OVERVIEW OF EXCAVATION AND GRADING CODES

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for the course

GE 441 Geotechnical Construction Practice

Part 1

EXCAVATION AND GRADING PRACTICES PRIOR TO DEVELOPMENT OF GRADING CODES

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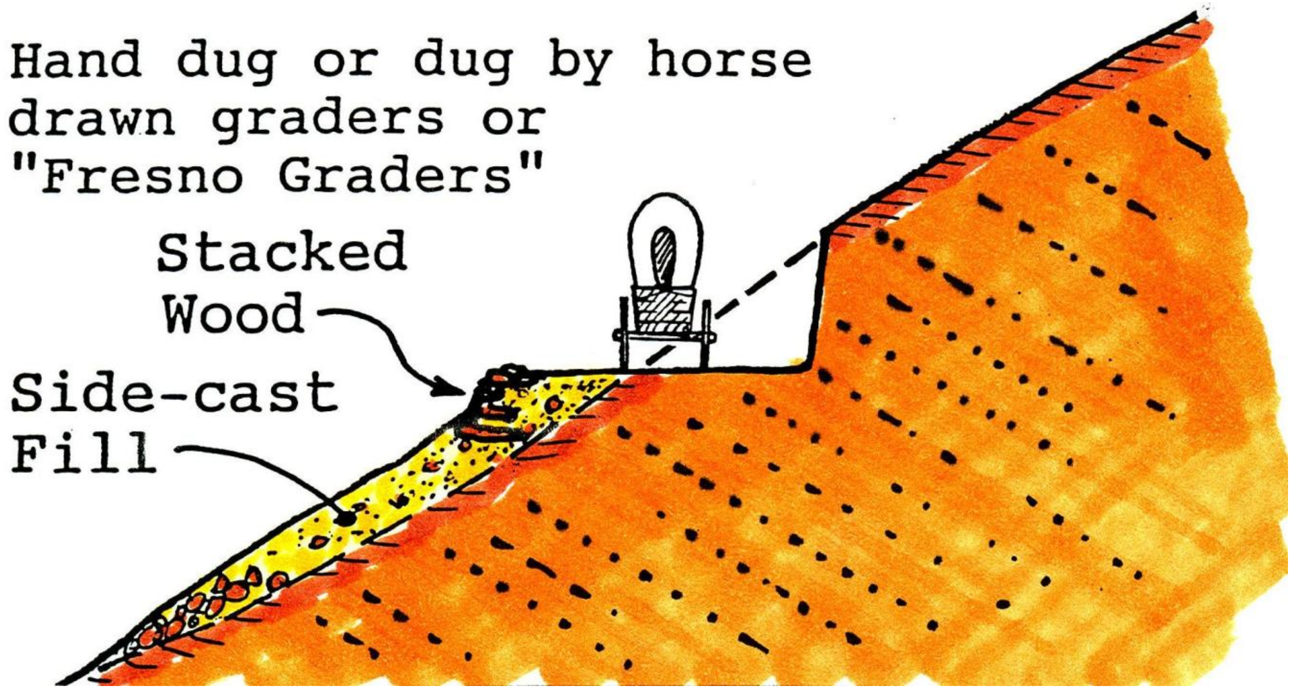
OLD ROAD CUTS AND FILLS

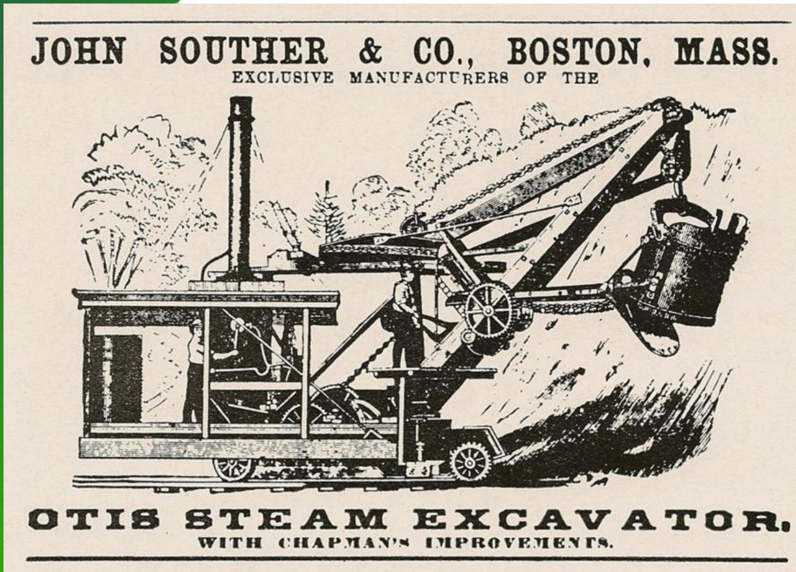


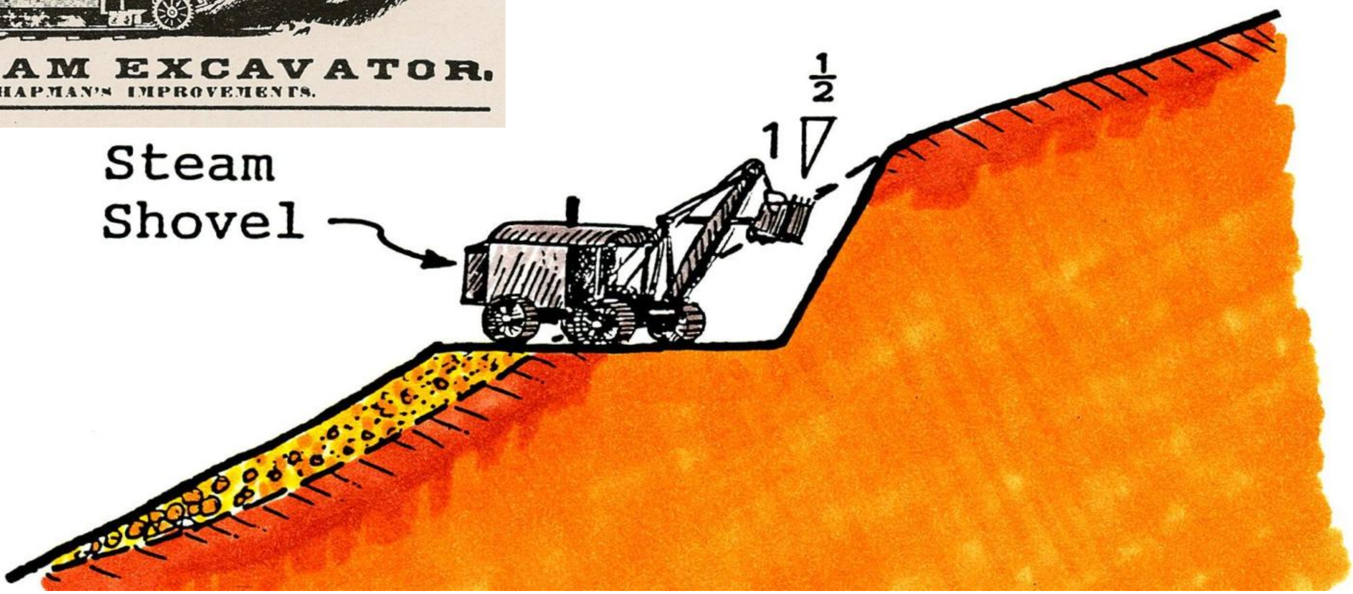
- **Typical cut and fill techniques employed in the 19th Century. Private parties were given 20-year leases to construct and manage toll roads or bridges, so long as they maintained them.**

Fresno Scrappers

- Invented by Frank Dusy and Abijah McCall in 1885 in Selma, California, it was given the name “Fresno Scrapper” by James Porteous of Fresno, who adopted the design as superior that he had invented in 1882
- Pulled by four mules, Fresno Scrapers slowly overtook the grading business, spreading eastward
- By 1920 they were the most widely employed earth moving device in America, as well as the cheapest, selling for $30 to $40 apiece, depending on the model

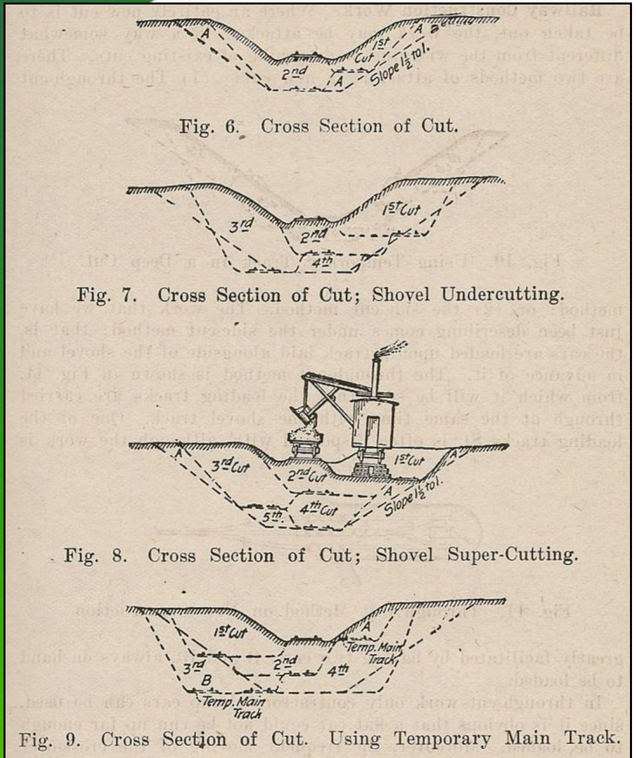
STEAM SHOVELS

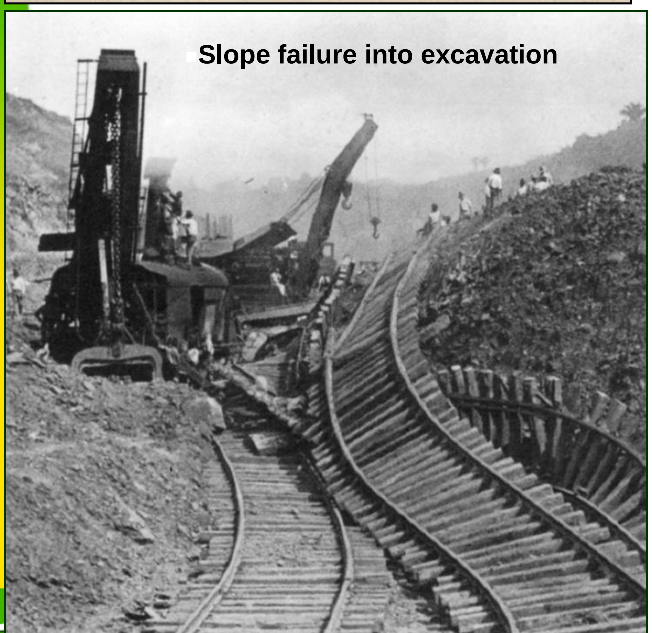


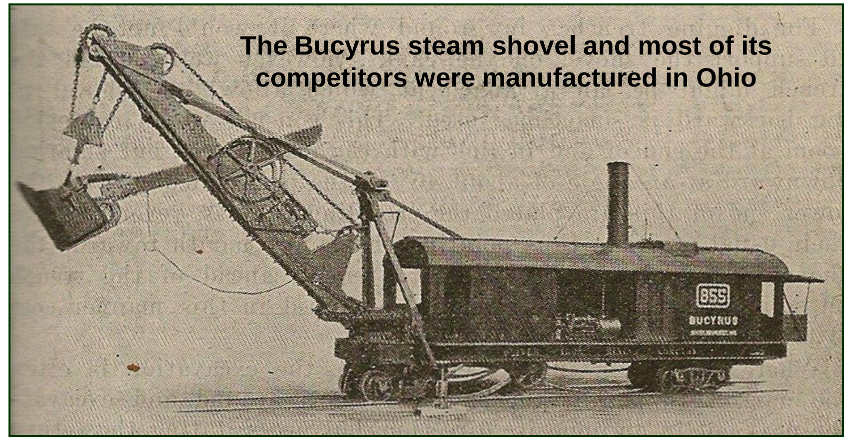


- **The steam shovel was patented in 1838, but not employed commercially until 1868, for use on the Union Pacific Railroad. From that date the major manufacturers were Otis, Osgood, Bucyrus-Erie, Harnischfeger (first gasoline powered), Koehring, P&H (first electric powered), and Lima Locomotive**.

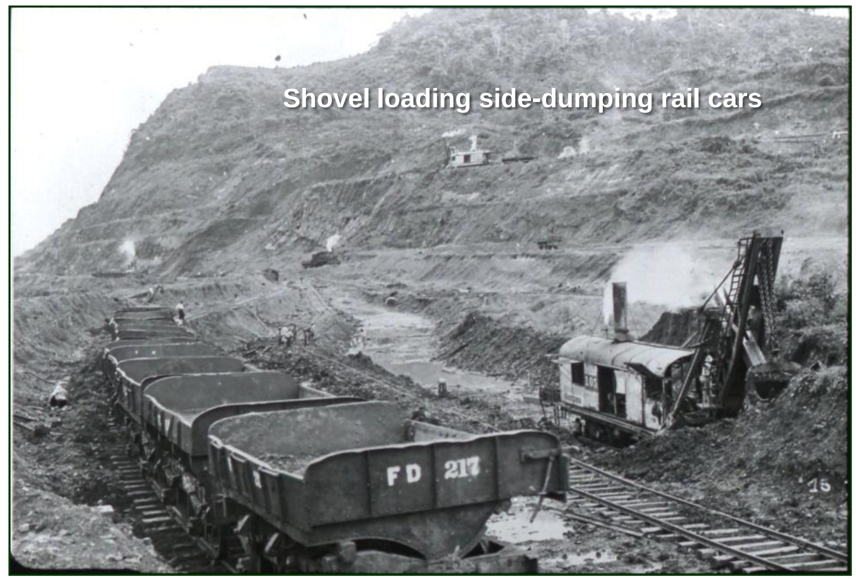
Rail-mounted Shovels




Slope failure into excavation

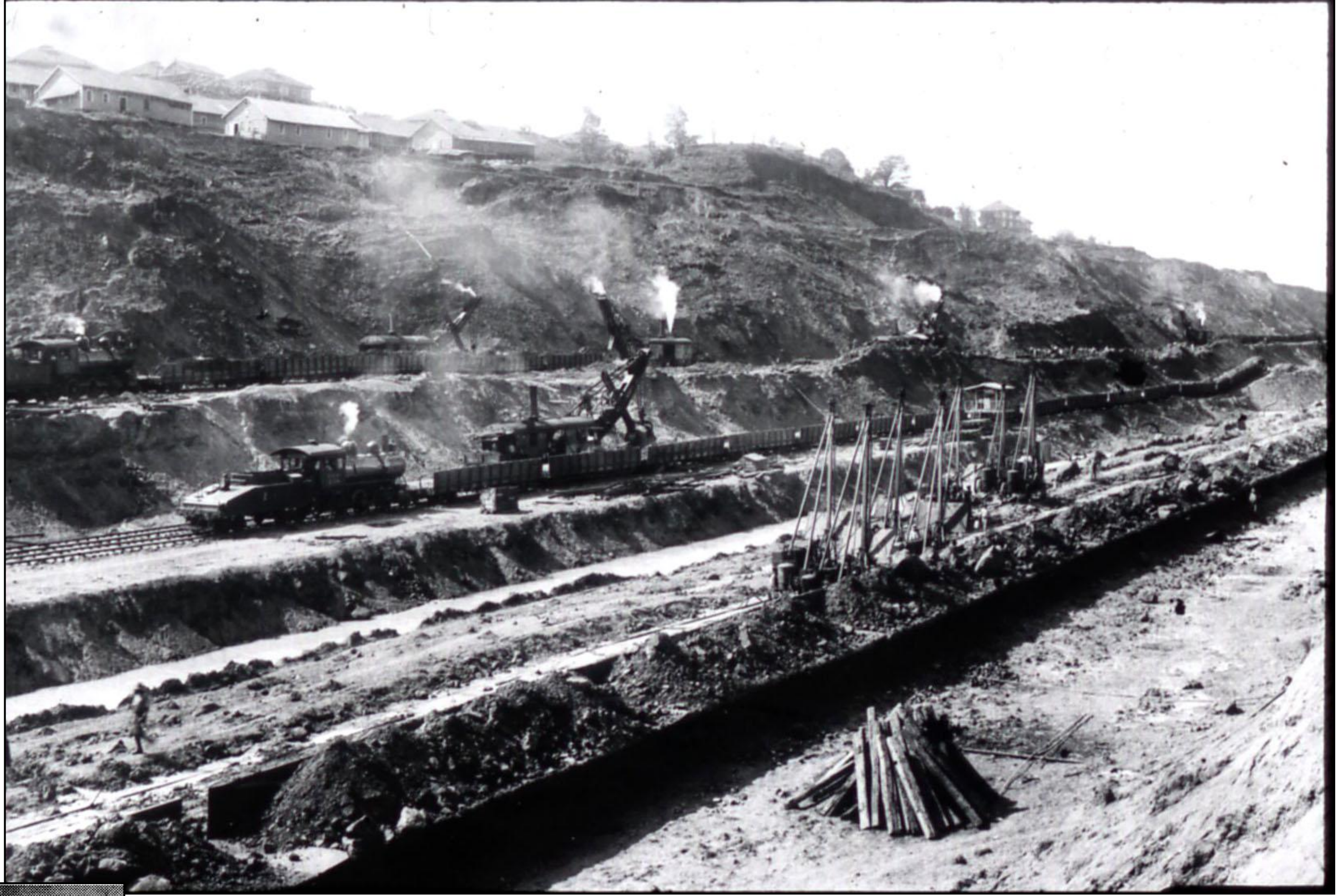


The Bucyrus steam shovel and most of its competitors were manufactured in Ohio



Shovel loading side-dumping rail cars

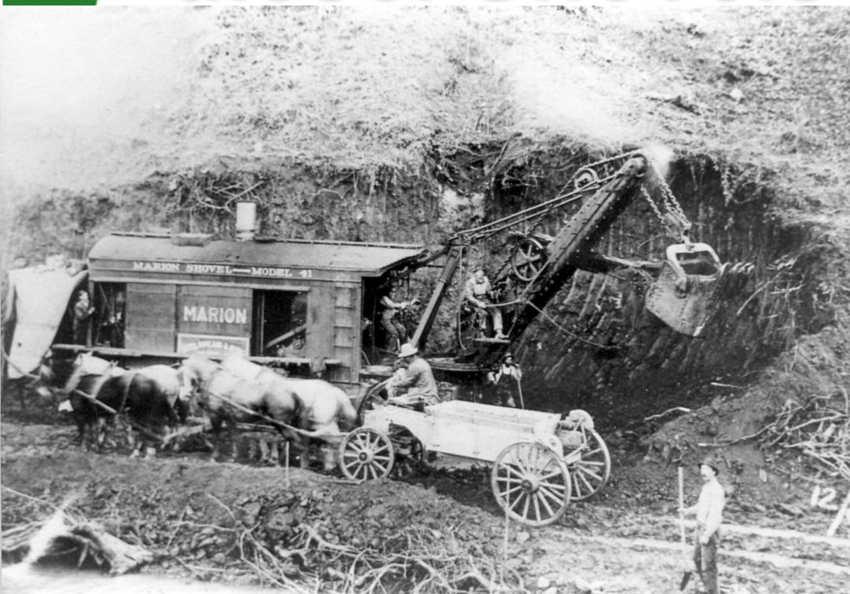
- **Rail-mounted Bucyrus steam shovels reigned supreme in Panama during excavation of the canal between 1905-14**



- **John F. Stevens** conceived the plan to construct a locked canal, using water from the Chagres River to create a vast inland lake.
- This reduced the required depth of excavations by 70 feet. The plan was favored by Teddy Roosevelt and approved by Congress on June 29, 1906.

- Looking into the gapping hole of the Panama Canal’s deepest excavations, across the Continental Divide, as seen on May 17, 1913. Note 0.5:1 side slopes.
- The Americans ended up excavating 245 million yds^3, almost equal portions being dredged below water and excavated in the dry.

Gasoline and diesel Shovels



- Steam shovels had been employed for railroad construction since 1868. As automobiles began being mass produced in the early 20th Century, the demand for roads increased dramatically.
- Steam shovels were only used on the largest jobs, where rock excavation made the use of Fresno scrappers impractical.
- Left view shows excavation for San Pablo Dam in 1920, while image at right shows excavation of US Hwy 50 across Altamont Pass in 1939. Both sites are in the San Francisco East Bay.

Tracked Shovels

- By the early 1940s tracked shovels were the dominant tool used for heavy excavation for highways and quarries. All of these were cable-controlled until the mid-1950s.

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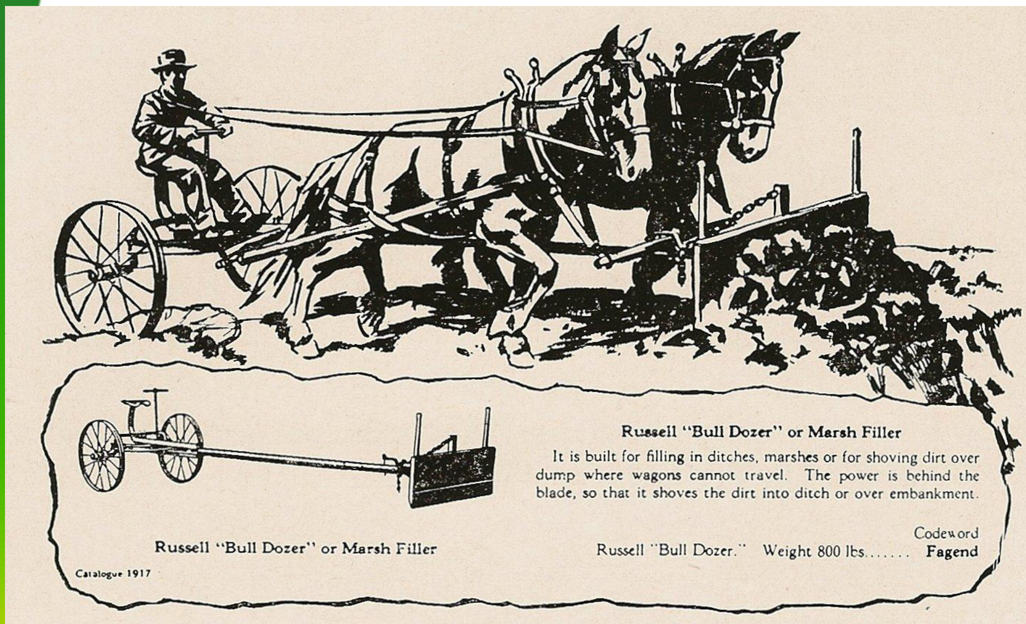
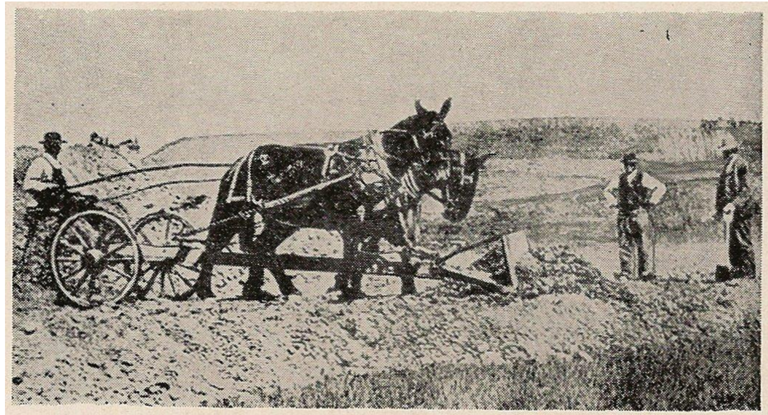
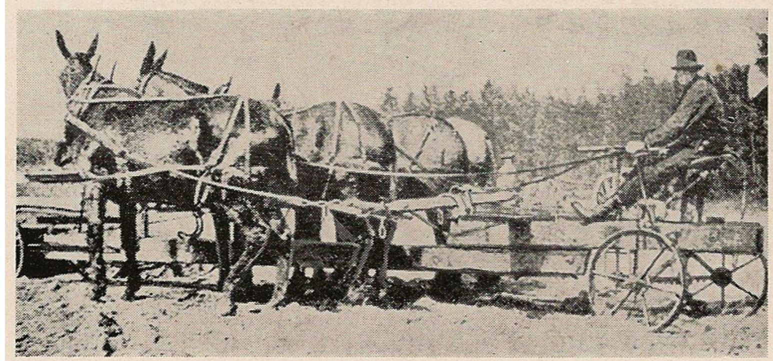
Increasing capacity and mobility

- By the end of the Second World War tracked shovels and mobile rock crushing plants had revolutionized the speed with which highways and airport runways could be constructed.

Bulldozers

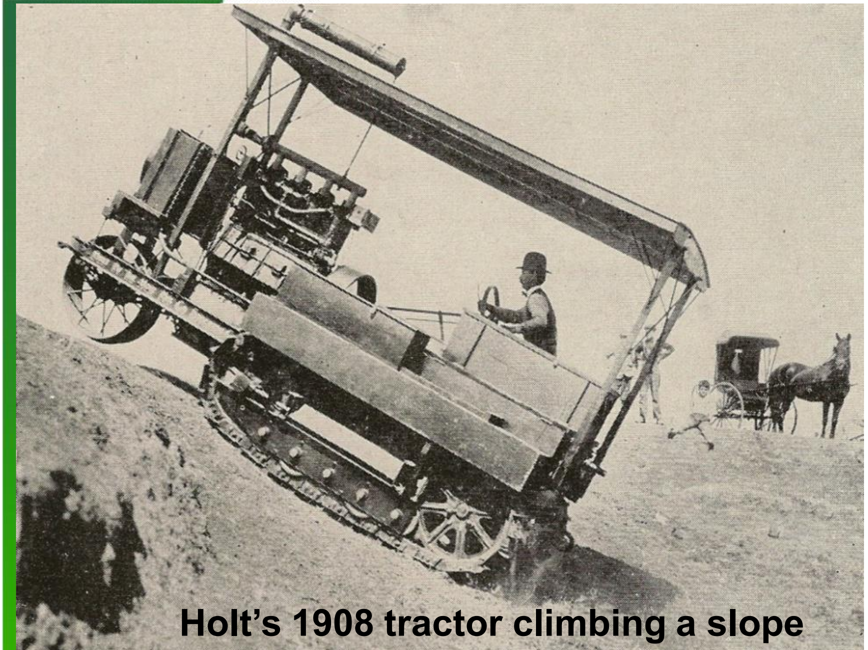




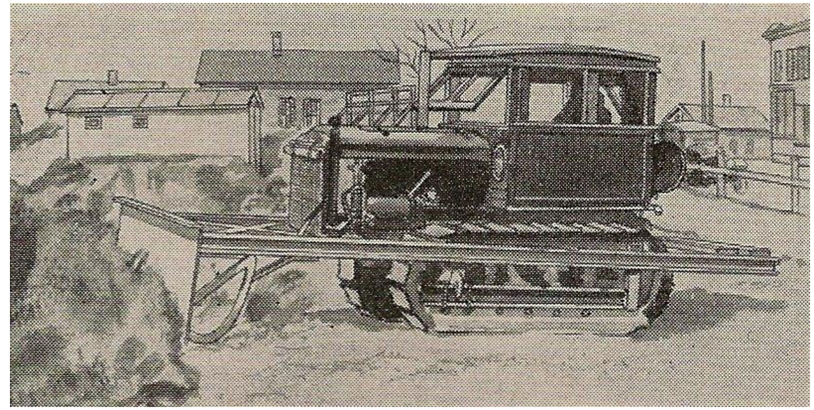


- The Bulldozer was developed in the late 19th Century to grade railroad lines. Two bulls or horses (upper right), or up to 4 mules (lower right), could be employed to pull a wheeled caisson attached to a stiff arm connected to a flat blade, which extended out in front of the animals, as shown above. The advertisement from the Western Wheeled Scrapper Co., above left, is from 1917.

Early Tracked Dozers

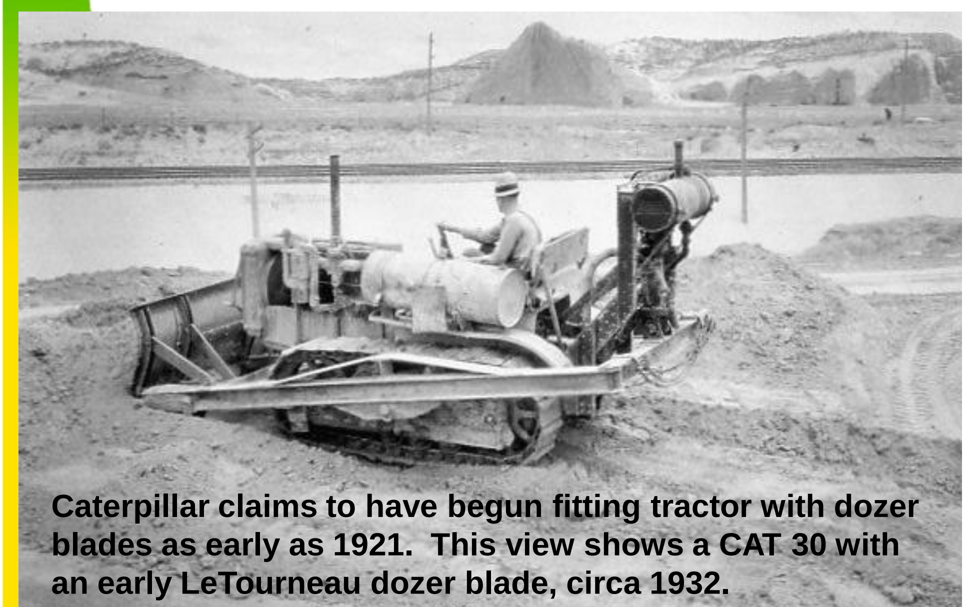


Holt's 1908 tractor climbing a slope

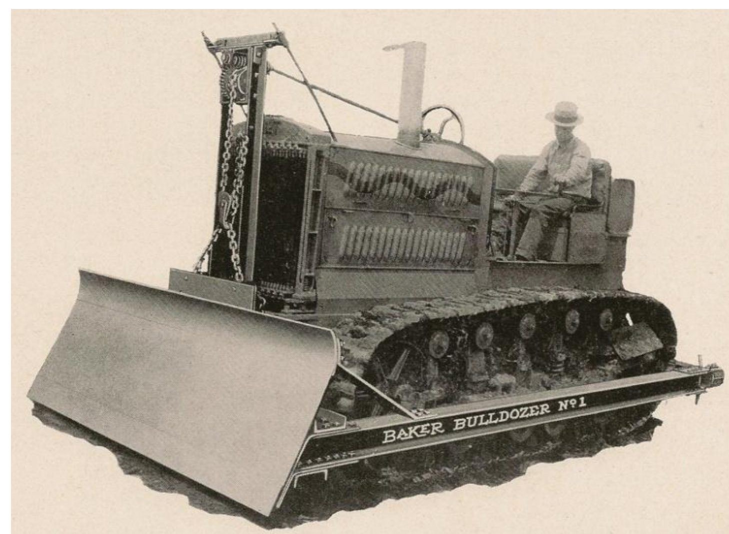


The LaPlant Choat tractor bulldozer appeared in 1923, but it lacked meaningful blade elevation and control

- Between 1885-1908 Benjamin Holt of Stockton, California gradually developing a gasoline-powered self-laying tractor, like that pictured at upper left. It began simply as a means of motive power, to replace horses and mules.

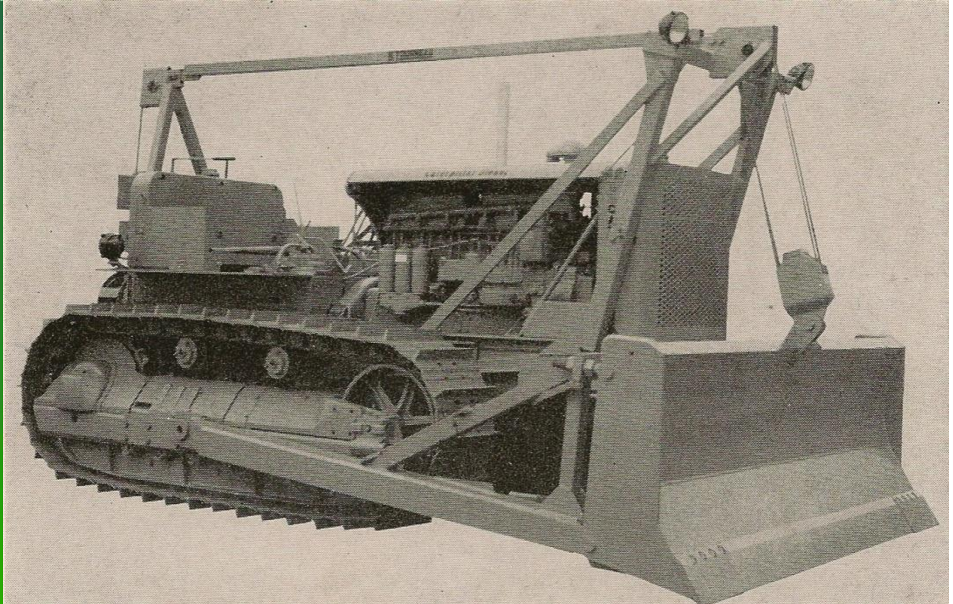


Caterpillar claims to have begun fitting tractor with dozer blades as early as 1921. This view shows a CAT 30 with an early LeTourneau dozer blade, circa 1932.



Baker Manufacturing of Springfield, Illinois' Dozer No 1, which used a chain hoist, appeared in 1927

Perfecting the tracked dozer

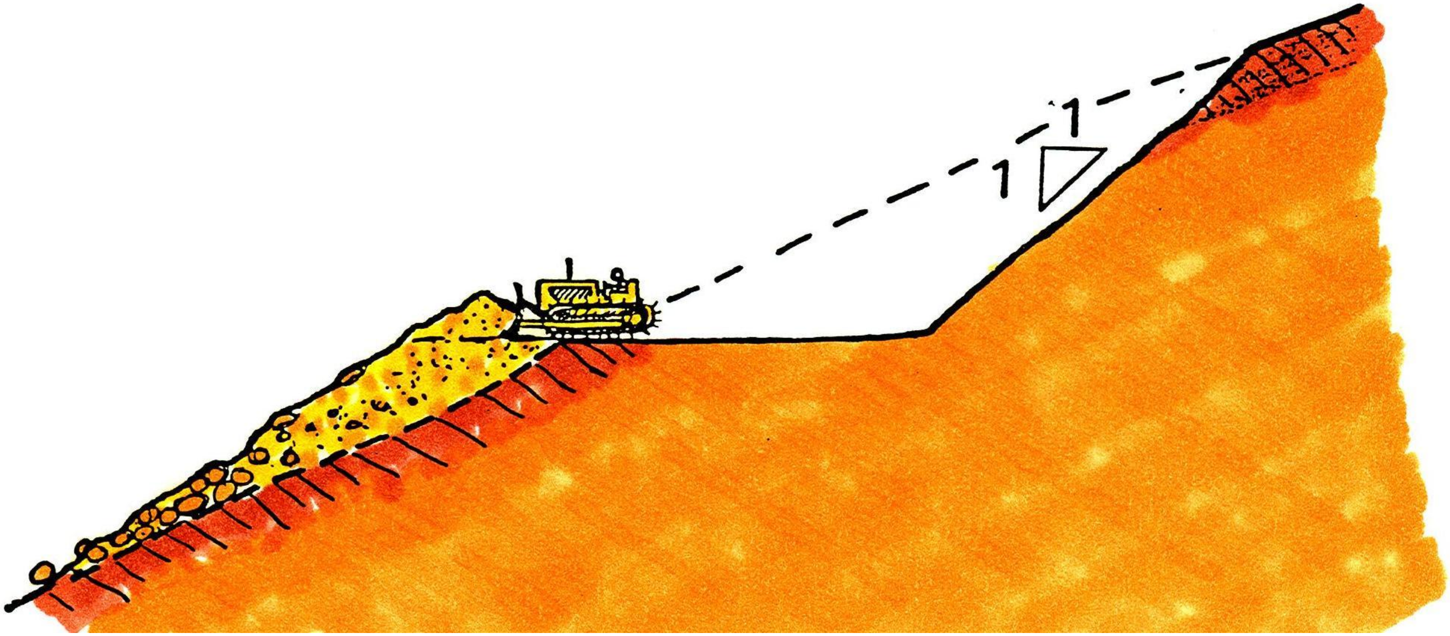


LeTourneau's cable and winch controlled dozer; which changed the earth moving business in 1928

Caterpillar-LeTourneau dozer with power-takeoff cable control at a dam site in Montana in 1937.

- **In 1928 LeTourneau began producing dozer blades for Caterpillar tractors, in Stockton, California**
- **At that time LeTourneau also introduced *cable and winch control* for lifting and tilting the big steel blades, which all their competitors adopted, soon thereafter.**
- **The power take-off winch (seen at lower left) using cable control became the dominant means of controlling the dozer blades until the adoption of hydraulic actuators, after the Second World War.**

The tracked dozer allows rapid excavation and drifting

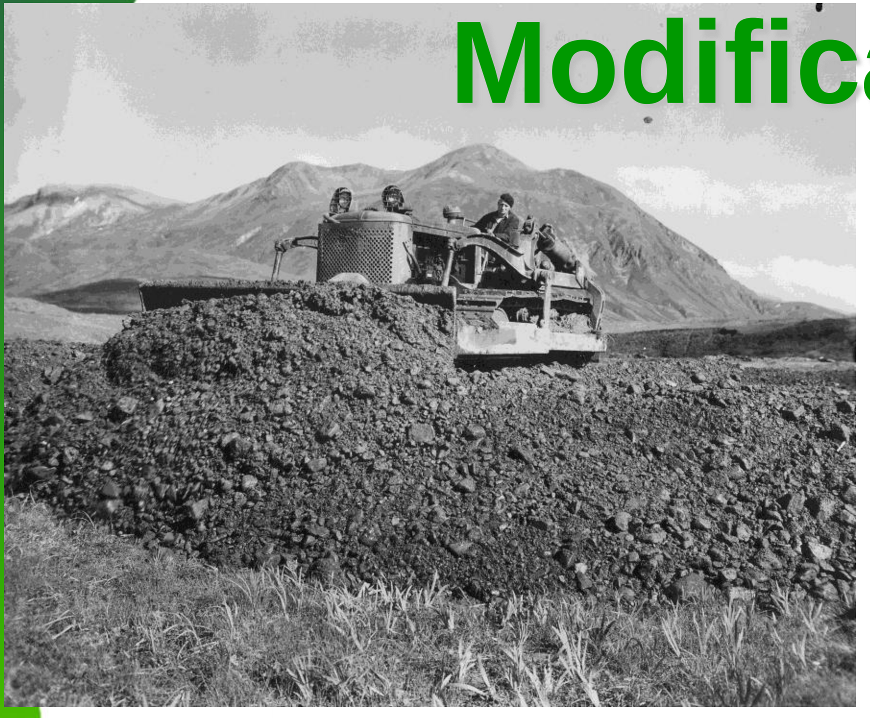


- LaTourneau pioneered the simple mechanisms that allowed dozer blades to be lifted, dropped, and angled downward, like a road grader.
- With that kind of control, tracked dozers could push, or “drift” loose earth and rock for a minimal cost, promoting an upsurge in road building activity during the 1930s and 40s.

Dozers at Hoover Dam

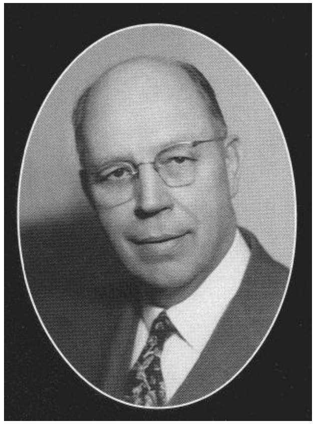
- **Tracked dozers played a staring role in the high-visibility Newsreels trumpeting the construction of the Boulder Canyon Project, between 1931-36**

Modifications

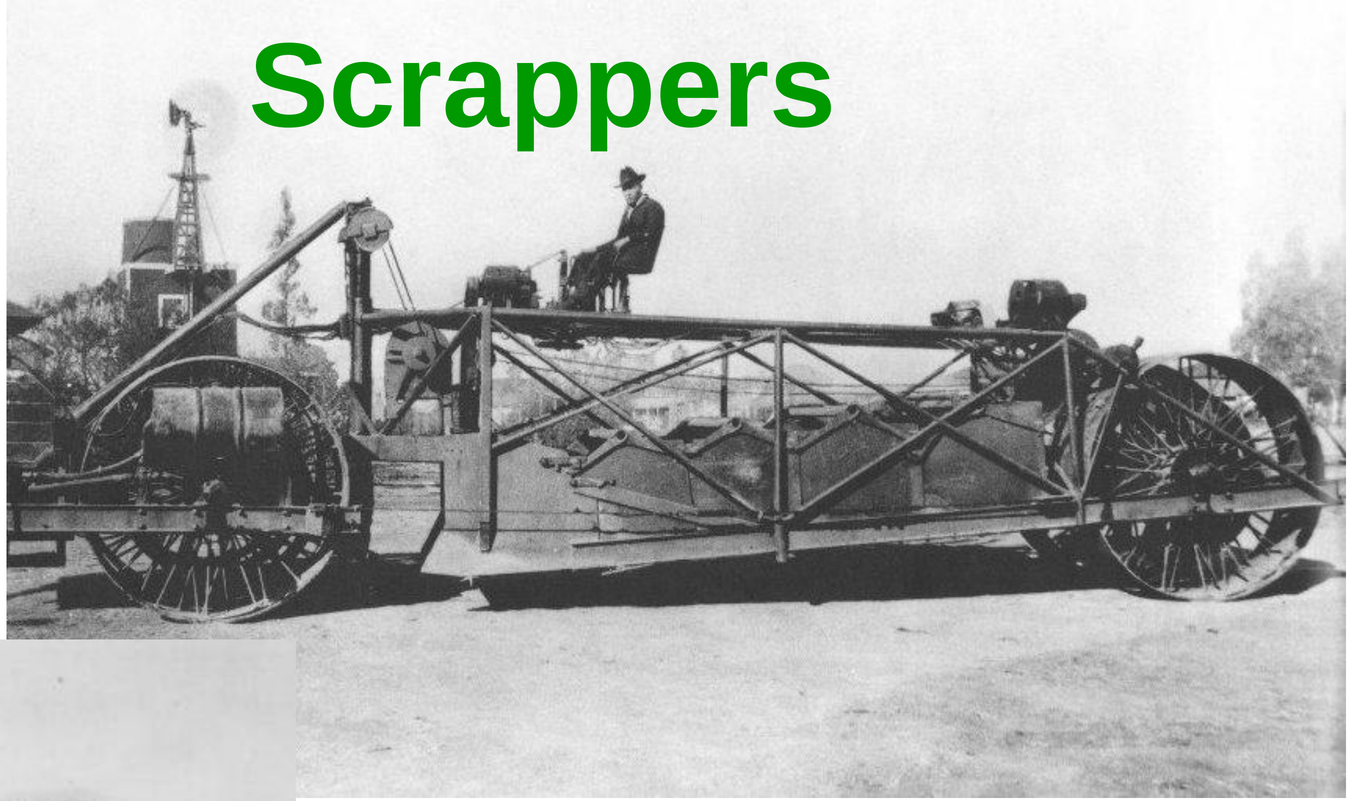


- Dozers are often modified to suit particular tasks.
- Upper left: Bucyrus Erie dozer grading an Aleutian airstrip in 1943
- Upper Right: International TD-18 dozer retrofitted with a Bucyrus-Erie dozer blade
- Lower left: Slope bar built by Peterson CAT for the Friant-Kern Canal job in 1940. These became increasingly common after the war.

Scrappers



R.G. “Bob” Letourneau (1888-1969) was a legendary figure in the earthmoving business

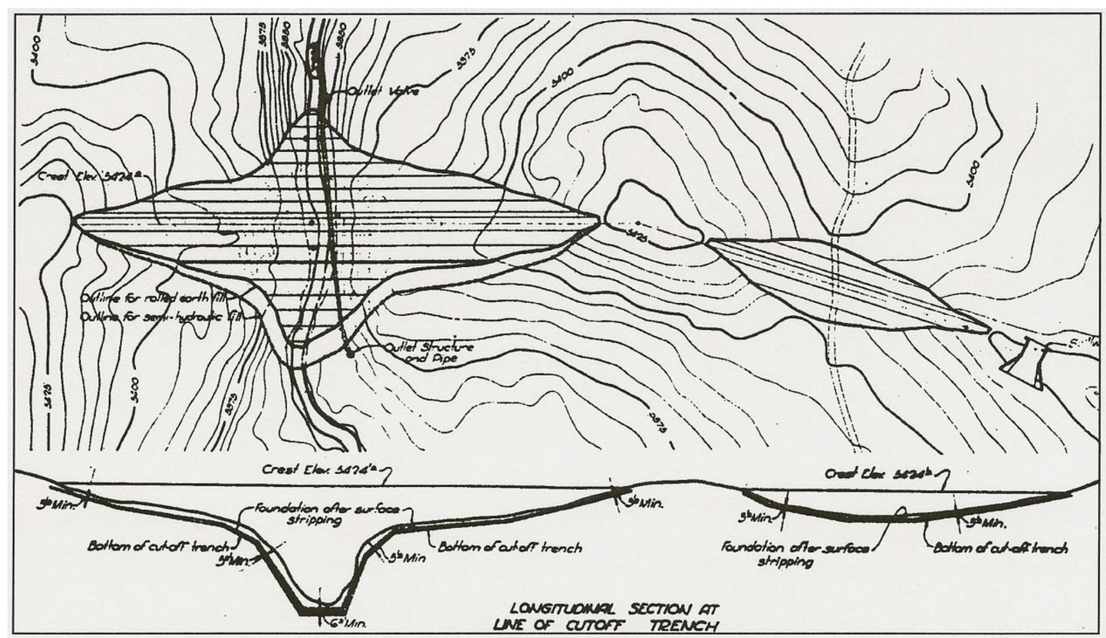


R.G. LeTourneau of Stockton, California began leveling farmer’s fields in the San Joaquin Valley around 1910, using a Holt Tractor and towed scrappers of his own design, like that shown here, in 1913.

- **In 1923 Letourneau invented the first self-propelled scrapper, shown above, which employed a series of five telescoping buckets that could carry 12 cubic yards of soil**
- **The 1923 scrapper employed all-electric drive, making it was the first machine that could excavate earth, carry it, and place it, all under its own power.**

FIRST DAM BUILT WITH SCRAPPERS

- **Philbrook Dam was an 85 ft high earth fill and wing embankment built by Kaiser Construction for PG&E as a power supply reservoir in 1926, off the West Branch of the Feather River**
- **Kaiser retained R.G. Letourneau Construction Co of Stockton to move the earth with his patented telescoping scrappers, shown at left. The fill volume in both embankments was 142,000 yds^3**
- **It was the first rolled fill dam in the world constructed with mechanical scrappers**

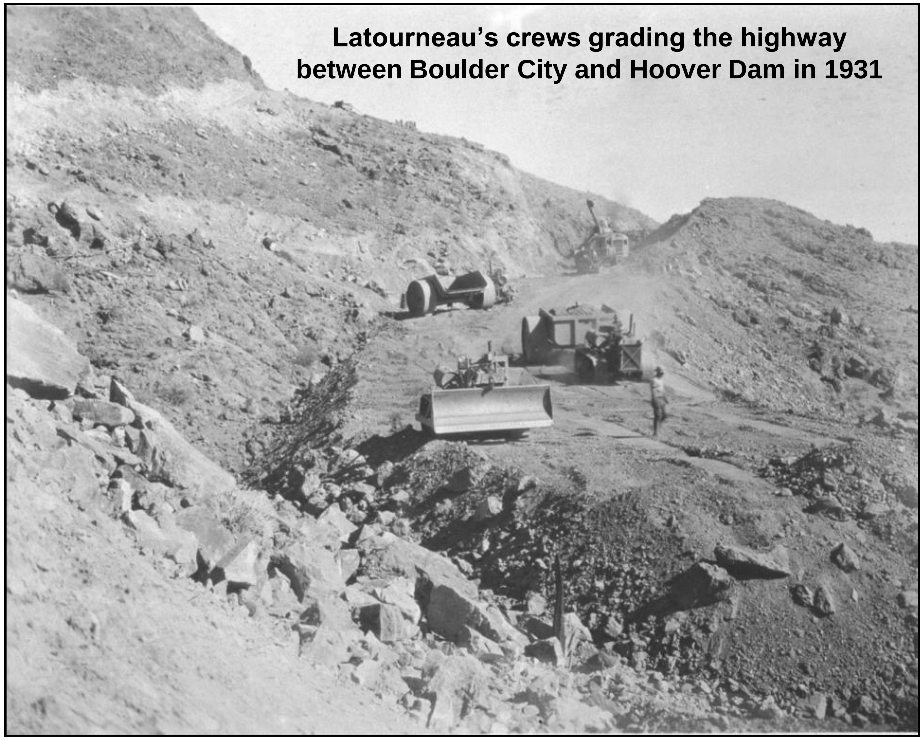


Pneumatic tires introduced in1932

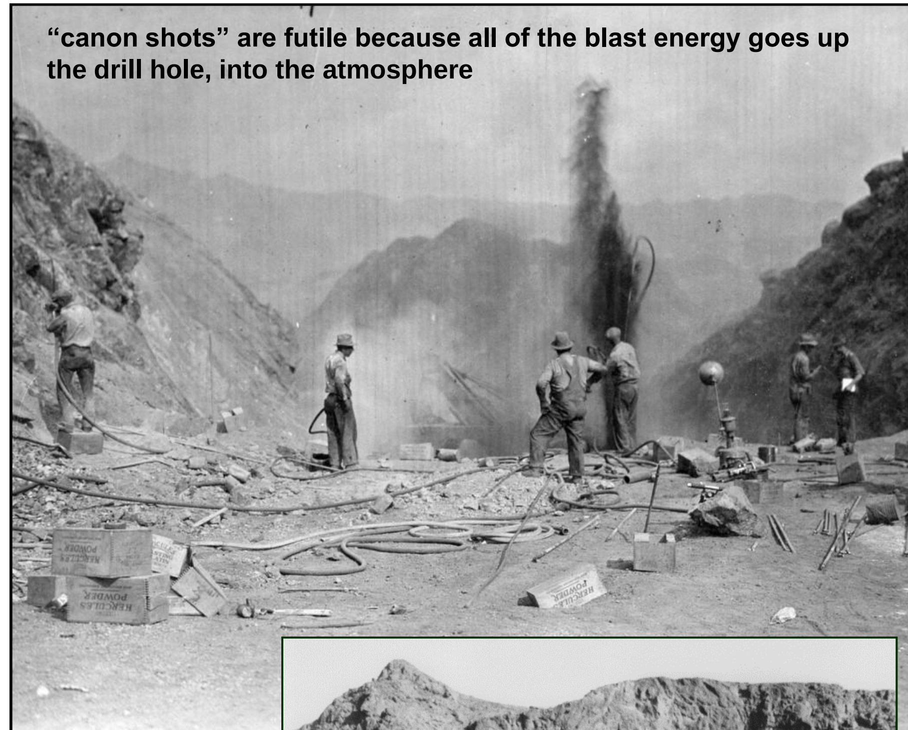
Old solid drum steel wheeled scrapper laying fill for the Bradley-San Ardo Highway in 1931

In 1932 R.G. Letourneau fitted *pneumatic tires* to some scrappers he built for a client that was grading a new state highway in the loose blow sands of the Salton Sink, in the Colorado Desert of southeastern California

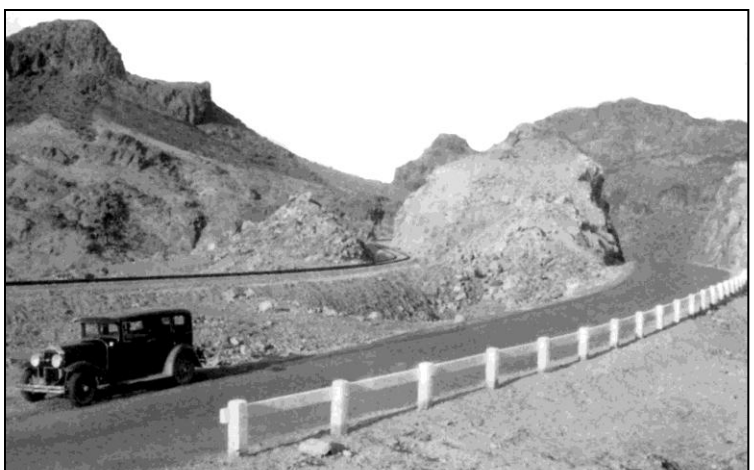
- **These worked so well the entire industry shifted over to pneumatic tires over the next few years.**



Latourneau's crews grading the highway between Boulder City and Hoover Dam in 1931

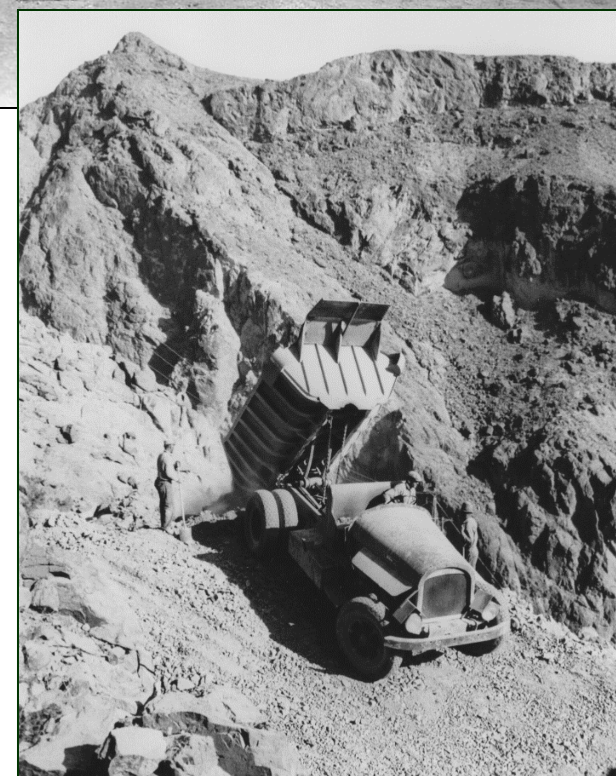


"canon shots" are futile because all of the blast energy goes up the drill hole, into the atmosphere



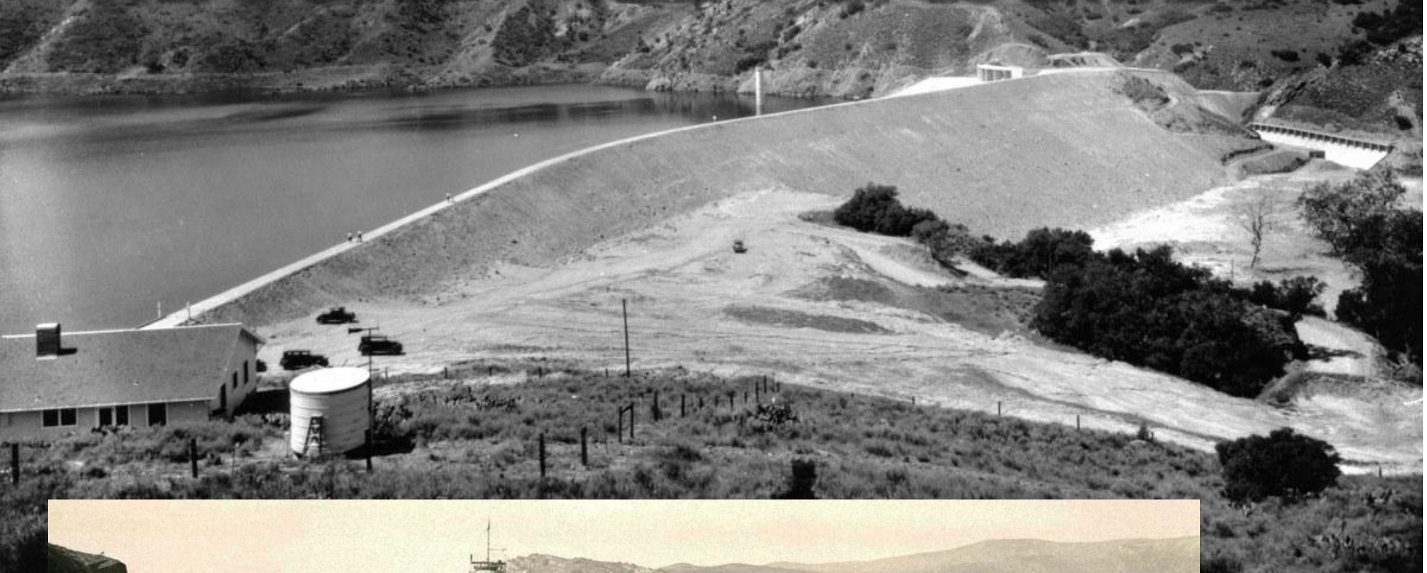
The highway as completed in January 1932.
The government railroad line ran parallel to it.

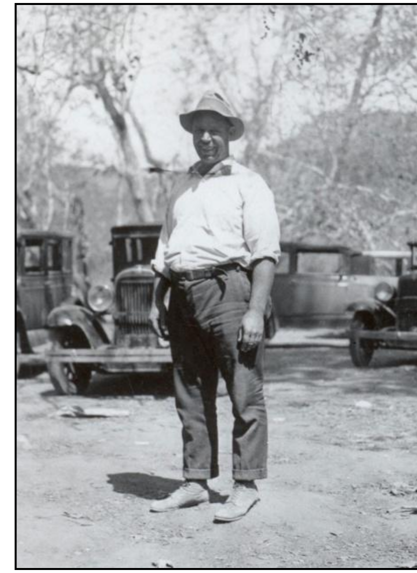
In 1931-32, during construction of the main highway access to Hoover Dam, R. G. Letourneau lost $100K on a $330K contract constructing the government highway between Boulder Junction and the Hoover Dam site, because the andesite proved so difficult to excavate



- **Tracked shovels were busily engaged whittling out switchbacks for temporary construction access, and creating valuable fill wedges along the channel**

RECORD FILL PLACEMENT



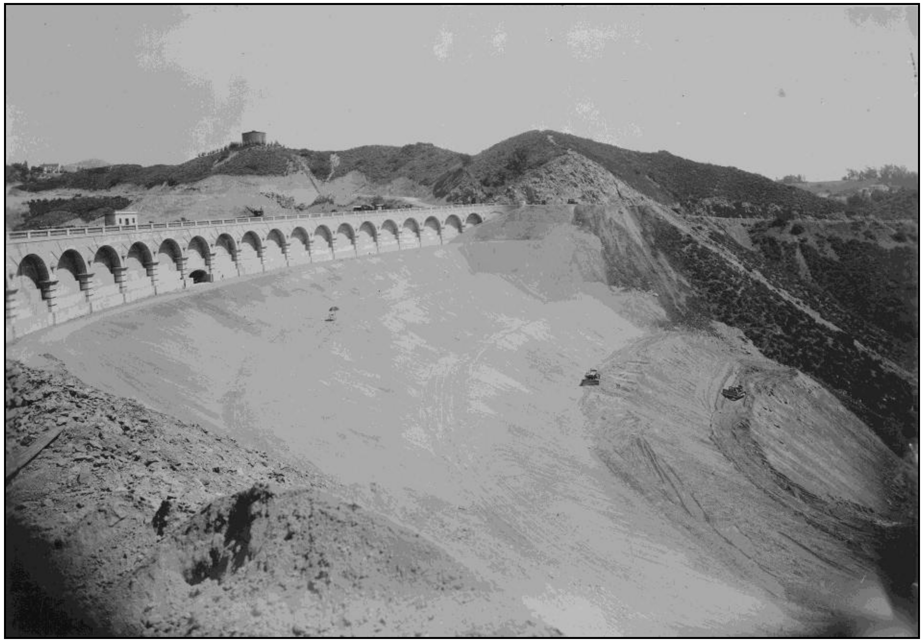


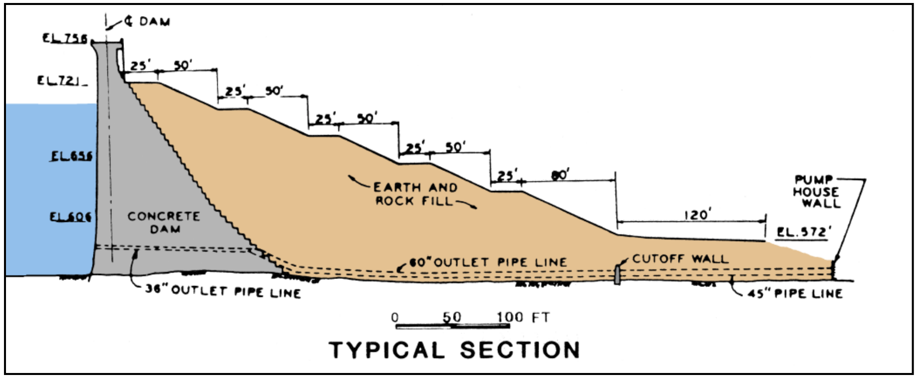
R. G. Letourneau in 1931

Letourneau Model A Carryall Scrapper
at Santiago Dam in 1931

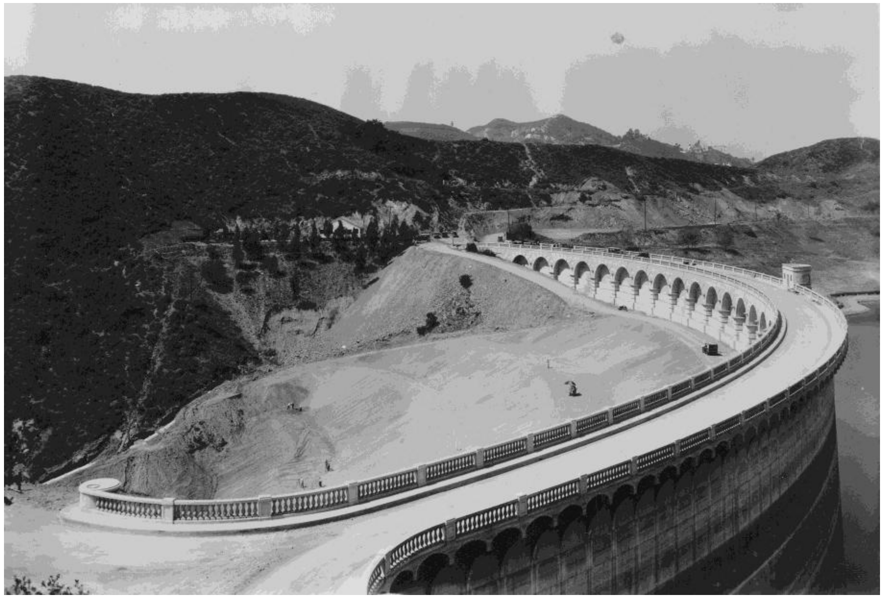
- In July 1931 earthmoving pioneer R. G. “Bob” Letourneau brought his 9 yd^3 capacity Model A Carryall scrappers to Orange County to grade the 136 ft high Santiago [Creek] Dam (Lake Irvine) for the Orange County Flood Control District
- Letourneau placed 400,000 yds^3 of compacted fill in the first month, setting a record for rolled fill construction
- The job was completed in the spring of 1932 with a final volume of 790,000 yds^3

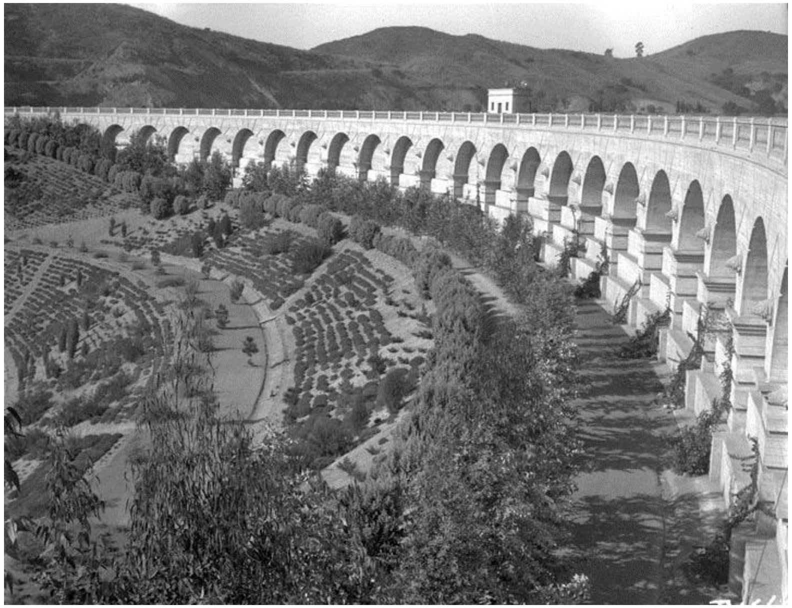
LOOSE DUMPED BUTTRESS FILL





In 1933-34 the City of Los Angeles placed 330,000 yds^3 of fill against the downstream face of Mulholland Dam, making it one of the most conservative dams in the state





- In 1937 Letourneau introduced the revolutionary Tournapull Scrapper, shown here. It employed a clever cantilever design with an articulated U-joint, which allowed it to turn a very tight radius, with straight-away speeds of up to 25 mph
- During the Second World War Letourneau turned out 70% of the earth moving equipment used by Allied forces, from five manufacturing plants, including one in Australia.

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- The weak link in the **Turnapull Scrapper** was the steel 'box' that housed the drive train gears, between the engine and the two drive wheels. The punishing environment of earthwork jobs (shown above) eventually torqued these welded boxes so the gears would no longer engage. When this occurred the machine was down for good. This is why there weren't any surplus Turnapulls after the war.

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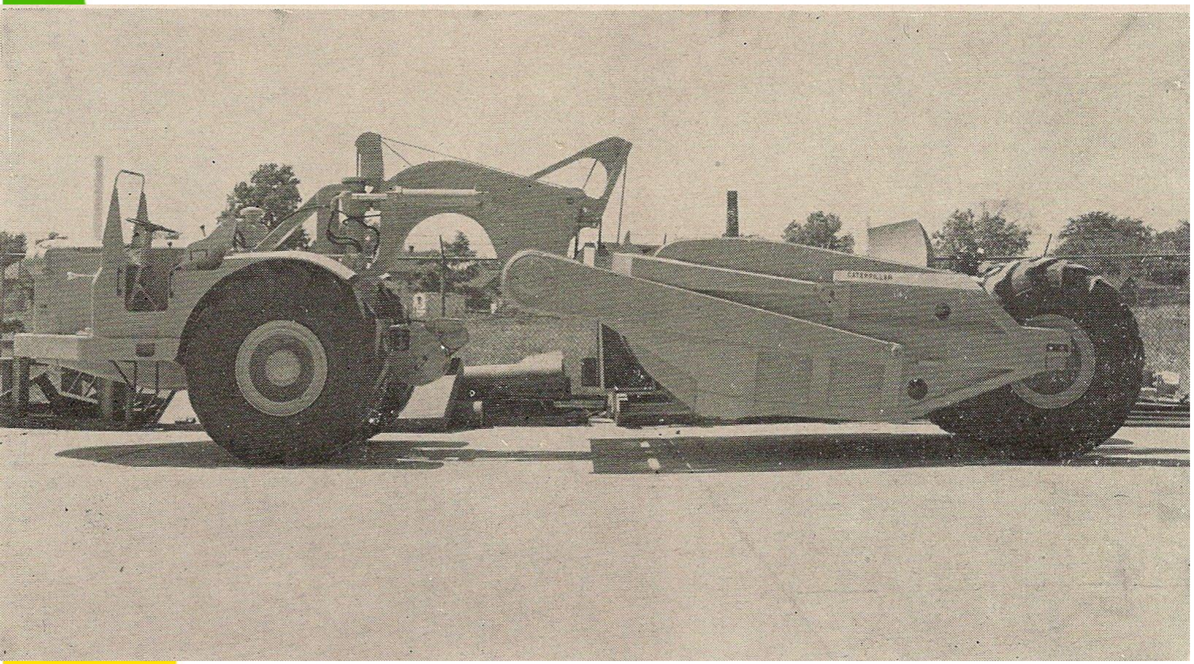
Letourneau Carryall Scrappers

- Upper left shows Letourneau Carryall scrappers working Yonton Airfield on Okinawa in July 1945.
- numerous scrapper for a decade thereafter.

Figure at left shows a Carryall being towed by an Allis-Chalmers tractor at NAD Attu in July 1943. Letourneau produced 75% of the Allied scrapers used in the Second World War

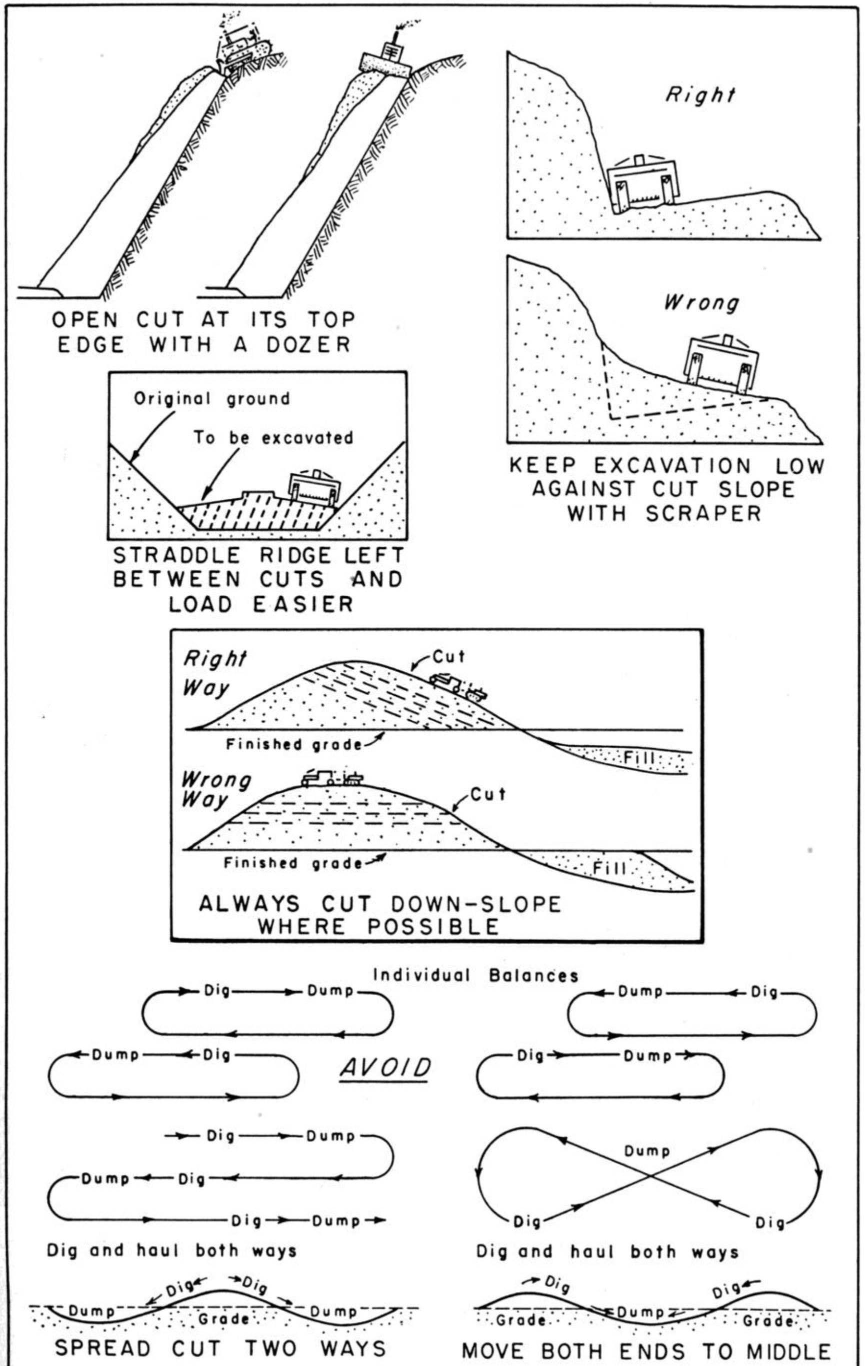
Thousands of these were sold as surplus after the war (1946-49), making them the most numerous post-war earthmoving equipment



Post-war Caterpillar Scrappers

- American experience in World War II showed the superior performance of diesel-powered equipment, borrowing on technology pioneered by the Germans.
- Upper left: CAT DW-10 tractor and No.10 scrapper, which gained great familiarity during the war.
- Lower left: CAT entered the self-propelled wheeled scrapper market that Letourneau had pioneered in 1949, with the introduction of their diesel-powered DW-21 scrapper, equipped with a 13.5 cubic yard drum.

Excavation and Grading Protocols

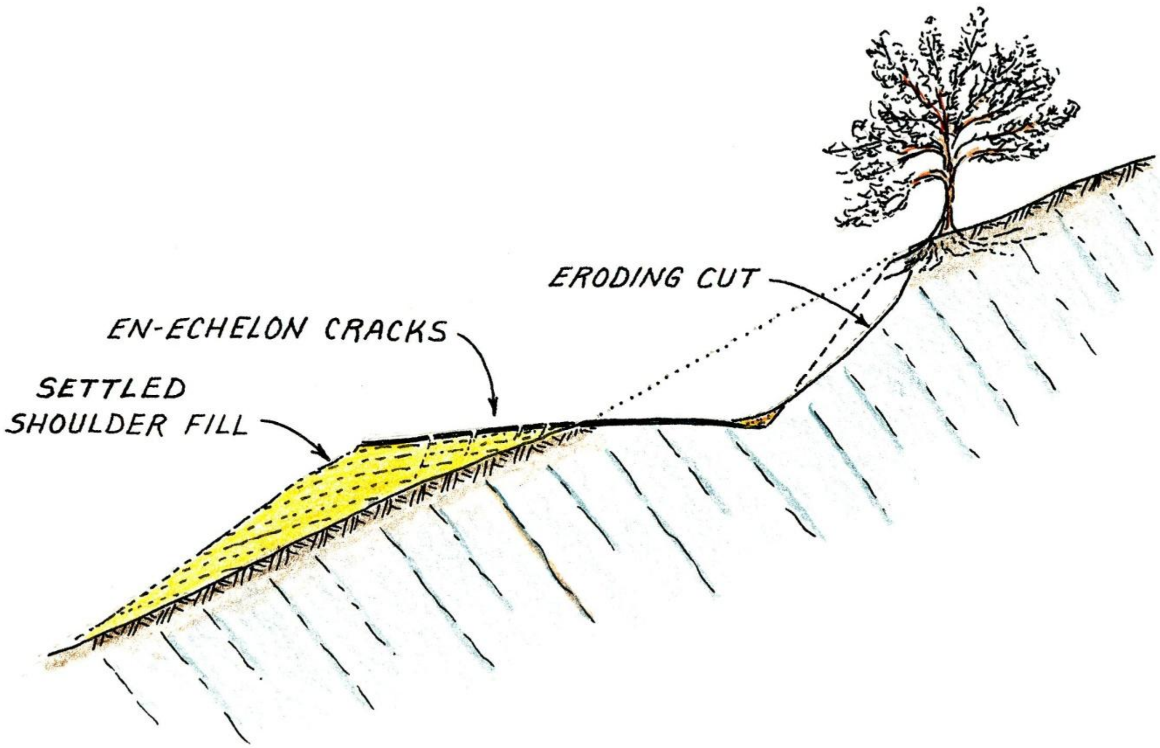


(After Park, 1942.)

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

- **The plethora of grading and excavation work carried out in the 1930s and 40s resulted in well-established protocols for how grading jobs could best be accomplished, employing gravity whenever possible, to reduce energy expenditures.**

SLIVER FILLS



- **Prior to the adoption of grading codes, fill materials were *cast* over the hillside, so called "*side-cast fill*" or "*sliver fill*". Sliver fills tend to compress and creep downhill, promoting tensile cracking of the road's downhill shoulder and pavement cracking.**

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SETTLEMENT OF FILL PRISM

- Progressive settlement of the fill prism beneath the shoulder of an old road is common.
- This settlement can eventually result in a slope failure

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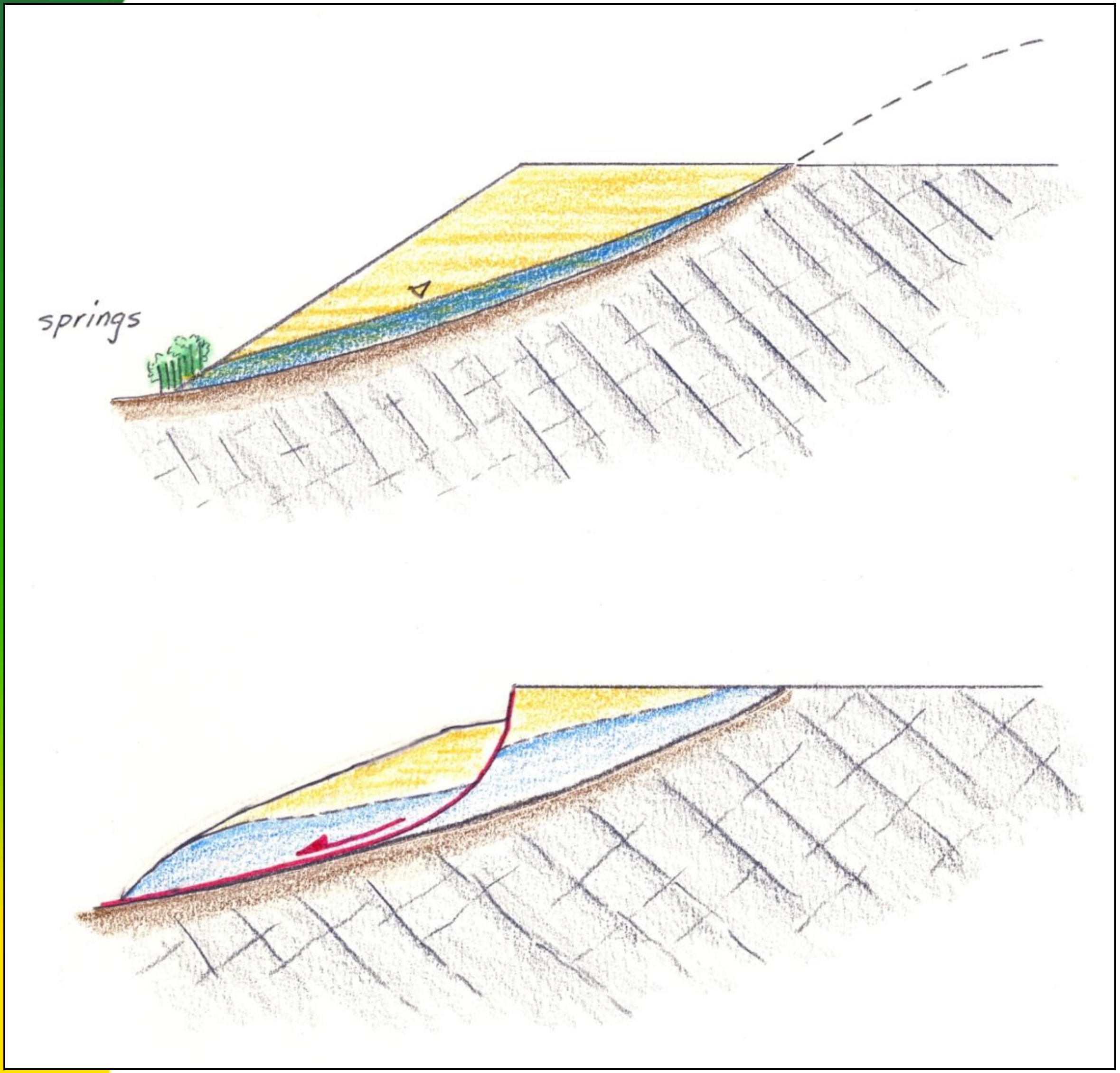
LARGE SLIVER FILLS

- **This shows the construction of sliver fill embankments along US Hwy 101 on Waldo Grade north of the Golden Gate Bridge in 1935. Sliver fills tend be stratified, with the largest rock fragments collecting towards the toe of the slope, fining upward.**



- Water tends to become trapped in sliver fills, perching on the unstripped soil horizon beneath the fill
- This condition often leads to moisture becoming perched within the embankment, leading to eventual slope failure

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Part 2

NATURAL SLOPE CREEP

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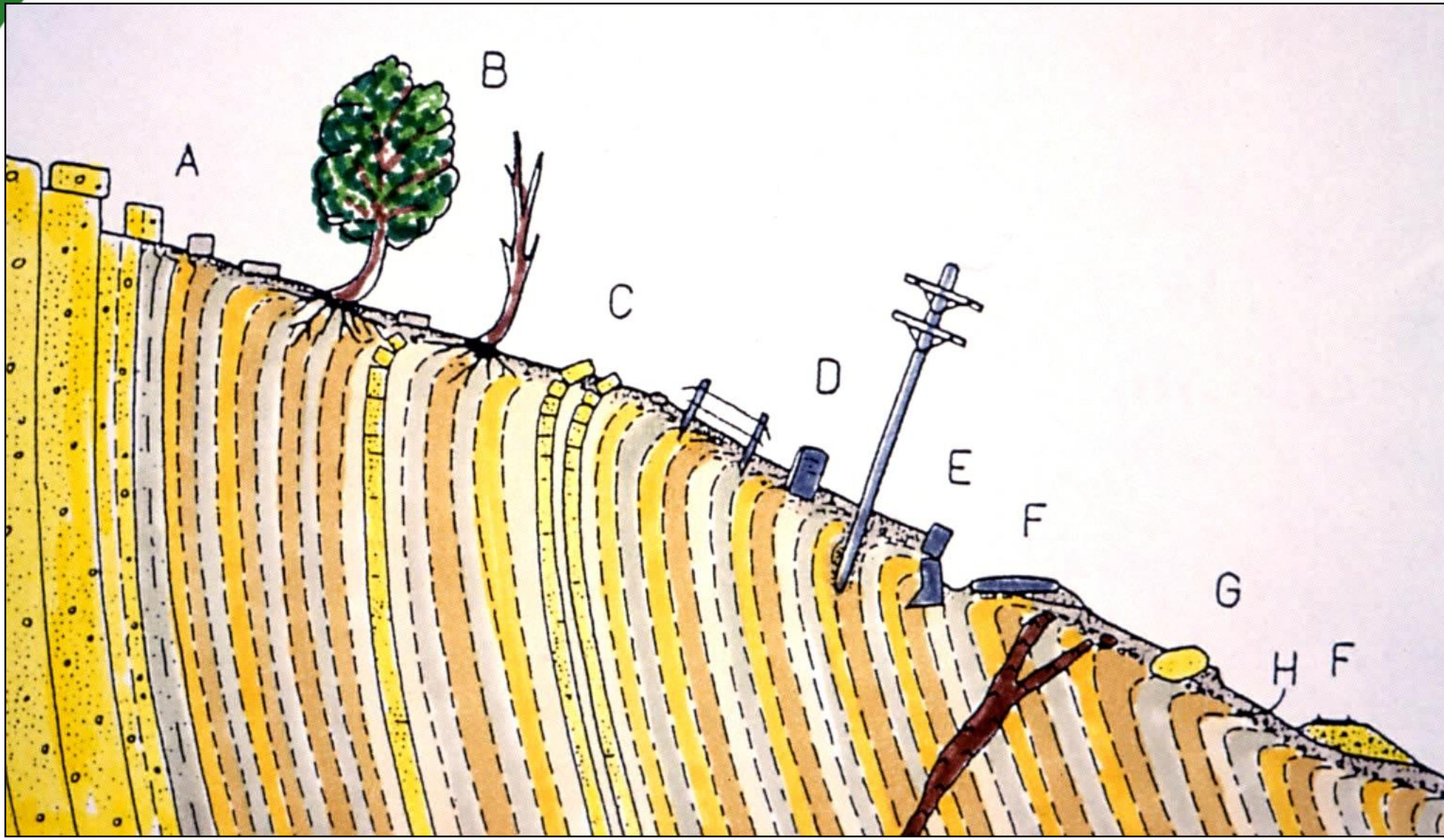

- Seasonal down-slope creep tends to decrease with increasing depth into the slope, as shown here (from Sharpe, 1938)
- It affects all types of structures and natural features

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Slope creep inhibits functionality

- Slope creep observed along westbound onramp of Interstate 44 at Exit 185 in Rolla, MO. Note sever slope of the concrete sidewalk and guardrail posts (inset), making it dangerous to use. Slope creep is usually most severe at the crest of a descending slope, as shown here.

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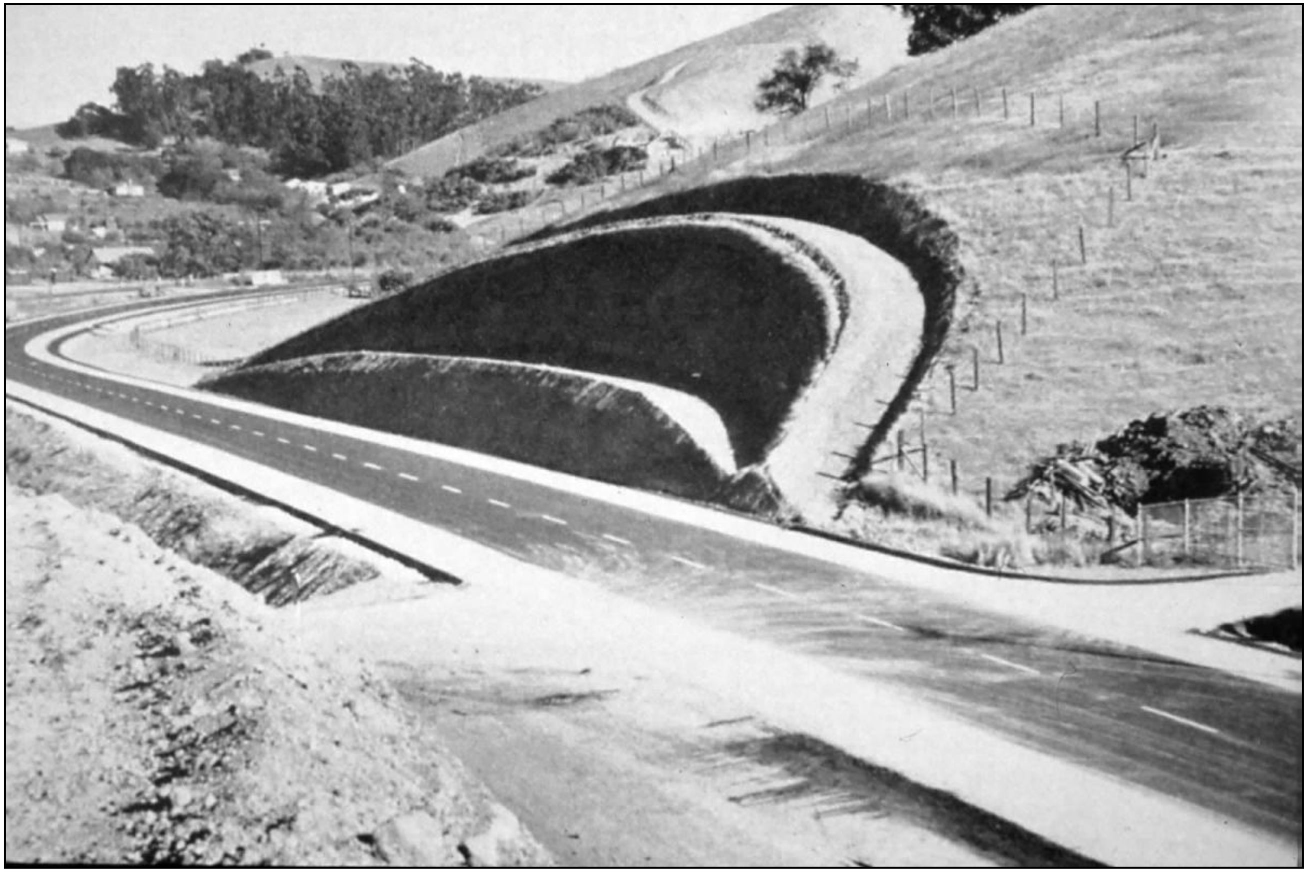
- Evidence of seasonal downslope creep abounds, provided we have some frame of reference for measurement, such as these telephone poles.
- Embankments must be designed to account for seasonal creep and weathering effects



- Soil and sedimentary rock are susceptible to rapid weathering and downslope creep; defined as strain under sustained load. Here is a fresh highway cut in Cretaceous age sandstone and siltstone, as viewed in 1954.

- **This is the same cut 33 years later, in 1987. The mid-slope bench and brow drainage interceptor ditch are gone. Plastic materials are subject to rapid weathering and erosion.**

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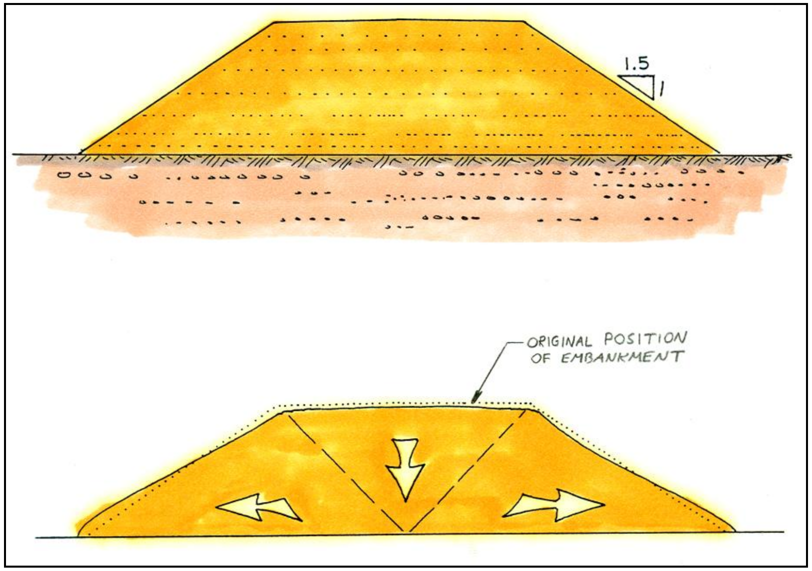
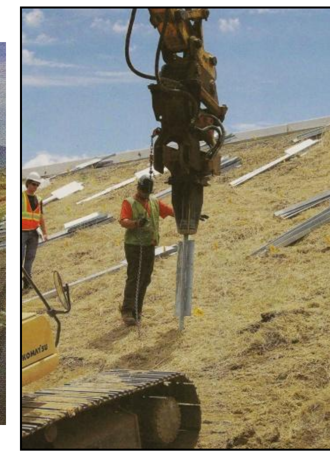
- **Shoulder cracking** is a common problem of pavements on descending embankments, caused by downslope creep, consolidation, and/or expansive soils heave and desiccation cycles.

Mitigating Slope Creep using plate piles



Richard D. Short, PE, GE received his BSCE in 1966 from Nevada-Reno and MSCE in 1972 from U.C. Berkeley



One of the emerging technologies to combat slope-creep driven pavement distress is to install galvanized “plate piles,” installed by tracked excavators, as shown here . These were invented by Bay Area geotechnical engineer Dick Short of California and marketed by his firm *Slope Reinforcement Technology*, based in Oakland, California.

- **Slope creep** exerts its greatest impact on those improvements placed on, or close to, the slope face. Notice the tilted posts supporting this deck.

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Part 3

EMERGENCE OF EXCAVATION AND GRADING CODES

1952-75

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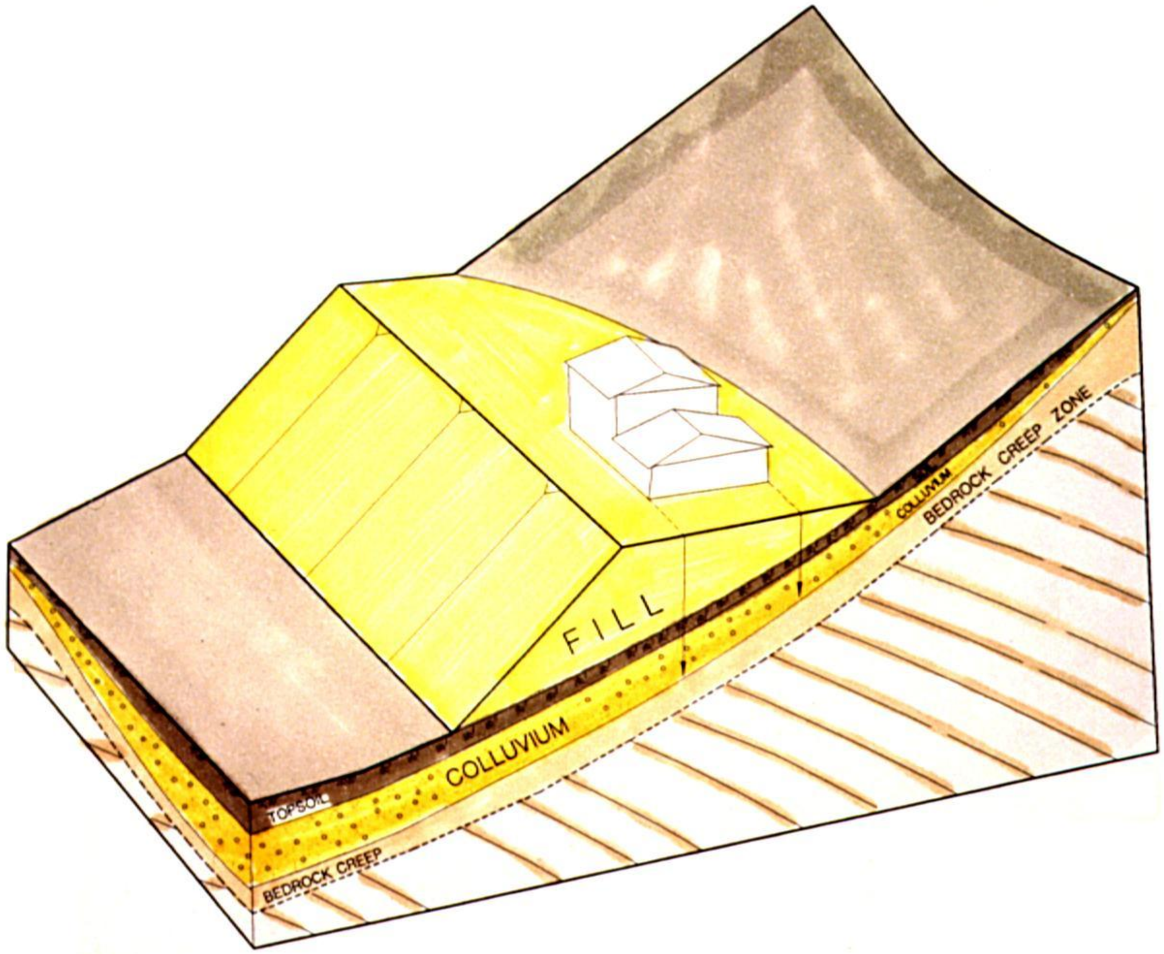

- **Early hillside lots were constructed on "sliver fills," or "wedge embankments," without keying or benching, like that shown above.**

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- Heavy rains of January 1952 caused $7.5 million in damage to hundreds of recently-built hillside homes in Los Angeles, like the one shown here, on a sliver fill.

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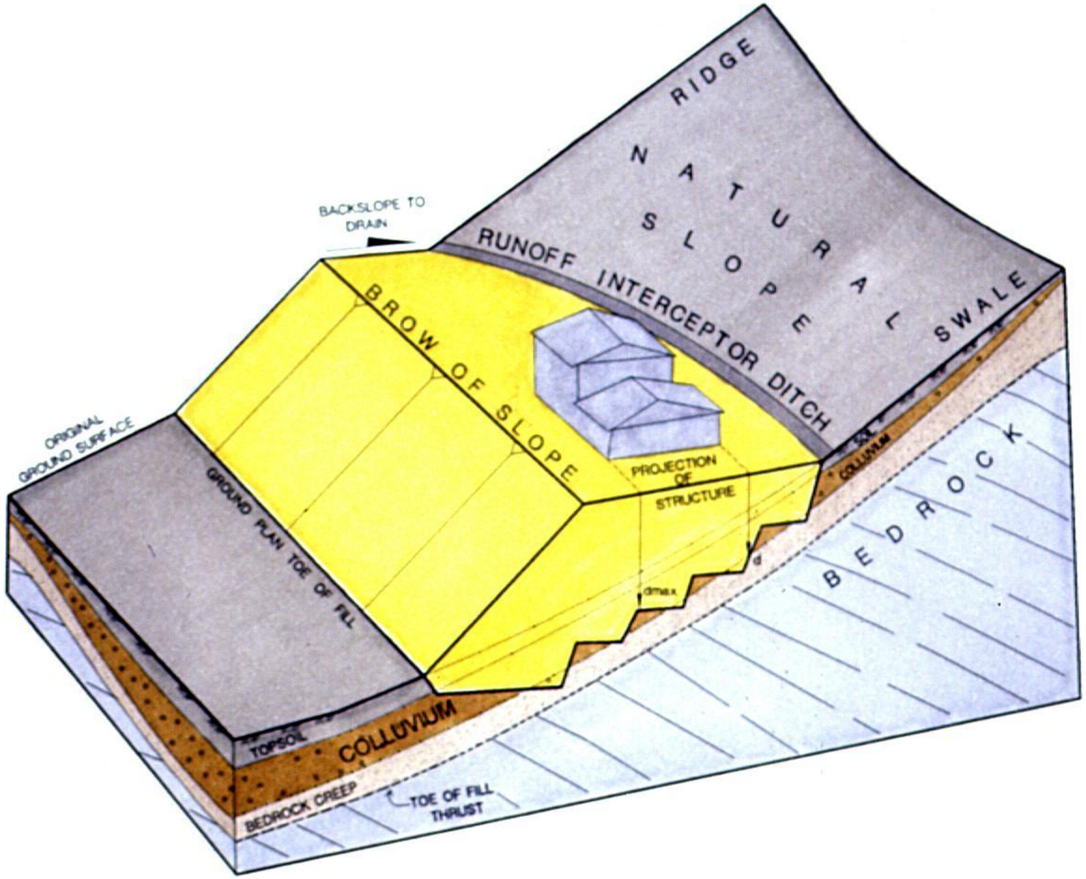
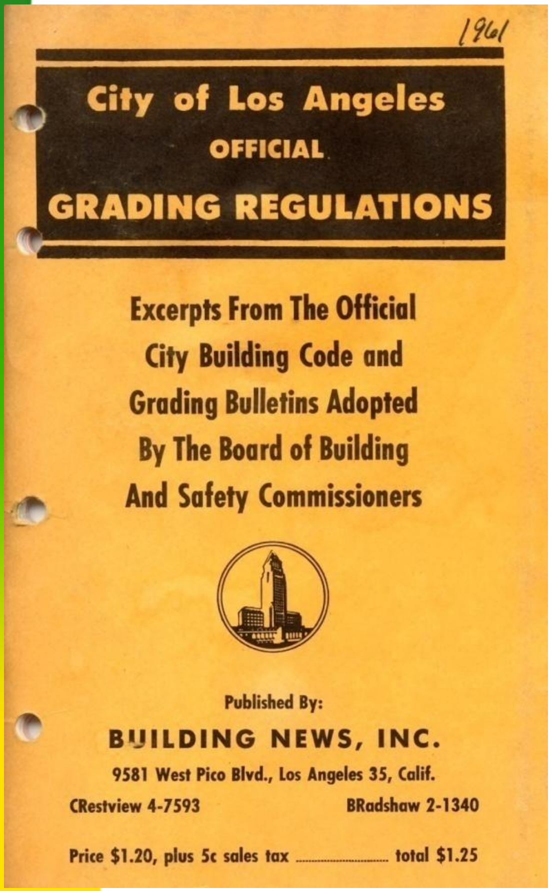


- **The 1952 Los Angeles grading ordinance required keying and benching of fill embankments, as depicted here. Other agencies in southern California adopted similar statutes soon thereafter.**

Agencies that adopted Grading Ordinances between 1952-64



- **Los Angeles and Beverly Hills (1952)**
- **Pasadena (1953) and Glendale (1954)**
- **Burbank (1954) and San Francisco (1956)**
- **Los Angeles County (1957)**
- **San Diego (1960)**
- **Orange County (1962)**
- **Adoption of *Appendix Chapter 70 - Excavation and Grading* into the Uniform Building Code (1964)**

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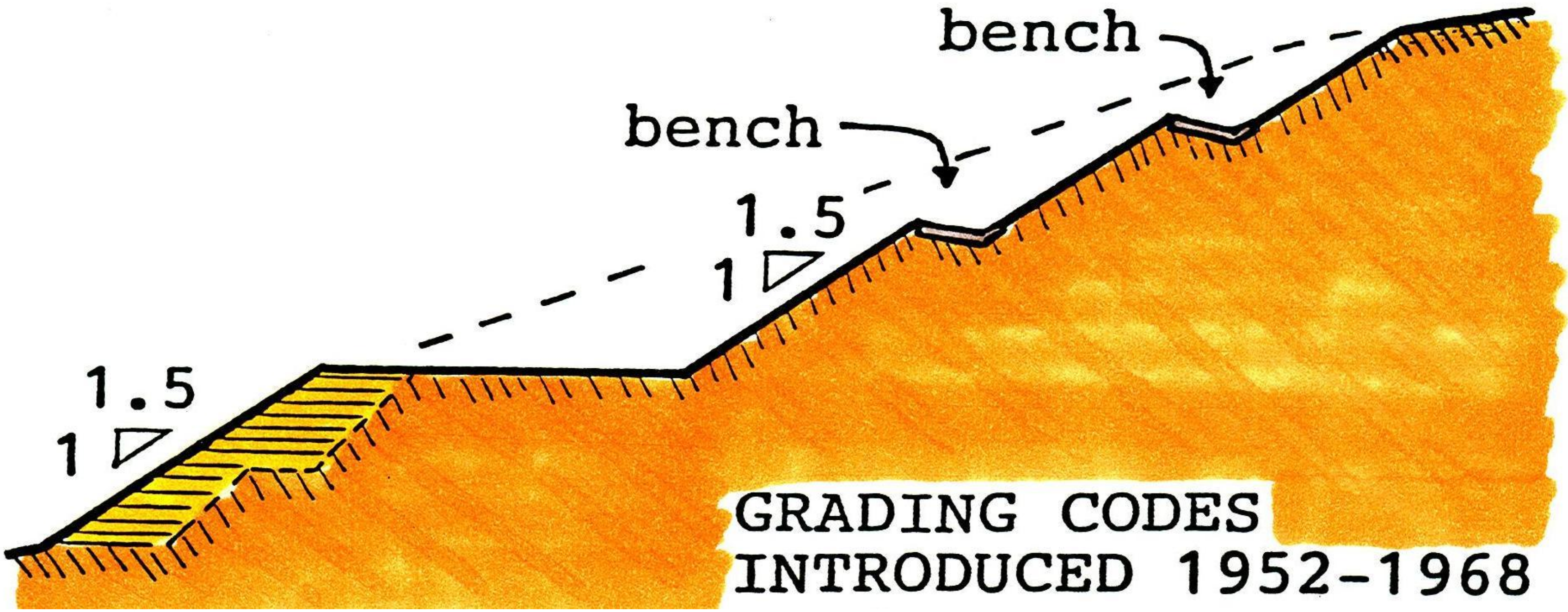
Evolution of Grading Standards



- **Most state highway departments established uniform standards for highway cuts and fills beginning in 1955, with the introduction of the Interstate and Defense Highway Program**

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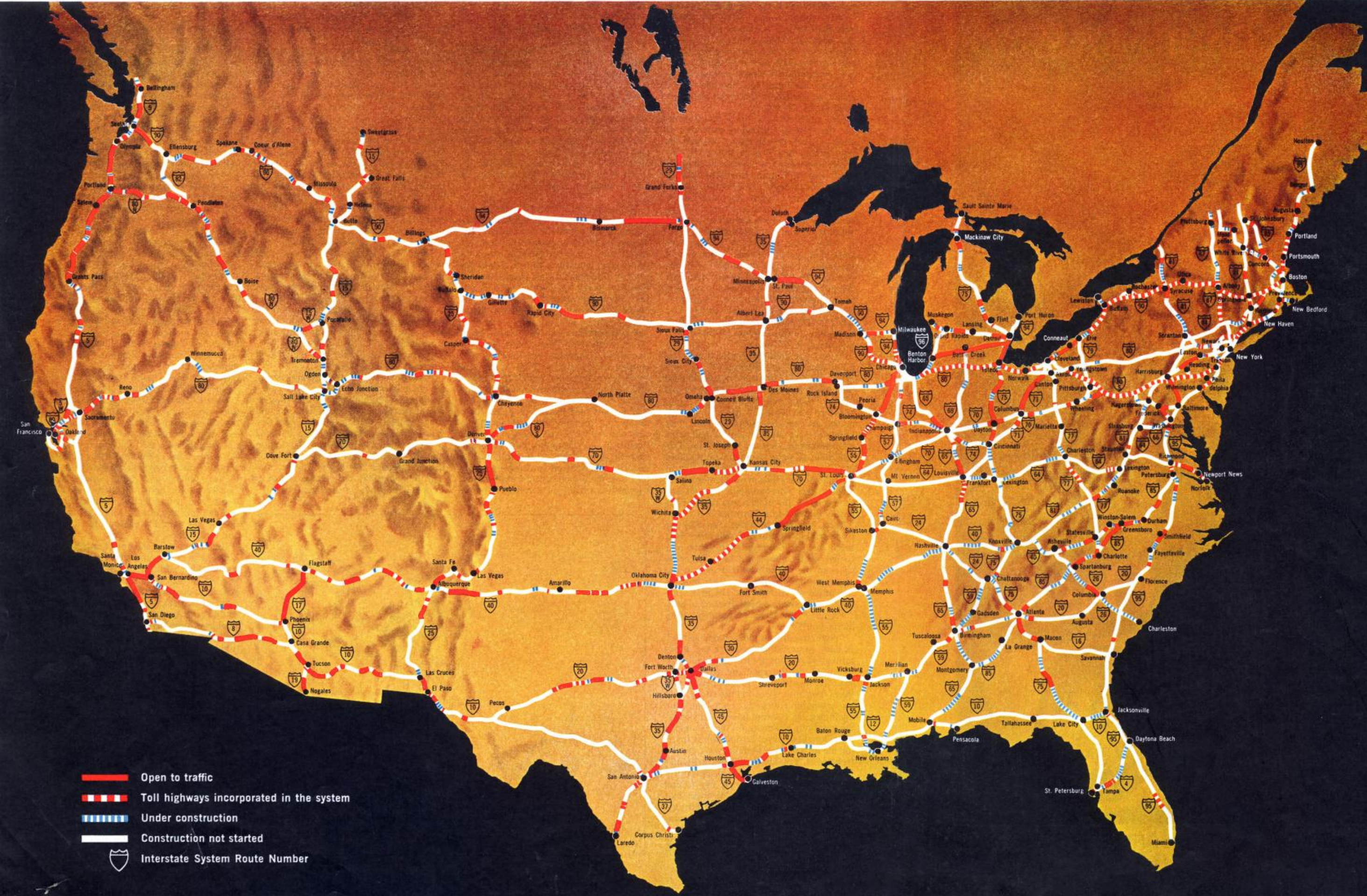


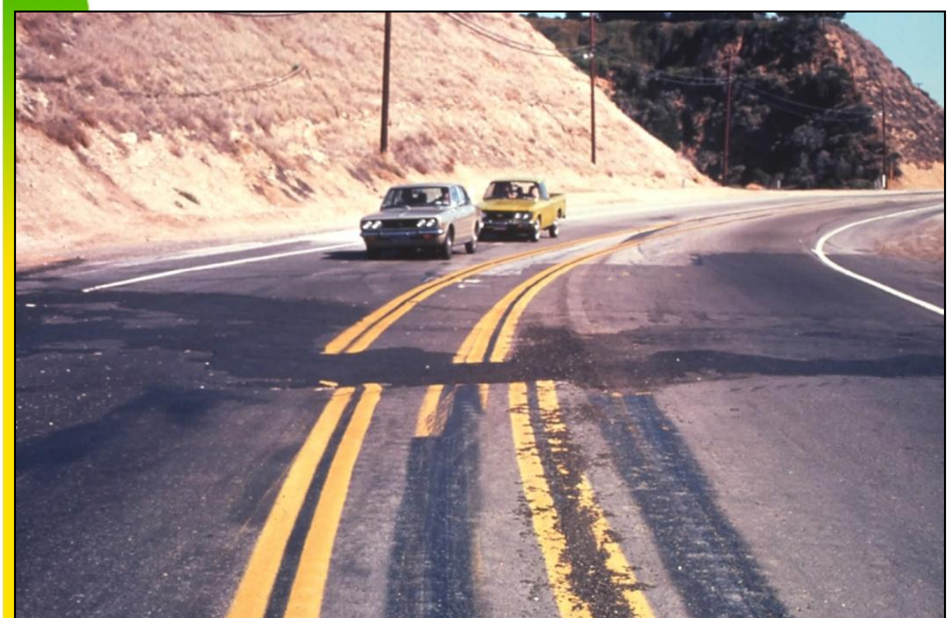
See the progress your state is making
(as of Dec. 31, 1960)

STATE	OPEN TO TRAFFIC (miles)	WORK UNDER WAY (miles)	WORK TO BE DONE (miles)
Alabama	59.5	360.6	453.8
Arizona	514.3	167.5	479.2
Arkansas	43.5	458.2	16.1
California	527.8	1,200.9	453.2
Colorado	228.7	175.2	544.1
Connecticut	138.6	136.8	21.8
Delaware	3.5	27.9	9.1
Florida	86.8	264.3	768.9
Georgia	169.4	269.2	670.9
Hawaii	4.6	00	43.5
Idaho	142.3	232	237.8
Illinois	492.2	622.9	471.4
Indiana	262.6	366.9	489.3
Iowa	213.2	258.9	236.6
Kansas	390.7	103.5	306.9
Kentucky	71	260.2	364.9
Louisiana	41.8	324.6	316.2
Maine	103.6	42.3	166.1
Maryland	120.3	199.9	33.5
Massachusetts	197.2	119.4	145.8
Michigan	382.1	370.5	327.1
Minnesota	79.8	367.1	451.2
Mississippi	43.2	305.5	329.5
Missouri	367.9	691.4	45.4
Montana	92.5	444.8	641.7
Nebraska	41.1	226.2	222.2
Nevada	56.2	158.6	319.2
New Hampshire	78.6	28.1	107.1
New Jersey	93.1	115.4	163
New Mexico	291.3	104.5	607.1
New York	668.1	317	242.1
North Carolina	285.3	145.2	338.4
North Dakota	197	50.8	320.1
Ohio	565.5	435.9	482.5
Oklahoma	303.8	258.8	233
Oregon	425.9	132.5	173.5
Pennsylvania	596.4	341.2	603.7
Rhode Island	20.7	15.6	34.6
South Carolina	126	241.3	311.9
South Dakota	115.8	279.4	282.4
Tennessee	15.4	518.2	514
Texas	879.4	1,426.1	717.9
Utah	69.3	183.5	681.5
Vermont	23.1	129.2	171.3
Virginia	158.1	342.1	552.9
Washington	297.6	287.6	140.1
West Virginia	89.2	106.5	188.9
Wisconsin	146	306.5	000
Wyoming	119.4	225.3	572.1
Dist. of Col.	0.5	11.7	16
	10,439.9	14,157.7	16,019.5

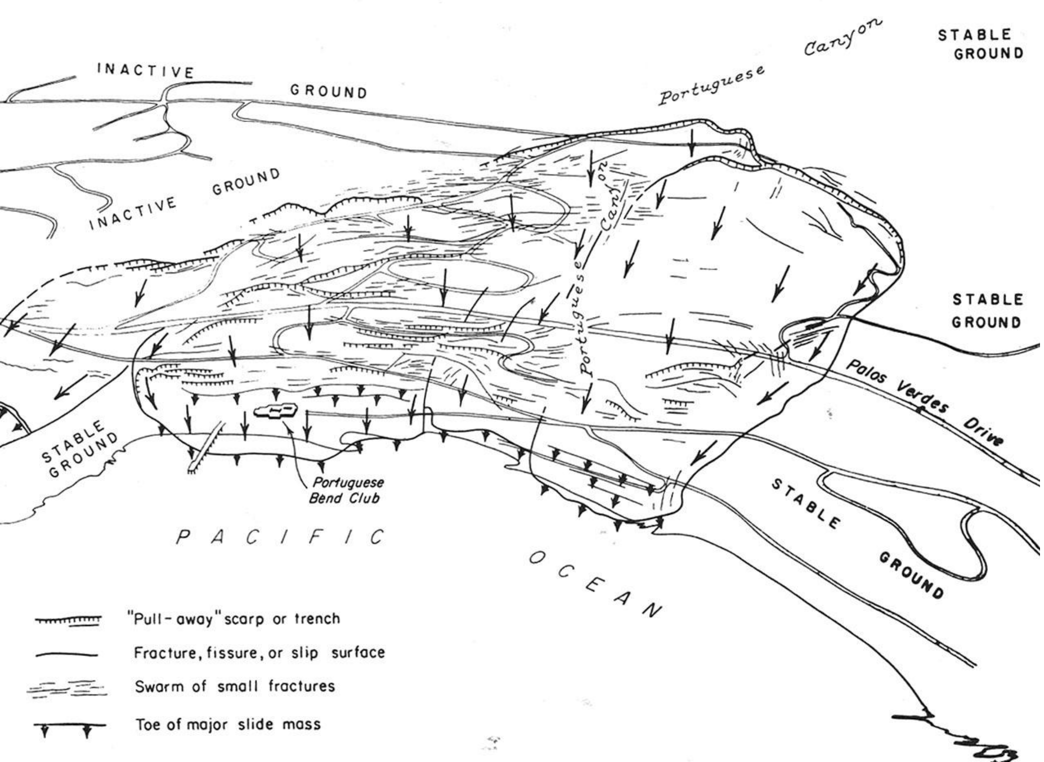
There are no Interstate Highways in Alaska.

1961 map illustrating the initial Interstate and Defense Highway Network, which revolutionized commercial truck transportation and introduced federal standards for excavation, grading, and pavement design.

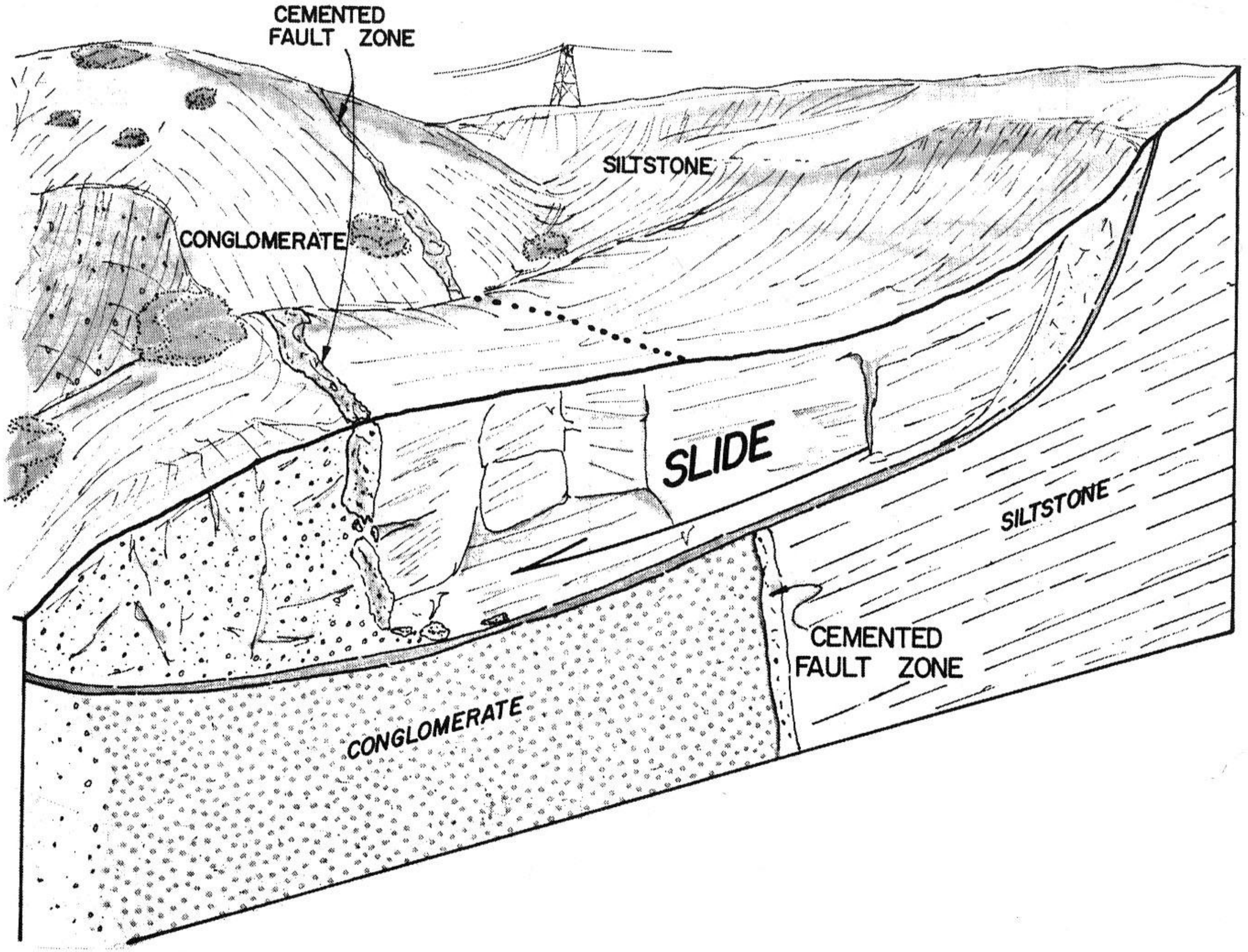
1956 PORTUGUESE BEND LANDSLIDE



Portuguese Bend Landslide



- The Portuguese Bend Landslide developed on volcanic ash (tuff) beds that were altered to montmorillonite, dipping 6 to 13 degrees, towards the ocean
- Note grading at upper right portion of photo, for extension of Crenshaw Boulevard.



- **A major problem in southern California were the countless dormant ancient landslides that mantled the region’s slopes, which were not properly identified or respected by many the engineers who drafted grading plans, who focused solely on balancing cut and fill quantities.**

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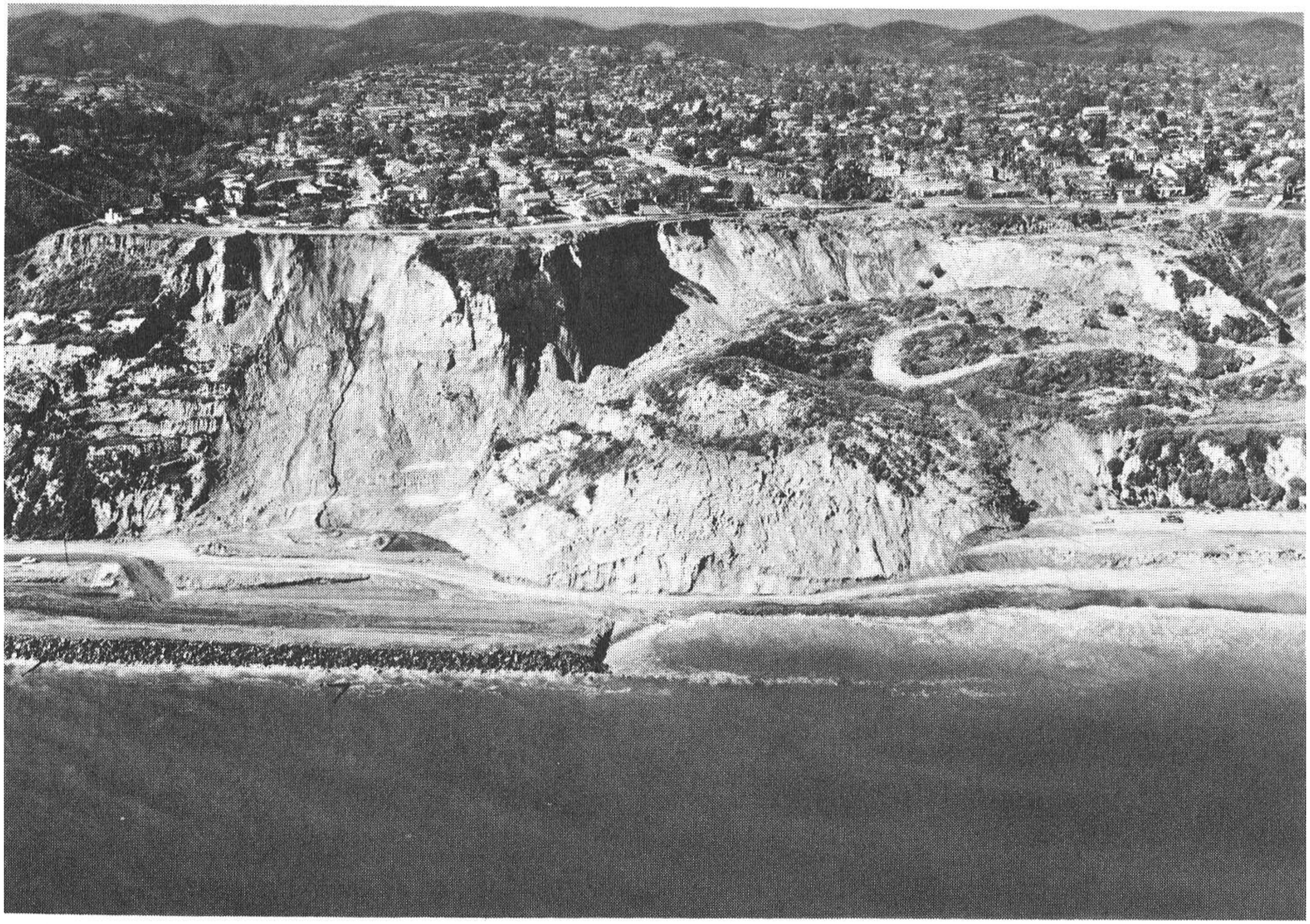
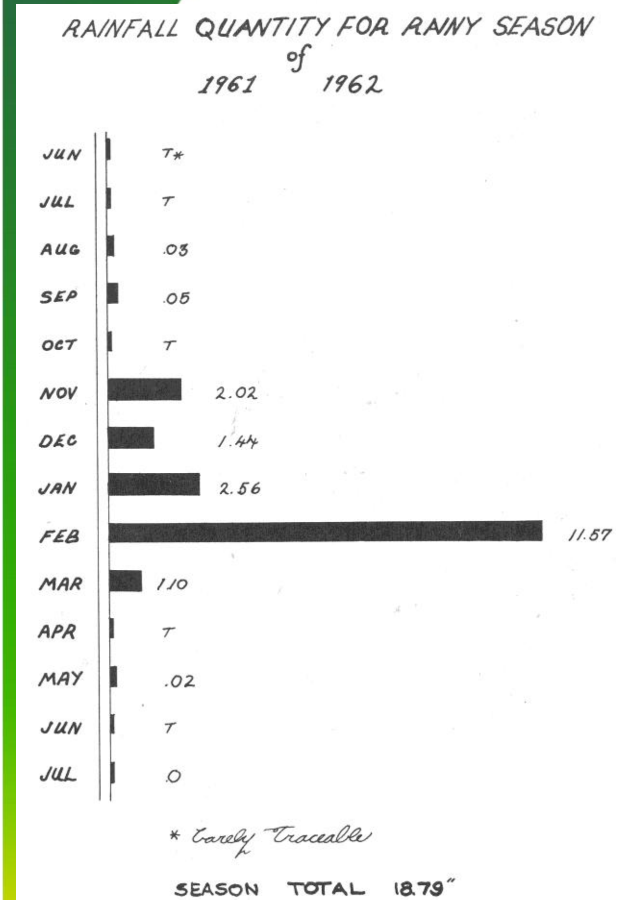


- The Via de las Ojas Landlide in Pacific Palisades in 1958 shut down the coast highway, bringing the problem of landslippage into the consciousness of every Los Angeles resident.



- **In 1962 a series of destructive storms struck Los Angeles County causing widespread damage, triggering development of so-called "Modern Grading Codes;" subsequently adopted by the City of Los Angeles, as well as Los Angeles and Orange Counties.**

The Second Generation: "Modern Grading Codes" (1962)

- City of Los Angeles took lead in developing a more restrictive grading code following poor performance of slopes during 1962 storms
- Much public attention was focused on the problem by the reactivation of the Portuguese Bend Landslide in 1956, which damaged or destroyed more than 130 homes
- Los Angeles County adopted a more restrictive grading ordinance after losing an inverse condemnation lawsuit in 1961,which alleged that the extension of Crenshaw Blvd triggered the 1956 Portuguese Bend Landslide. The County had to pay for 130 homes!

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Storms of January and February 1969

- Numerous slope failures were triggered by near-record storms in early 1969 in southern California. Grading & Excavation standards were amended to limit cut and fill slopes to inclinations no more than 2:1 in the 1970 Uniform Building Code (UBC).

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STORMS OF JAN-MAR 1978

- Storms in early 1978 came on the heels of the worst 2-year drought in over 100 years, triggering countless debris flows and slope failures in southern California.

Damage Associated with Destructive Storms of 1969 in Hillside Areas of Los Angeles

	Sites developed prior to 1952	Sites developed 1952-1962	Sites developed 1963-1969
Number of sites constructed	10,000	27,000	11,000
Total damage	$3,300,000	$2,767,000	$184,400
Average damage per site	$300	$100	$17
Percentage of sites damaged	10.4%	1.3%	0.15%

SOURCE: Slosson, 1969

Slope Failures in City of Los Angeles, 1978

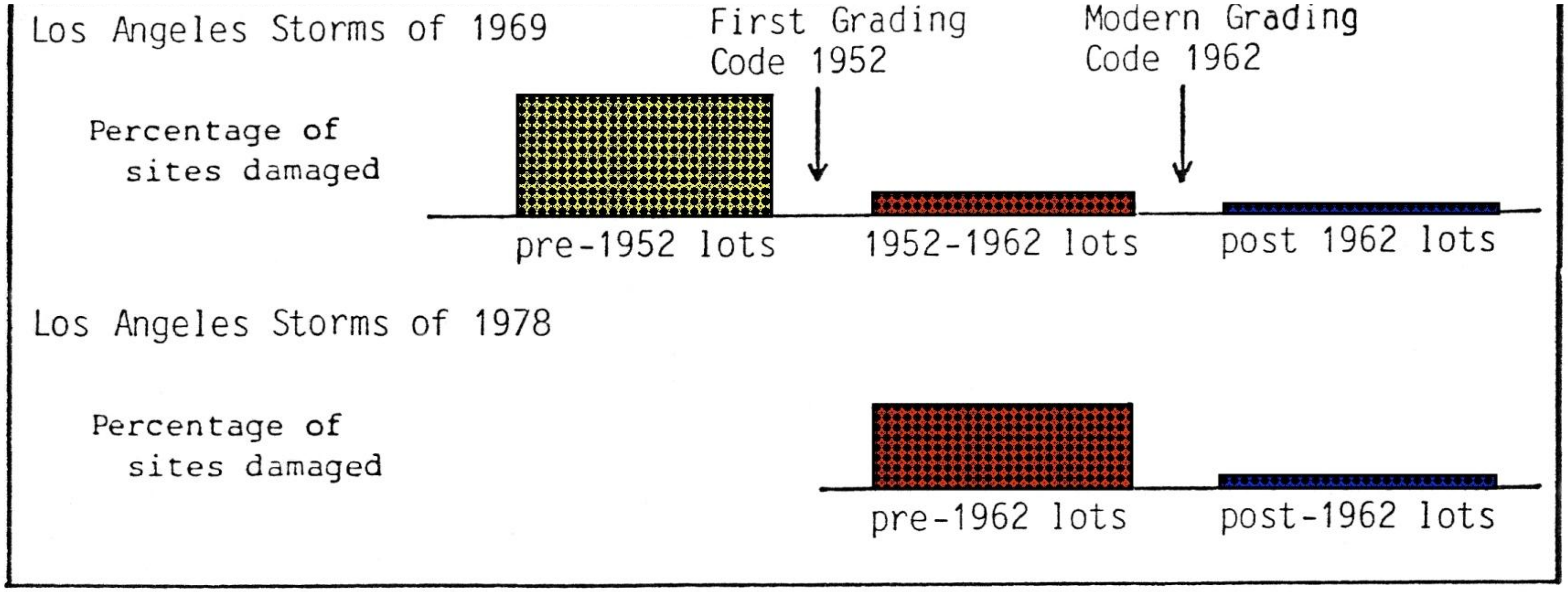
	Sites developed prior to 1963	Sites developed after 1963
Number of sites constructed	37,000	30,000
Number of failures	2,790	210
Percentage of sites damaged	7.5%	0.7%

SOURCE: Slosson and Krohn, 1979

- **Statistical data of storm-inflicted damage to hillside areas of Los Angeles in 1969 and 1978 confirmed the societal benefits of grading and excavation codes.**

Grading Codes Work:

Grading codes, if thoroughly enforced by local government, have been shown to be very successful. The City of Los Angeles, which has the most comprehensive grading code in the world, has reduced slope failure problems by over 90%.



- **Modern grading codes were successful in reducing 90% of hillside slope problems**

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Part 4

STANDARDS FOR KEYING AND BENCHING OF EMBANKMENTS

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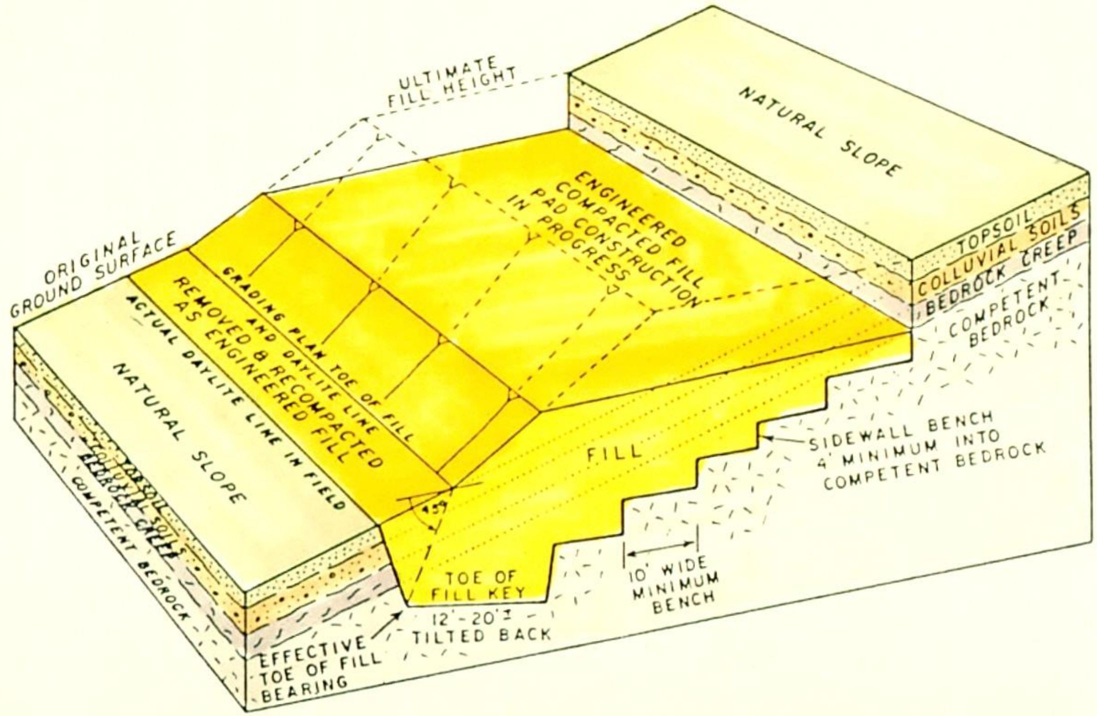
A typical toe-of-fill key for the construction of a sidehill fill in siltstone or shale terrain. The toe-of-fill key frequently requires keying and benching through several feet of topsoil, several feet of colluvium, and several feet of bedrock creep in order to key into competent bedrock. Toe-of-fill keys 10-20 ft. deep are common in such areas. Note that the effective bearing point of this toe of fill (45° from the horizontal) moves laterally downslope from the proposed grading plan toe.



- **The Modern Grading Code introduced standardized requirements for over-excavation of embankment foundations similar to what had been developed for earthfill dams. This shows Orange County’s standard, introduced in 1965.**

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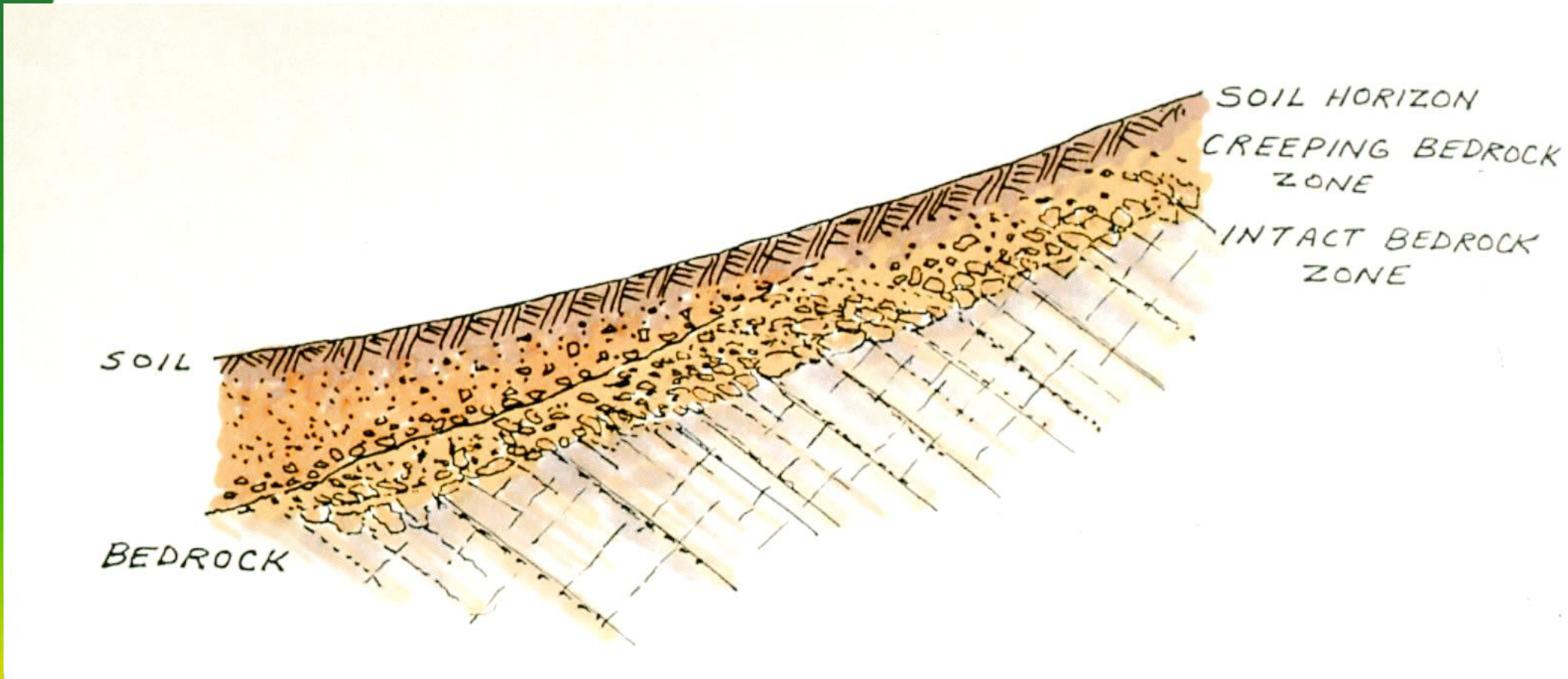
OVEREXCAVATION



- **Overexcavation involves removing poor quality foundation materials, such as the soil horizon, colluvium and the bedrock creep zone.**

- **Modern grading ordinances required engineering geologic assessment of embankment keyways and deep foundation excavations to ensure that the assumed depths to suitable foundation material were adequate.**

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- **Mapping of the bedrock creep zone is important on sloping ground, especially in expansive soils and slopes floored in siltstone or shale, because this zone serves as a conduit for percolating water.**

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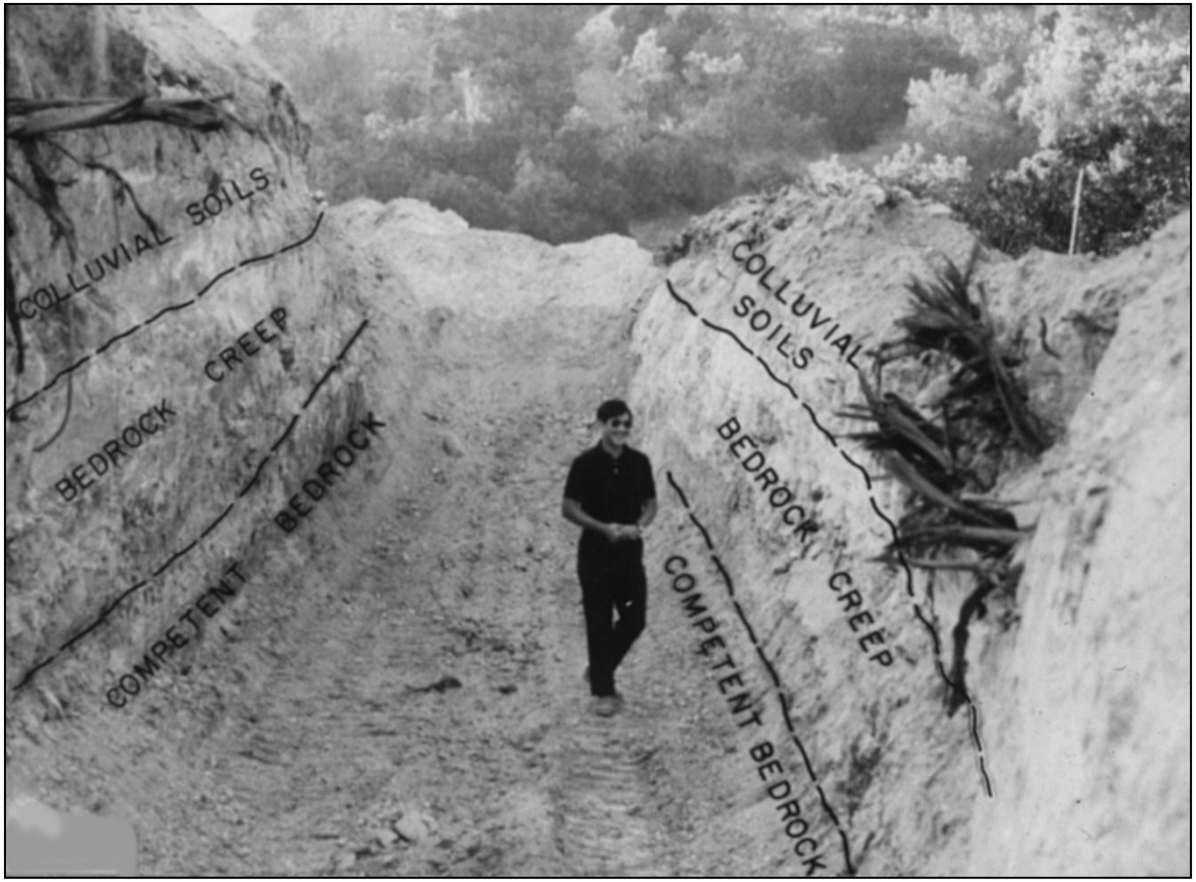
- **Another important aspect of grading inspection is to verify if deleterious materials, such as roots, trees and organic debris, are buried in the embankment. These can create unwanted zones of increased permeability and weakness.**

- **Keyways should extend through unconsolidated materials, such as older fill (shown here), topsoil, colluvium and the bedrock creep zone**

DOCUMENTATION



- **The as-built report should document the conditions encountered and any changes from the approved plans that were made in the field during construction.**

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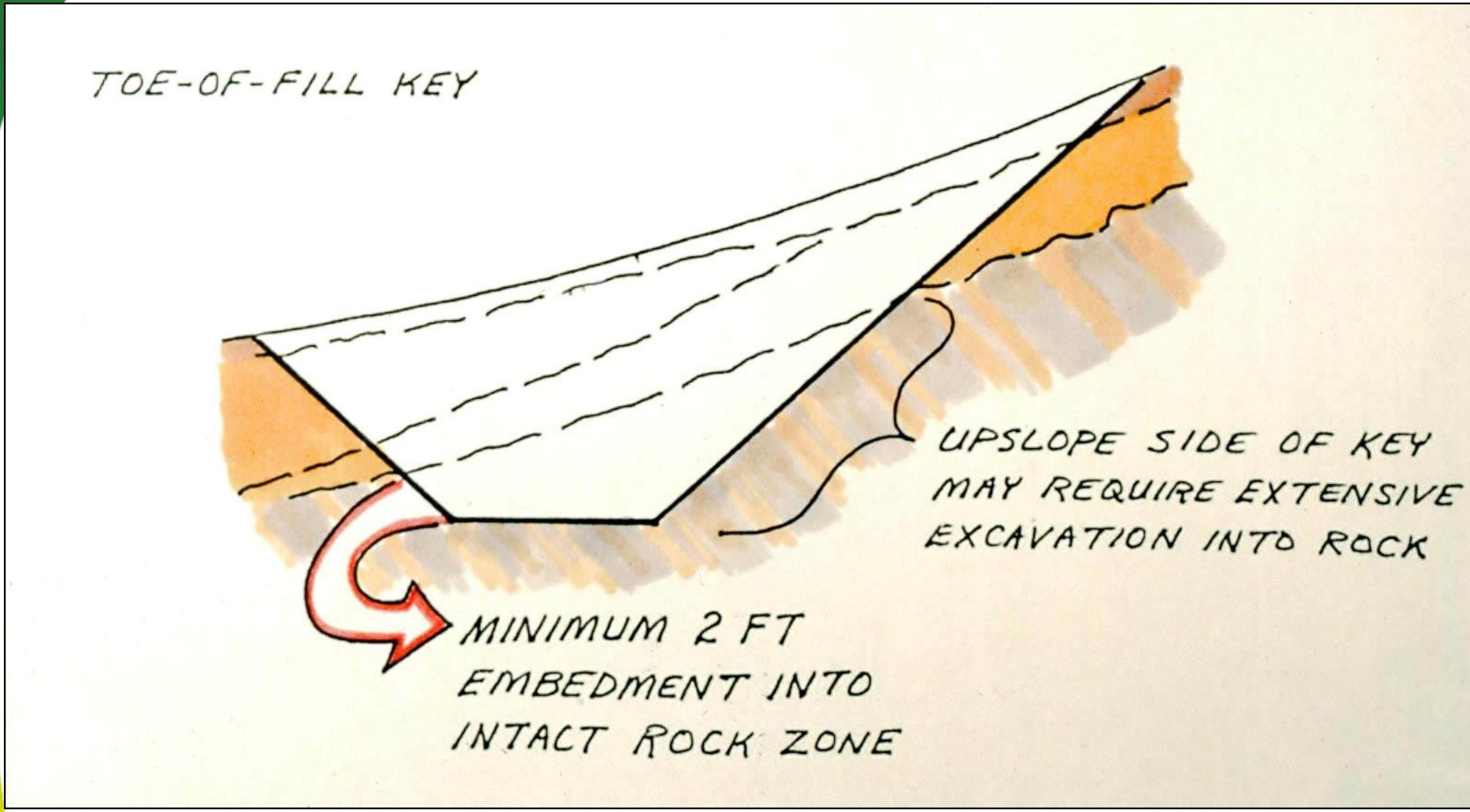
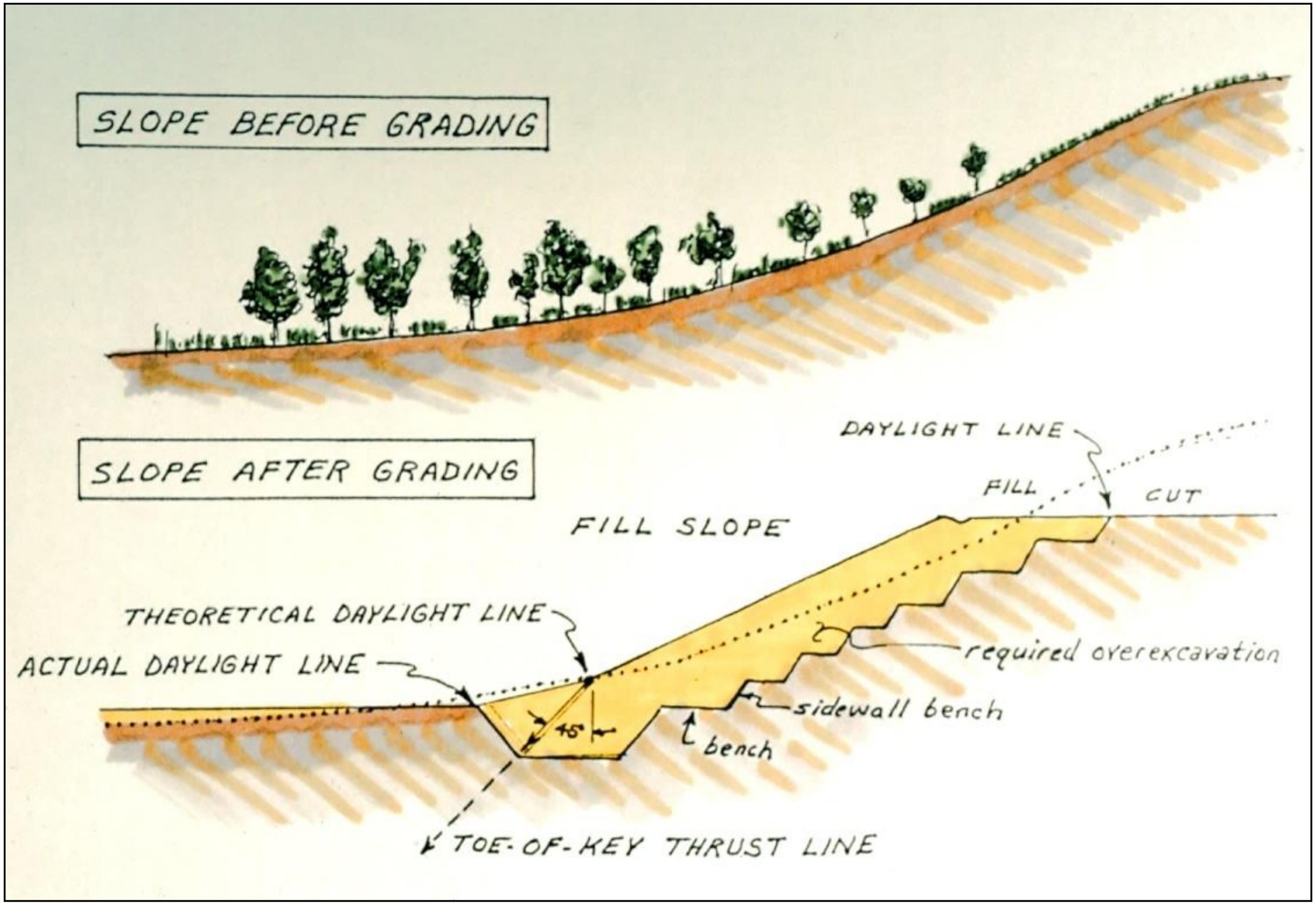


- **Keyways should extend a minimum of 2 feet into intact foundation materials on the downslope, or frontslope side, of the toe-of-fill keyway, as sketched here.**

VERIFICATION OF ASSUMED CONDITIONS

- **Bedrock attitudes should be measured and verified to ascertain whether or not the material has been involved in prehistoric movement**



- **<u>Engineered fill</u> is a technical term applied to embankments or subgrades that have been constructed with engineering oversight, utilizing established standards.**

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

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Part 5

BACKSLOPE FAILURES, CANYON CLEAN OUTS, AND CUT-FILL TRANSITIONS

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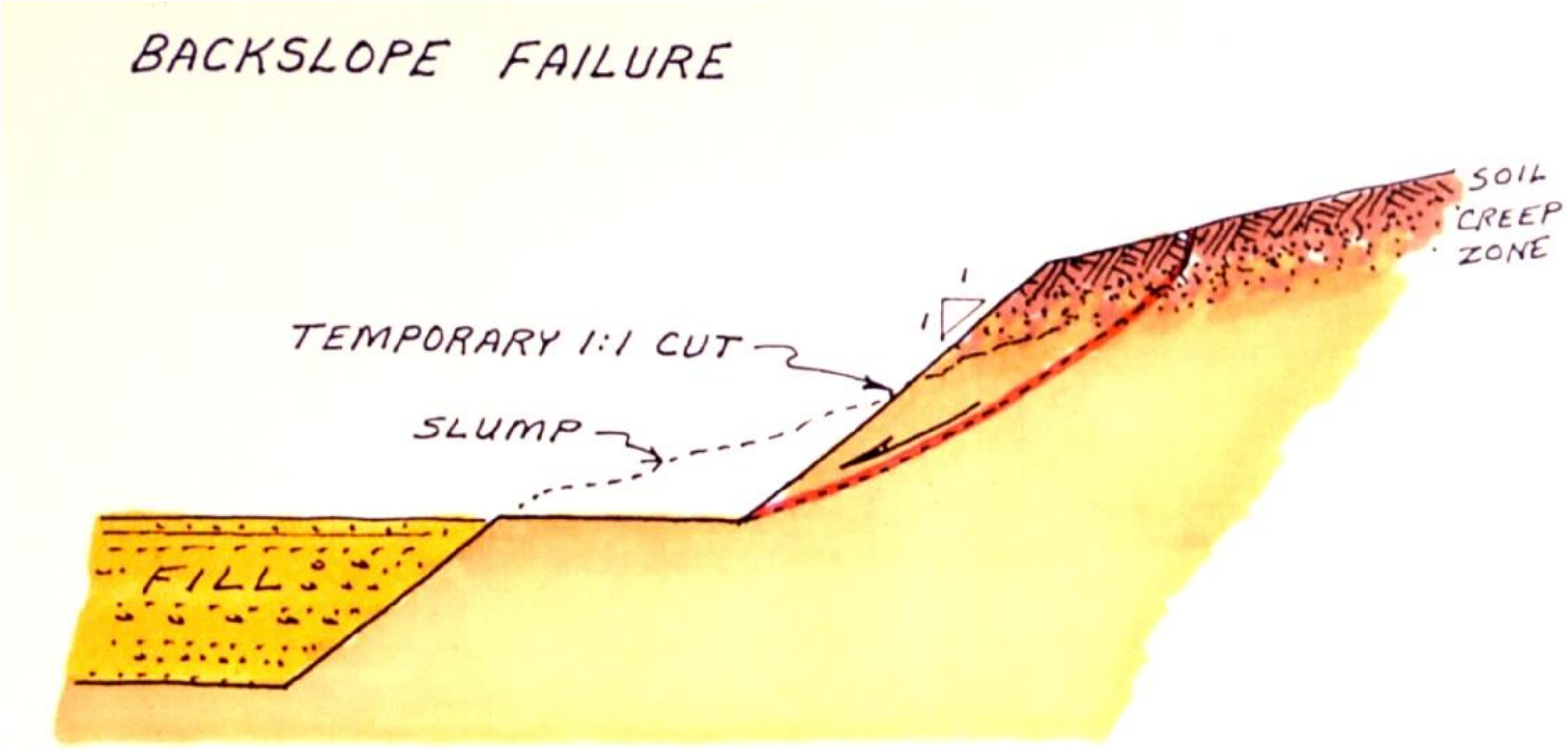
BACKSLOPE FAILURES



- **Keyways are usually constructed with temporary oversteepened slopes, as sketched above. When these slopes fail, the sliding material must be removed and recompacted as the fill is brought up.**

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TEMPORARY BACKSLOPE FAILURE

- Backcuts are temporary excavations, usually made at steep inclinations to minimize volume. Backslope failures are usually triggered by: 1) strain relaxation and dilation sufficient to cause strain softening; 2) accelerated creep, due to rapid unloading, and, least often; 3) absorption of moisture, such as rainfall.

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- <u>**Canyon cleanout excavations**</u> **can provide significant challenges for equipment access**
- **The engineering geologist should check these excavations for evidence of past seepage and emplace adequate underdrainage**

- The deepest overexcavations usually occur in "canyon cleanouts", similar to that shown here. <u>**Ample subdrainage is always recommended along the axes of former watercourses**</u>

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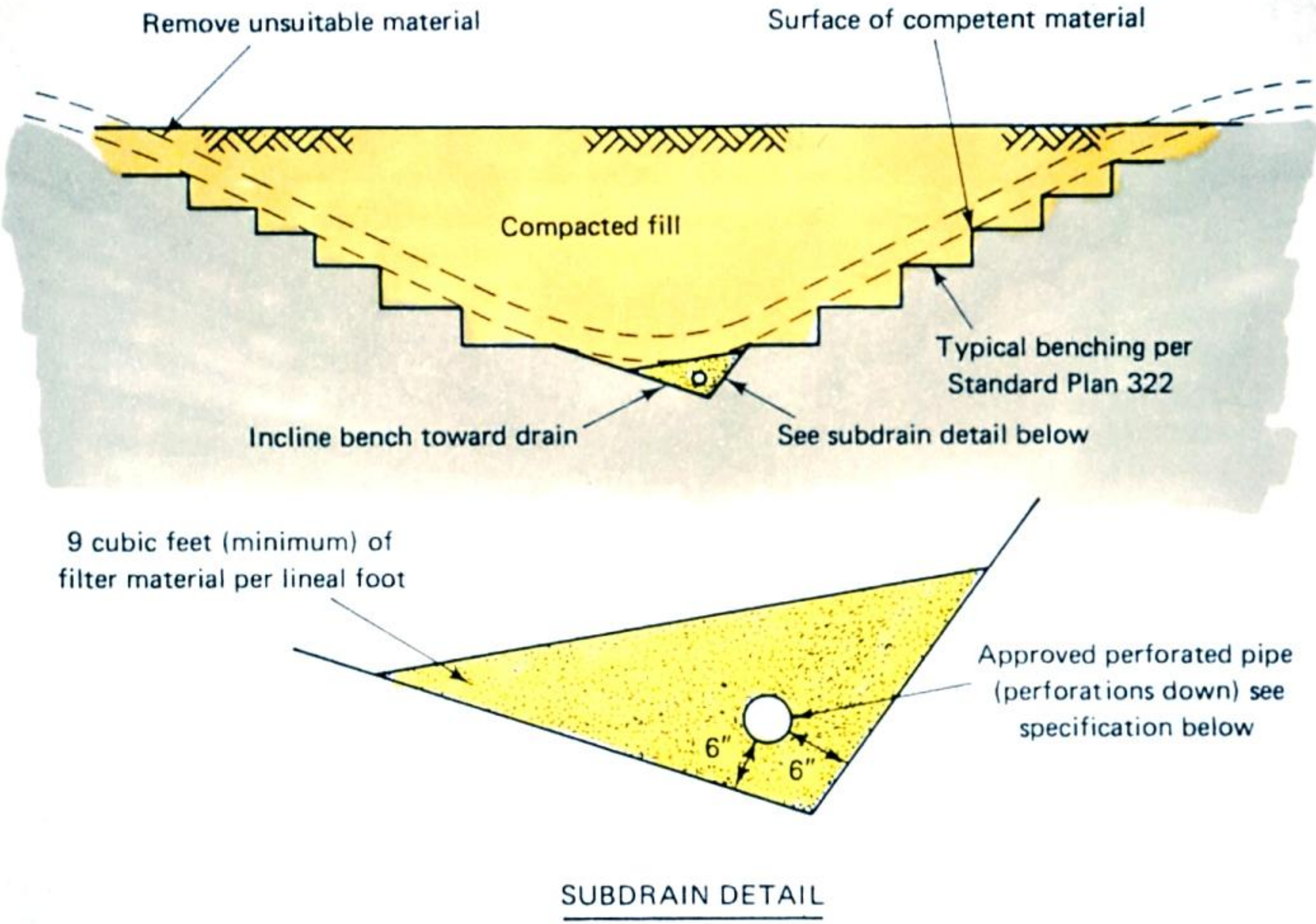
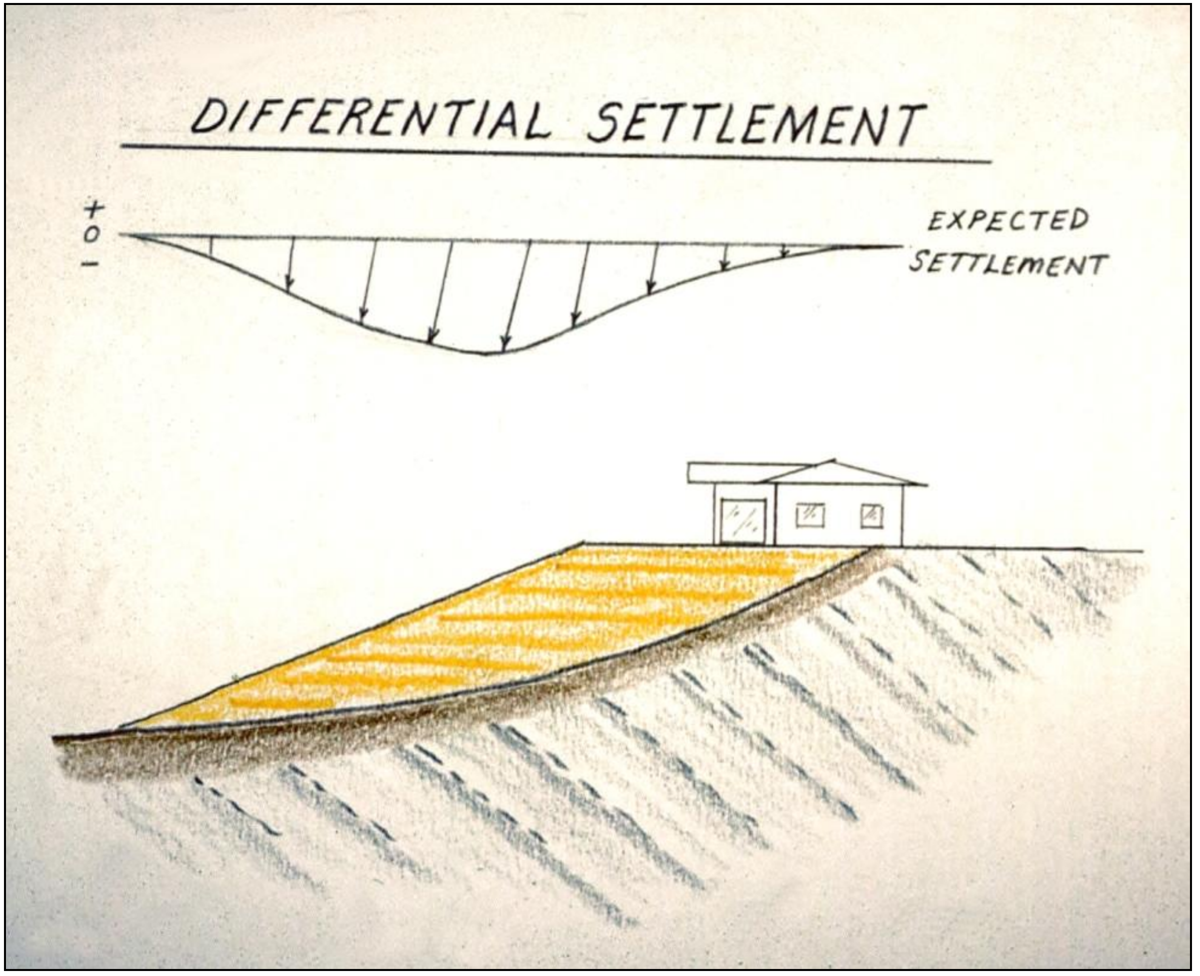
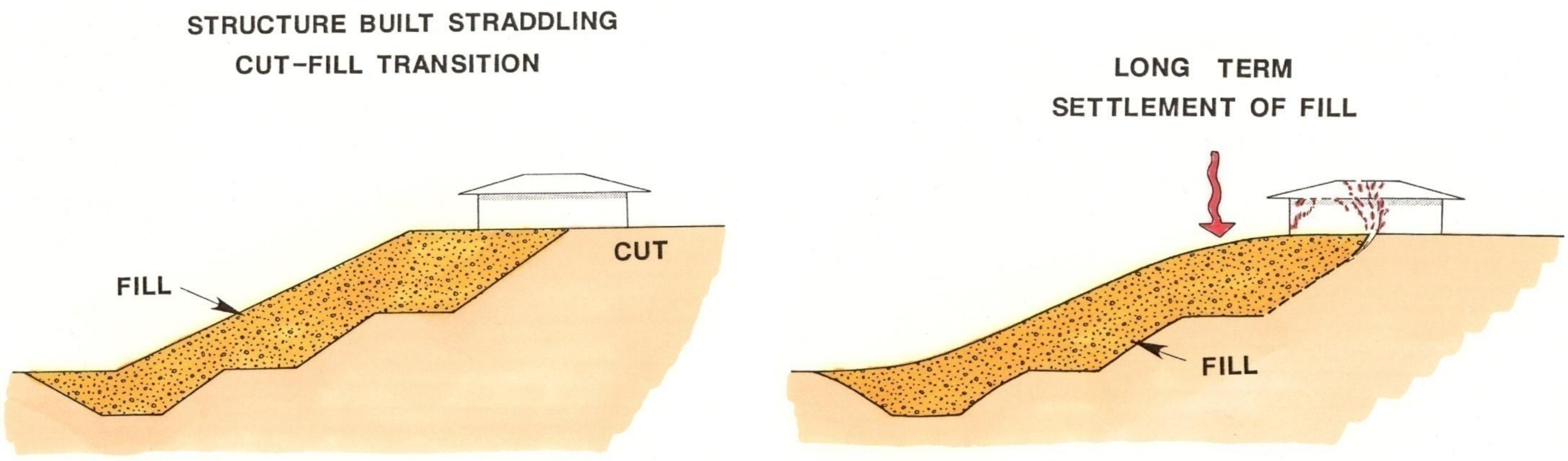


- **Typical canyon cleanout and subdrain details. The UBC specifies 9 cubic feet of drain rock per lineal foot of subdrain and a perforated collector pipe.**



- **Fill wedges tend to settle differentially, as sketched here. The horizontal component of this settlement can pull wood frame structures apart, causing loss of structural integrity.**



- **Cut-fill transition lots** are known for exhibiting problems with differential settlement and/or differential heave. They are especially vulnerable to earthquake-induced settlement and structural damage.

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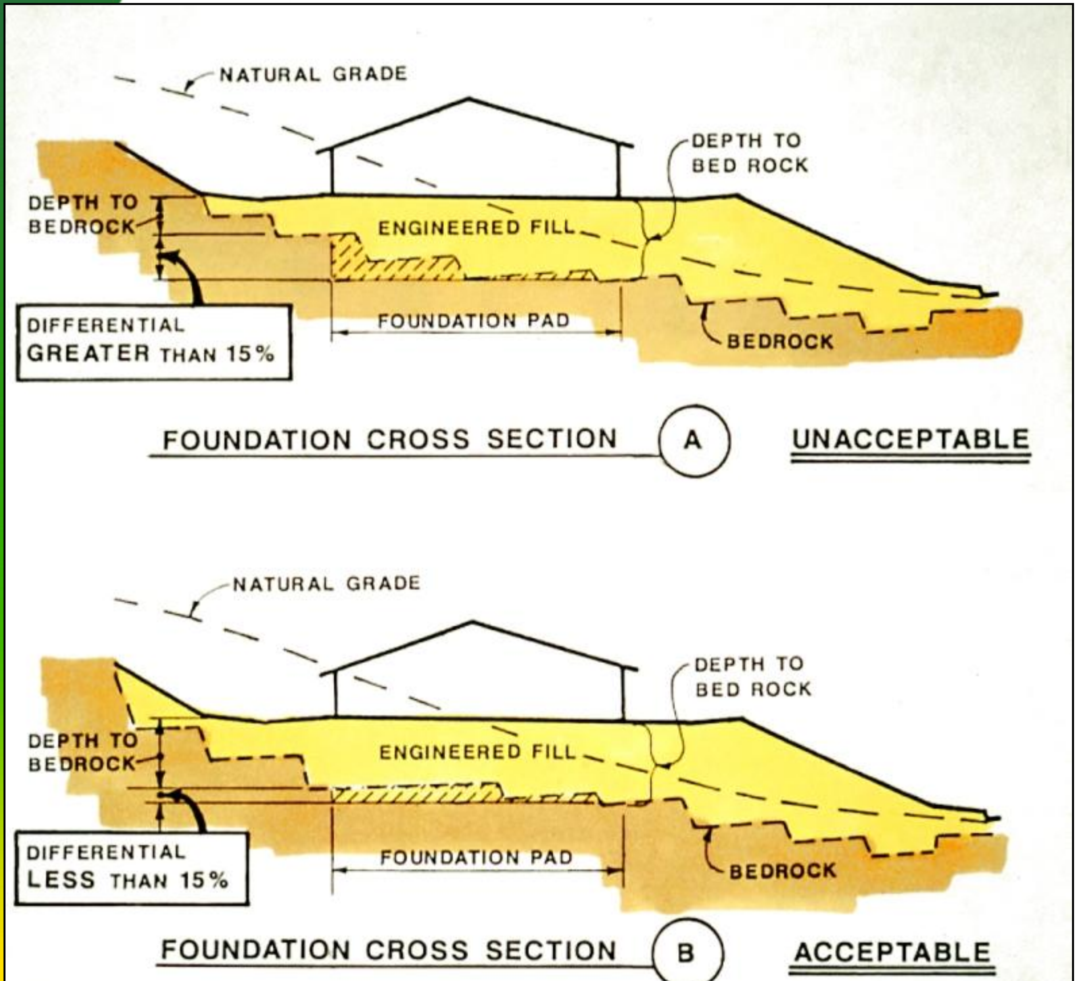

Structures founded upon fill as in Section A could be subject to damage resulting from differential settlement of fill. This damage potential can be reduced by overexcavation as shown in Section B. Drilled piers would also reduce this damage potential.

- **Cushion fills** are typically employed on cut-fill transition lots slated for development
- Los Angeles County requires 3 feet overexcavation below the deepest element of the foundation
- Rogers (1992) recommended fill thickness differential of < 15%, shown at bottom left

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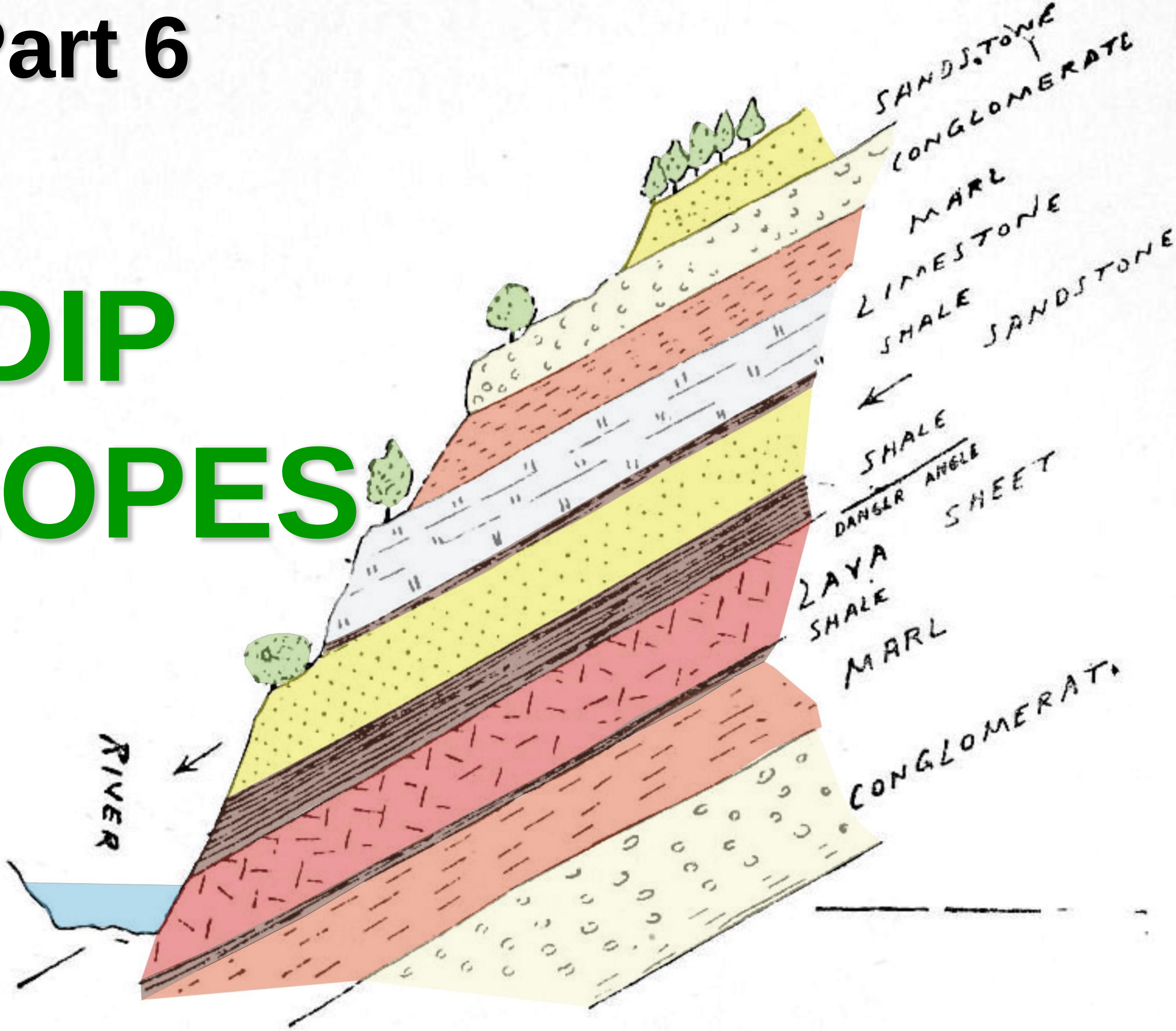
Part 6

DIP SLOPES



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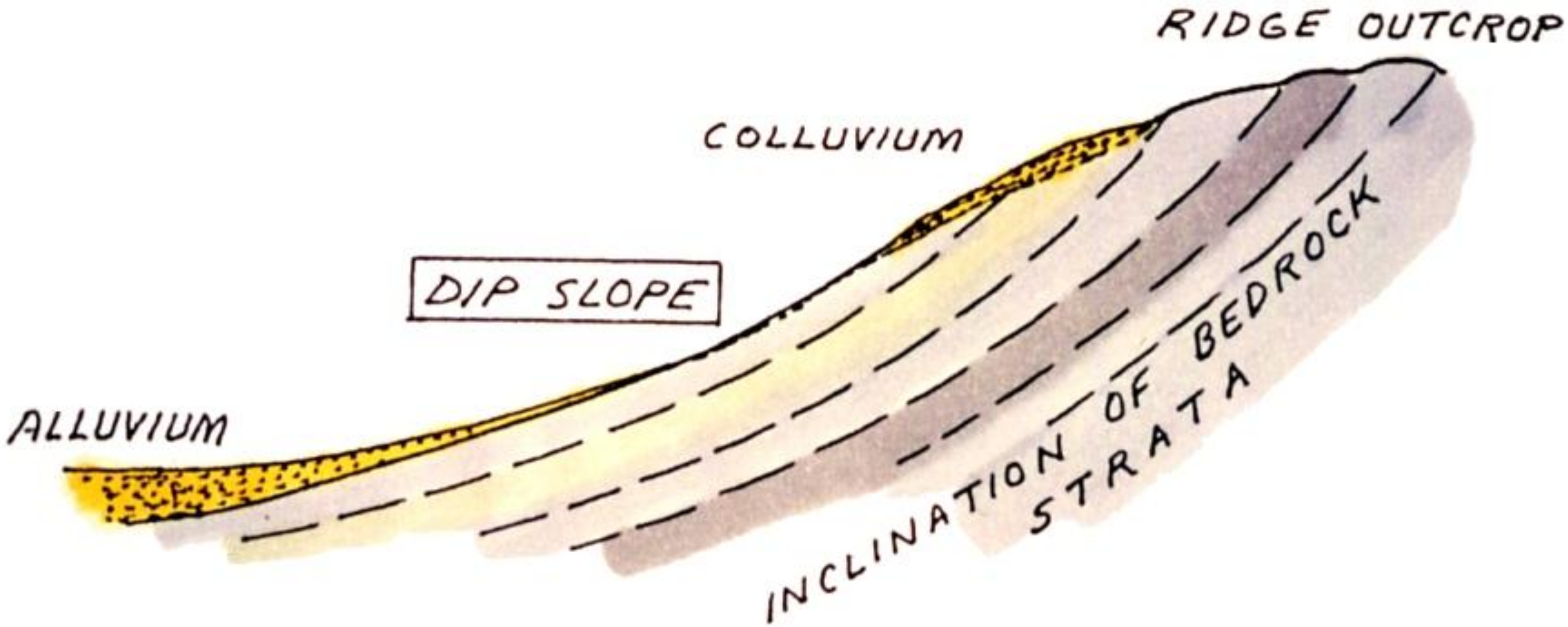
CLASSIC DIP SLOPES



- **Dip slopes are situations where the underlying strata are inclined semi-parallel to the natural slope**
- **Dip slopes can exist in either bedded or foliated strata**

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DIP SLOPES and ANTI-DIP SLOPES

STRUCTURAL CONTROL OF SLOPE FORM BY UNDERLYING GEOLOGY

- **Dip slopes tend to form long, gradual ridges and may foment enormous slope failures**
- **Obsequent, or anti-dip slopes, tend to be steeper, but not as long. About 70% of slope failures occur on anti-dip slopes, but these tend to be of much smaller volume than dip slope failures.**

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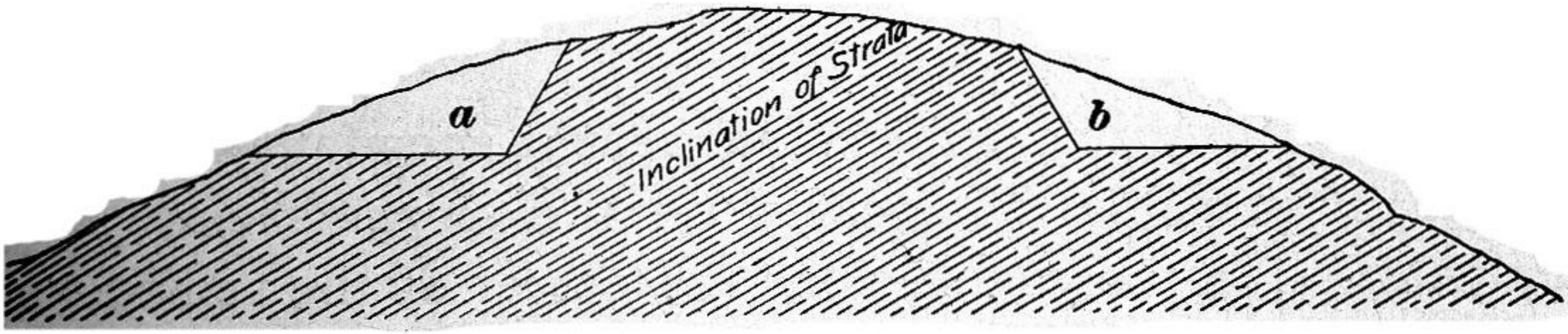
Adverse Dip Slope Conditions



- **Excerpt from Int'l Correspondence School text on civil engineering published in 1908 illustrating how planar strata dipping into an excavation at left was considered "adverse" to long-term stability and/or erosion; in contrast to the condition at right.**

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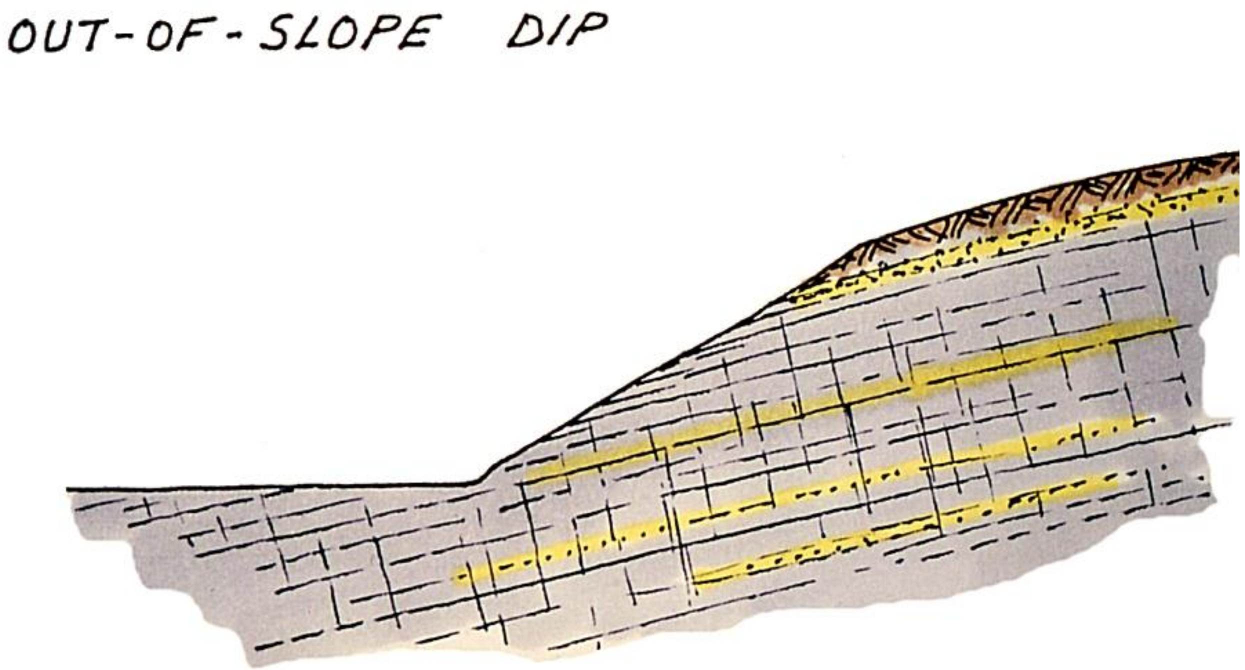
DAYLIGHTED CUT SLOPES



- **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**

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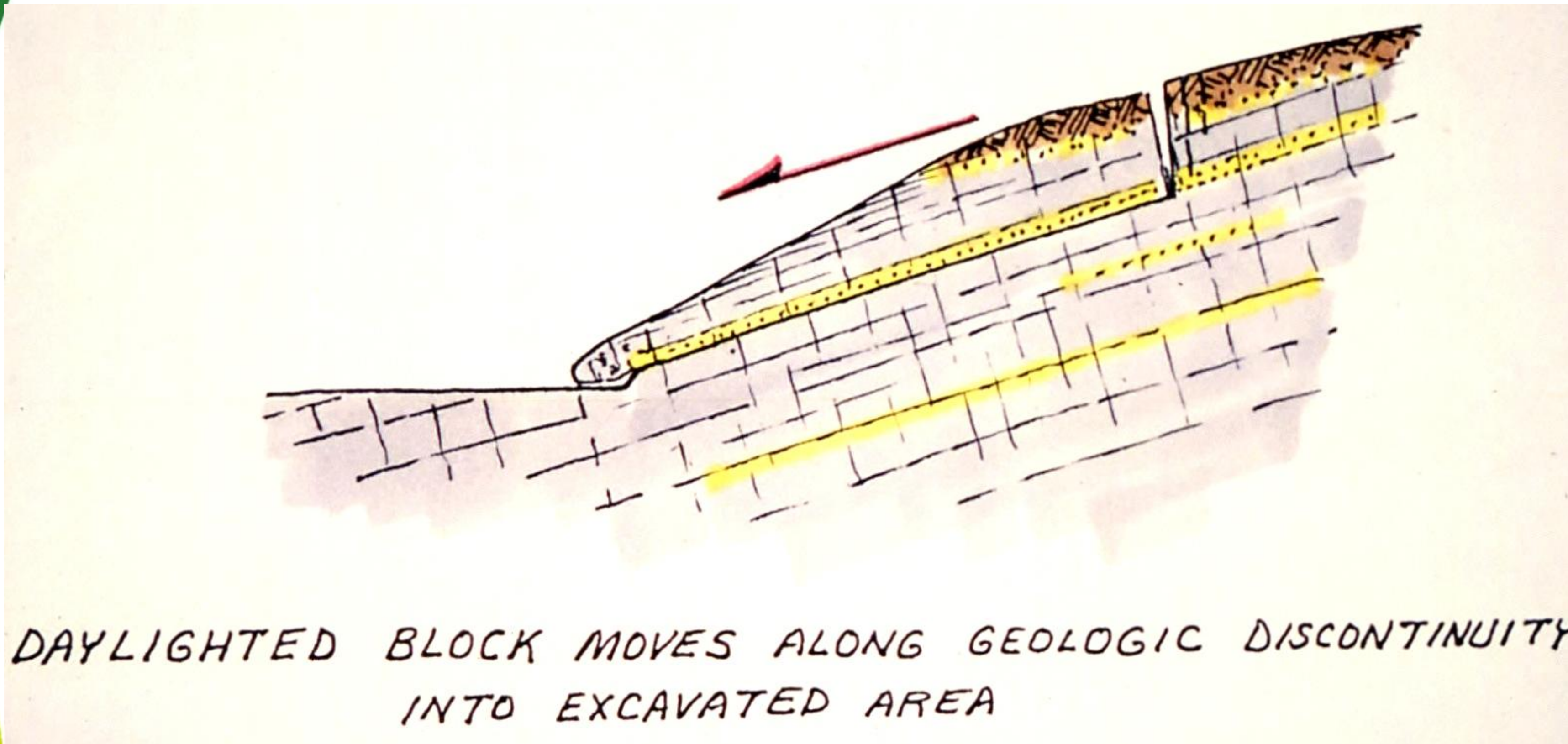
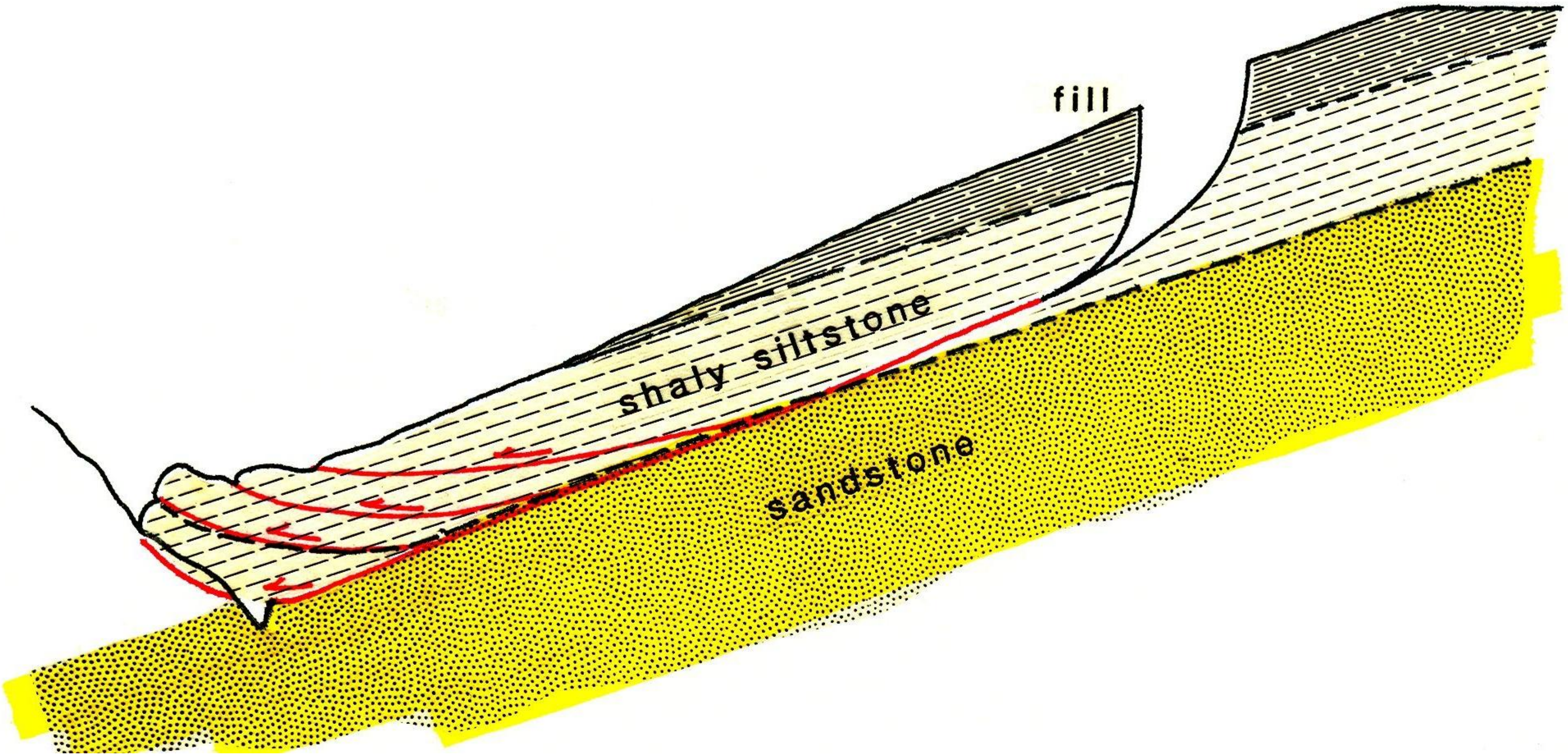
SLIPPAGE OF DAYLIGHTED BLOCK



- **Daylighted blocks can translate downslope if the slope has not been buttressed in some way. Such failures are common during construction, usually along contacts between dissimilar materials**



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

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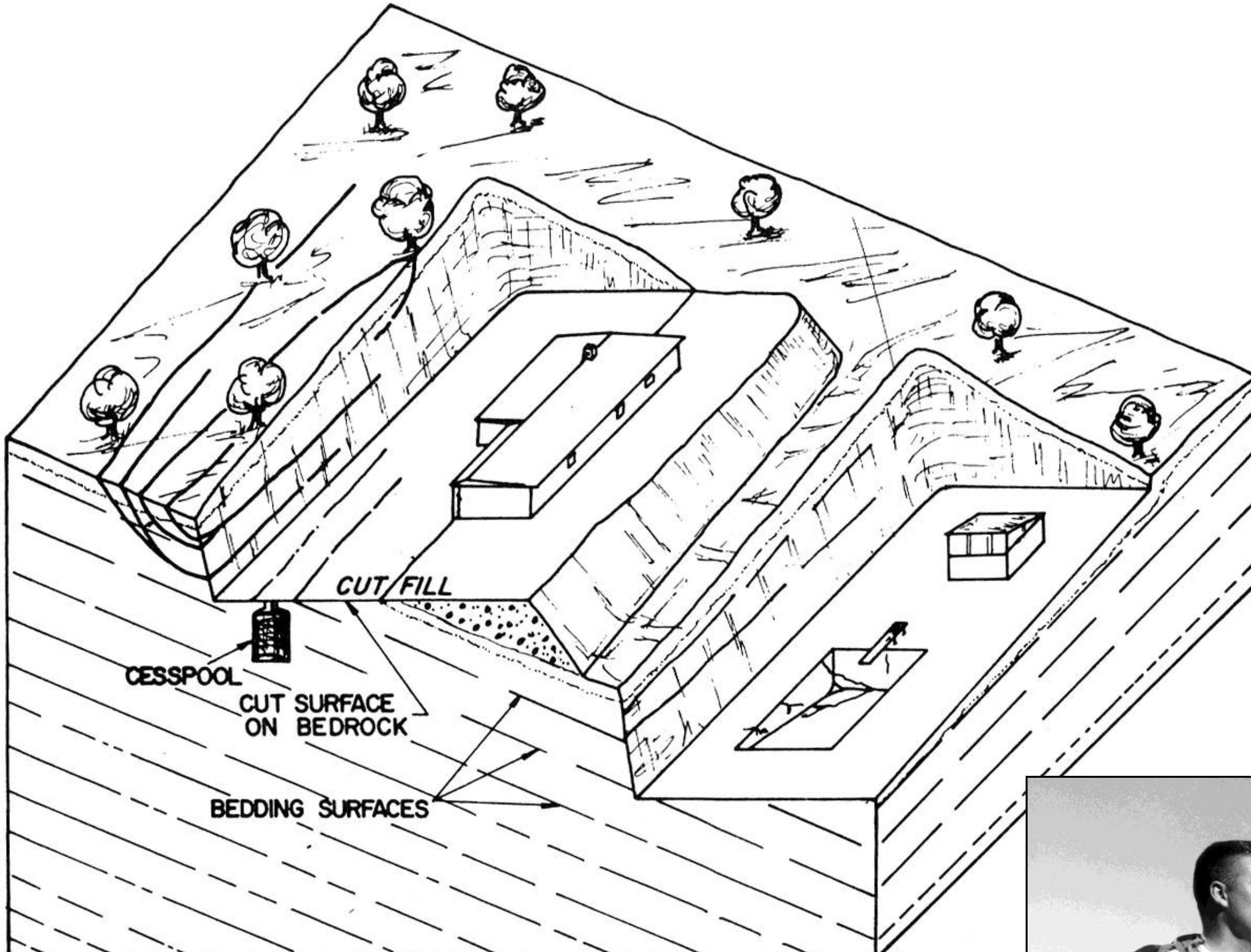
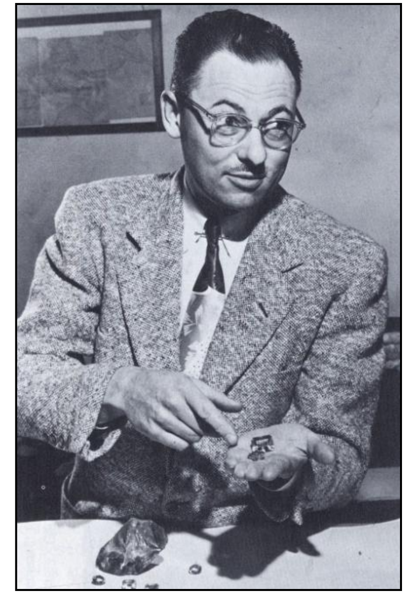
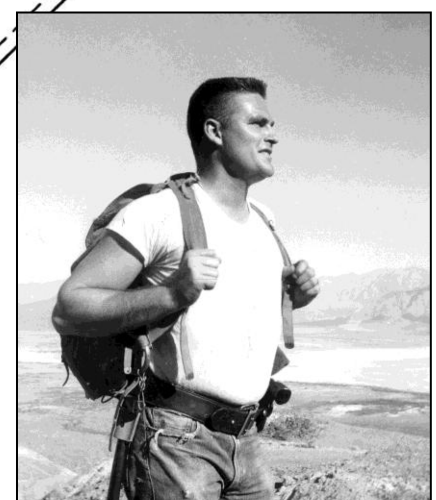




Caltech Geology Professor Richard H. Jahns (1915-83)

- **Geologists began drawing block diagrams, like this one by Dick Jahns in 1958, which show a daylighted dip slope cut failures in bedded sequences. Shale stringers usually played a dominant role in triggering these sorts of failures**



Orange County Geologist Mike Scullin (1932-95)

Consulting Geologist Dr. James E. Slosson (1923-2007), who served as State Geologist in 1973-75

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 7

FILL-OVER-CUT,
STABILITY FILLS, SUBDRAIN NOMENCLATURE
AND RECOMMENDED STANDARDS

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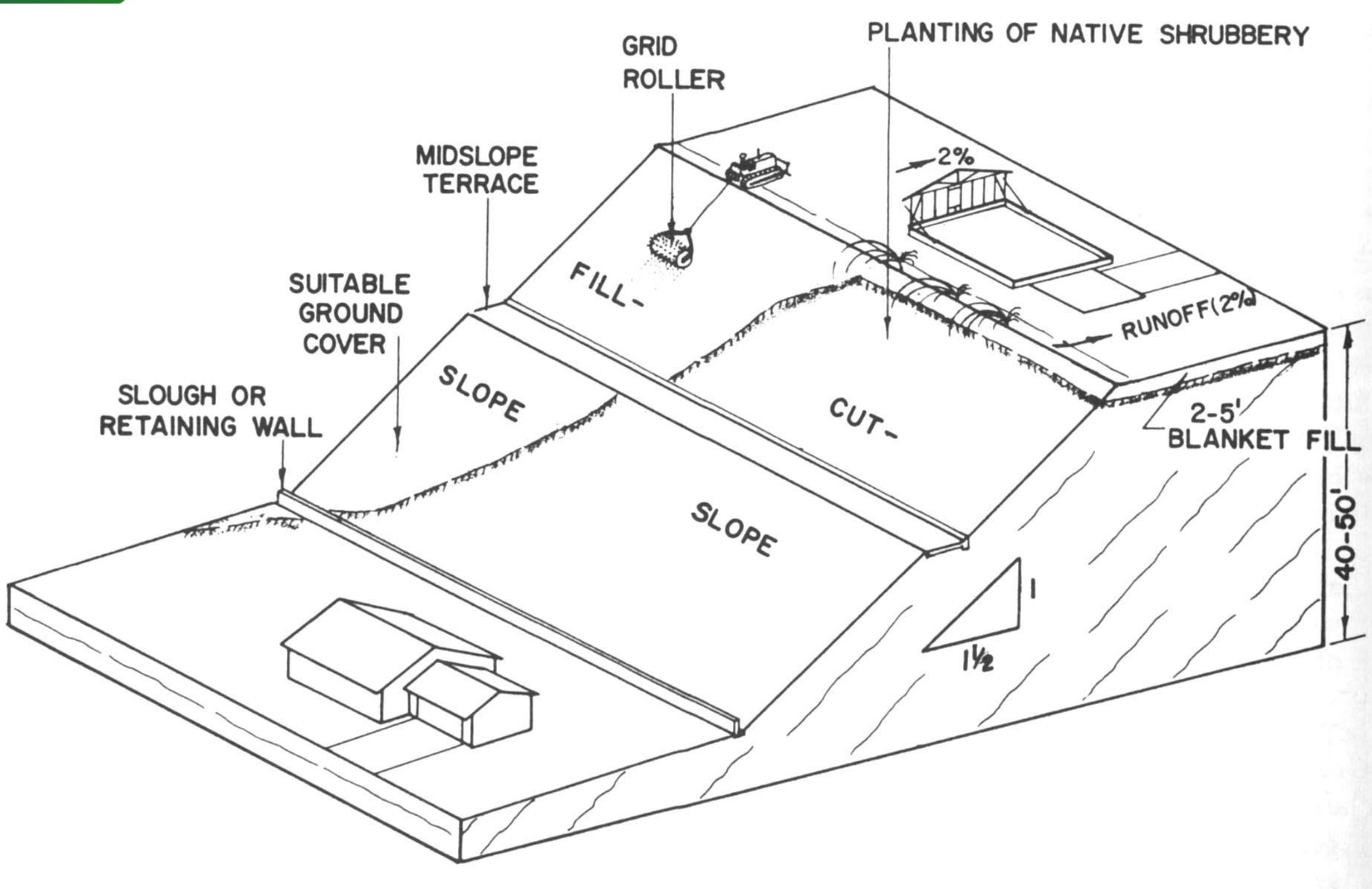
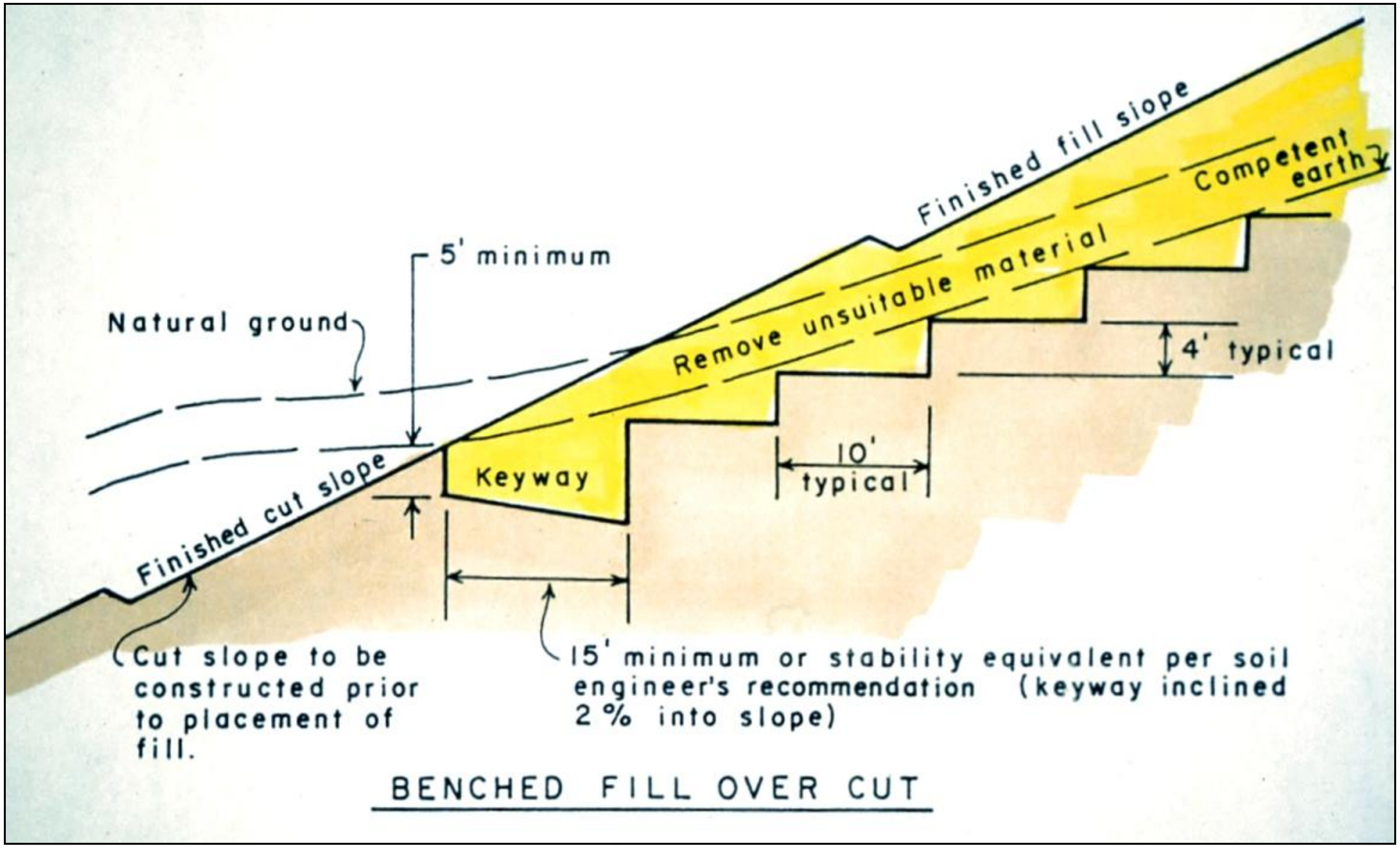


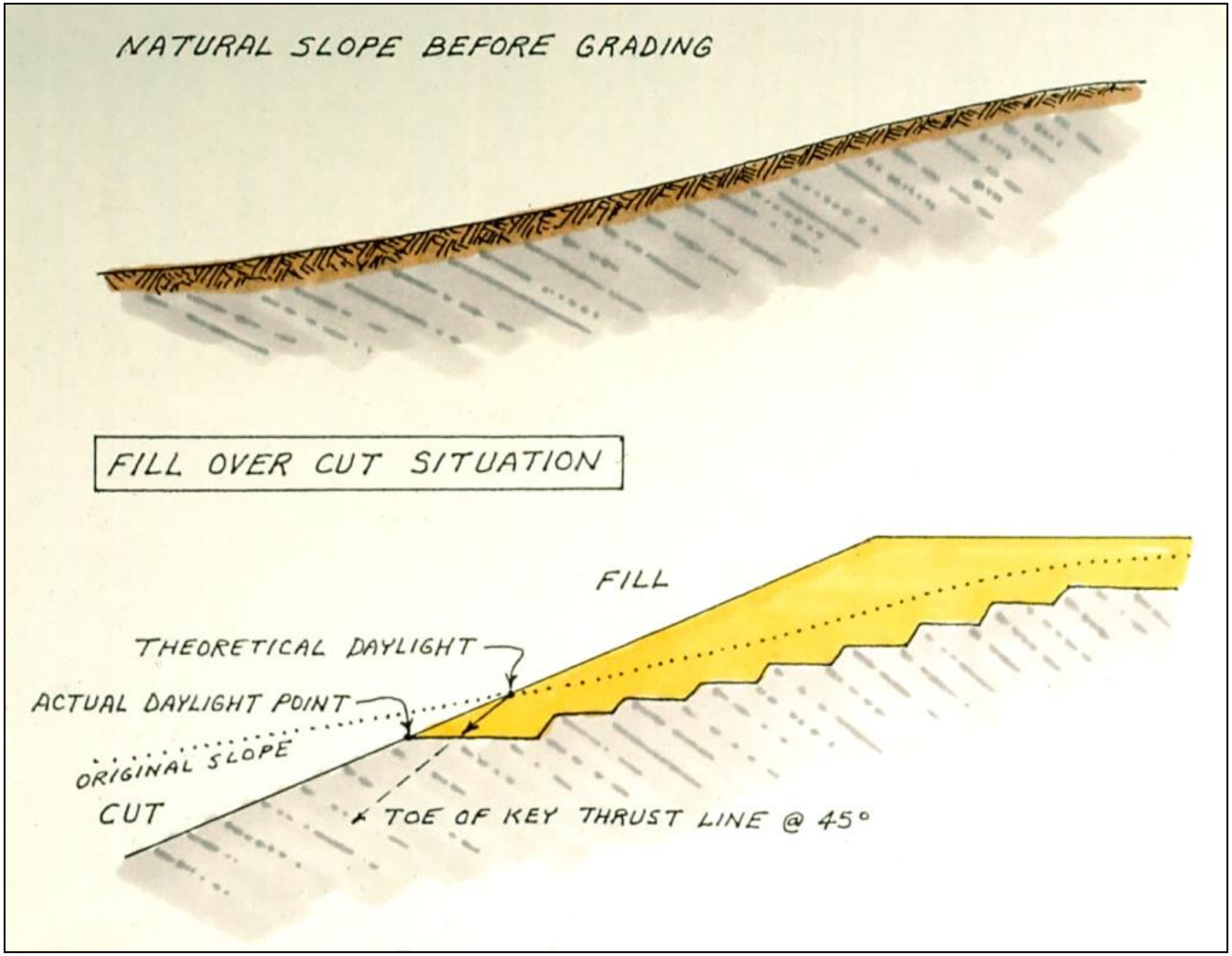
- **Classic Fill-over-cut situation created by mass grading of hilly areas.**

FILL OVER CUT

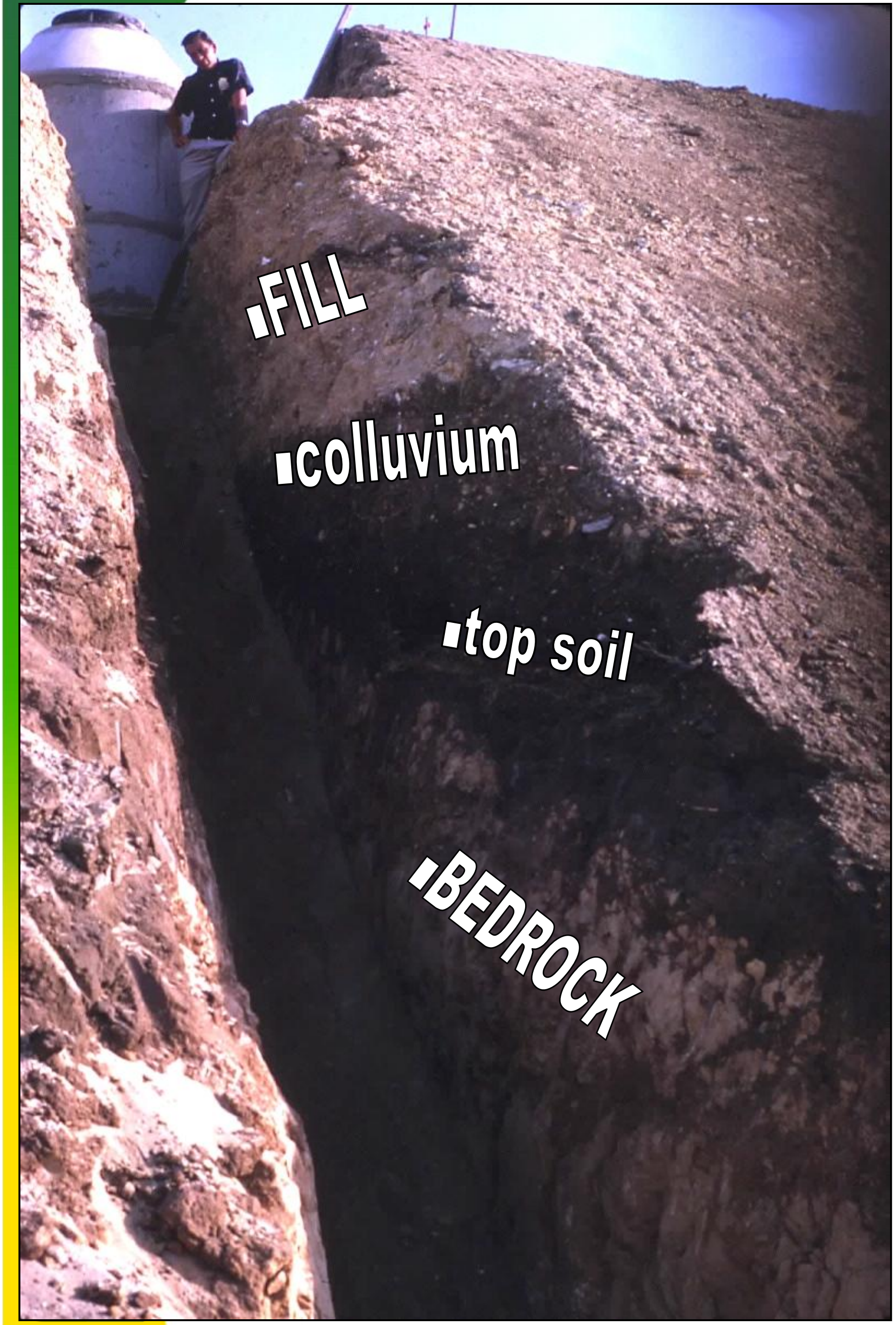


- **Fills placed above cut slopes are a special case that demands attention to details, especially overexcavation. This shows the design standard employed by Orange County in the late 1960s.**

- **Fill over cut** situation where the topsoil was not adequately overexcavated, leaving a potentially low strength horizon between the cut and the fill.

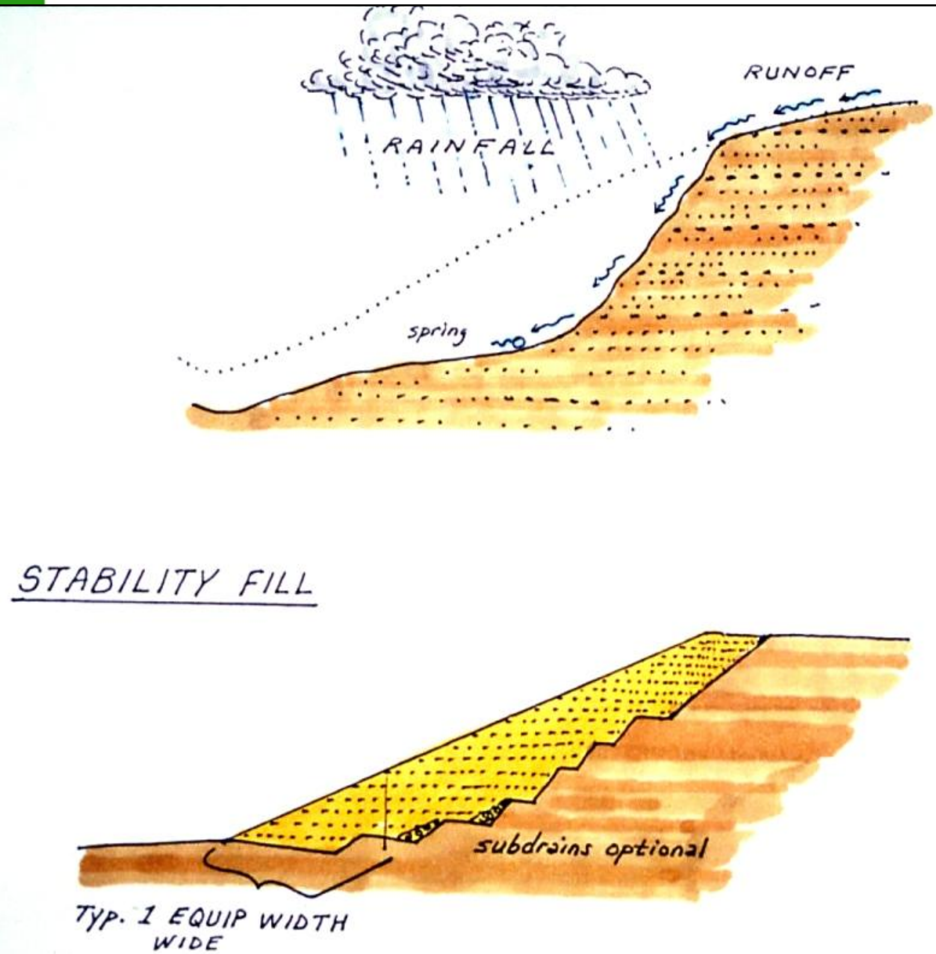


- The **toe-of-fill keyway** on a fill-over-cut situation should be excavated across the entire bench, as shown above; so a small island of native material will not be left between the cut and fill.

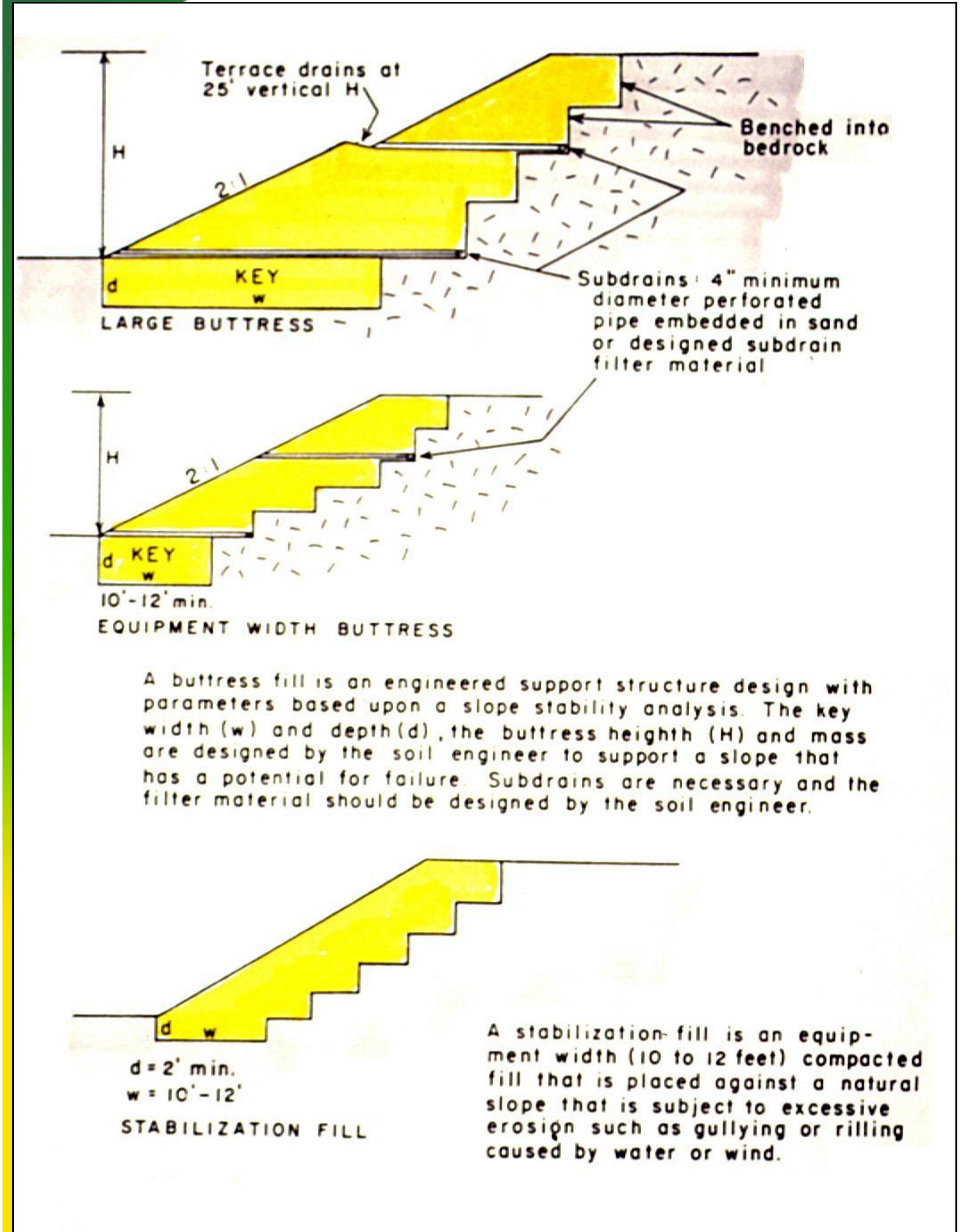


- Inadequate **cut-over-fill** situation revealed in utility trench for sewer-storm drain.
- This view shows engineered fill over a thick sequence of native soils and weathered rock
- This points to the reason why on-scene grading inspection is so important during construction

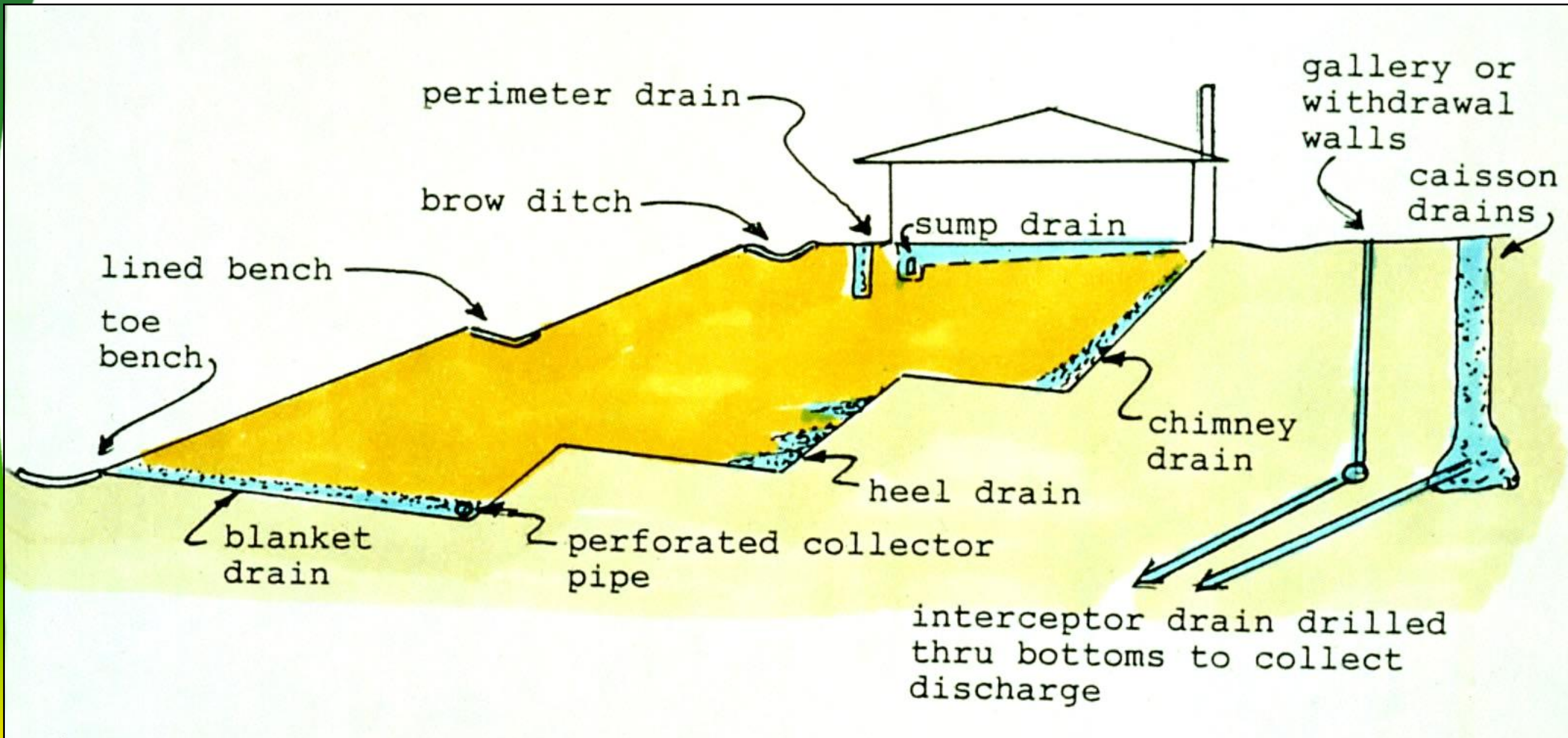
Stability Fills



- **<u>Stability fills</u> are engineered fill embankments constructed against *potentially unstable* or *actively eroding* slopes**
- **They are typically fairly narrow, with limited subdrainage.**



- Typical design standards for **stability fills**
- The may be fairly thin, down to just one equipment width (10 to 12 ft)
- Subdrainage should be employed if evidence of past seepage is noted during excavation



- **Colloquial terminology used to describe various kinds of subdrainage measures.**
- **You can never have too much subdrainage, but you can often have too little**

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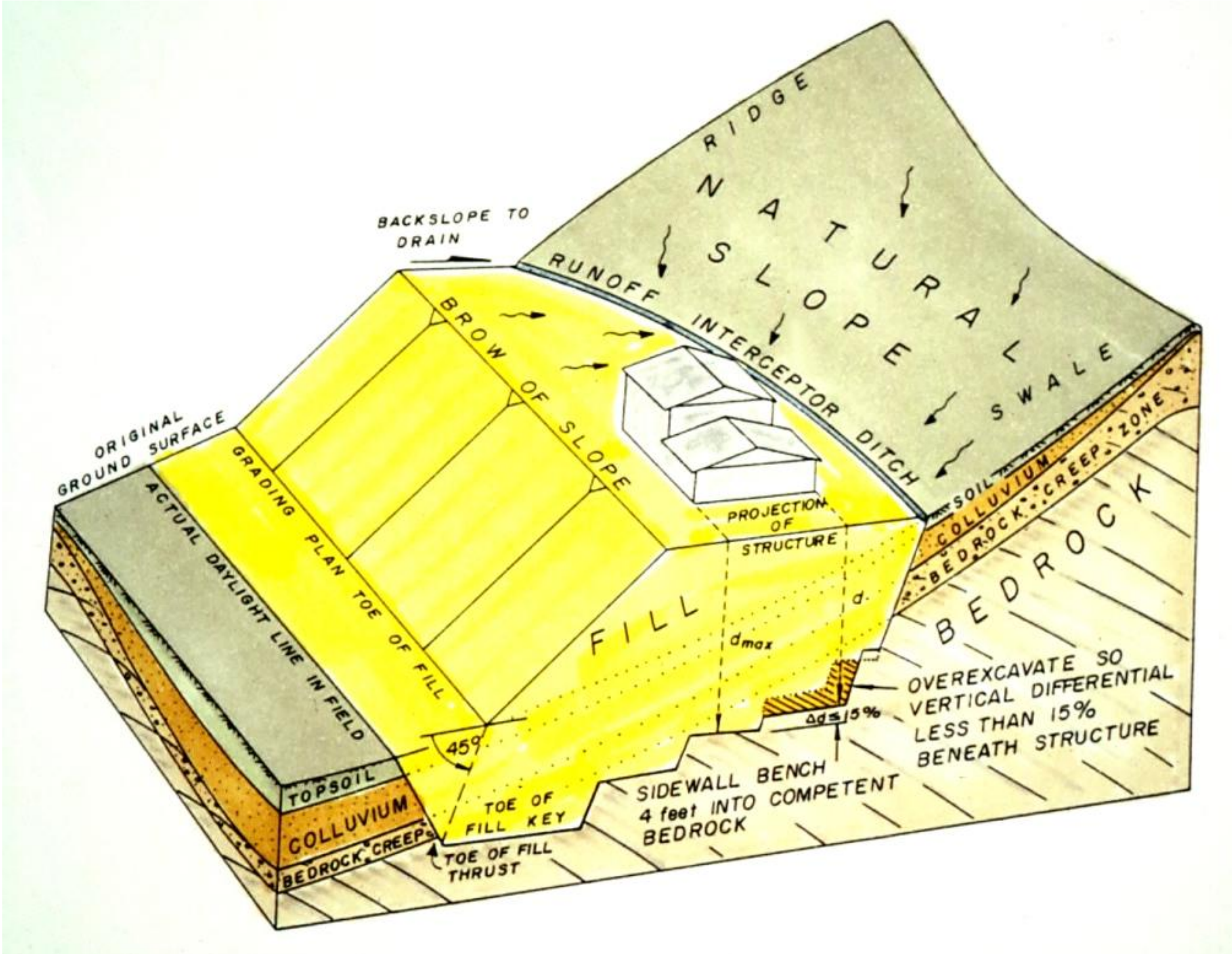

- **Recommended standards for sidehill embankments supporting structures, taken from Rogers (1992). Note 15% vertical fill differential beneath structural footprint**

About the Presenter

Dr. Roy Letourneau (on left) and Dr. J. David Rogers (on right) in September 1997. Dr. Letourneau is the son of R. G. “Bob” Letourneau (1888-1969), the inventor of the modern bulldozer and scrapper. Rogers 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.

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