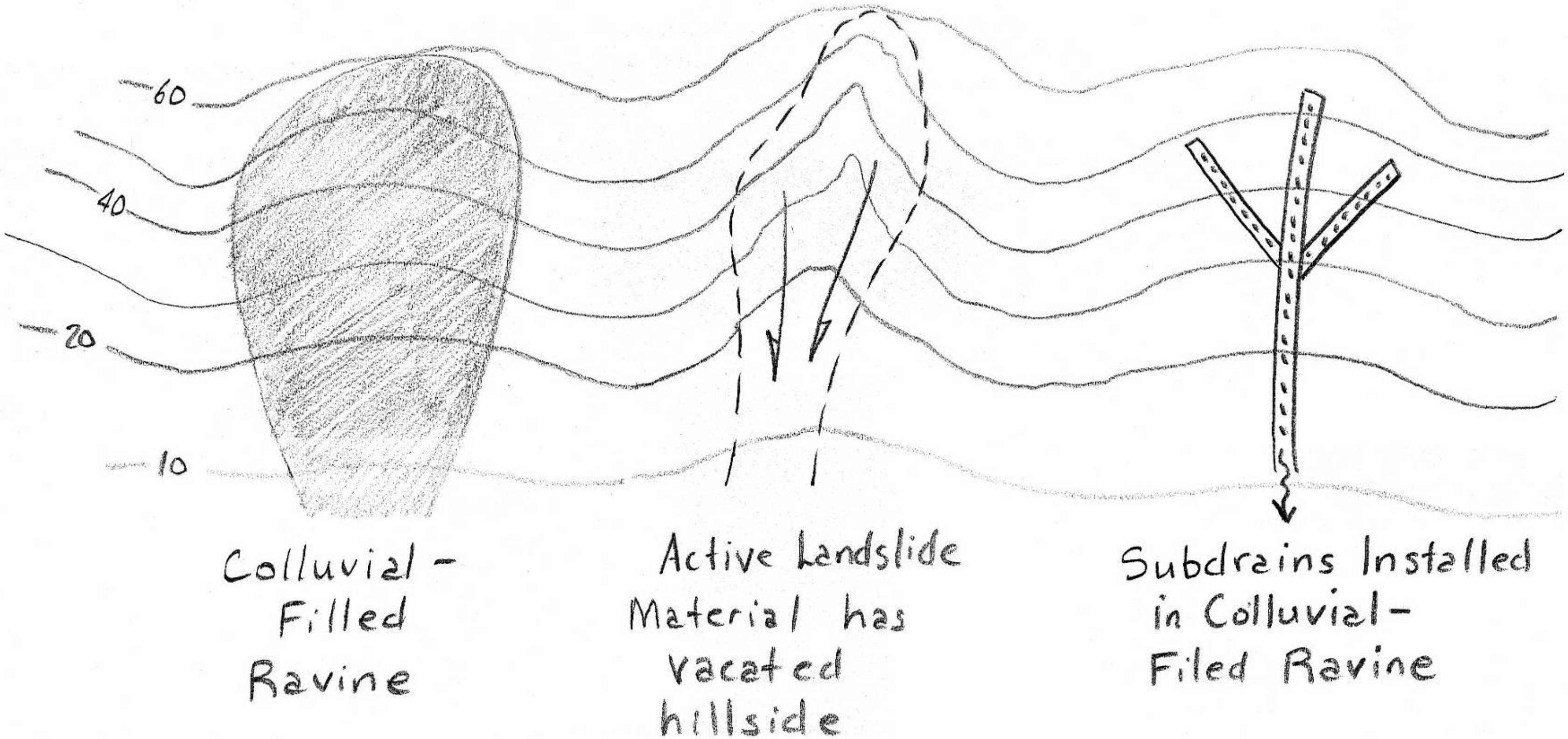


- **Drainage measures come in a wide variety of types.**
- **Inclined horizontal drains (hydraugers) can be used to intercept seepage back beneath undisturbed ground or used to convey discharge from other drainage measures, which are bereft of gravity outlets**

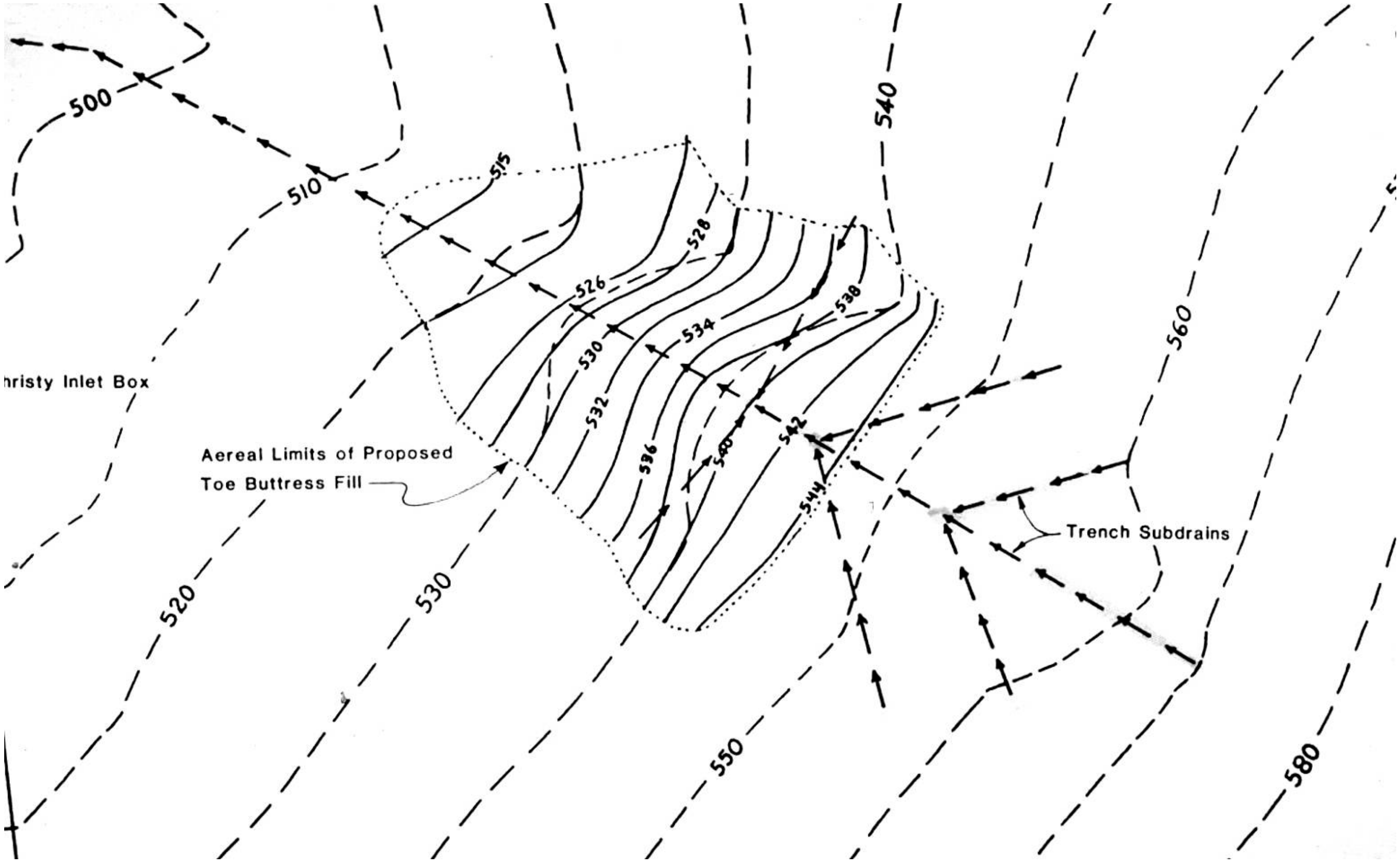
Drainage nets the most return on dollars invested, but requires ongoing monitoring and maintenance



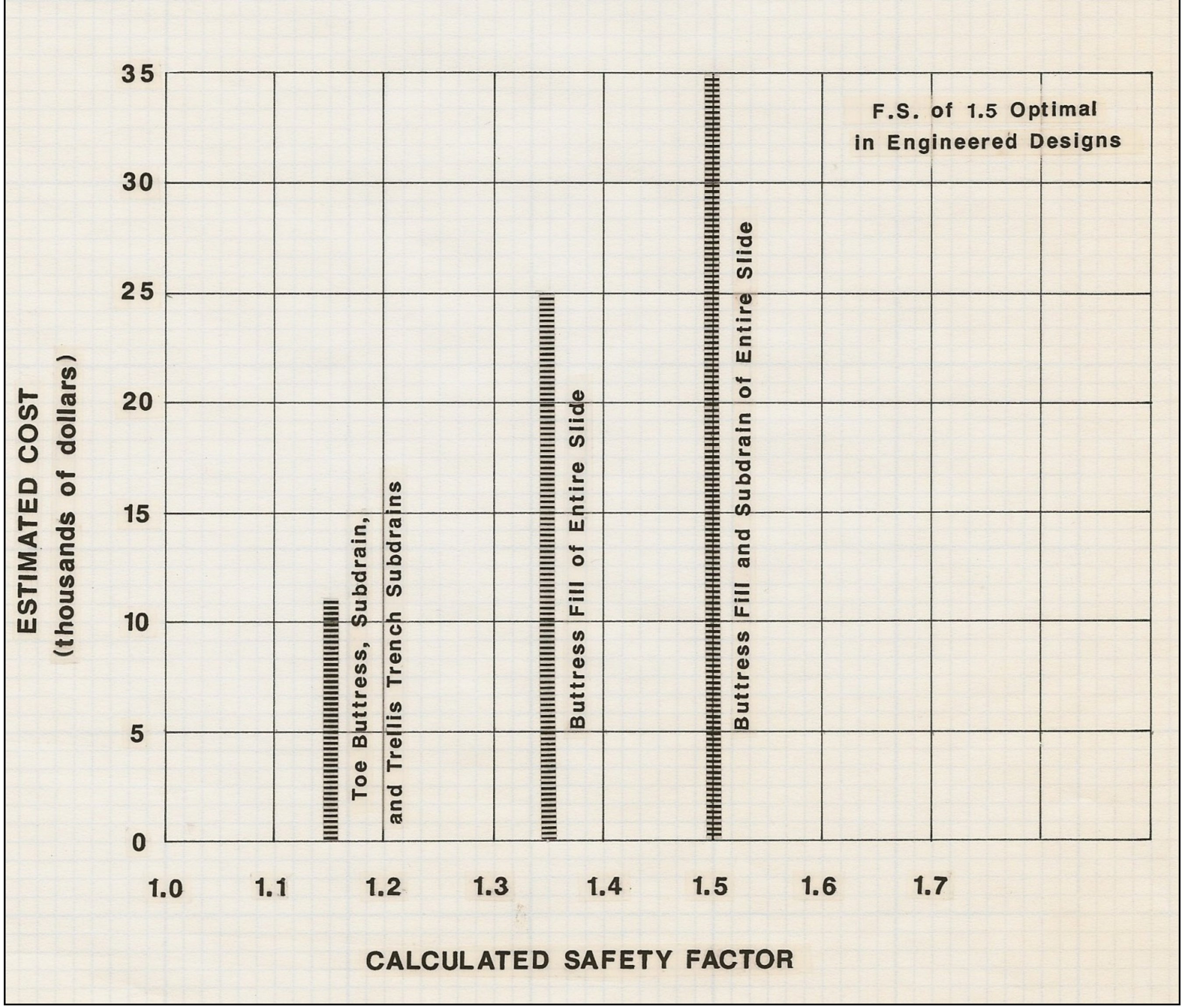
- **Drainage galleries can be installed by excavating a line of wells on close spacings or using underreams to connect caisson drains, then decanting collected seepage through horizontal drains.**



- **Interconnected trench subdrains**, **or "birdfoot drains," can be an economical way of stabilizing active landslides, if sufficient quantities of free-draining materials are available nearby**

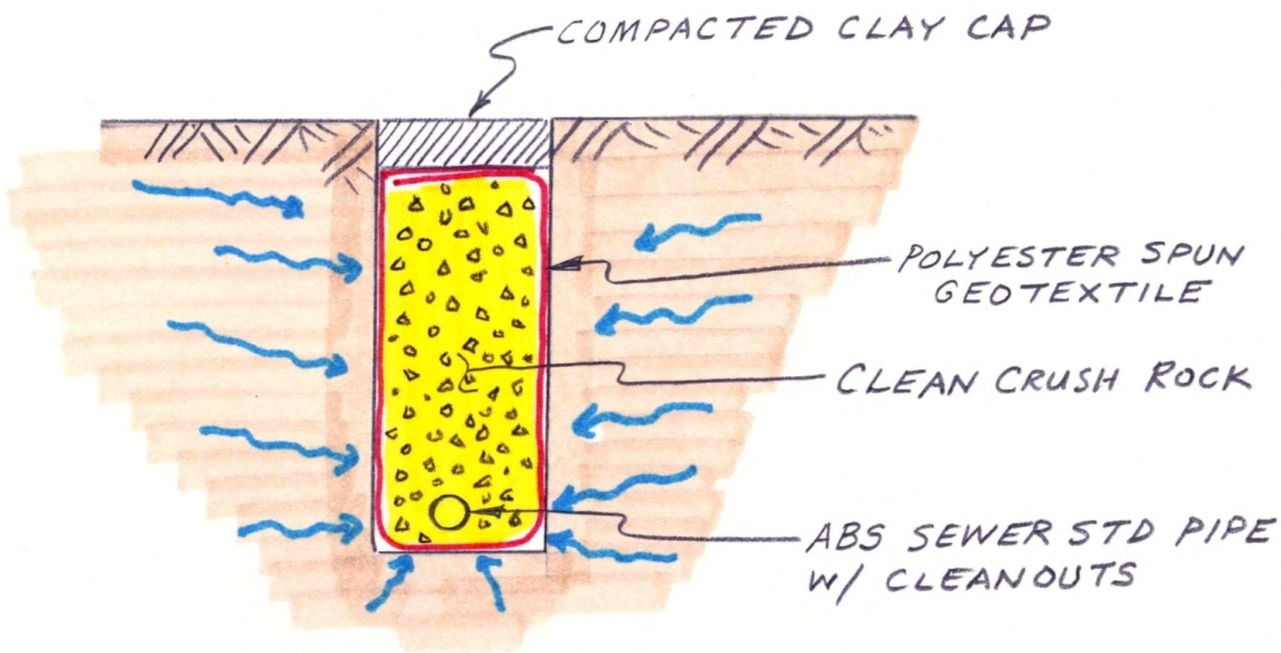


- **Typical work plan for a “birdfoot drain” slope repair, employing a herringbone-shaped array of rock-filled trenches, sloped downhill to promote gravity flow (without collector pipes).**



- **Cost-benefit analysis of various schemes to repair a recently-active landslide, employing birdfoot drains or conventional buttress fill with subdrains. Note diminished factor of safety, which should be assessed using a risk-consequence matrix.**

GEOTEXTILE FILTER ENCASING A TRENCH SUBDRAIN

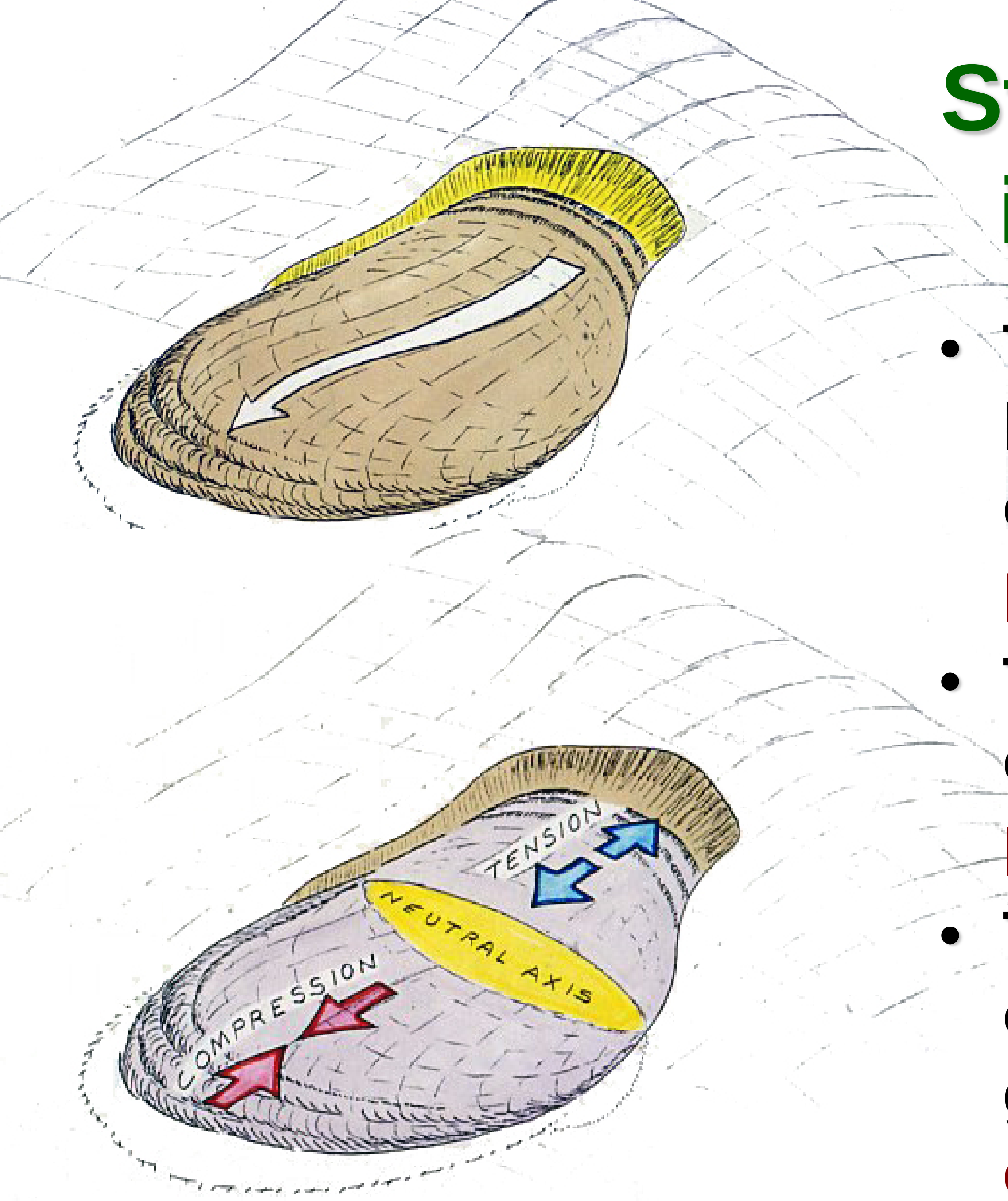


- **Subdrains should be placed along the axes of former water courses, where they will be most effective – collecting water that percolates along "seepage conduits" developed over eons of time in native ground.**

Part 4

Overview of RETENTION STRUCTURES FOR LANDSLIDE MITIGATION

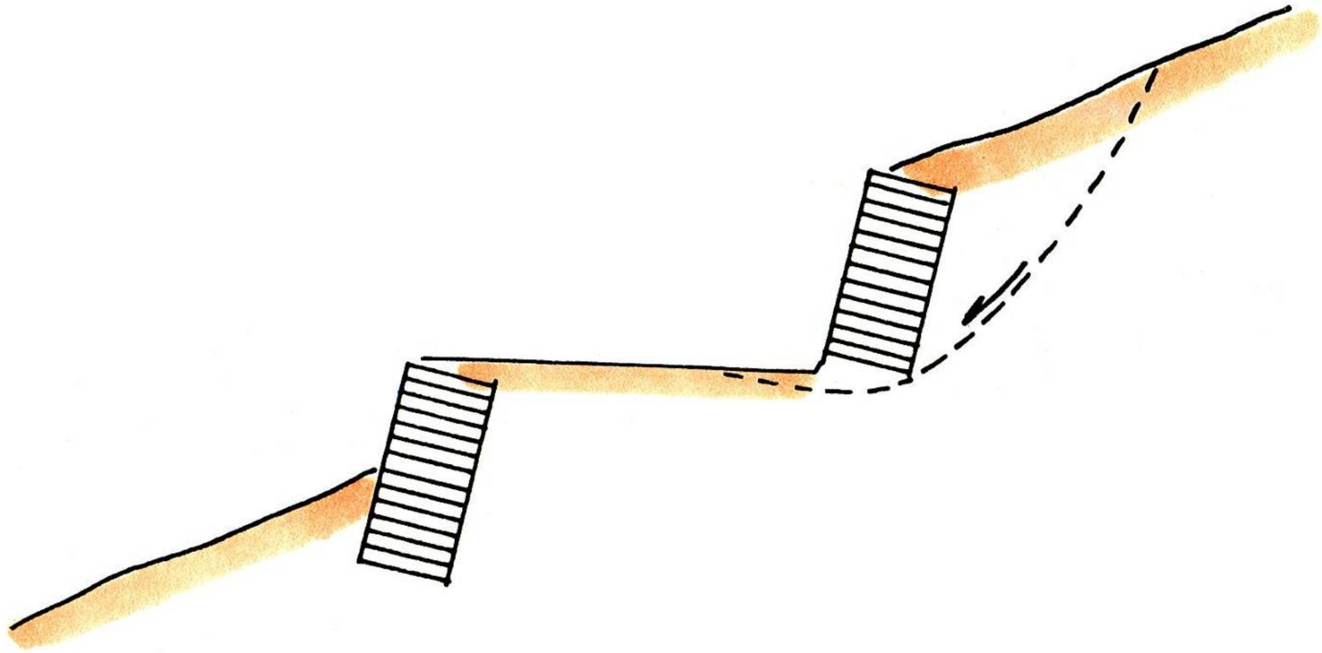
States of Stress in a landslide



- **The upper third of a landslide usually exhibits active earth pressures**
- **The neutral axis exhibits at-rest pressures**
- **The lower two-thirds of the slide can generate passive earth pressures**

- **Bending failure of a 36-inch wide flange H-beam retaining wall constructed at the base of a creeping slope in Richmond, CA.**
- **The wall was not designed to resist the passive loads to which it was subjected**

Inadequate Toe Embedment

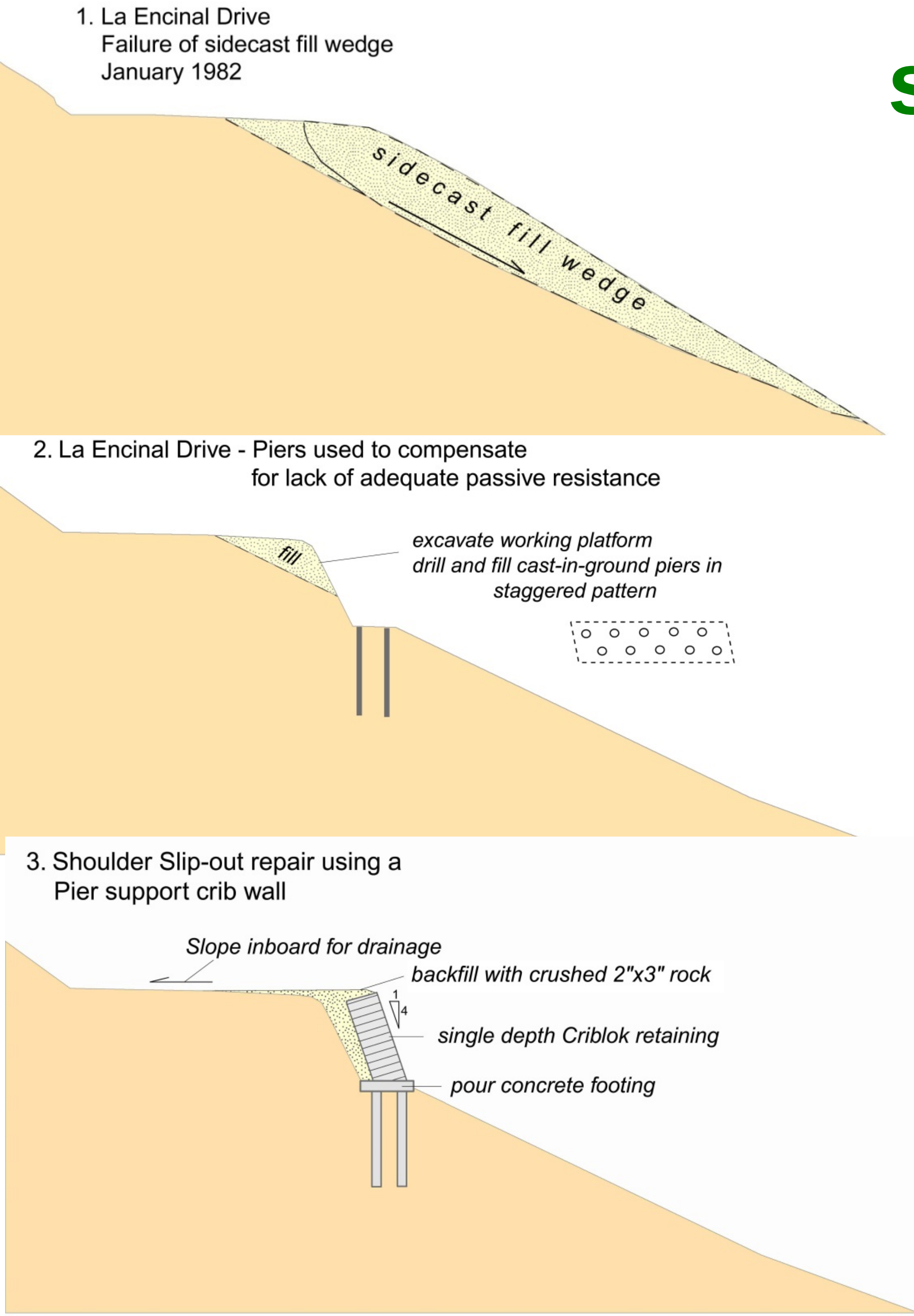


- **Another common failure mode for crib walls constructed on hillsides is inadequate toe embedment, on either uphill or downhill walls, as sketched above.**

These failures occurred due to inadequate toe embedment. The contractor constructed the walls, but did not pave the road at the base of the walls because the job was shut down for the winter.

The thick pavement section (18 inches) was intended to buttress the toe of the walls, which were supporting road cuts.

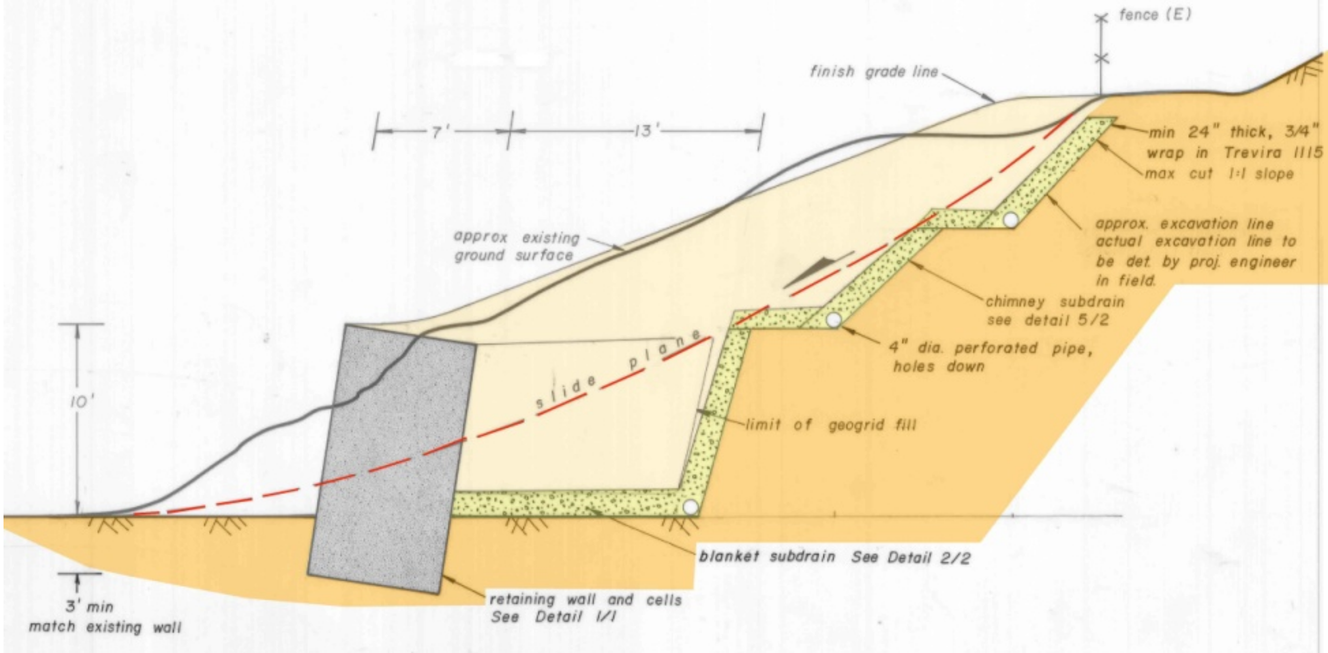
supported crib wall

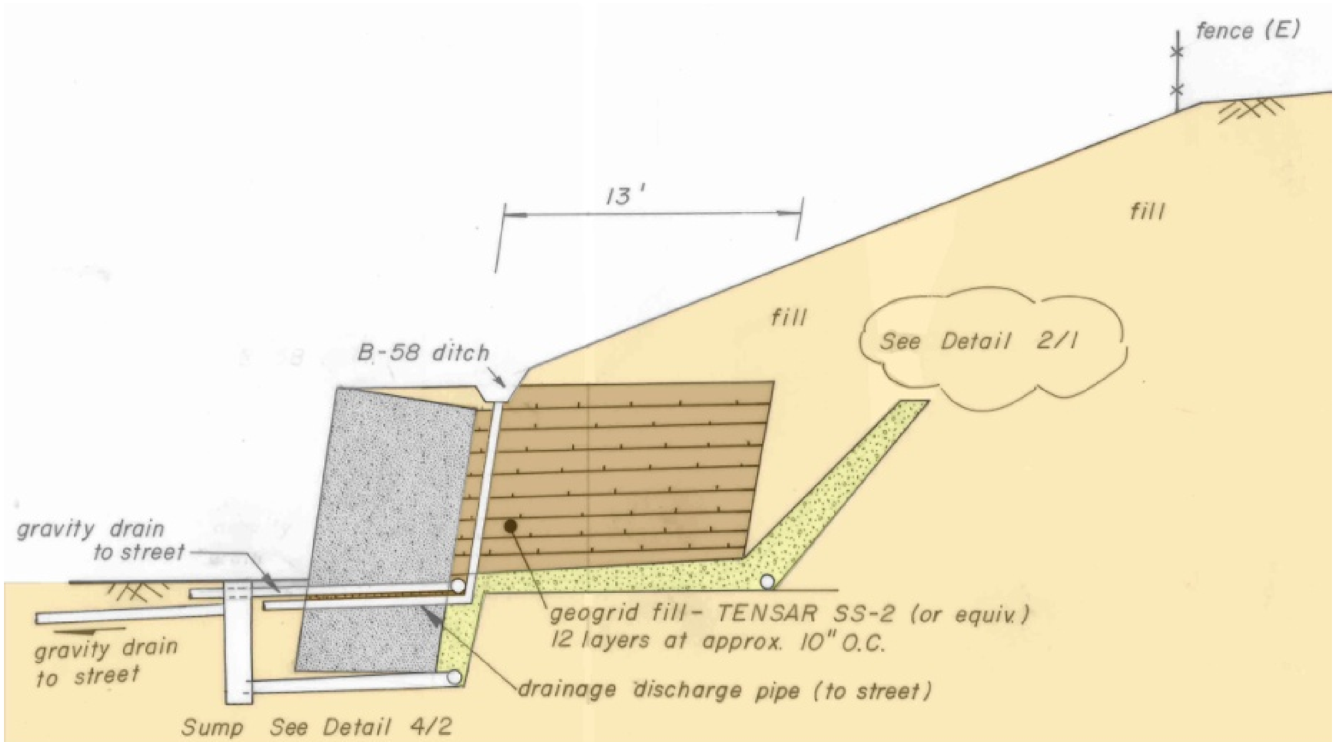


In cases where landslides create over-steepened descending slopes below paved rights-of-way, it may be advantageous to install drilled piers from truck-mounted drilling rigs on the remaining pavement, because it will require a minimum tonnage of import materials (steel reinforcing, concrete, and rockfill).

- **Steel bin walls** are designed using the same basis as crib walls and are generally conservative. This steel bin wall failed because it was designed for active soil pressures, not the landslide feature that lay above the wall.

Bin Wall Repairs





- Steel bin walls can be employed much like crib walls
- Check adequacy of embedment and subdrainage
- Backfill with crushed rock

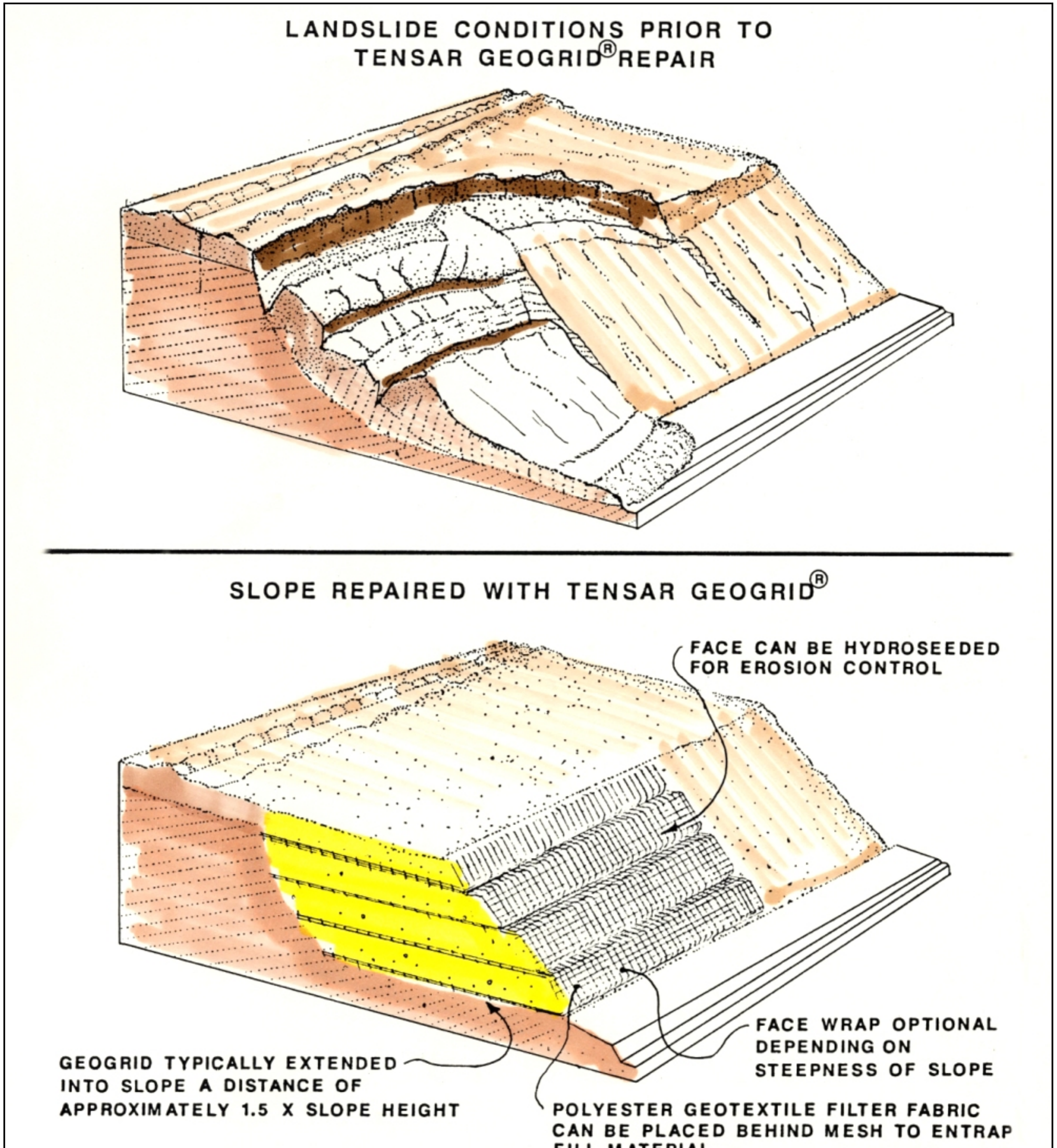
- **Toe kick-out failure** of cantilever walls often occurs when the cantilever elements are excessively thin, as shown here.
- Common examples of thin elements are railroad rails, telephone poles (shown here), and recycled I-beams
- This wall was tied back

- **Titled tied-back cantilever wall being replaced. It is very difficult to design a cantilever wall on slopes steeper than 2:1 because of the paucity of passive reaction area and slope creep loads.**

Part 5

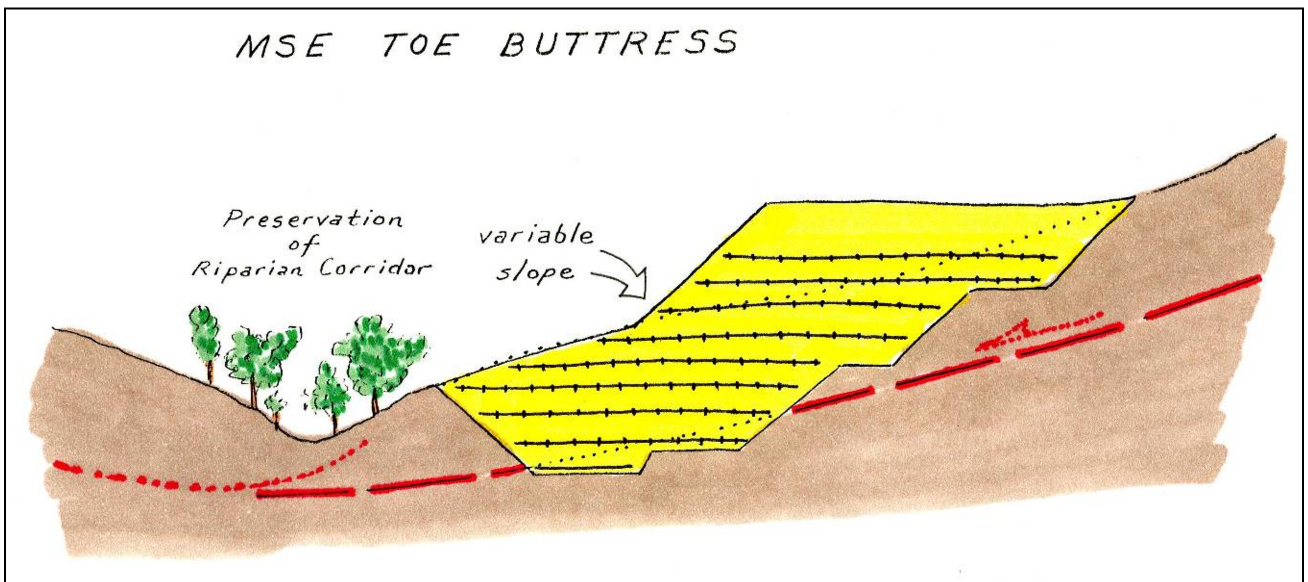
MECHANICALLY STABILIZED EMBANKMENTS

- **Nature's concept of soil reinforcement shown to good effect in the root network of a banyan tree, stabilizing a near-vertical cut along a trail leading up to Diamond Head, Oahu, Hawaii.**



- **Geotextiles and reinforcing grids can be combined with low strength soils to engender additional shear strength; greatly enhancing repair options when space is tight.**

Tensile soil reinforcement can also be applied to landslide repairs, allowing selective reinforcement of limited zones, as sketch below left

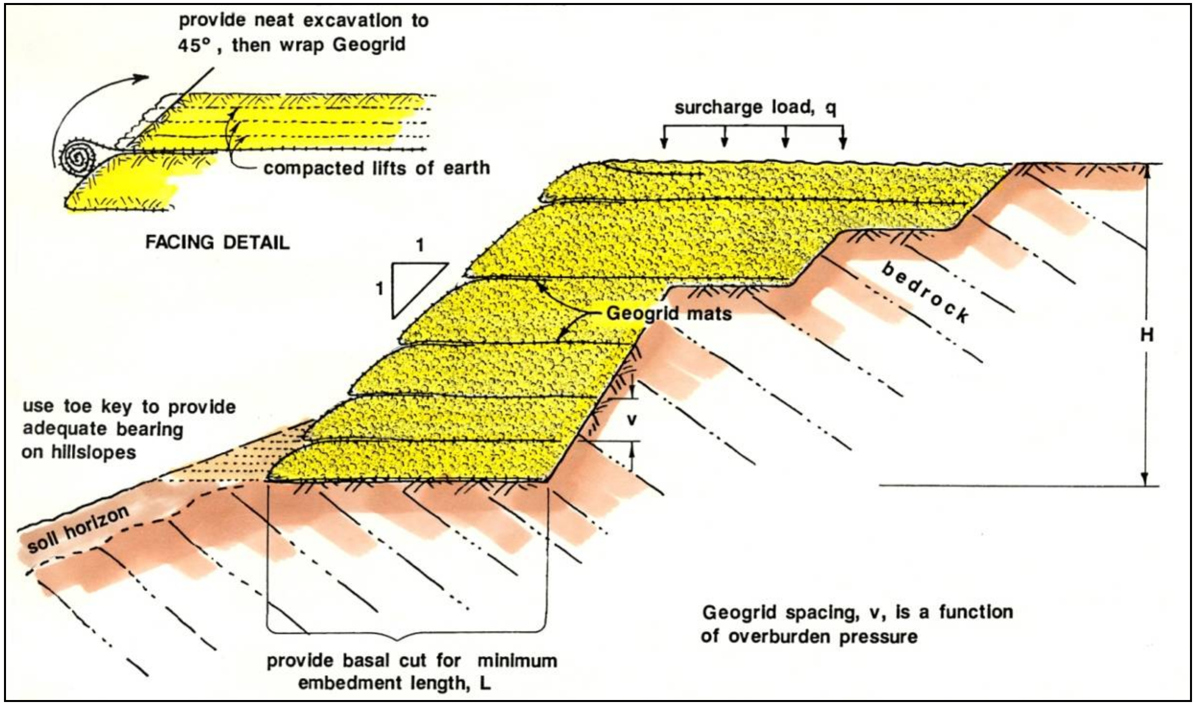


MSE shear key at toe of ancient landslide complex

First Reinforced Earth wall in USA -1969

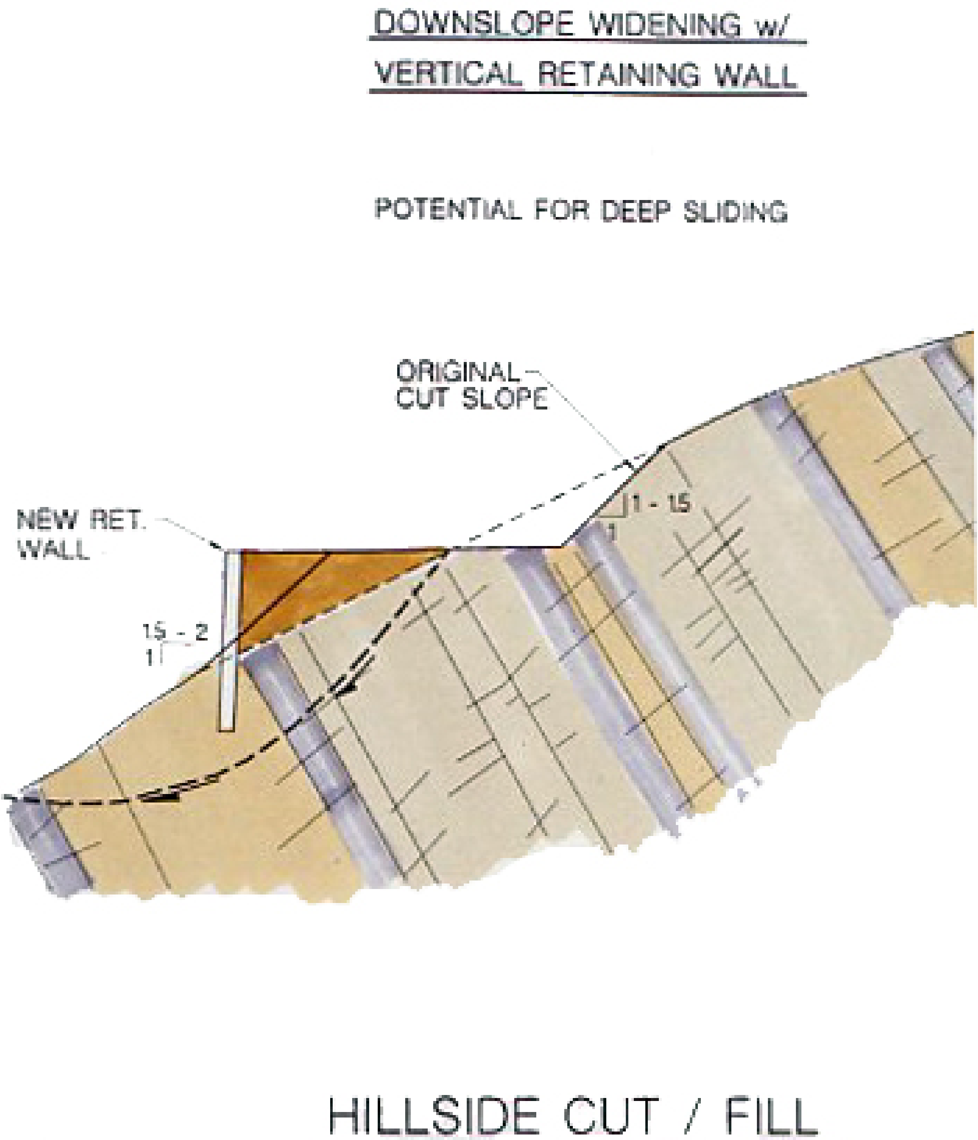
Reinforced Earth wall on US 50

Mechanically Stabilized Embankments (MSEs) utilize tensile reinforcement in many different forms: from galvanized metal strips or ribbons, to HDPE geotextile mats, like those shown above right. This reinforcement increases the shear strength and bearing capacity of the backfill.



Geotextiles can be layered in compacted fill embankments to engender additional shear strength. Face wrapping allows slopes of almost any desired inclination to be constructed with relative ease.

Internal versus *global* stability



- **Retention systems need to be evaluated for both internal, local, and global stability**
- **Global stability usually controls the design in landslide mitigation applications**

- **Tight face wrapping with geogrids can produce a neat face with near-zero erosion**

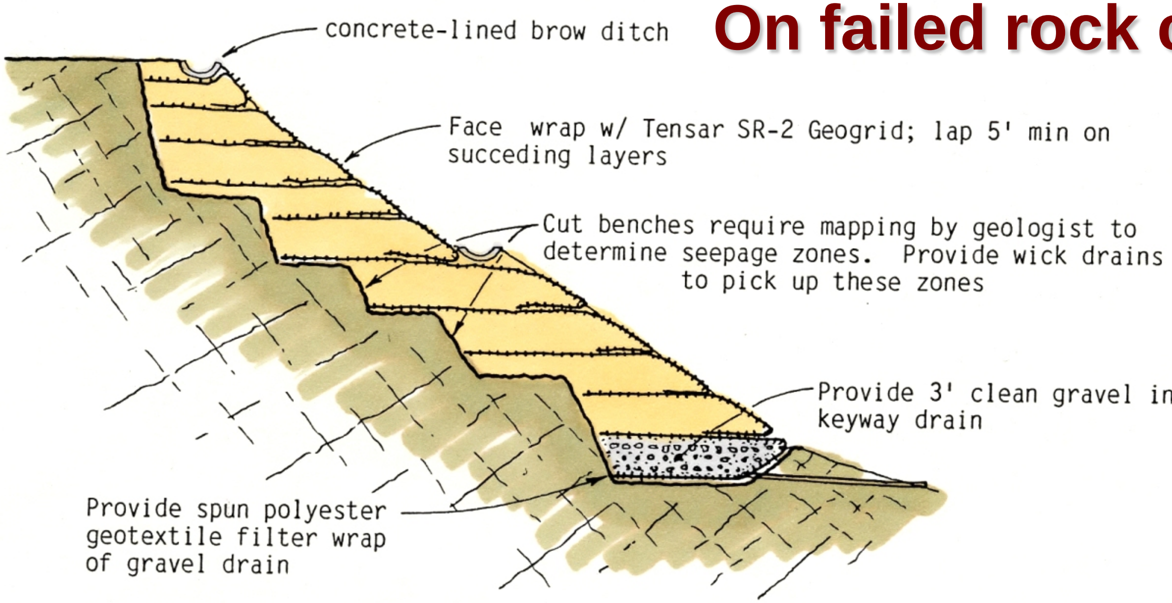
- **As each lift of grid is set, the last layer is brought up and wrapped, to create the finished face**

Neat 45 degree face

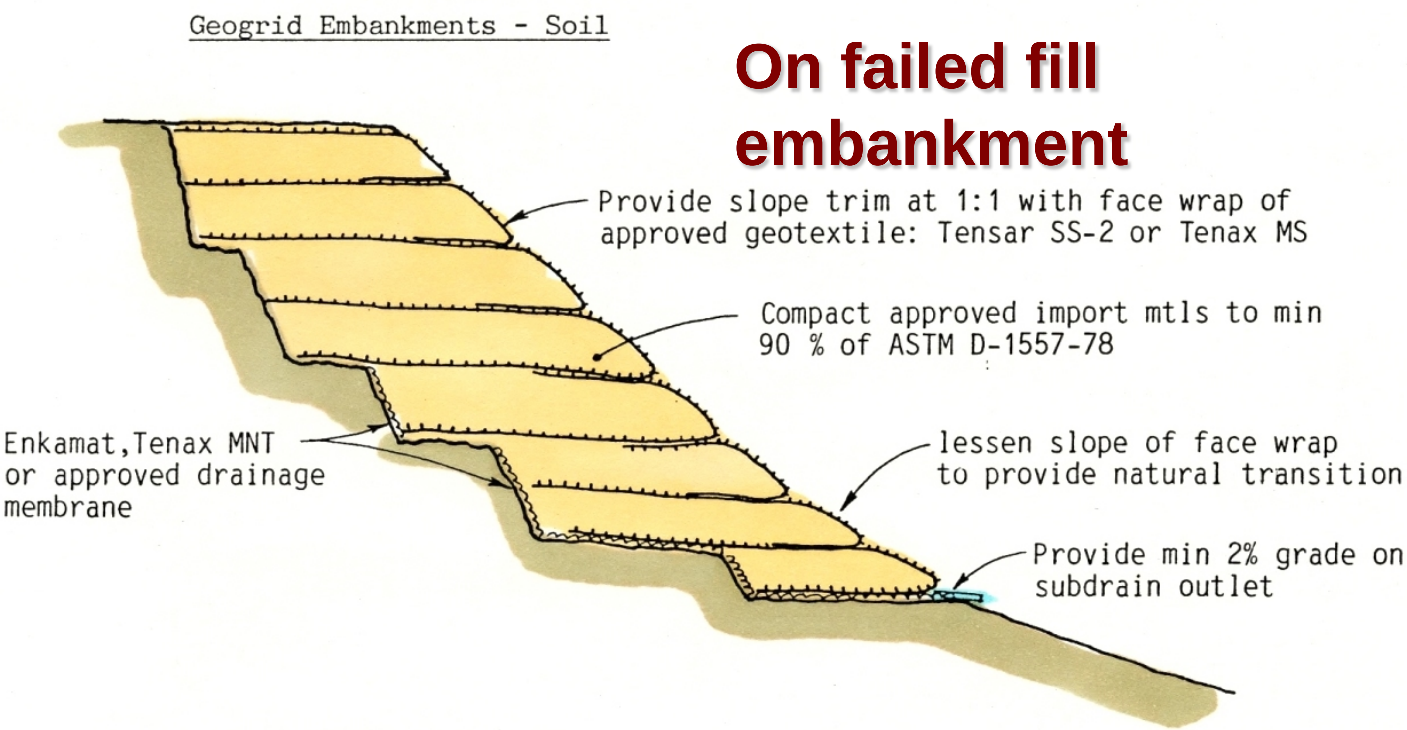
- These images show the finished form of the MSE using face wrapping of the geogrid to eliminate erosion.
- Photos contrast vegetation cover during wet and dry seasons

Typical MSE sections

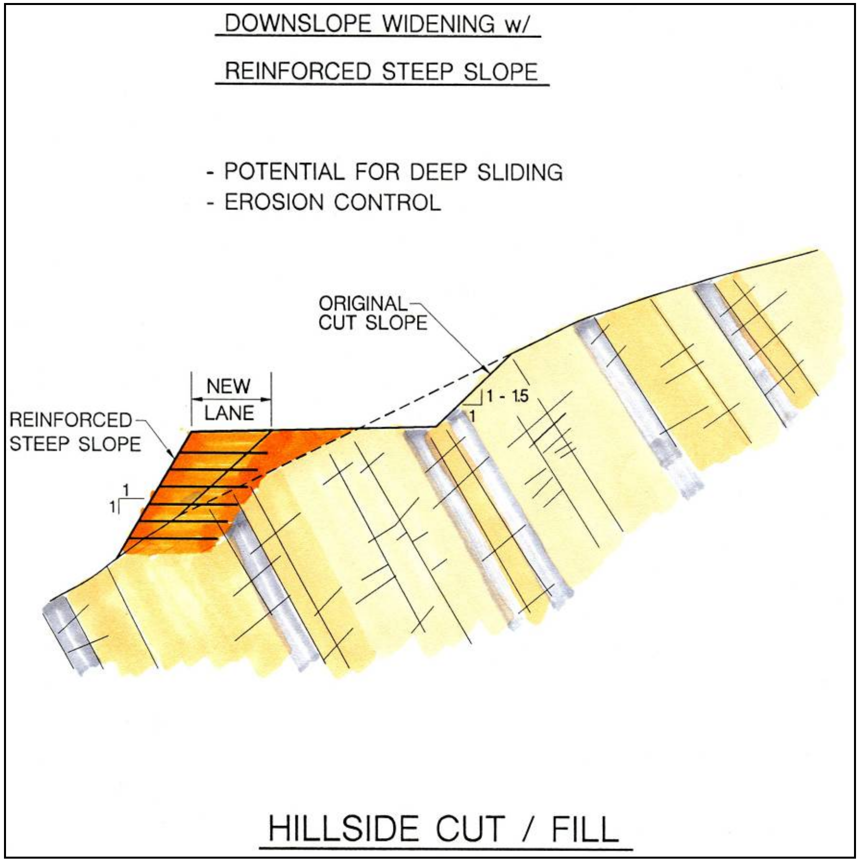
On failed rock cut

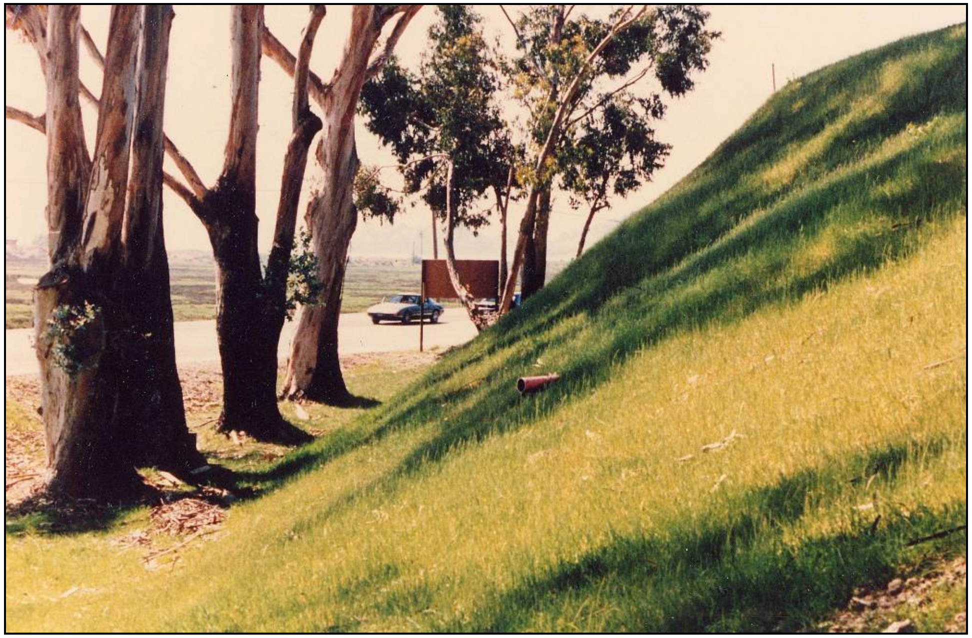


On failed fill embankment



- Note how much *less grip distance* is required on weathered rock cut slopes, as compared to soil slopes

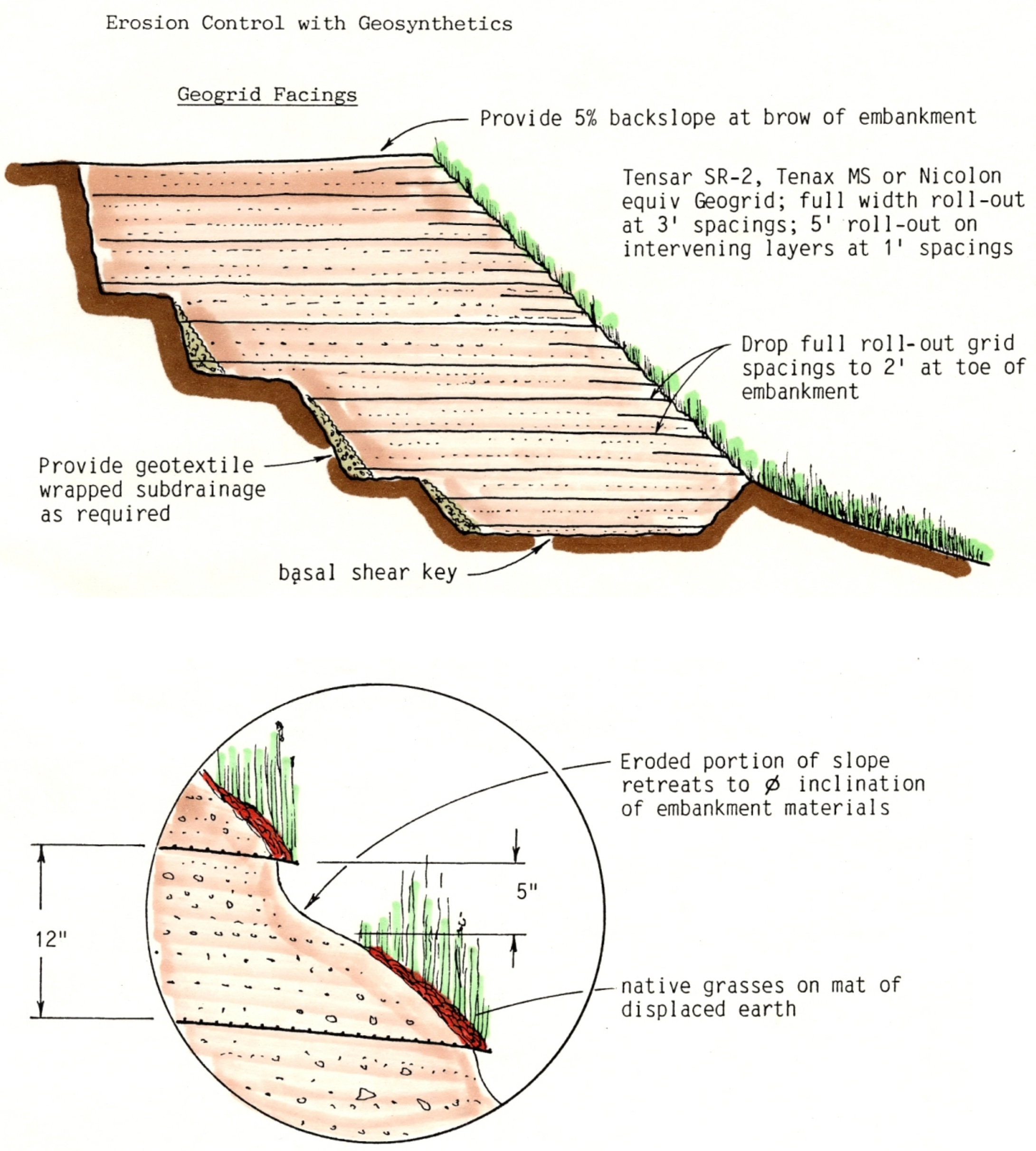




45 degree embankment slope along San Pedro Boulevard in San Rafael, CA

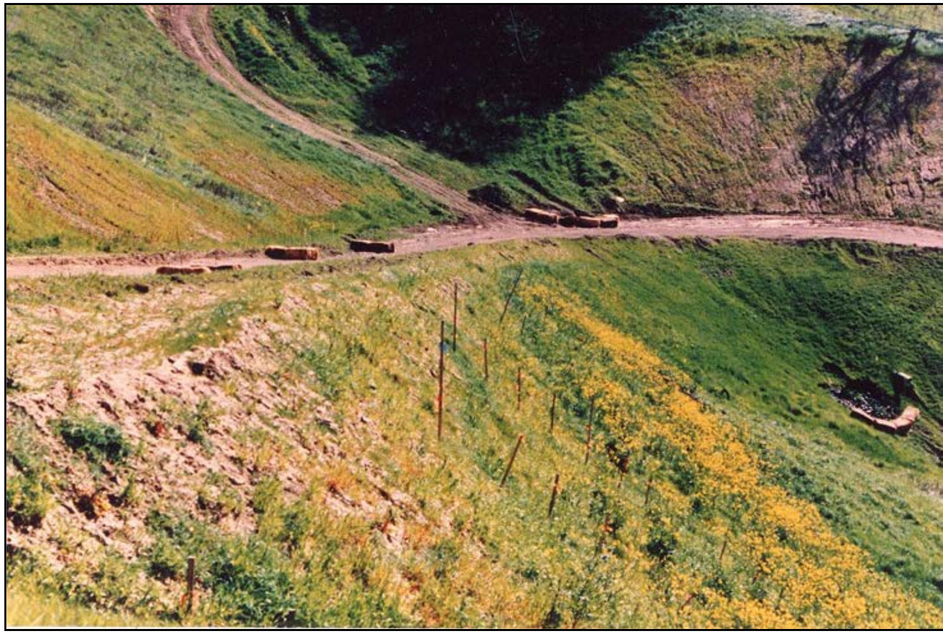
Geotextile soil reinforcement allows near unlimited latitude in designing earth support systems, with minimal corridor disturbance and right-of-way impact.

False Layers



Detail view of the erosion which can be expected to occur between Geogrid layers. The effective slope height is reduced to 12" by embedment of the Geogrid.

- Short strips, or “false layers” of geotextiles can be incorporated between reinforcement layers of mechanically stabilized embankments (MSE) to restrict slope raveling and erosion
- Section through a MSE embankment with a 1:1 (45 degree) finish face inclination. The embankment utilized false layers every 12 inches, extending 5 feet into the slope.

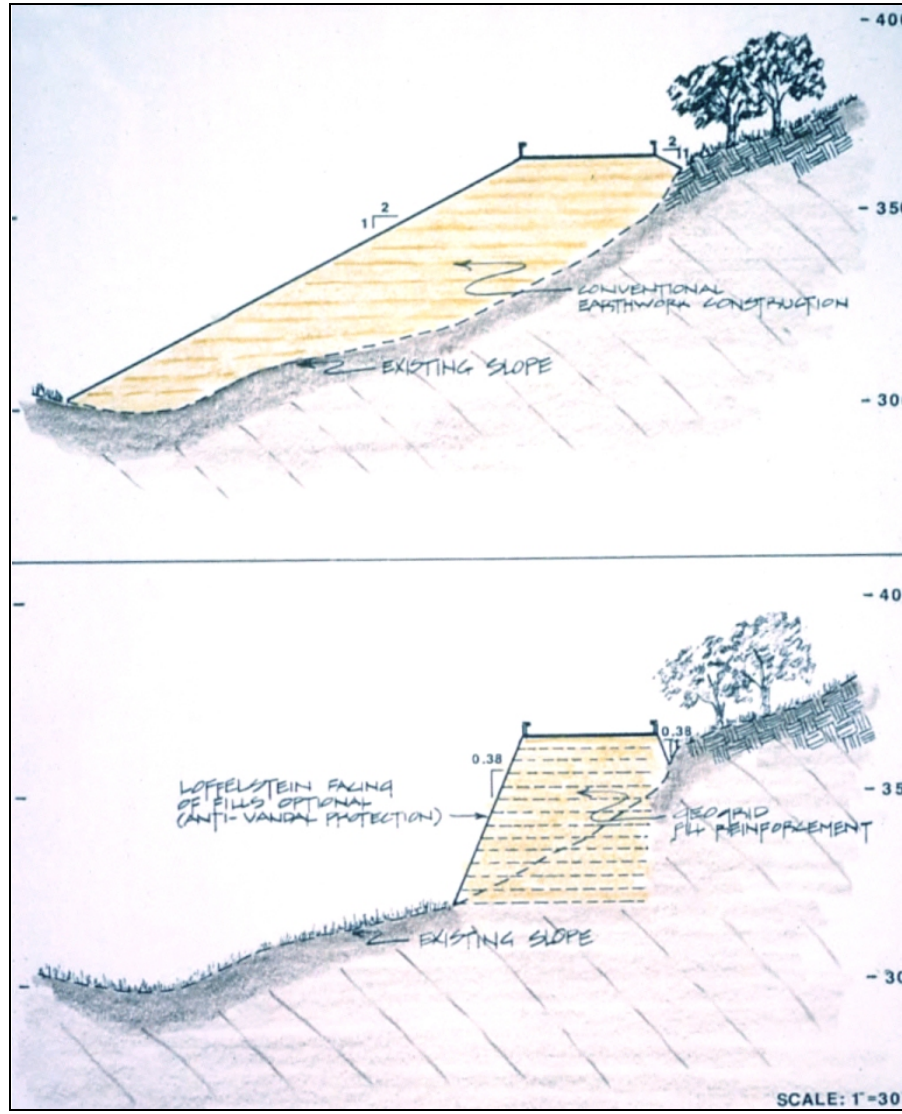


45 degree slope using false layers

• Upper left: Construction of 45 degree side-hill embankment for a road in steep terrain. False and full depth geotextile mats were incorporated into the fill, spaced every 12 inches
• Lower Left: Same slope after hydroseeding with a mix of fescue and wild mustard, two months later
•Upper right: Same project, as seen 20 years later, in 2007. It had weathered a brush fire, as well as numerous storms and record rainfall events.

Part 6

VARIOUS FACING ELEMENTS FOR MSE’s



MSEs also allow roads to be constructed in steep terrain with a minimal corridor of disturbance as compared to employing conventional 2:1 cut and fill slopes

Any number of **facing elements** may be used with MSEs.

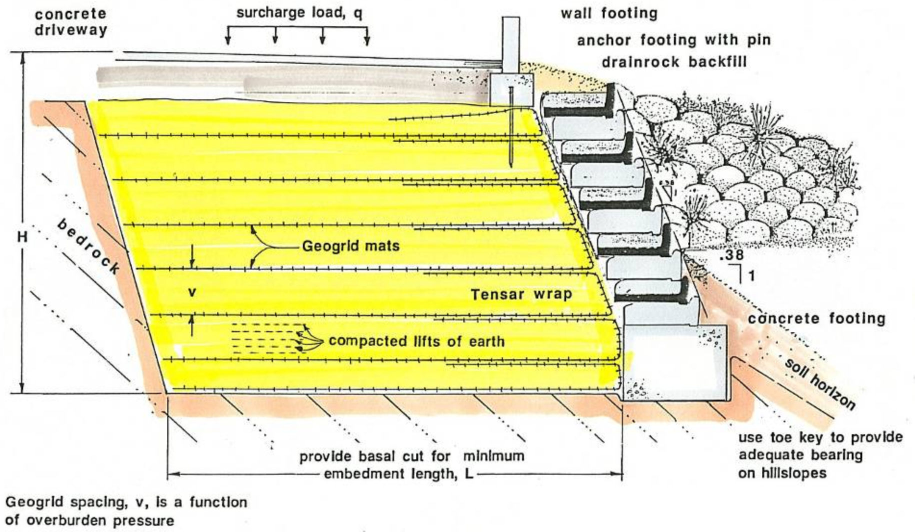
These photos illustrate the use of hay bales wrapped with HDPE grids and galvanized welded wire mesh (WWM)

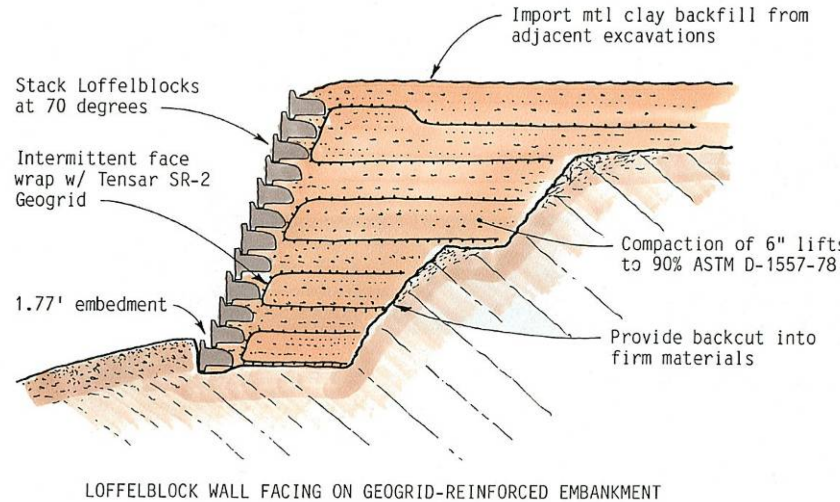
WWM faces are useful for controling the inclination of the finish slope.

- A “shoofly” is a temporary re-routing of a rail line or highway while repairs are being effected. This shows the 6-lane shoofly for the “Pinole Hole” landslide along Interstate 80 in the San Francisco Bay Area 1969.

Facing elements

More examples of facing elements, including face wrapping of geotextiles, which can be employed with Mechanically Stabilized Embankments

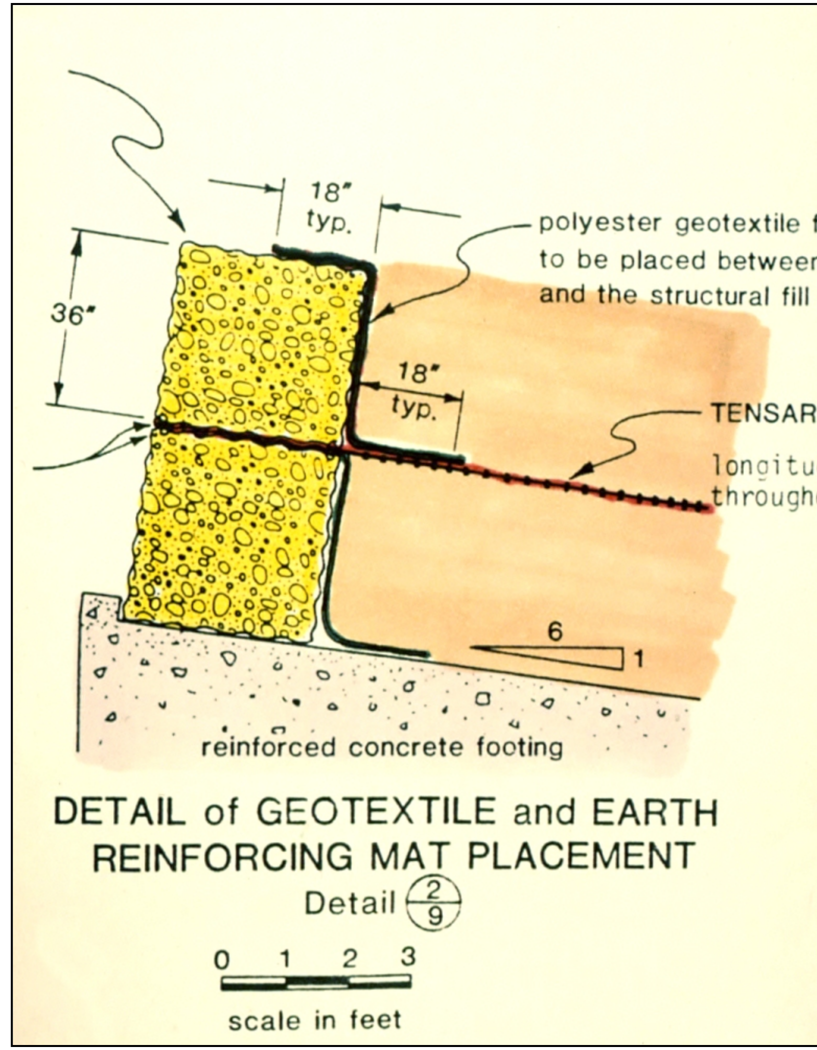




- **Battered flexible MBU walls supporting cohesive soils are difficult to design for heights greater than about 5 or 6 feet.**

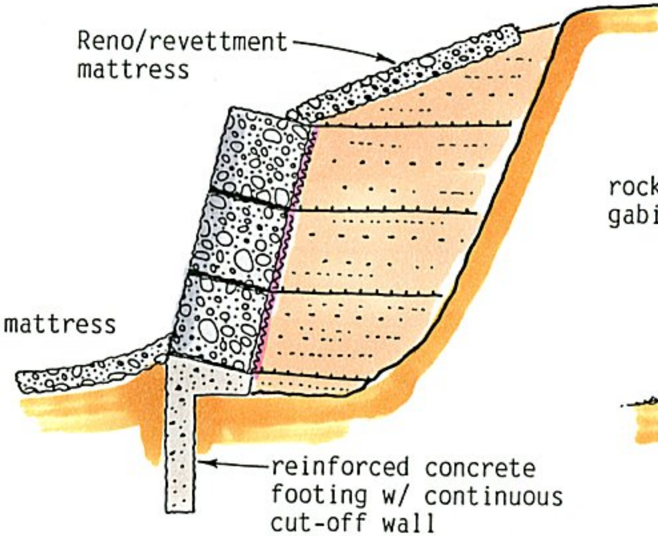
- **Tensile soil reinforcement (HDPE grids, etc) can be used to engender sufficient strength to the backfill to allow walls of heights up to 30 feet to be constructed, provided that stiffness variances between the backfill and the MBU blocks are considered.**

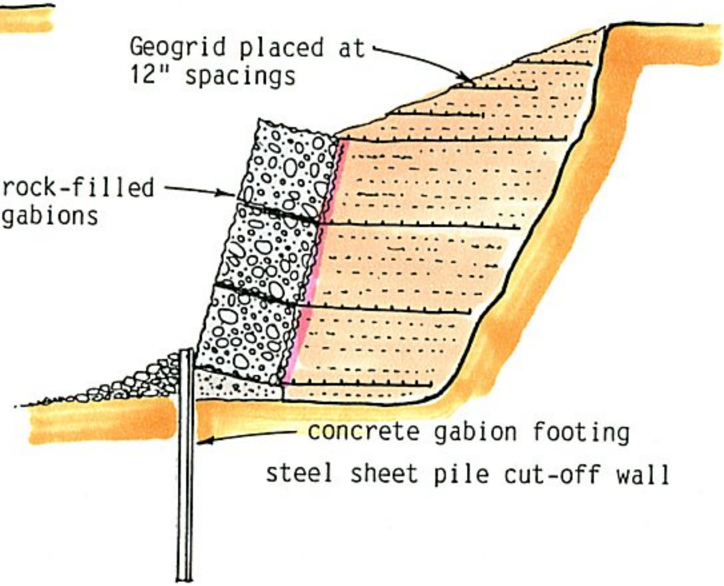
- **Note that these details do not provide active attachment between the grid and the blocks. Other MBU systems, such as Keyblock, provide for mechanical attachment.**

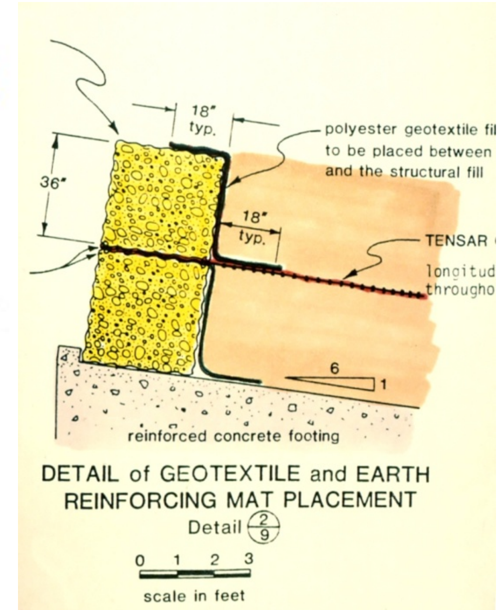


HDPE geotextiles can be used as wrapping elements, as shown at left above, or attached to conventional gravity retention elements, such as rock-filled gabion baskets, sketched at right.

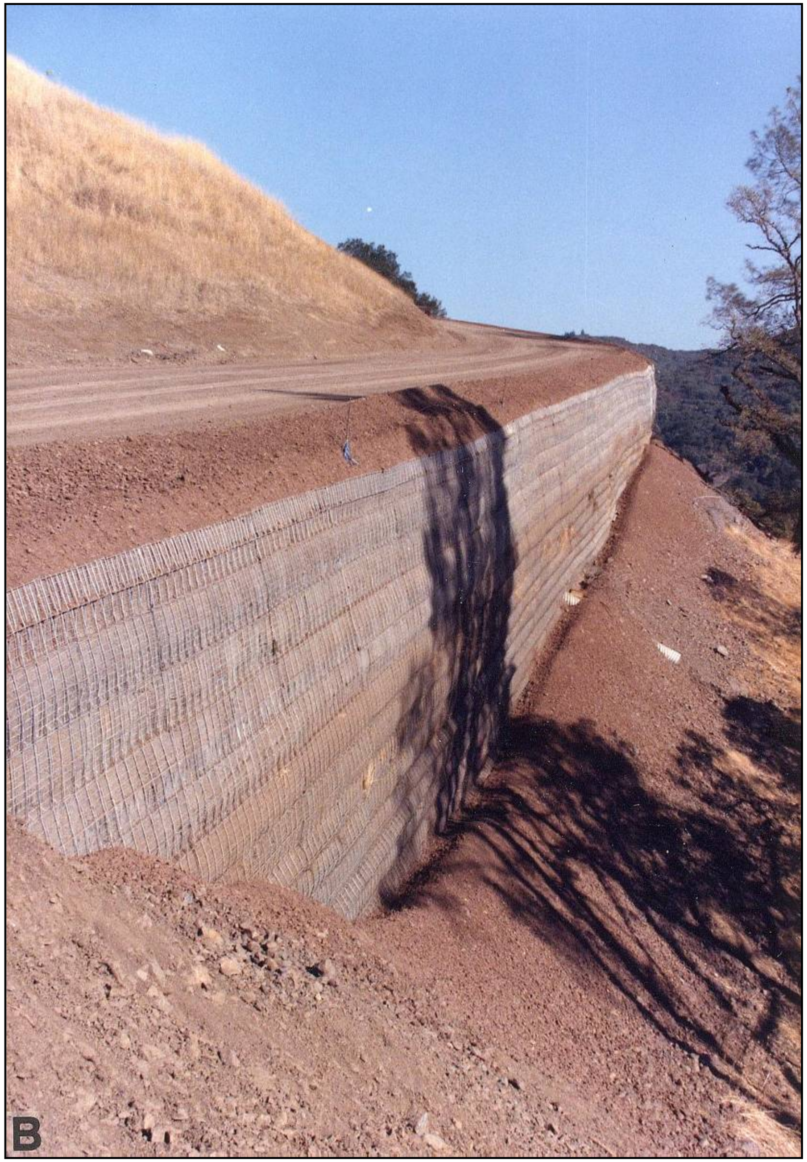
HDPE grids are subject to long-term creep relaxation, which allows noticeable "sagging"







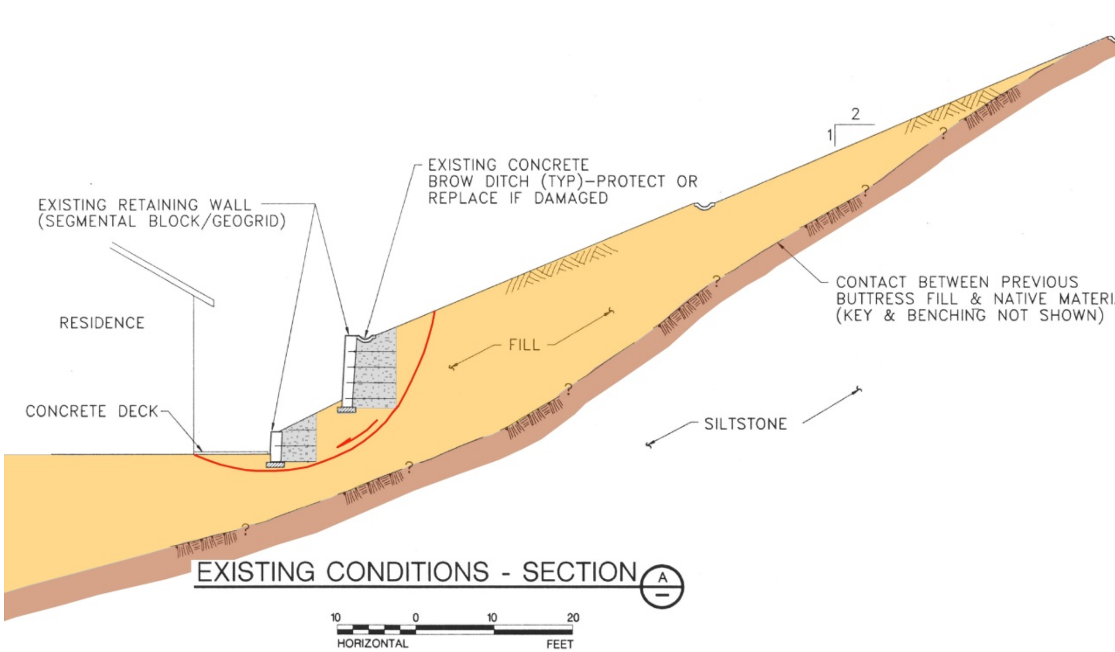
Gabions work well in *unimproved channels* because they provide surface roughness more in harmony with natural channels. Gabions can also absorb significant deflections when undercut by the stream.

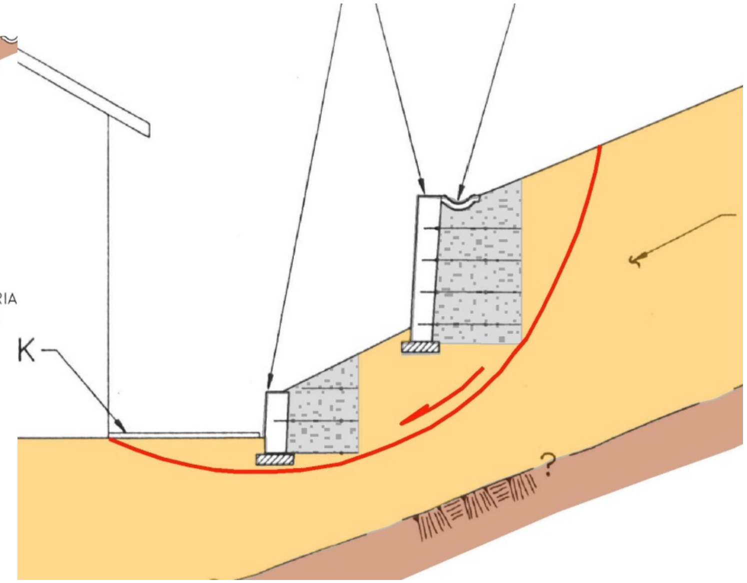


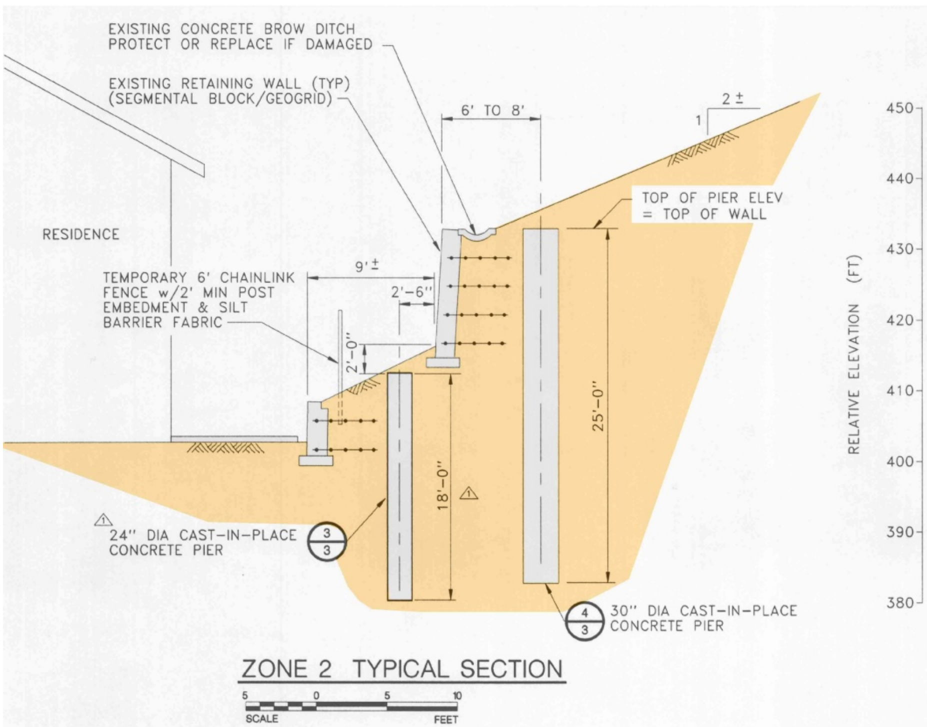
Welded wire mesh walls are constructed using the same design methodology for MSE structures, but employ the welded wire mesh as the reinforcing grid

Part 7

STRAIGHT SHAFT CYLINDRICAL PIERS

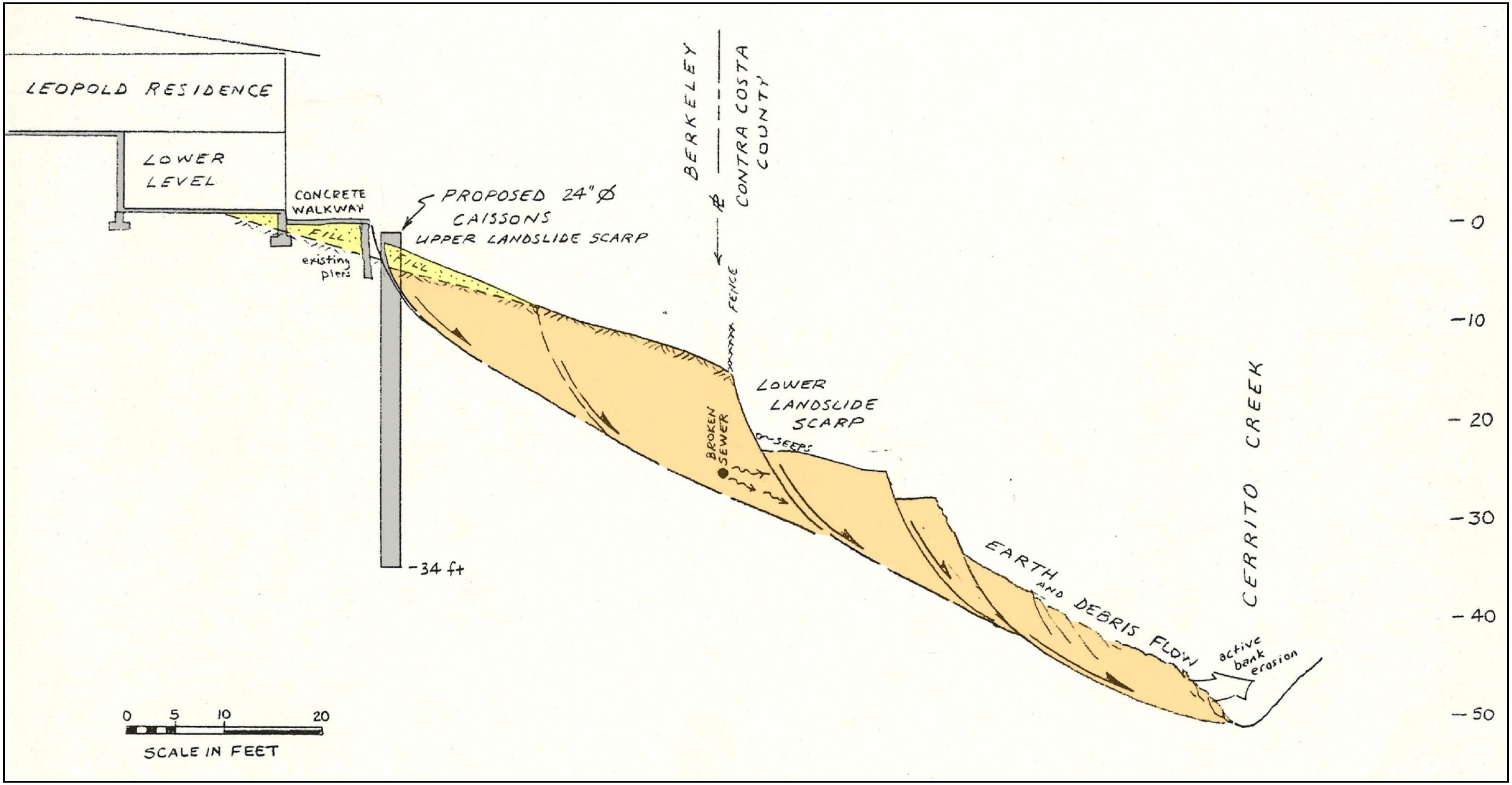






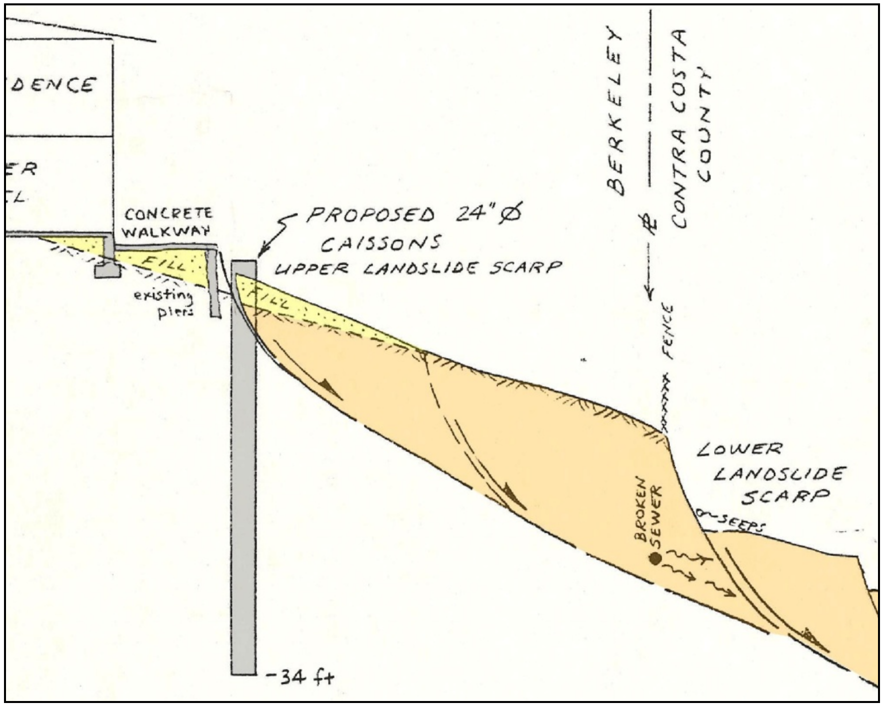
Global stability problems common with stacked MSE Walls

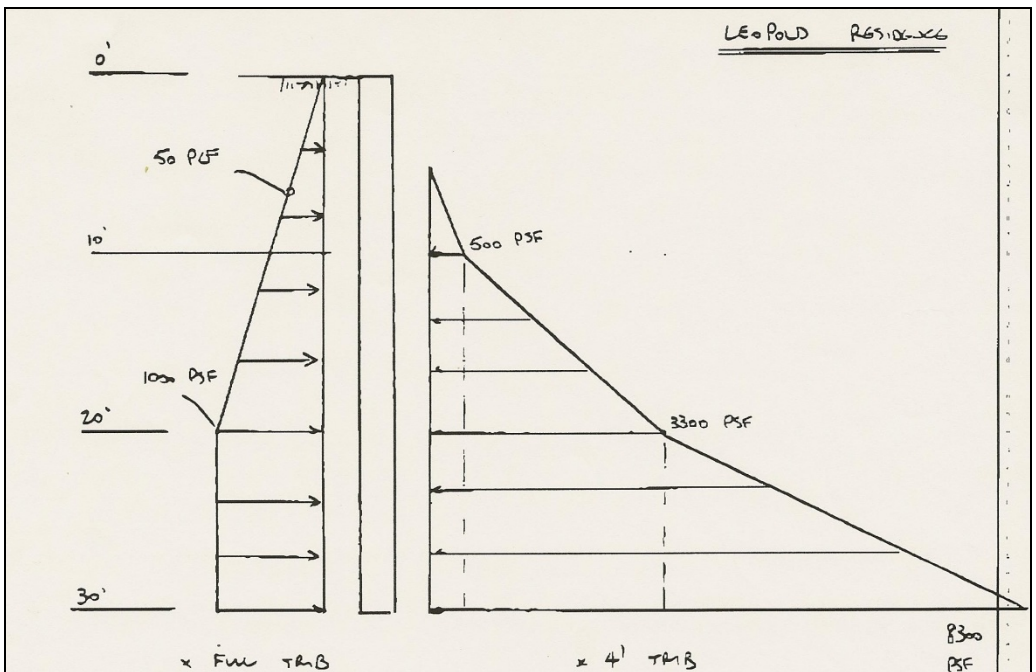
Repairs are often expensive, if adjacent to high value structures or highways where closure is not a viable option.
In this case shown here cylindrical piers were used to stabilize the support system.



If we're trying to restore the slope up near the crest of a landslide we have all sorts of options, depending on construction access. We will profile a case where 34 ft deep straight shaft cylindrical piers were employed to protect a hillside structure from further landslide damage. Site access was limited to foot traffic only, along a series of concrete steps, just 48 inches wide, adjacent to one side of the building.

Reduced Passive Loads

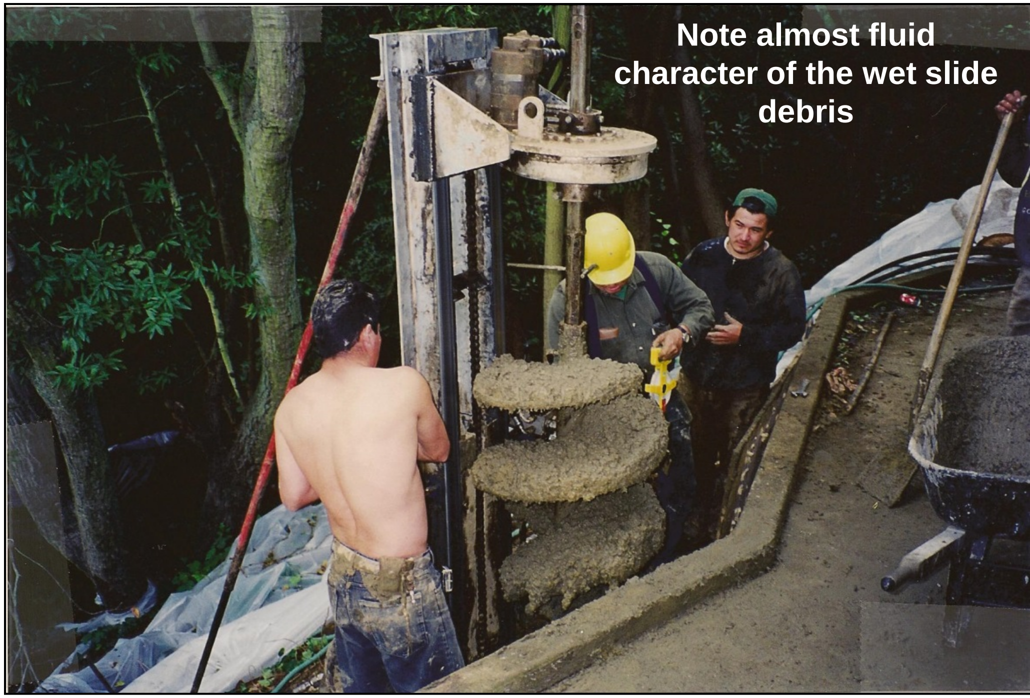


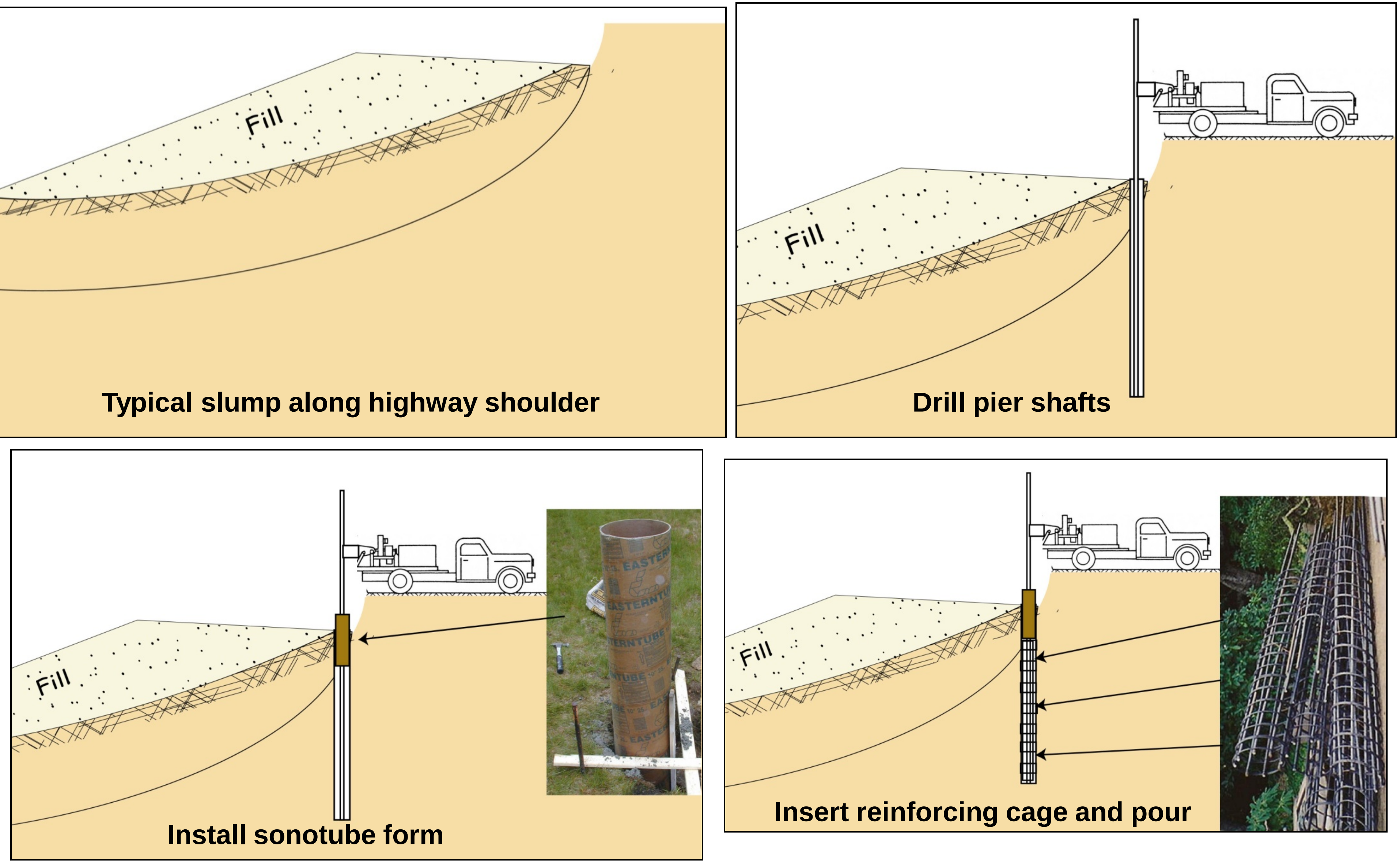


- **Upper: The resisting passive earth pressures on the downslope side of the piers is significantly reduced by the presence of the landslide, which *cannot* be depended upon, because it could reactivate and translate further downslope.**
- **Lower: *Always define the design loads* with a loading diagram, as shown here.**

Drilling the Piers

- Drilling was carried out using a remote-hydraulic power, fed by hoses 200 ft long connected to a fluid compressor in the driveway above the residence.





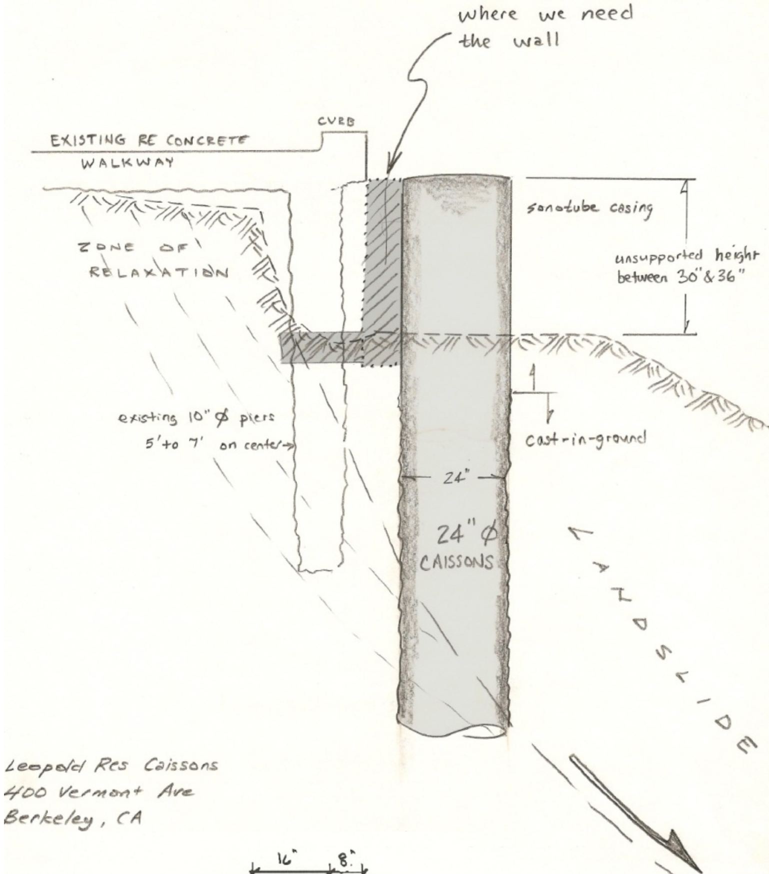
Typical sequence employed to construct straight-shaft cylindrical piers for a slide repair, working off a small platform or highway shoulder adjacent to the crest of the slide.

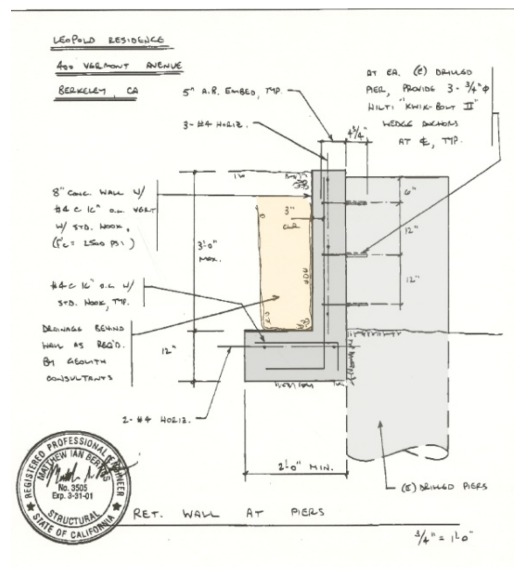
One-third length rebar cages, each 14.67 ft long

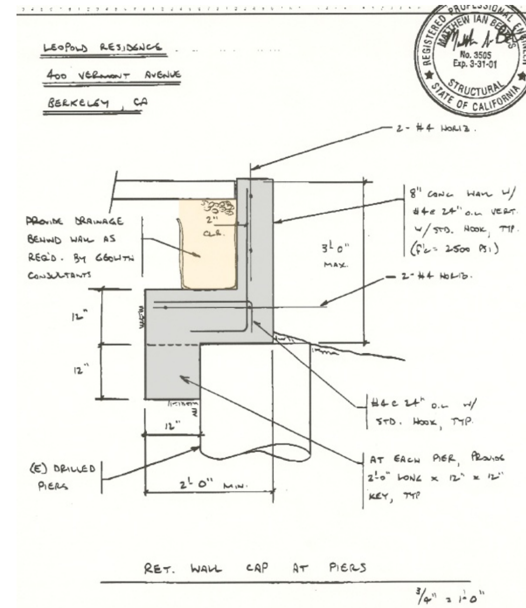
Sontube forms were used to extend the piers above grade

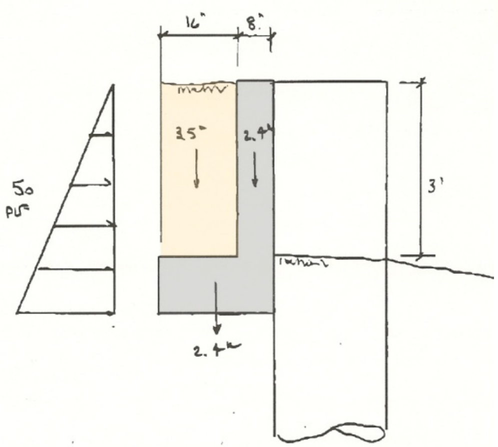
The reinforcing cages were split into thirds, 11.33 ft long, with 20 inch laps at either end, making the sections 14’-8” long. These were carefully lowered into the shaft immediately after cessation of drilling, and checked using boards, until the next section could be lapped and tied off.

Concept Sketch and designs for tie beam









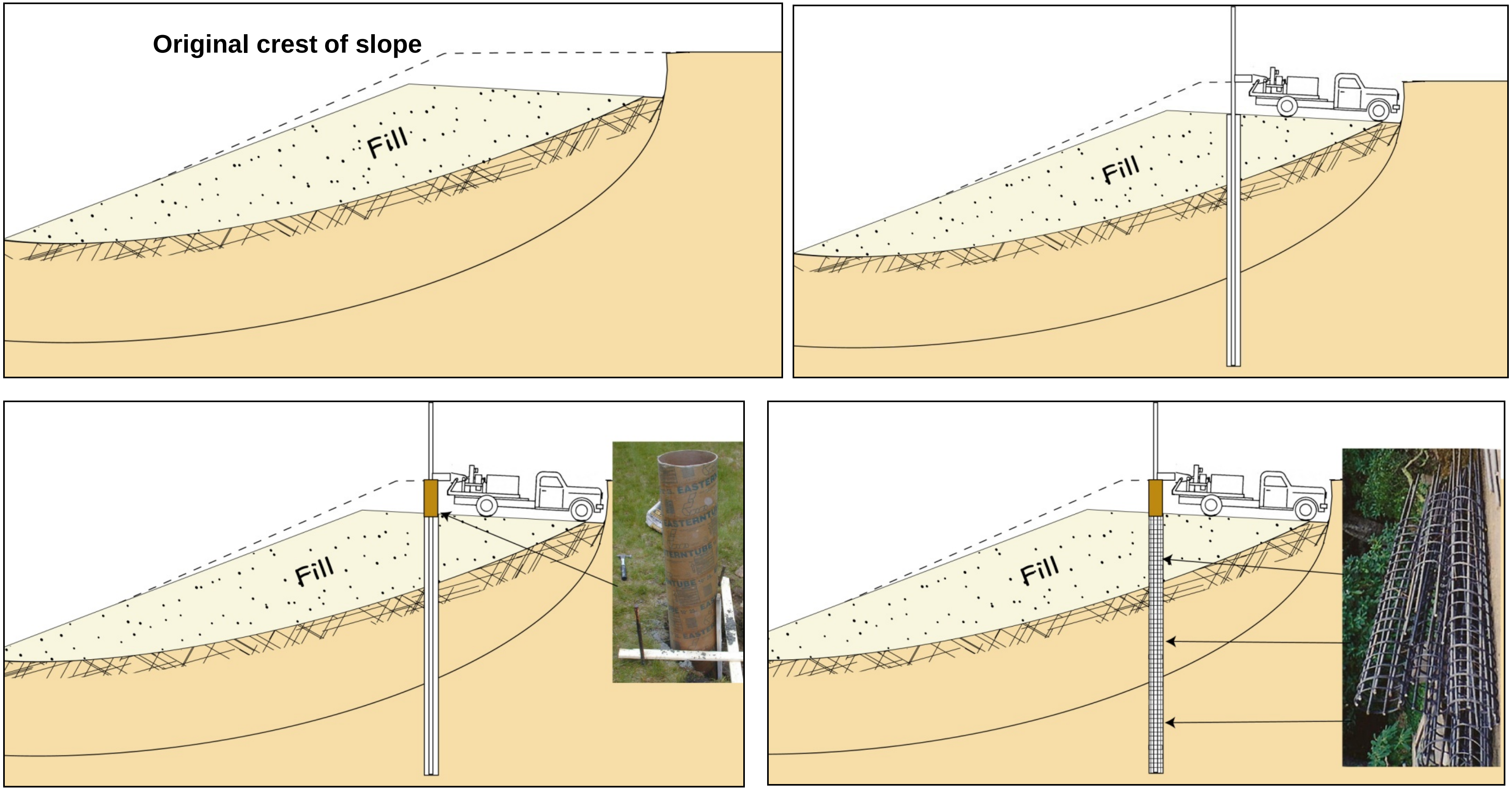
A simple L-beam was selected, doweled into the pier shafts

It was felt that a connecting tie beam should be emplaced to better resist the differential deflections that could be expected across the breadth of the landslide.

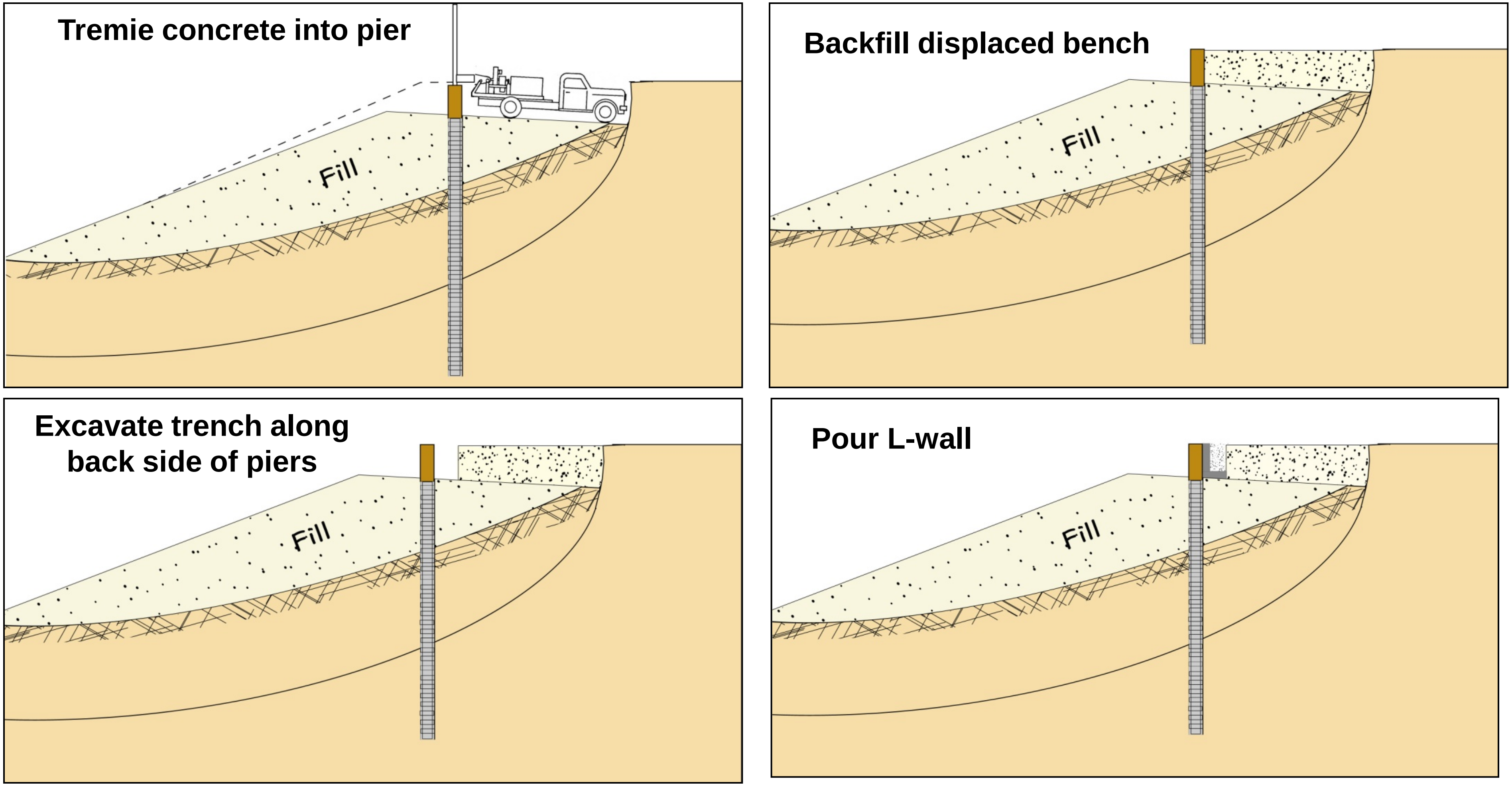
A number of possibilities for a connecting tie beam attaching the piers were sketched out and structurally detailed before a decision was made, based on constructability

Completed tie-beam pier wall

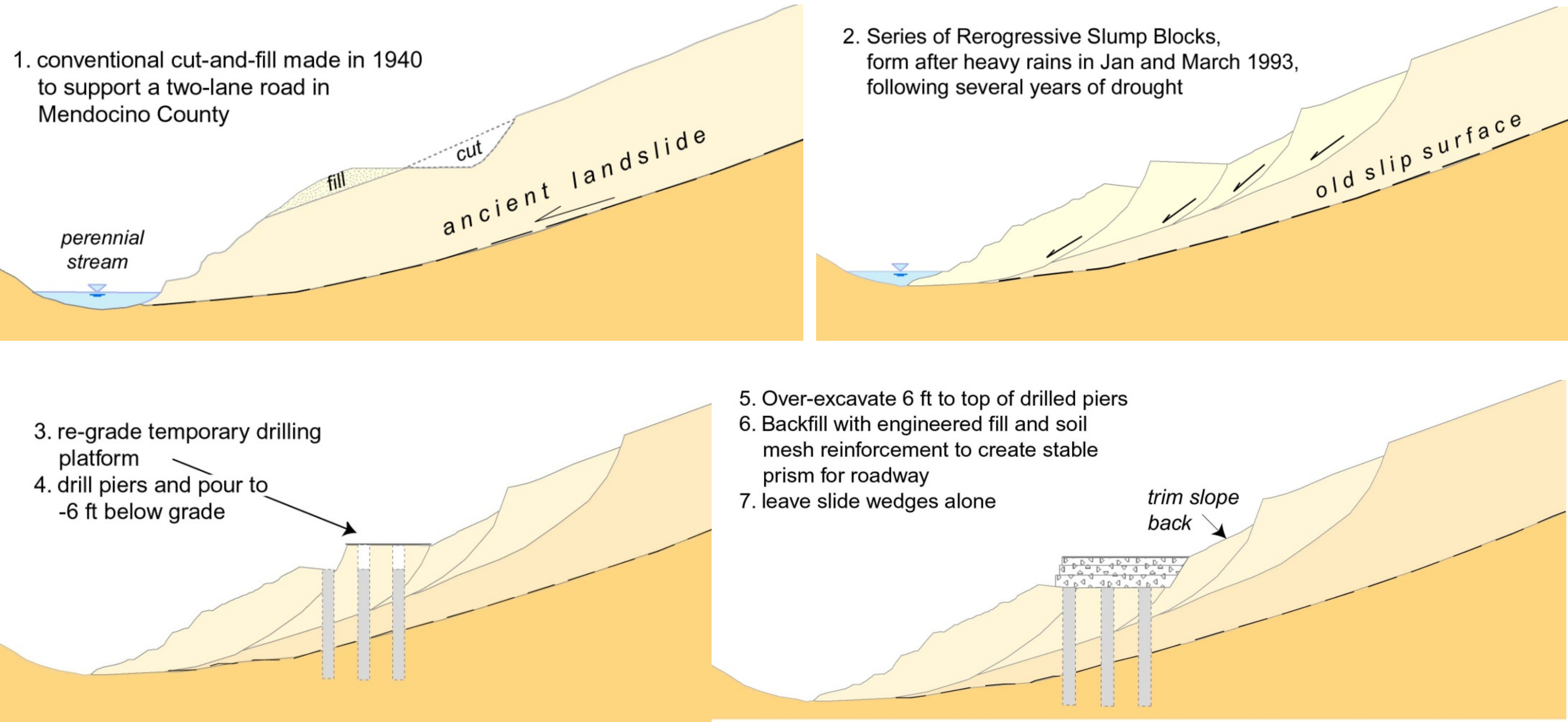
- The tie-beam wall was backfilled with free-draining gravel with a subdrain collector
- The pier wall is capable of supporting all the structural loads if the entire landslide *disappears* downslope



The same sort of approach can be taken for repairing a sidehill embankment along a highway, as sketched here. In such cases the drilling occurs at the crest position of the pre-failure slope (shown by the dashed line), to recover the lost right-of-way. This often necessitates drilling from the displaced block.



Upper left: After the hole is drilled, fix sontube extension and drop rebar cage into hole, then tremie concrete into the hole, while vibrating cage. Upper right: the down-dropped area is then back-filled. Lower left: a trench is then excavated by backhoe along the upslope side of the piers, typically 2 ft wide and 3 to 6 ft deep. Lower right: An 12 to 16 inch thick footing for an L-wall is then poured, along with a 9 to 12 inch wide stem, dowelled into the pier heads.



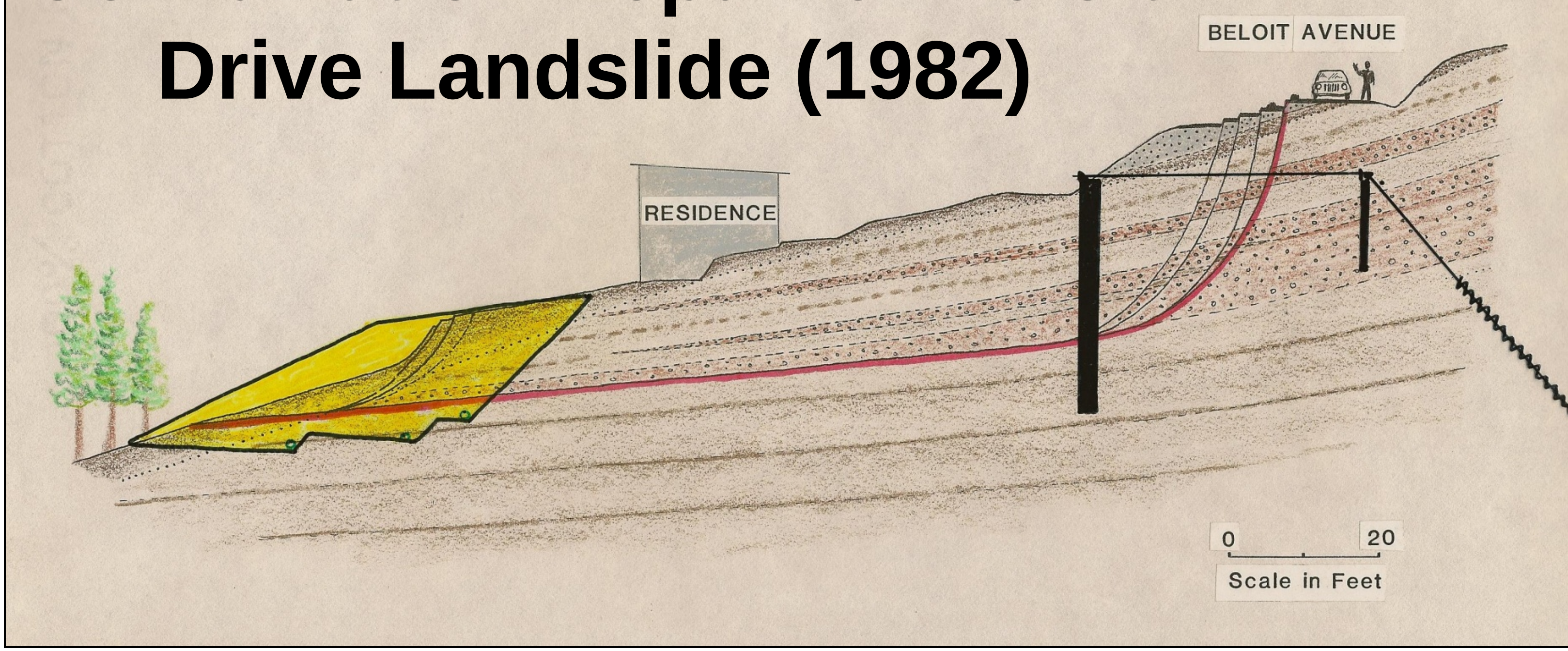
Try to keep all of the heavy work on the roadway
Try to incorporate drilling spoils in the MSE fill prism
Minimize import / export of reg'd construction materials

Piers can be useful structural elements to provide temporary as well as permanent support. In this case, the piers were drilled fairly deep to provide temporary support against retrogressive slump blocks as well as a deeper-seated landslide. The highway prism was then overexcavated and an MSE wall was placed upon the piers, to provide a stabilized road, that would behave as a coherent unit. The cost of stabilizing the larger, deeper slide mass was prohibitive.

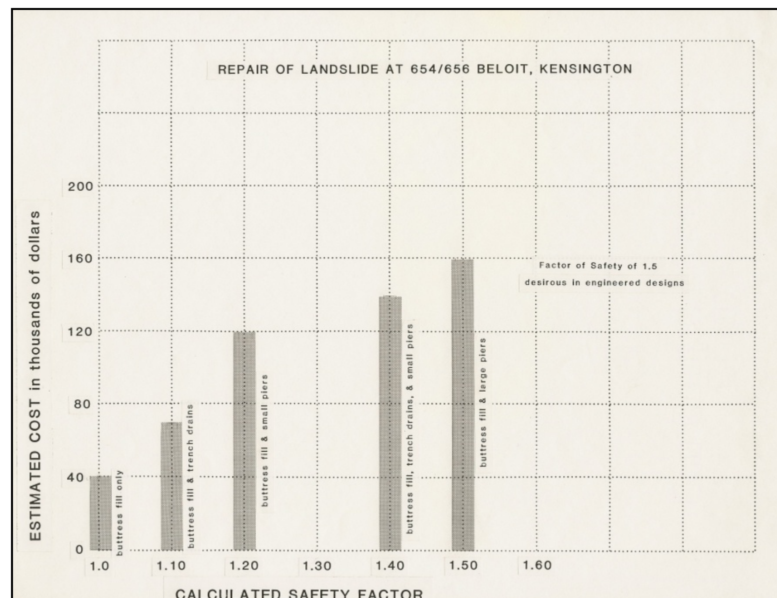
Part 8

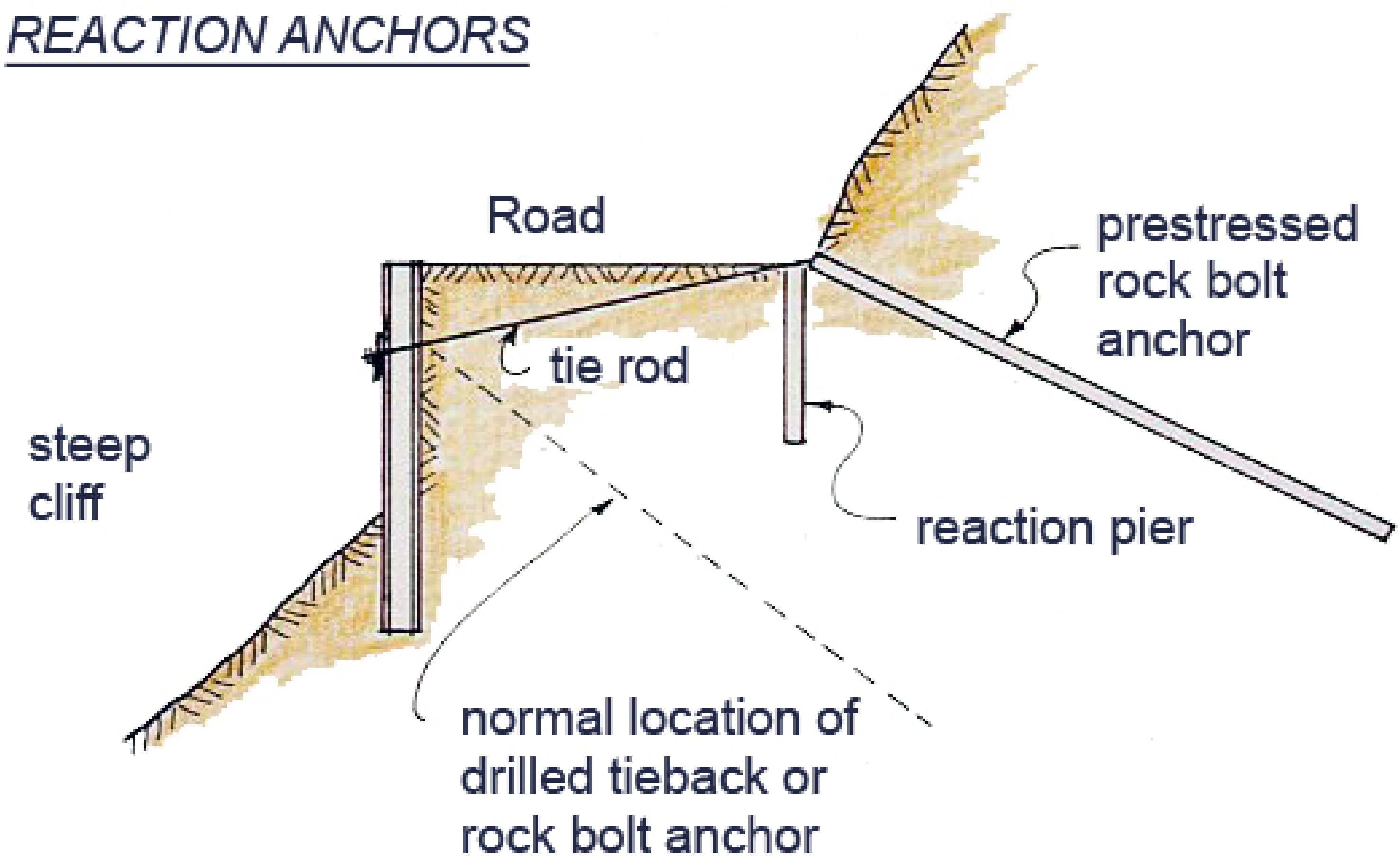
CASE STUDIES of some COMBINATION RETENTION SYSTEMS

Combination Repair of Beloit Drive Landslide (1982)



- **The most cost-effective repairs are combination techniques, dictated by construction access and the haul distances of any imported materials**

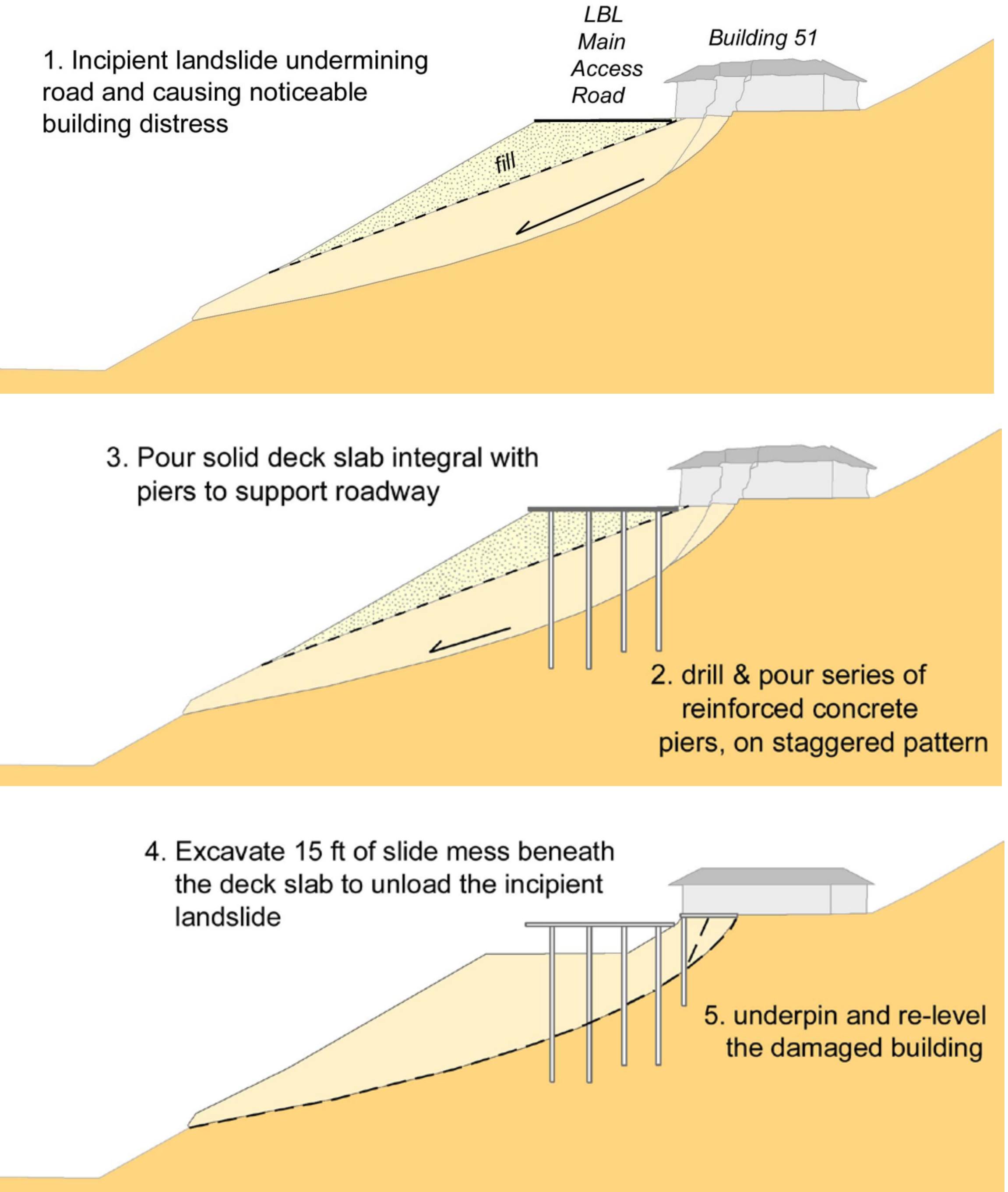




- **Various support systems and elements can be *combined* to craft *creative solutions* for slope instability problems, as illustrated here.**

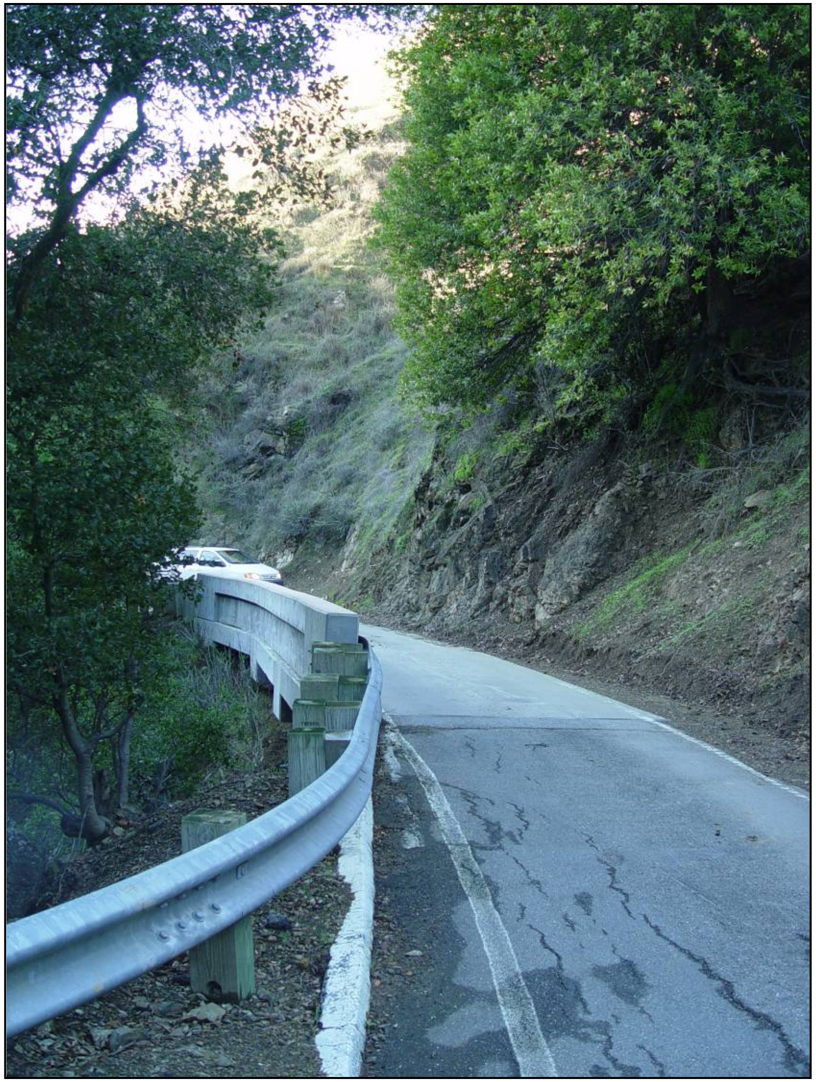
- **Sidehill viaducts** have occasionally been employed when right-of-way encroachment or environmental restrictions limited design options.

Bridging a slide to reduce driving force

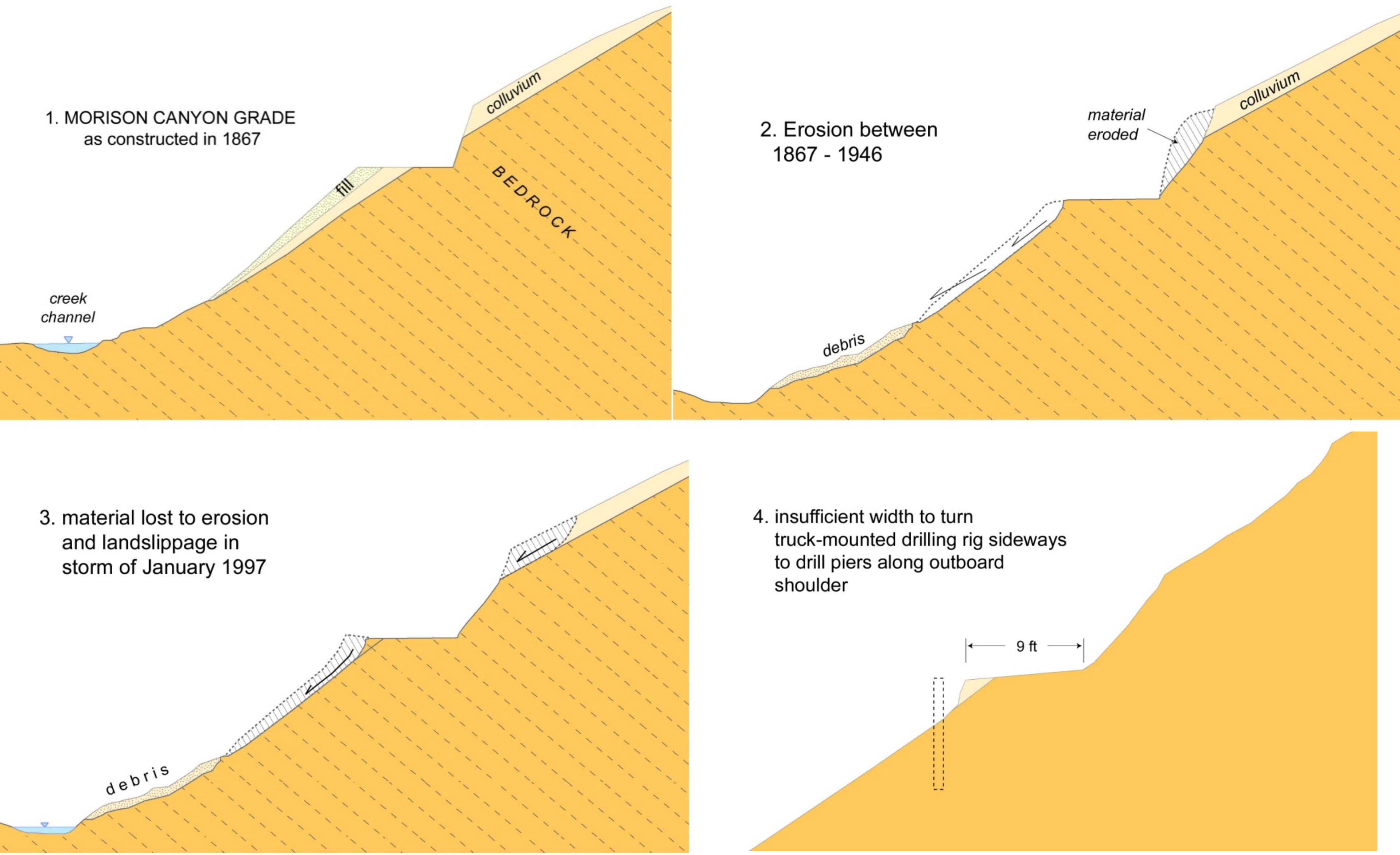


- **Bridging can be a cost-effective means of slide repair if a solid deck can be poured on-grade**
- **In this case, cast-in-ground caissons were drilled and poured first, followed by placement of the solid deck, to support the road.**
- **The old fill material was then excavated from beneath the deck slab (without interrupting traffic) to reduce the effective driving force on the slide.**

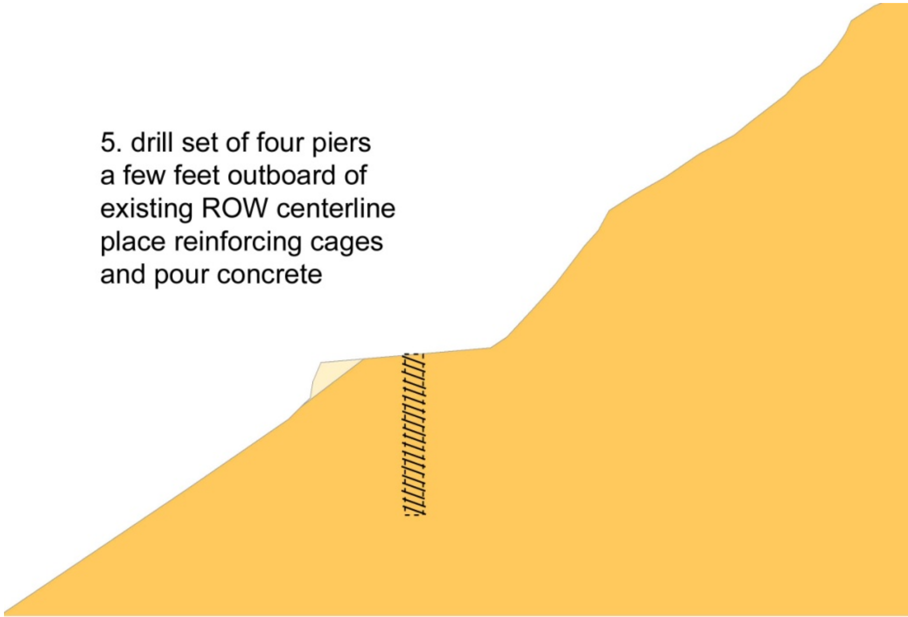
BRIDGING OVER SLIDES

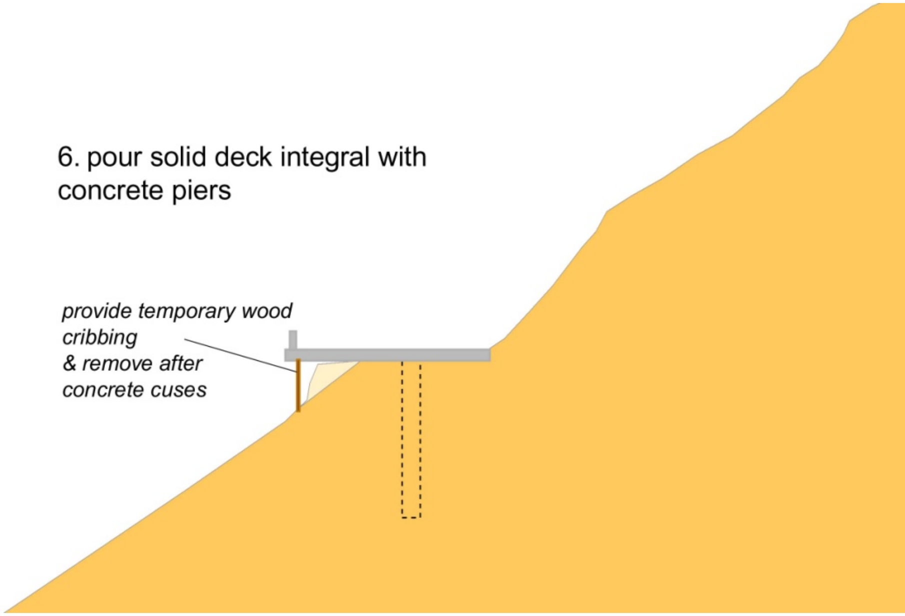


A **structural bridge** can be a cost-effective solution for maintaining a vehicular right-of-way over an active landslide or raveling rock fall site; if the structural deck can be poured-in-place as a *slab-on-grade*, founded on deep caissons. The troubled slope is then free to slide downslope, without impacting the road.



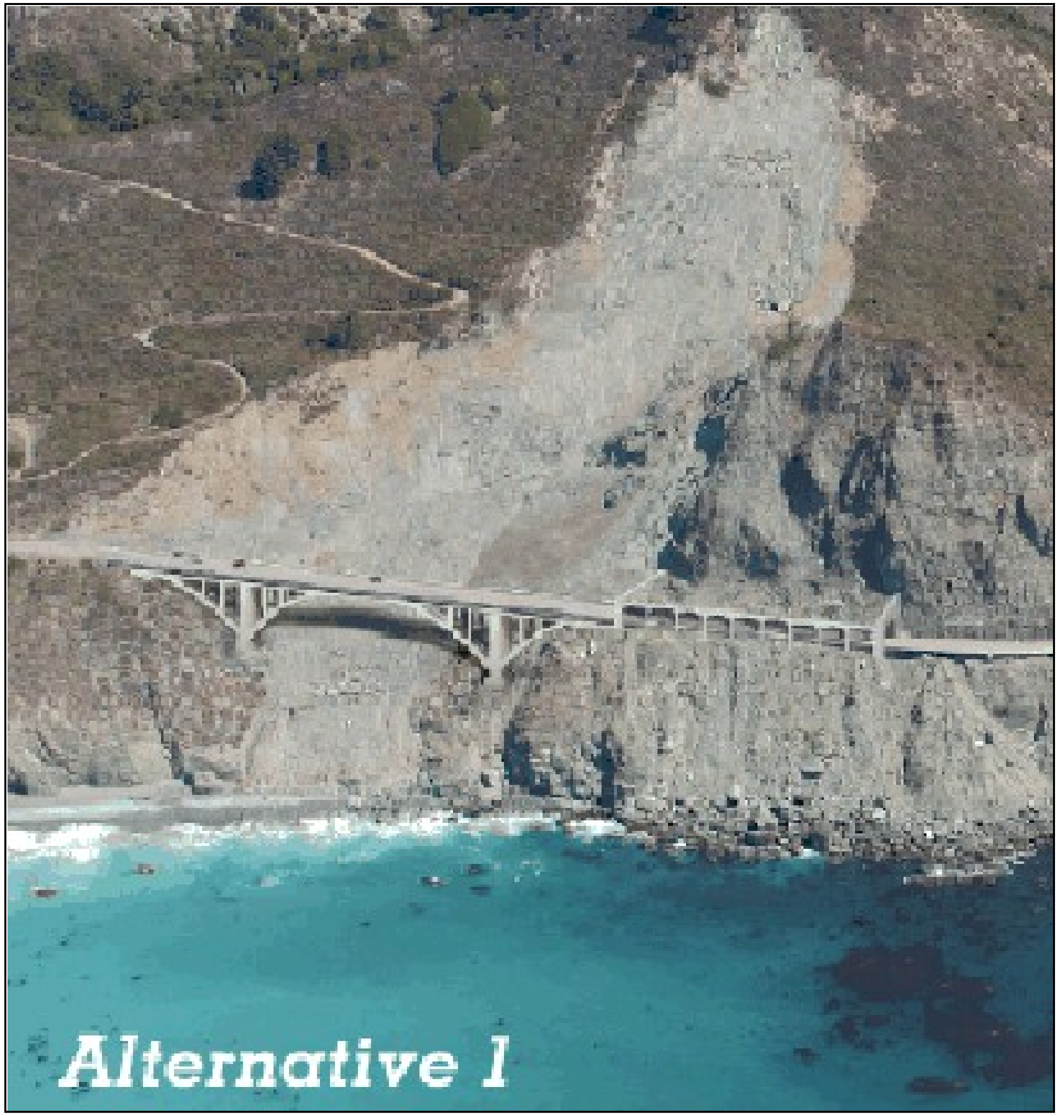
In some cases, the narrowness of the road may preclude truck-mounted drilling of piers or caissons along the descending shoulder of the road, as shown here.





A solid deck bridge can be poured-in-place on the bare ground, with a minimal amount of falsework supporting the overhanging areas.

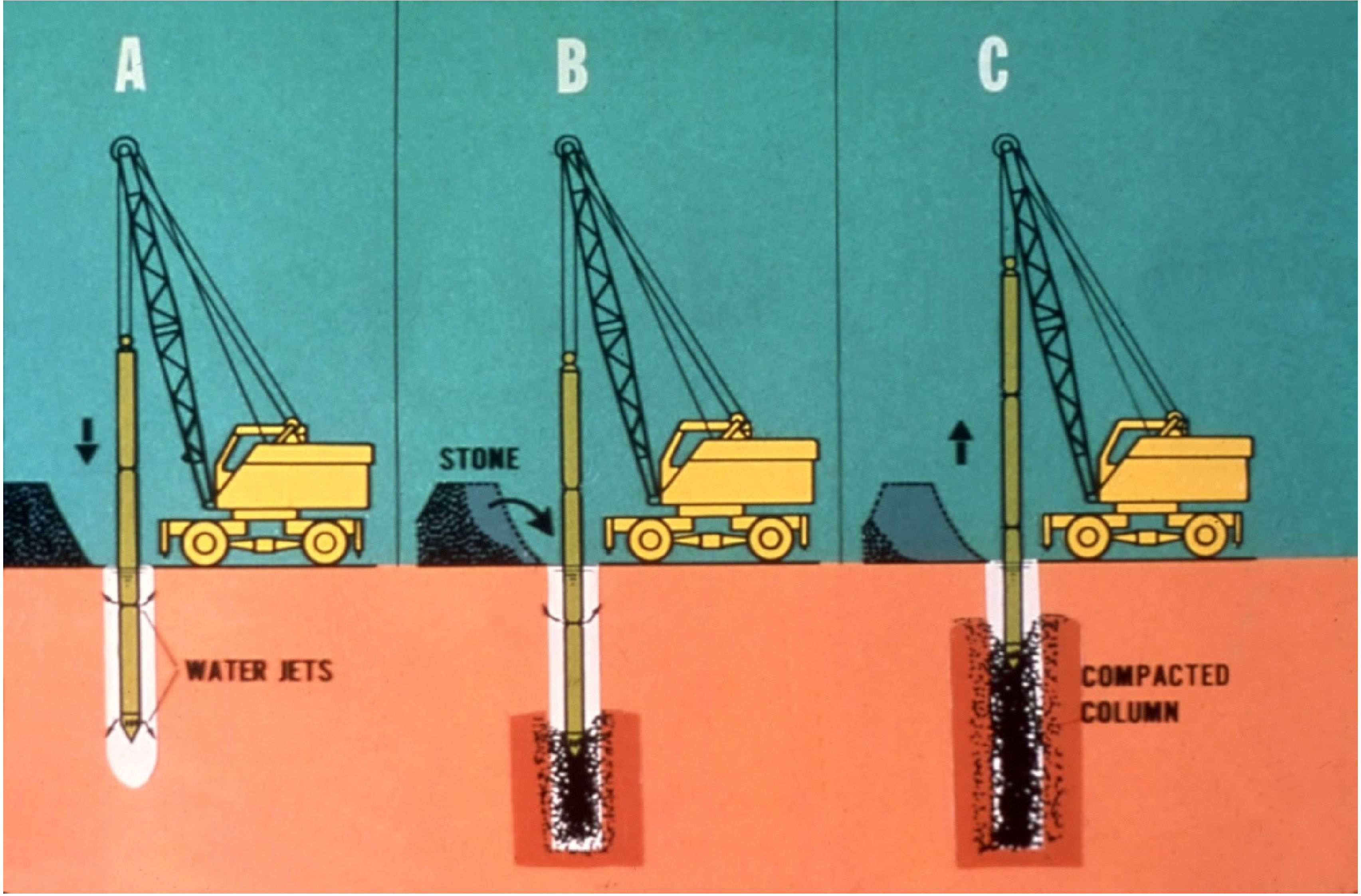
Reinforced concrete shelters have been employed along highways and railroads around the world to safely convey debris flows over these corridors. Such structures still require maintenance. These examples are from Taiwan and British Columbia.



Proposed structural repair employing a debris shed along California Route 1 in Big Sur, similar to what is used for mitigation of debris and rock slides.

Large Landslides

- **In many cases the least expensive and quickest way to mitigate a major disruption of an Interstate highway is to either: 1) excavate the slide debris and leave a 100 to 200 ft wide buffer along the highway, or, 2) construct an inclined section, employing minimal excavation of the debris (which can destabilize the scarp).**



- *Deep ground mixing* **is being used to create retention structures in soft ground situations with high water tables.**

Part 9

REPAIR OF DEVIL'S SLIDE along CA ROUTE 1 between Pacifica and Half Moon Bay in 2006

Devil's Slide Repair

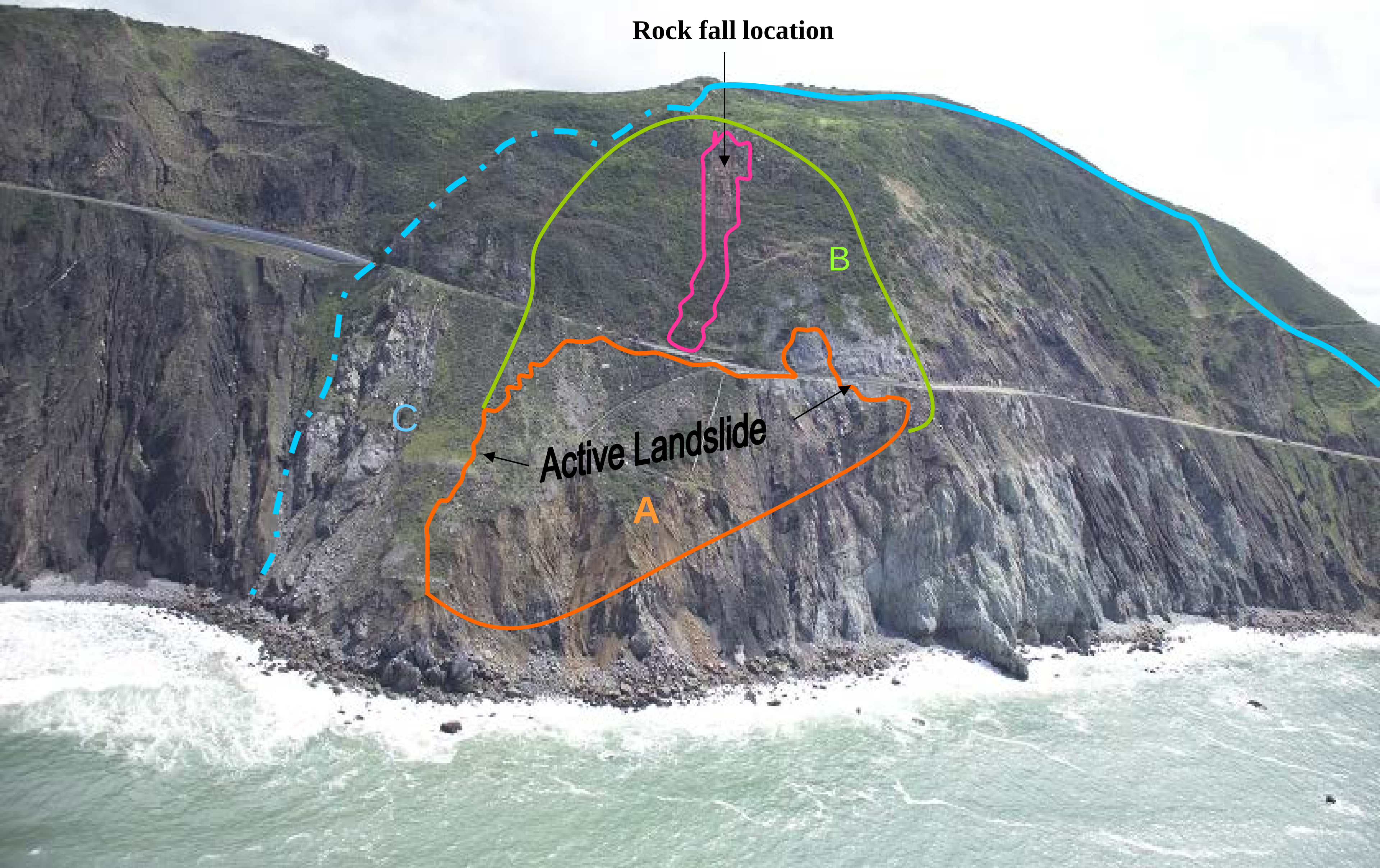
April 2006

Grant Wilcox, P.E., C.E.G.
Caltrans Senior Engineering Geologist

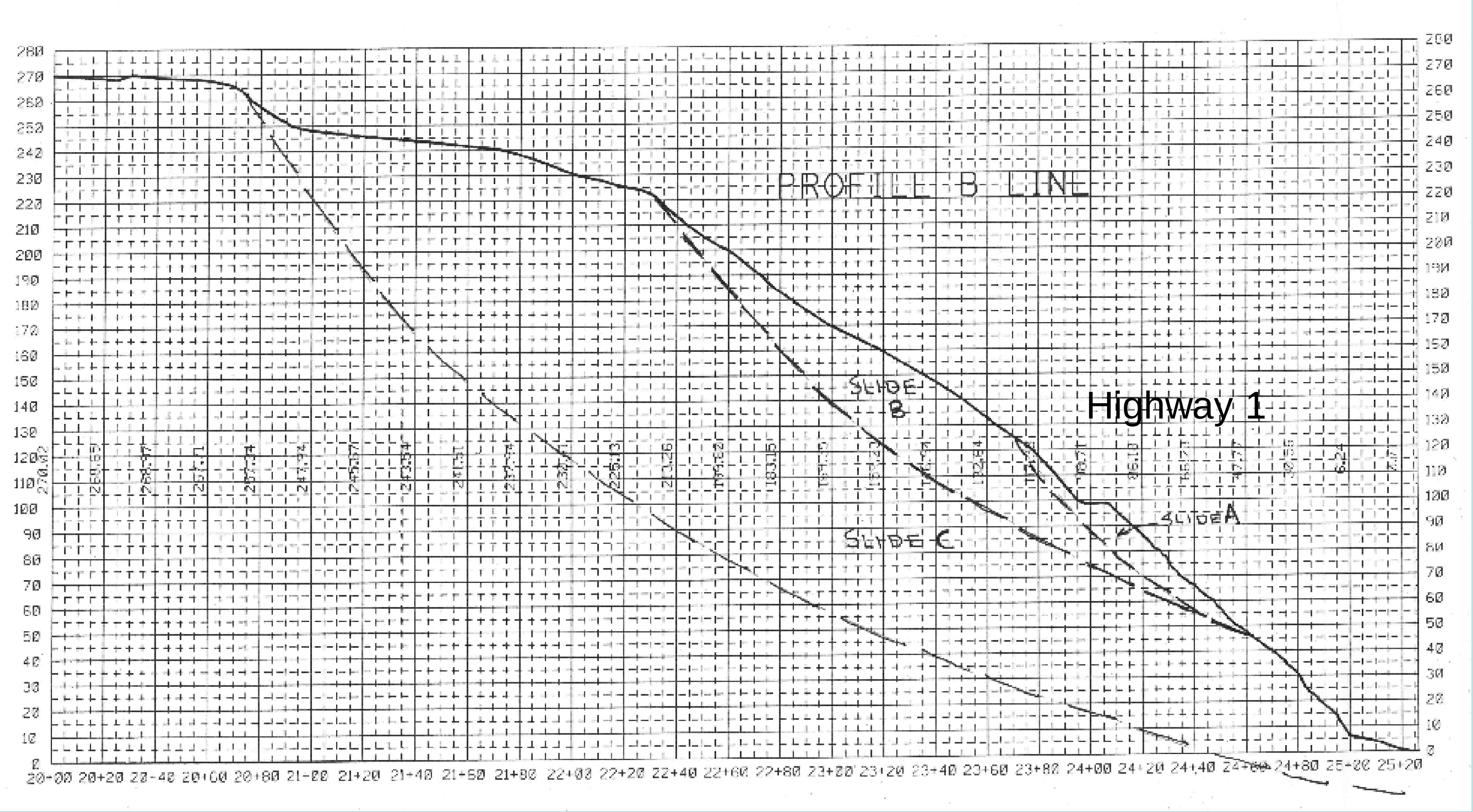
Offset pavement hazards

Rockfall hazards

Most natural slides pose multiple hazards that require mitigation



Devil's Slide Landslide Complex



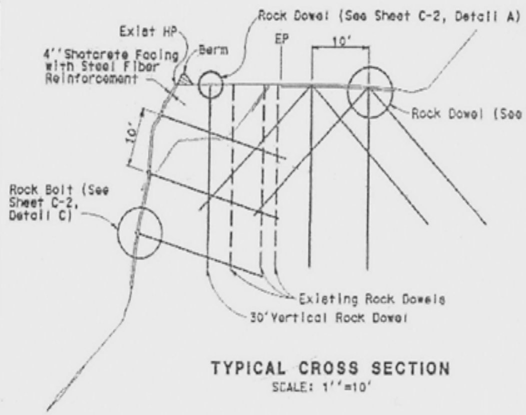
DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
04	SM	1	39.1	9	18

4/13/95
REGISTERED GEOLOGIST

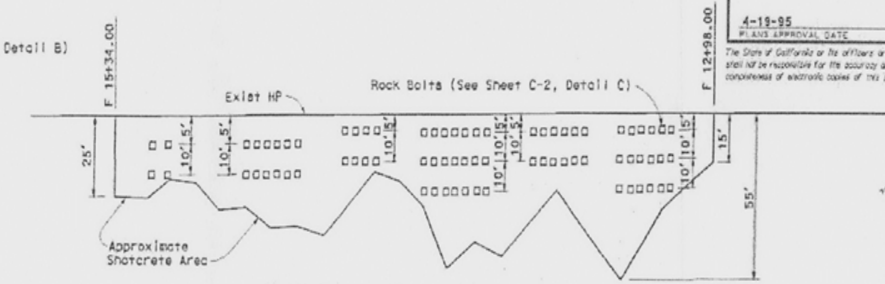
4-19-95
PLANS APPROVAL DATE

The State of California or its officers or agents shall not be responsible for the accuracy or completeness of electronic copies of this plan sheet.

REGISTERED PROFESSIONAL GEOLOGIST — J.E. Van Velsor — No. 1377 — Exp. 6-30-98 — STATE OF CALIFORNIA

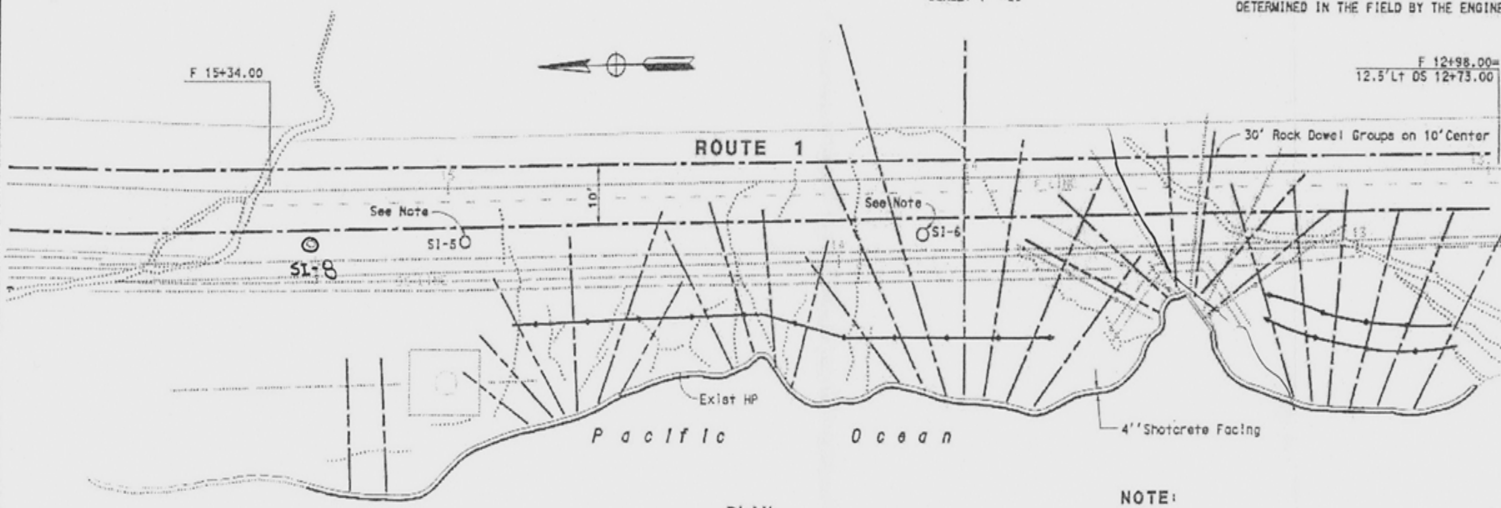


TYPICAL CROSS SECTION
SCALE: 1''=10'



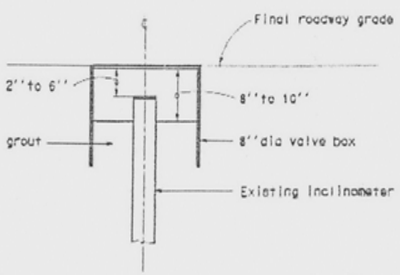
ROCK BOLT LOCATIONS
ELEVATION VIEW OF VERTICAL FACE
SCALE: 1''=20'

NOTE:
EXACT LOCATION AND LENGTH OF ROCK BOLTS TO BE DETERMINED IN THE FIELD BY THE ENGINEER.



PLAN
SCALE: 1''=10'

NOTE:
ADJUST INCLINOMETERS SI-5 & SI-6 TO GRADE.



LEGEND

- 30' ROCK DOWEL GROUPS AT 10' CENTERS
- EXISTING 30' VERTICAL ROCK DOWELS AT 4' CENTERS
- ROCK BOLTS
- EXISTING ROCK BOLTS
- 30' VERTICAL ROCK DOWELS AT 5' CENTERS
- FISSURES

CONSTRUCTION SEQUENCES:

1. INSTALL ROCK DOWELS.
2. INSTALL SHOTCRETE.
3. INSTALL ROCK BOLTS.

NO Construction Changes

CONTRACT No. 04-196304
DATE ACCEPTED 5-31-96
AS BUILT
RESIDENT ENGINEER Welsner

CONSTRUCTION DETAILS
SCALE AS SHOWN

C-1

STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION
Caltrans
GEOTECHNICAL

PROJECT ENGINEER: J.E. VAN VELSOR

CALCULATED/DESIGNED BY	HG	DATE 4/95	REVISED BY
CHECKED BY	GNR	4/95	DATE REVISED

-VIEW LOOKING SOUTH-

DEVIL'S SLIDE ROADWAY REPAIR


14


2006.05.24


CAT
17 10:24AM

About the Presenter

Dr J. David Rogers, PE, PG, CEG, CHG holds the Karl F. Hasselmann Chair in Geological Engineering at the Missouri University of Science & Technology. He can be contacted at rogersda@mst.edu

- Professor Rogers owned engineering consulting firms in Los Angeles and San Francisco and a general engineering contracting firm prior to entering academia.
- He served as Chair of the Building Codes Committee of the Association of Environmental & Engineering Geologists between 1990-97 and was AEG representative to the International Conference of Building Officials (ICBO) while the 1991, 1994 and 1997 UBC's and 2000 IBC were developed.
- Since 1984 he has taught short courses on grading and excavation codes for ICBO, the University of Wisconsin, University of California, the Association of Bay Area Governments, and the City of Los Angeles.