ENGINEERING HANDBOOK

AGRICULTURAL ENGINEERING DIVISION
PROJECT 13, SPENCER, WEST VIRGINIA
J. S. CUTLER—ACTING REGIONAL DIRECTOR

U. S. DEPARTMENT OF AGRICULTURE
1935

Glenn Grubb

ENGINEERING DIVISION HANDBOOK

UNITED STATES DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

PROJECT NUMBER 13

SPENCER, WEST VIRGINIA

J. S. CUTLER
ACTING REGIONAL DIRECTOR

1935

RESPECTFULLY DEDICATED TO

HUGH HAMMOND BENNETT

DIRECTOR OF

the Soil Conservation Service, whose insight to the ravages of wind and water erosion has awakened public interest into a nation wide program of erosion control.

-P R E F A C E-

The mission of this handbook is to serve as a guide to engineers engaged in soil conservation work in the state of West Virginia. In preparing the handbook, methods of erosion control developed by other agencies currently engaged in similar activities, and believed applicable to the problems encountered have been liberally drawn from.

A sincere effort has been made to acquaint the reader with the more general aspects of erosion control from an engineering standpoint and to bring to mind the technical specifications of the many structures developed to aid in conserving our soils. It should be clearly understood with respect to dams and similar control structures that these are to be regarded only as temporary aids in a process that has for its ultimate goal soil conservation through revegetation. Vegetative recovery must mark the way towards permanent control.

The present dearth of fundamental knowledge with respect to proper and complete methods of erosion control is keenly felt. It is realized that this handbook in many instances merely intimates a possible solution. There is still a vast amount of pioneering to be done before we can hope to lay down rules acclaiming positive control. Until such a time we can but try to improve as we build. Criticisms and suggested improvements to the subject matter of this publication will be welcomed. Much that is found herein will be antedated as experience either proves or disproves present practice.

The writer takes pleasure in giving recognition to Mr. Harold C. Hebb, Chief Forester; Mr. Boyd D. Gilbert, Chief Soils Expert; Mr. Ivan McKeever, Chief Agronomist; Mr. Lowell A. Yost, Assistant Agricultural Engineer; and Mr. James H. Lillard, Junior Soils Expert and Acting Assistant Agricultural Engineer. These gentlemen have contributed their time and ability to make this handbook possible. Credit is also due the engineers from the E.C.W. Camps assigned to the Spencer project. They gave helpful assistance covering specifications for erosion control structures. Mr. Harold M. Rhodes, Engineer for Camp SCS-WVA-1 assembled these specifications into final form. The drawings for this handbook were contributed by Mr. Harold S. Ronning, Chief Draftsman of the Spencer project.

Hans G. Jepson,
Assistant Agricultural Engineer,
Acting Chief Engineer.

Spencer, West Virginia
April, 1935

- T A B L E   O F   C O N T E N T S -

- T A B L E O F C O N T E N T S -

PART FOUR

EROSION CONTROL STRUCTURES

PART FIVE

ESTABLISHMENT OF VEGETATION TO SUPPLEMENT EROSION CONTROL STRUCTURES

SOIL CONSERVATION SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE

PROJECT #13 SPENCER, WEST VIRGINIA

P A R T O N E

GENERAL INFORMATION

CHAPTER I

TOPOGRAPHY OF THE SPENCER PROJECT

The 152,000 acre Reedy Creek soil erosion control project located in midwestern West Virginia comprises large portions of Roane and Wirt counties and a small part of Wood County. The area is drained by Reedy Creek, Spring Creek, and Tucker Creek. All three creeks empty into the Little Kanawha River, which forms the north-eastern boundary of the area. Reedy Creek - the largest of the three streams - measures 32 miles including its meanders. The rate of fall is about 3.7 feet per mile. The watershed drained is approximately 84,000 acres. Spring Creek, next in size, is also 32 miles in length as measured by its meanders. However, its rate of fall is even greater than Reedy Creek, being 4.1 feet to the mile. The watershed approximates 57,000 acres. It might be of interest to note that both Reedy Creek and Spring Creek have sufficient fall to indicate that their channels are still cutting deeper. Tucker Creek - the smallest of the group - has a length of about 11 miles along its meanders. Its fall is well over 10 feet per mile. The drainage area approaches 12,000 acres.

Spencer, Reedy, Elizabeth, and Palestine are the larger towns within the Project area. Spencer, the county seat of Roane County, is the Project headquarters.

The Reedy Creek area is a part of the Cumberland Allegheny plateau, which extends all the way across the state from the Appalachian mountains to the Ohio River. The land surface is rough and broken, with narrow ridges and "V" shaped valleys. The creeks in this area have eroded deep canyon-like gorges with steep valley walls. These steep hillsides are well adapted to grazing, but should not be tilled for grain and similar products that require extensive cultivation. The outcrops of dark red shales produce a fertile soil adapted to blue-grass. When this cover of grass is replaced by cultivated fields, washing results, and this together with frequent slips soon impoverishes the land. Much of the land now under cultivation should never have been cleared.

The climate is moderate, with an annual mean temperature of 54 degrees F. The warmest month is July, and the coldest is January. Protracted spells of uncomfortably warm weather are infrequent and cold periods are of short duration. Alternate freezing and thawing occurs in winter. The erosion resulting from such frost action is very excessive.

Average precipitation for the area is approximately 43 inches, with the highest average in July and the lowest in November. Snowfall occurs in winter but the snow does not remain on the ground for any length of time, due to frequent thawing periods. Elevation varies from 640 feet above mean sea level where the Little Kanawha River leaves the area to approximately 1200 feet at the higher points.

CHAPTER II

ORGANIZATION AND PROCEDURE ON THE SPENCER PROJECT

The erosion control work of this project consists of a complete land utilization program designed to meet the needs and requirements of each individual farm in the project area. Strip cropping, contour stripping, crop rotation, stream control, gully control, reforestation, pasture management, grass seeding, and other methods will be used to meet the particular problem of each individual cooperating farm.

The work program is carried out jointly by the following technical divisions: Soils Division, Erosion Specialist Division, Agronomy Division, Forestry Division and Engineering Division. Division chiefs are responsible for carrying out the details of the program for their particular division. Another division - Operation and Maintenance - is responsible for keeping all equipment in good condition and for the delivery of all materials. An Extension Division takes care of general publicity and dissemination of information.

The Regional Director administers and directs the entire soil erosion program for the project while the Division Chiefs are responsible for carrying out the details of the program for their particular division.

The general duties of the technical divisions are outlined below:

SOILS DIVISION

The soils work of this project consists of classifying, designating and mapping soils and soil erosion conditions on the farms within the area of the project. When such is required a generalized state soils survey is also made.

EROSION SPECIALIST DIVISION

The Erosion Specialist Division is responsible for working out the land utilization program for all farms in the area that wish to cooperate with the Soil Conservation Service. The land utilization program includes agronomy, forestry, and engineering. However, each separate phase of the program receives the approval of the division chief in question.

After the land utilization program has been reviewed and approved by the technical divisions it is incorporated in the Cooperative Agreement made between the government and the farmer.

AGRONOMY DIVISION

The agronomic work consists of developing crop rotations and strip cropping plans which will tend to control erosion and build up the soil and of outlining methods to be used in controlling various forms of erosion on the different kinds of soils. The Agronomy Division is responsible for the procurement and utilization of lime, fertilizer, and agricultural seeds used on the project. The division also has charge of photographic work.

FORESTRY DIVISION

Forestry work on this project consists of the planting of suitable and desirable species of trees and shrubbery on suitable areas and the protection and proper cultivation of areas already in forest or semi-forest condition. Studies are carried out in forest research, proper community forest management, seed production and forest nursery cultivation.

The Division is also responsible for woodlot management, game conservation and the collection of meteorological data.

Reforestation of suitable areas is a vital part of erosion control on this project.

ENGINEERING DIVISION

The direct relationship of engineering work to soil erosion control on this project consists mainly in the construction of gully control structures such as rock, brush, log, stake, wire, sod, stopper, and bag dams; rock and brush overfalls; brush or straw matting and stripping; diversion ditches and outlets; retaining walls; terraces and terrace outlets; revetments, levees, jetties and wing dams; bank protection; concrete, masonry, and earth dams where more permanent structures are desired. Terracing and stream control are undertaken to a limited extent on this project.

The Engineering Division is responsible for the design, construction, and maintenance of roads, bridges and buildings needed on the project. Experimental studies dealing with runoff, silt gaging and stream gaging are carried out. The fencing, planting and seeding of eroded areas adjacent to or surrounding control structures comes under the jurisdiction of the Engineering Division. Assistance is given to the cooperators in designing and laying out water reservoirs, in land reclamation through drainage, in the improvement of springs, and in location of farm roads to minimize erosion. All contour stripping and furrowing is staked out by the engineers.

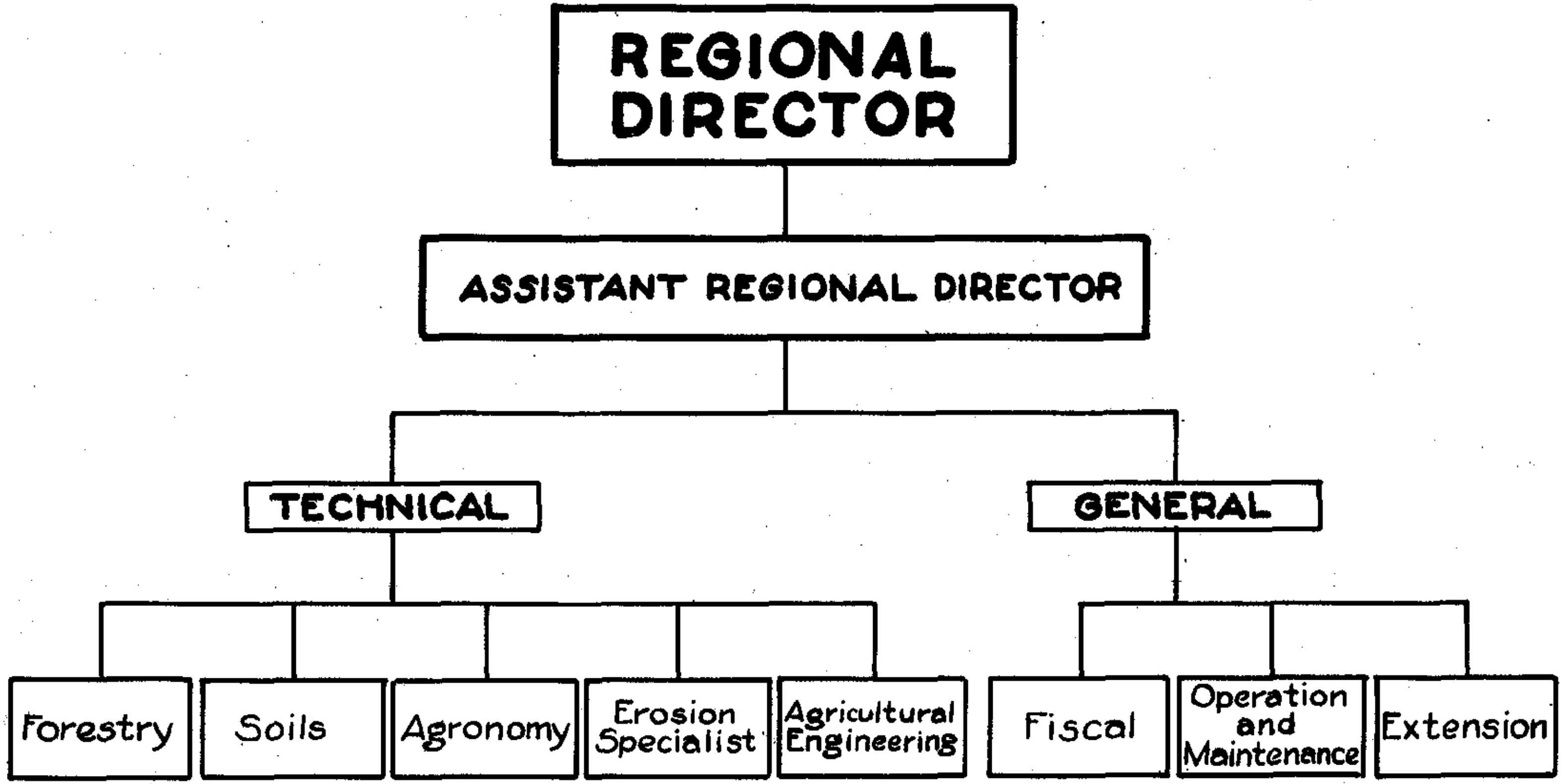
The Engineering Division is further charged with all drafting and mapping work required with the exception of the mapping carried on by the Soils Division.

The accompanying chart, page 9, will indicate more graphically the set-up of the S.C.S. organization.

Organization Of

PROJECT NO. 13

SPENCER, W. VA.



It is Imperative That All Procedure Be Routed Through Proper Channels

Project 13, Eng. Div.

CHAPTER III

RELATION OF THE SOIL CONSERVATION SERVICE TO THE ECW.

The Soil Conservation Service is responsible for developing methods of erosion control and effectively demonstrating their uses. This means that all available data and the ideas of trained experts must be coordinated into the best possible plan of land use. The plan must then be put into effect in cooperation with the land owners.

The establishment of an effective erosion control program of any size involves a tremendous amount of labor. This was one of the important problems that had to be solved immediately after organizing the several control projects established. Fortunately, the ECW organization was able to assist in solving this problem. The ECW organization and labor have made possible the construction of check dams, diversion ditches and terraces, the correction of stream channels, reforestation, timber stand improvement, and the production of agricultural lime on a scale that would have otherwise been impossible. The establishment of the forest nursery at Reedy will make possible the production of forest planting stock on a large scale for future reforestation. Truly the ECW organization has in its relationship with the Soil Conservation Service, put into effect the aims, ideals, and purposes of its founders which are:

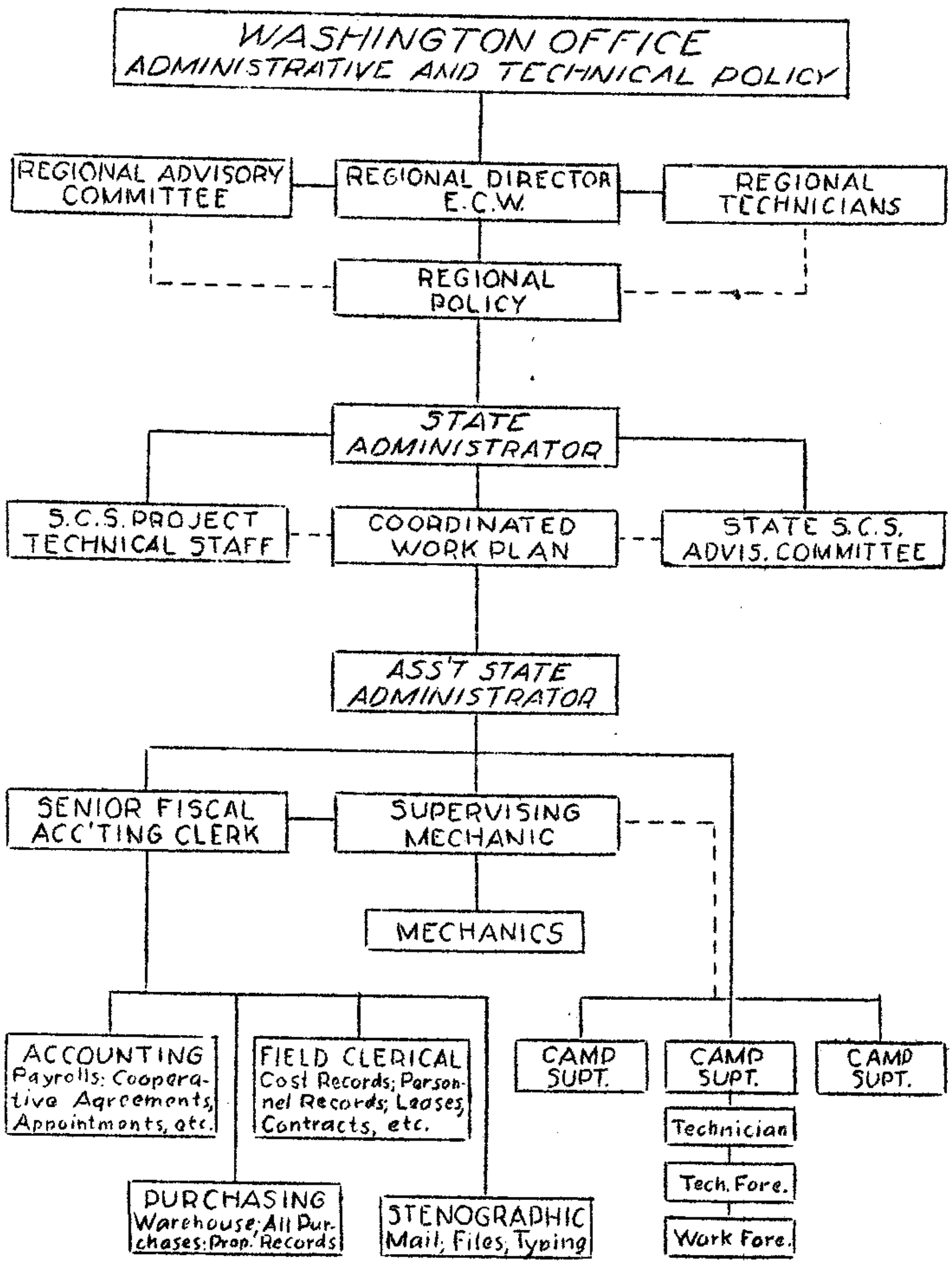
"The building of men and the restoration of confidence."
"Help to protect, develop, and perpetuate existing forests."
"Help to prevent Soil Erosion."
"Help to establish new and re-establish old forests."

ECW activities in West Virginia are directed by a State Coordinator who in turn is responsible to the Regional ECW office. The region comprises several states. The ECW camps assigned to the Soil Conservation Service are utilized by it in the control program. The work program is formulated by SCS technicians and through the state coordinator is turned over to the camp superintendent who is responsible for its completion. All technical SCS men attached to a camp are subject to its regulations while there.

In answer to a question frequently asked as to what connection the Army has with the ECW organization it may briefly be stated that the Army clothes, feeds, and houses the men. The ECW personnel takes charge of the men during work hours. Discipline of the men while at camp is, of course, the responsibility of the Army.

An organization chart (chart 2, page 11) is included to indicate channels of authority. It is imperative to the success of the entire program that routed procedure be followed at all times.

ORGANIZATION CHART
SOIL CONSERVATION SERVICE
EMERGENCY CONSERVATION WORK CAMPS
WEST VIRGINIA



SOIL CONSERVATION SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE

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P A R T T W O

SOIL CONSIDERATION IN ENGINEERING

CHAPTER IV

SOILS AND TOPOGRAPHY IN THEIR RELATION TO EROSION

The outer portion of the earth is covered with a thin, disintegrated layer known as soil which has been formed by decomposition brought about through the action of climatic forces. It is the medium with which we must deal in all of our erosion control practices and therefore warrants careful consideration and intense study. Soils having similar climatic, geologic, and profile developments constitute a division known as soil series. The subdivision of the series on the basis of the texture of the surface layer gives the final division called a soil type. Many of the soil series are characteristic of definite geological positions which is not true for the different soil types. Each soil series offers its own complex problems in erosion control. A great number of series may be closely related in their resistance or susceptibility to erosion but upon careful examination individual characteristics can be determined which warrant consideration in erosion control programs. These characteristics are brought about by many factors, chief among which are physical structure, geological position, texture, chemical composition, vegetative covering, and derivation.

Experience with different soils has very definitely proven that texture has an important influence on the development of both sheet and gully erosion. A sandy soil absorbs water rapidly thus reducing the percentage of runoff to a figure materially lower than for the heavier textured soils which always have low absorbtive capacities. This fact is very important because the bulk of West Virginia soils are silt or silty clay loams and are, therefore, very susceptible to severe washing. Another very important factor directly affecting the development of erosion is topography. The steeper the slope the greater is the erosive action of the water. When the slope is increased four times the velocity of the water is approximately doubled and its carrying capacity theoretically increased 64 times. However, according to the best available data, the relation between slope and erosion does not follow any definite dynamic law. The multiplicity of ever present variables in the soils prevents any such relation. At present it is believed that both the type of vegetative cover and the physical characteristics of the soil have a greater influence on erosion than slope. Since the effect of slope cannot be materially altered by human efforts, it becomes necessary to concentrate on the development of a desirable vegetative cover wherever possible.

The inherent structure and consistency variations within a soil type noticeably affect the rate of absorption and runoff. The materials of highly weathered soils do not go into solution as rapidly as materials of the less oxidized soils. The different horizons of the disintegrated soil materials usually react very differently to the same erosional influences. For this reason careful consideration should be given to the depth of gullies when designing erosion control methods. Gullies which have not developed deep enough to reach the parent material (C-horizon) usually cut through the compact subsoil layer in a V-shape. It is in this stage of development that erosion control measures can be used most effectively for complete reclamation or stabilization. The physical structure and chemical composition of the soil to such a depth is usually good enough to support vegetation and also to securely anchor the necessary engineering structures. If the gully has penetrated through the subsoil into the layer of parent material the erosion control problem becomes more complete. The channel is usually developed in a U shape. The loose, partially decomposed, material of this layer (C-horizon) washes readily. The gullies grow in width, depth and length very rapidly, with the valuable upper layers (A & B horizons) continually being undermined and caving in. This cutting away of valuable lands constitutes a vital factor for consideration and study.

Engineering structures must be carefully designed and constructed if they are to accomplish their purpose when subjected to all the different erosive reactions of the entire soil profile. In most soils the surface soil or A-horizon is of a coarser texture, is less compact, and has a more desirable physical structure and chemical composition than have the underlying layers. These conditions bring about a greater absorptive capacity which makes it necessary to determine the amount and condition of the remaining surface soil in studying rate of runoff prior to the design of control measures. The subsoil (B horizon) is finer textured, more compact, and thus more impervious than is the surface soil. Gullies usually develop slowly while cutting through this strata. Observation seems to indicate that such gullies increase in depth much faster than in width.

The subsoil layer varies in depth from about 2 to 6 feet depending upon the soil series. Immediately beneath it is the layer of parent material which as already pointed out, is extremely erosive. It represents an intermediary condition between unweathered rocks and shales and completely decomposed soil material. The physical structure and chemical composition of such material is very poor so that little or no plant growth can be supported. Engineering structures must be designed and constructed with great care or they will fail through undermining and bank caving.

Many of the problems encountered lie almost wholly outside the scope of present day knowledge. Very little experimental data is available on the relative erosiveness of the different soil types and series or the individual properties influencing the runoff and absorptive qualities of each. These factors are now being studied at the different Soil Erosion Experiment Stations under the direction of the U. S. Department of Agriculture. The studies, however, are new and necessarily limited to small experimental areas. They must be supplemented by information secured in the field. It appears that the only fair and equitable basis on which to compare the erosive qualities of the different soil series is to set up standard conditions of occurrence and distribution for each series rather than compare all series to a single standard. Such a comparison is of greater practical value because it recognizes the many conditions peculiar to the different soils. For example, one series may be less erosive than another because of its inherent fertility and ability to maintain a desirable physical structure while another series may be less erosive because of the nature of the parent material from which it is derived. An almost unlimited number of factors have contributed their influence to the establishment of existing field conditions of the many different soils. It evolves upon us to study and isolate the dominant factors in a concerted effort to devise the best methods of erosion control and soil conservation.

The engineer must familiarize himself with the various soil types and through an understanding of their complexities must be continually on the alert to pick out practical methods of control wherever mechanical devices appear necessary. A key to the various soils has been included in this discussion with the intention that the engineer acquaint himself with it sufficiently to enable him to identify the more common soils. The key will be found under Chapter VI. It cannot be emphasized too strongly that as time goes on we are finding more and more that the various soil types vitally affect the kind of structure to be placed as a measure in erosion control. We are continually finding that critical scouring and sedimentation velocities deviate sharply from a mean. To make generalized assumptions is therefore dangerous. Many years of experimental work are required before definite conclusions can be gleaned from the results of the various erosion control methods put into practice.

CHAPTER V

SOIL ENGINEERING

The soils of West Virginia lie almost completely within the Appalachian Mountain Plateau Province. The only exception is a small area (Shenandoah Valley Area) in the eastern panhandle which lies in the limestone valley and upland Province. The geological origin of these soils is mainly sandstone and shale, with occasional beds of limestone throughout the State. West Virginia's topography, being typical of the Appalachian region, is very rough and broken and only in a few instances do the ridges broaden out into a plateau. Most of the valleys are V-shaped with little or no bottom land.

In the design and application of a comprehensive soil erosion control program it is imperative that consideration and study be devoted to erosion on different soils and slopes. The soils and slopes found within the Reedy Creek erosion control project represent, with few exceptions, the predominating soils and topography of West Virginia. The Shenandoah Valley section in the eastern panhandle is the most notable exception. In this area limestone is the geologic origin of the soil.

SCS Project #13 represents the first concerted effort to curb erosion on West Virginia soils. As yet little is known of many of the problems encountered, still, enough information has been gained to indicate a real beginning in soil erosion investigations. It is believed advisable to present for further consideration and study the various factors which have manifested themselves as erosion control work progressed on the different soils and slopes. These relations will be discussed from the viewpoint of state-wide application insofar as it is practical with the limited data available.

One of the most important soils of the state is the Meigs series. It occupies more than 60% of the Project area and is the predominating soil of the western one-third of the state. Typically, it occupies positions of rather steep topography but frequently it is found in areas less steep. Meigs soils are rather susceptible to erosion and wherever they are found a definite erosion control problem exists. Several factors are responsible for such conditions, chief among which are slope, vegetative cover, and physical structure. Agriculturally, Meigs soils are important and considered to have medium to high fertility. However, in many cases the physical structure has been badly broken down through leaching of the plant nutrients brought about by poor farming practices. Once this condition is reached severe gullying develops almost immediately because the alternate layers of red and gray shales erode very rapidly. In developing erosion control methods for Meigs soils the following facts should be borne in mind:

1. A desirable physical structure can be developed by proper farming methods.

2. The layers of red shale in the subsoil are usually calcareous and thus are conducive to successful gully plantings.

3. Where gullies have developed into the C-horizon it is necessary to extend the engineering structures well into the banks and bottom of the gully in order to prevent failure.

Soils of the Dekalb series occupy approximately one-fifth of the Reedy Creek Project Area and are widely distributed throughout the State. These soils are important probably more because of their extensive distribution than because of their agricultural value for they are of low fertility. They occupy positions of topography from slightly rolling to excessively steep with very rough and stony areas prevalent. Erosion on the Dekalb series varies from slight to complete destruction. Under reasonable care and management the A and B horizons are not excessively erosive and with the application of proper farming practices a desirable physical structure and vegetative cover can be fairly successfully maintained on areas which are not too severely eroded. Gullies start quickly on areas which have suffered severe sheet erosion probably due to the decrease in absorptive capacity through the loss of loose surface soil. Shallow gullies (in A and B horizons) can usually be easily and successfully controlled, because the soil to such a depth is fertile enough to support vegetative growth as well as to properly anchor the engineering structures.

Deep gullies in Dekalb soils present a complex problem. The C-horizon or parent material layer is composed of loose, disintegrated and partially decomposed shales with occasional mixtures of sandstones. Practically all elements necessary for plant growth are lacking. In this layer erosion develops very rapidly and gullies grow in width, depth, and length with each rain. When the base is broadened by lateral washing the result is great loss of valuable soil from the upper layers through bank cavings. In designing engineering structures for such soils the following points should be borne in mind:

1. Dekalb soils have a fairly low inherent fertility.

2. It is extremely difficult to establish vegetation on gullies extending into the C-horizon.

3. Because of the poor physical structure and lack of cohesion of the material of the C-horizon it is very difficult to safely anchor engineering structures.

The Brooke Clay Loam is a limestone soil of high inherent fertility. It occupies positions on ridge tops in the northwestern part of the area. It has also been mapped in small areas widely distributed over the northwestern part of the state. The topography of this soil generally is not excessively steep. It is relatively flat and seldom extends far down the hillsides. In most cases it has been subjected to fairly good farming practices and thus has been able to maintain its high fertility and desirable physical structure. Consequently, in most areas erosion has not developed to such devastating stages. Occasional gullies have developed in sections, generally as a result of over cultivation. In such cases engineering structures can be very successfully used in cooperation with the planting of proper vegetation for effective erosion control.

The Westmoreland soils are rather important in West Virginia and occur in almost every place where limestone exists. They are important agriculturally because of their fertility and workability. Their topography is variable with some areas gently rolling and others excessively steep. Practically all of the smoother areas are intensively farmed. Erosion is usually moderate although severe erosion is not uncommon. The presence of the inner bedded layers of shale gives the soil a particular structure which is more susceptible to erosion than soils derived wholly from limestone. Occasional gullies are characteristic of this series but it is generally possible to establish an effective cover of vegetation on them with the aid of properly designed engineering structures.

The Belmont silty clay loam occurs in conjunction with Brooke and Westmoreland in most of the limestone sections. It cannot be considered a very important soil because it occurs only in small areas. Its topography is usually rather steep with very few areas smooth enough for cultivation. It has a low absorptive capacity and does not have as good physical structure as the other limestone influenced soils. After the A-horizon is lost through erosion, gullies immediately develop. One of the main factors influencing their development is the layer or layers of red calcareous shale which usually occur in the B-horizon. The soil is fairly productive in the few areas which are adapted to cultivation. In such instances engineering structures can be effectively used.

The Hagerstown and Frederick series are among the most valuable agricultural soils of the State. They are derived wholly from limestone and are materially fertile. They occur mainly in the eastern panhandle and in counties along the eastern and southeastern border of the state. Neither of them are found within the present Project Area. Their topography is usually favorable for cultivation or pasture and as a result probably the most intensive farming of West Virginia occurs on them. According to a recent reconnaissance erosion survey of the series, erosion varies from slight to moderate and occasionally to severe. Intensive cropping and poor farming practices have influenced the vegetative cover and also the physical structure of the soil. In designing erosion control methods for such soils the engineer should consider the following points:

1. They are among the most productive soils of West Virginia.

2. Their physical structure and chemical composition are both favorable for effective erosion control measures.

The Franktown soils are found only in the eastern panhandle of the State. Their topography is variable but generally is smooth enough for satisfactory cultivation. Although Franktown soils are not extensively distributed they are important because of their productiveness and wide range of workability. The physical structure and chemical composition is very similar to that of the Hagerstown and Frederick series. Generally the erosion is moderate with occasional areas of severe washing and gullies. Erosion control methods developed for the Hagerstown and Frederick soils should prove satisfactory in most cases for the Franktown soils.

The Decatur soils occur in small areas in Jefferson County. They possess a state of high fertility as well as a fairly smooth topography, so erosion is not very serious in most cases. In cases where erosion control structures are needed those designed for the other more fertile limestone soils can be satisfactorily used.

Undoubtedly the most erosive soil in West Virginia is the Upshur series. It is rarely or never found in the uneroded state because its heavy texture and narrow range of workability is always conducive to severe erosion. The Upshur Clay occurs in small areas throughout the Project wherever deposits of red calcareous shale have been formed in appreciable quantities. The deposits occur mainly in Jackson, Clay, and Braxton counties together with a few scattered areas throughout the State. The topography of the soils is seldom excessively steep. Usually they occupy positions on hilltops or rolling shelf lands. Many areas have been completely covered by landslide of sandstone and shaly materials.

Upshur soils are productive but cultivation is very difficult due to their narrow range of workability. They are extremely tenacious and bake very readily when exposed to a hot sun. Such physical properties favor low absorption and excessive runoff. Every effort should be made to maintain a desirable vegetative or forest cover on soils of this nature by introducing well planned farming practices. Many areas have already been severely damaged, and in many cases destroyed, by gullies resulting through poor land use. Such gullies can be controlled best by properly designed engineering structures supplemented by sufficient bank sloping, seeding and planting. In designing such structures, the engineer must bear in mind the inherent susceptibility of such heavy textured soils to severe washing. The partially decomposed red shale found in the C-horizon (three to four feet below the surface) offers little resistance to erosion, consequently structures are likely to fail if they are not carefully constructed.

Another soil similar to the Upshur is the Lehew series. It occurs only in small areas in West Virginia, usually in association with Meigs or Upshur. Sandstone has influenced its formation and, hence, it possesses a broader range of workability than the Upshur soils but is less fertile. The continued cultivation of most Lehew areas has resulted in rather severe soil losses with gullying developed to varying extents in many areas. Generally the topography of the Lehew series is not very steep, as it is found mostly on hilltops, and occasionally on the smoother bench formations found on many hillsides. Most Lehew soils are either in cultivation or in pasture and are valuable from an agricultural viewpoint. Engineering structures can justifiably be used on such area.

The Berk soils found in the eastern panhandle and the Tilsit series occurring in several counties along the eastern border of the state are relatively poor agricultural soils. They occupy undulating to rolling topography but their low productivity prevents them from being considered among the important soils of West Virginia. The relatively smooth topography occupied by these soils is probably their greatest protective factor against erosion. Most of the areas have suffered only moderate losses from washing even though the vegetative cover is thin and of poor quality. It is believed that erosion on the Berk and Tilsit series can be effectively controlled by proper land utilization, aided by necessary engineering structures. It must be remembered that these soils have a low agricultural value and should be treated with the most economical methods of erosion control possible.

The steep and broken topography of West Virginia has promoted appreciable colluvial depositions along the bases of many of the higher hills. These depositions are generally fertile, especially where the material has come from hillsides that were not already severely eroded. In most cases the erosion has been negligible but occasionally gullies have developed to a depth of several feet. These should and can be controlled by engineering structures and plantings.

West Virginia embodies large areas of stream terrace or second-bottom land. Such soils are water-deposited and occur on recent overflow (second bottom) lands along all the larger streams of the state. They constitute an appreciable percentage of the cultivatable land of this region.

The more widely distributed alluvial soils are the Tyler and Holston series. They occur along streams which have received their wash from sandstone areas. Like other water deposited soils, they were originally laid down on level terrace formations. Many of these terraces have been so badly broken up by severe erosion that is is sometimes hard to recognize the present topography as being remnants of stream terraces. The soils are generally infertile due to over-cropping without the application of soil treatments. Such practices have resulted in an unfavorable chemical composition and a physical structure which is a ready prey for the devastating action of runoff water. When subjected to a correct system of farming, stream terrace soils will improve to a fair state of productivity. This factor, along with favorable topography, make such soils valuable to the farmers. The physical and geological nature of second bottom soils lend themselves to the application of diversified erosion control methods. Many areas are adapted to strip cropping and terracing practices. Others require gully structures and diversion ditches while still others can be successfully controlled by contour farming alone.

Other stream terrace soils which have been mapped in West Virginia are the Monongalia, Wheeling, and Elk series which in most respects are similar in both chemical and physical characteristics to the Tyler and Holston series already discussed. The same general plan of erosion control should prove satisfactory for them.

Most of the streams of West Virginia are subject to overflow during heavy rains. These flood plains or first bottoms vary in width from a few feet to rather broad cultivatable fields. The principal soils series occupying such positions are Pope, Moshannon, Huntington, Adkins, and Holly. These soils generally do not present a serious erosion control problem because the depositions received from flood water equals any erosion which may take place. Drainage may become a problem however, because of flat slopes of the terraces. When it is necessary for the farmer to utilize all available bottom land for intensive crop production it is often justifiable to drain such areas in order that steeper land can be retired from cultivation.

A number of other soil series have been mapped in West Virginia but they are not of sufficient extent or importance to warrant a lengthy discussion here. Erosion control methods devised for soils of similar characteristics should suffice.

The discussion of West Virginia soils is given to acquaint field engineers with the individual characteristics of the more important soil types and series. It is important that these different qualities be carefully studied in any well developed erosion control program. Their existence is evident but the extent of their influences in any direction is relatively unknown. Definite methods for measuring and controlling such factors must be devised by engineers in the field.

There has been included a graph showing percent slope and percent erosion distribution on Project #13. (Chart #3, page 23). Both curves have been plotted on the same sheet to indicate how closely percent of erosion parallels percent slope. Surface soil especially shows a high rate of erosion where slope is excessive. Once the subsurface strata is reached we find excessive erosion occurring even on relatively flat slopes. The steep slopes occurring on Project #13 are very apparent from the graph. For instance we note that on 28% of the area we have 25% slopes and approximately 30% of the surface soil gone.

In West Virginia there has been observed a type of erosion which, it is felt, justifies a distinct classification. Its effects are very insidious and widespread. We have termed it subsurface erosion because of its characteristics. It is prevalent on steep slopes and on benches below such slopes, which indicates that seeping water channels beneath the surface of the soil cutting out veritable gullies which later cave in. These gullies may take years to form and may be of great magnitude before their existence is even suspected. In time they evolve into open gullies, sometimes overnight. Stock will frequently break through their thin covering of soil. Where an impervious strata of rock or soil occurs near the soil surface we sometimes have subsurface erosion in the form of sheet washing which ultimately results in a slip. Little as yet is known of this type of erosion.

The accelerated erosion resulting from the action of water in West Virginia may be classified as follows:

1. Sheet Erosion
    (1) Moderate (almost imperceptible)
    (2) Severe
        (a) Pockets (Evident along crest of benches)
        (b) Galled areas
        (c) Slips

II. Gully Erosion
    (1) Head erosion (active eating back of gullies)
    (2) Channel erosion (primary gullies)
    (3) Lateral erosion (secondary gullies, may become primary)

III. Subsurface erosion
    (1) Channel
    (2) Sheet

The nomenclature used is self-explanatory so will not be taken up in detail.

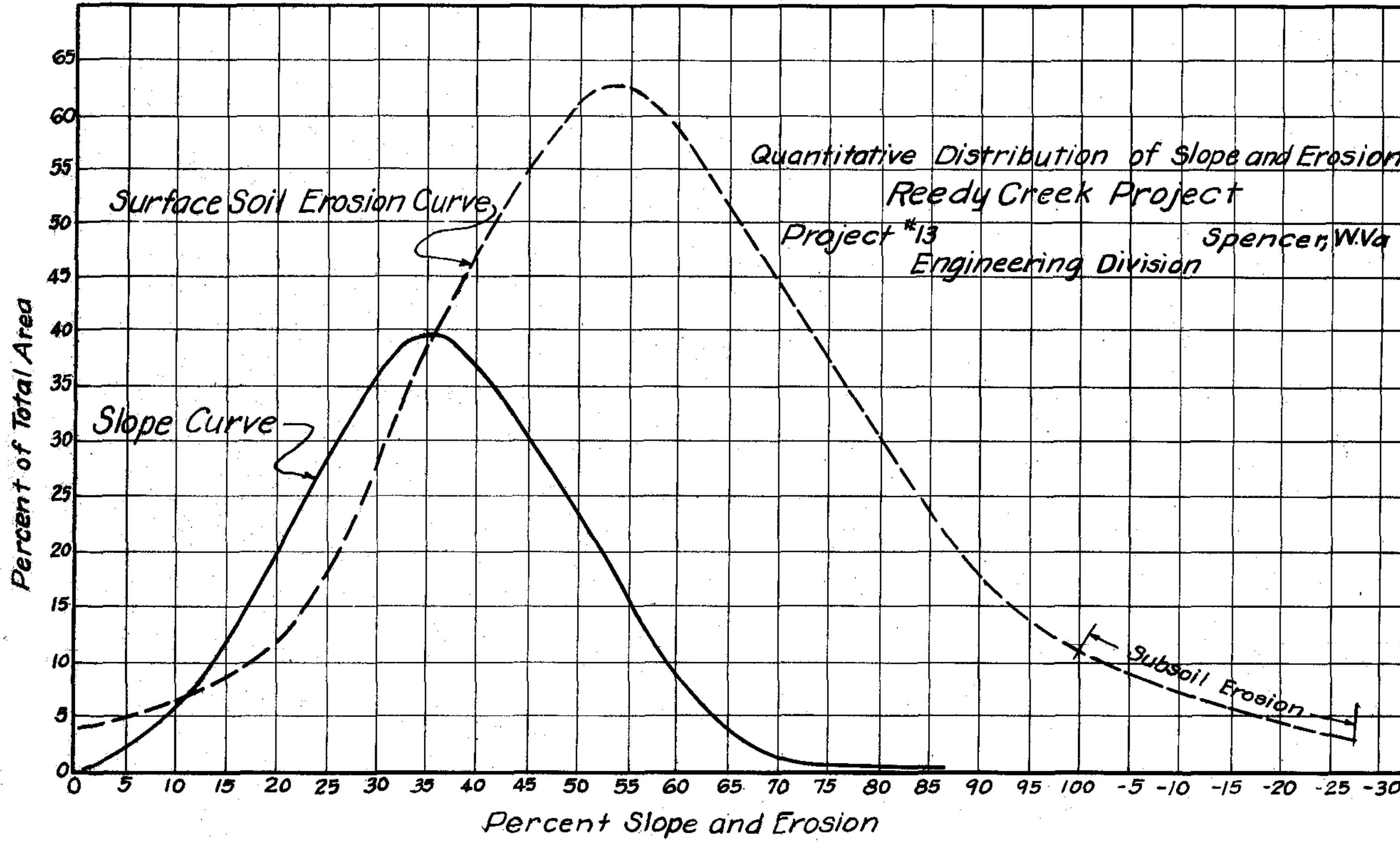

Quantitative Distribution of Slope and Erosion
Reedy Creek Project
Project #13
Engineering Division
Spencer, W.Va
Surface Soil Erosion Curve
Slope Curve
Subsoil Erosion
Percent of Total Area
Percent Slope and Erosion
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 -5 -10 -15 -20 -25 -30
0 5 10 15 20 25 30 35 40 45 50 55 60 65

Chart 3

CHAPTER VI

WEST VIRGINIA SOILS KEY

Section I: SOILS OF REEDY CREEK SOIL EROSION CONTROL PROJECT #13

I UPLAND SOILS

A. Mixed red and gray land -- Meigs.

Meigs Clay Loam

The surface soil is light grayish-brown, silty clay loam, 2 to 5 inches deep.

The subsoil is yellowish-brown clay loam extending into red clay.

Derived from sandstones, sandy shales, and red shale, usually calcareous.

Fairly productive and one of the most important agricultural soils of the state.

Comprises about 53,000 acres, or 34.7% of the total project area, scattered throughout the area. Fifty-one percent (51%) of it is on 25-40% slopes, and 68% has lost 25-75% of the surface soil.

Occurs in all counties in western part of state and in small areas in all other sandstone and shale sections.

Meigs Stony Loam

Surface soil is dark grayish-brown to brown loam or silty loam 2 to 5 inches deep.

Subsoil is yellowish-brown to reddish-brown clay loam.

Derived from sandstones, sandy shales and red (calcareous) shale, mixed by slipping and sliding on hillsides.

Comprises about 47,000 acres, or 30.8% of the Project area, widespread over the area.

Low agricultural value due to rough and stony topography.

Forty-three percent (43%) of Meigs stony loam occurs on 25-40% slopes and 42% on 40% slopes. 70% has lost 25-75% of its surface soil.

Occurs in association with Meigs clay loam.

B. Gray sandstones and shales -- Dekalb.

Dekalb Silt Loam

Surface soil is grayish brown or yellowish gray silt loam 3 to 6 inches deep.

Subsoil is brownish-yellow heavy silt loam, extending into clay or clay loam.

Derived from sandstone, sandy shale, and soft gray shale of non-calcareous nature.

Naturally not a strong soil but rather important because of wide distribution.

Most frequently occupies hilltops and ridge-tops, extending down the sides, widespread over the area. Comprises about 20,000 acres or 13.1% of the area. Forty-one percent (41%) occurs on 25-40% slopes, 64% has lost 25-75% of its topsoil.

Occurs mainly in central and southern counties but appreciable areas are found throughout the state.

Dekalb Stony Silt Loam

Surface soil is yellowish-gray or grayish-brown silty loam from 2 to 5 inches deep.

Subsoil is yellowish-brown to yellow, slightly compact, heavy loam to clay loam.

Has low agricultural value.

Derived from sandstones, sandy shales, and soft gray shales. Quantities of angular stones lie on the surface and in the soil mass. Comprises about 4,000 acres or 2.6% of the Project area. Thirty-five percent (35%) is on 25-40% slopes, 51% on 40%+ slopes; 70% is in 25-75% erosion class.

Found in association with Dekalb silt loam.

Dekalb Stony Sandy Loam

Normally the Dekalb stony, sandy loam has a light yellow or yellowish-gray sandy loam surface soil about 6 inches deep. Erosion has removed all but 1 to 4 inches of the surface soil as it is now mapped. The subsoil is lemon-yellow sandy loam to the full depth of the soil mass. Angular sandstone fragments in numbers sufficient to interfere with cultivation, lie scattered on the surface and in the soil mass.

Has low agricultural value.

Derived from sandstones, sandy shales, and soft gray shales of non-calcareous nature.

Found in association with other Dekalb soils.

Dekalb Sandy Loam

The surface soil is light gray to yellowish-gray sandy loam 1 to 4 inches deep. When uneroded it should be at least 6 inches deep. The subsoil is lemon-yellow sandy loam to the full depth of the soil mass.

This soil is similar to the Dekalb stony sandy loam except that stones in the soil mass are not numerous enough to interfere with cultivation.

Naturally of low fertility but responds to treatment.

It is widespread but mostly confined to the southern part of the Project area, comprising about 3,600 acres or 2.4%. Forty percent (40%) of it is on 25-40% slopes, 30% on 40%+ slopes, 70% is in 25-75% erosion class and 25% has lost over 75% of its topsoil.

Found in association with other Dekalb Soils.

C. Limestone, grayland -- Brooke.

Brooke Clay Loam

All of the Brooke clay loam within the Reedy Creek Project area has been cleared of timber, so that no true profile is available. It is probable that the A horizon may have been at least 10 inches deep in the uneroded state. The surface soil now consists of 4 to 6 inches of dark brown or dark grayish-brown clay loam or silty loam containing a considerable quantity of organic matter. The subsoil to a depth of 2 feet is chocolate brown, heavy silty, clay loam to clay, lighter in color, and more compact than the surface. This, in turn, is underlain by olive-gray plastic, tenaceous clay.

Derived entirely from limestone weathered in place.

Possesses high inherent fertility.

The Brooke clay loam is confined to a small area, about 1,800 acres or 1.2% of the total Project area, in the northwestern part. Fifty five percent (55%) of it is on 12-25% slopes, 25% on 25-40% slopes, 64% has lost less than 25% of topsoil and 34% is in 25-75% erosion class.

Occurs typically in the Northern Panhandle. Taylor, Wetzel, Marshall, Ritchie, Pleasants, Mason, Putnam, Hancock, Brooke, Ohio, Roane, Wood, Wirt, may be associated with Hagerstown soils in the eastern part of state.

D. Mixed limestone, sandstone and shale, light brown color -- Westmoreland.

Westmoreland Silty Clay Loam

The surface soil is light-brown or yellowish brown silt loam, and should be normally about 10 inches deep. Much of the A horizon has been washed away, and the silt loam surface soil is now found to be from 2 to 6 inches deep. This is underlain by brownish-yellow to yellow, fairly compact silty clay loam to about 24 inches depth. Below that, the subsoil takes on a pinkish cast and becomes clay loam, occasionally extending into ashy-gray limestone residue.

Derived from the disintegration of intimately interbedded limestone, sandstone and clay shale. Considered a strong soil.

The Westmoreland soil is found associated with the Brooke in the northwestern part of the Project area. It comprises about 2,800 acres or 1.8% of the total Project area. Thirty-nine percent (39%) of it occurs on 25-40% slopes, 31% on 40%+ slopes, 77% is in the 25-75% erosion class.

Occurs in association with Brooke and in Harrison, Marion, and Monongalis counties in association with the Hagerstown and Frankstown series.

Belmont Silty Clay Loam

It is probable that the Belmont silty clay loam originally had an A horizon of silt loam at least 10 inches deep. As it now occurs, the surface soil is 3 to 6 inches deep of yellowish-gray to brownish-gray silt loam, underlain in the upper subsoil by yellowish-brown slightly compact silty clay loam or clay loam. At 12 to 18 inches, the color changes to salmon pink, grading to red, compact, tenaceous clay in the lower subsoil. A few remnants of limestone lie scattered on the surface and in the soil mass, also angular fragments of sandstone appear.

Derived from interbedded limestone, sandstone and red calcareous shale.

Slightly less fertile than the Westmoreland Series.

It is closely associated with Westmoreland and Brooke in the northwestern part of the Project area, comprising about 2,000 acres, or 1.32% of the area. Twenty-six percent (26%) of the soil occurs on 12-25% slopes, 35% on 25-40% slopes, and 34% on 40%+ slopes, 68% falls in 25-75% erosion class, 17% has lost over 75% of its topsoil.

Occurs in association with Brooke and Westmoreland.

Upshur Clay

This soil was undoubtedly a silty clay loam in its original state. Probably all of the original A horizon has been eroded away, but subsequent treatment has resulted in the formation of 2 to 4 inches of dark chocolate-red clay loam surface soil. The subsoil is Indian-red plastic, tenaceous clay.

It is derived entirely from red clay shale of a calcareous character.

Naturally a strong soil but a narrow range of workability.

Small areas of Upshur clay are scattered throughout the Project area, the larger areas being confined to the southern part. It comprises about 2,000 acres, or 1.32% of the total Project area. Fifty-nine percent (59%) of the soil occurs on 12-25% slopes, 26% on 25-40% slopes, 60% of it falls in 25-75% erosion class and 33% has lost more than 75% of surface soil. Small areas have been totally destroyed for cultivation by gullying.

Occurs largely in Jackson, Clay and Braxton Counties but is also found in small areas throughout the State.

Lehew Silty Clay Loam

The Lehew is similar to both the Upshur and the Meigs. It is probable that this soil originally had a light red or pinkish silt loam surface soil several inches thick. The surface soil is now a light-brown, yellowish-red or pinkish silt loam 2 to 5 inches deep. The upper subsoil is light red silty clay loam to a depth of 12 to 20 inches. The deep subsoil is usually red clay.

Derived from sandstone which usually contains a quantity of iron and weathers red, the common red shale, and often the gray or greenish clay shale. Most of the parent materials forming Lehew are of a non-calcareous character.

Slightly less fertile than Upshur but possesses a broader range of workability.

Lehew occurs in small scattered areas, comprising about 2,000 acres, or 1.32% of the total Project area. Fifty-six percent (56%) of it is on 12-25% slopes, 29% on 25-40% slopes, 83% of Lehew is in the 25-75% erosion class, 12% has lost less than 25% and 5% has lost more than 75% of surface soil.

Found in association with Upshur and Meigs series.

II. COLLUVIAL DEPOSITION

This soil has no well developed profile. The surface layer is dark brown or reddish-brown yellow loam to a depth of 10 or 12 inches, grading into slightly compact, somewhat heavier loam to a silty clay loam of lighter brown color. In general the soil is being added to rather than eroded, although gullies appear and erosion is mapped largely on the basis of gullies. The soil usually represents the best of the materials washed from the steeper slopes above it.

Rates as one of the strongest agricultural soils in the Project Area.

This soil may occur at the bases of slopes anywhere in the area, comprising about 3,100 acres or 2.4% of the area. Two percent (2%) occurs on 4-12% slopes, 45% on 12-25% slopes, 78% is in 0-25% erosion, 10% in 25-75% erosion classes.

Occurs throughout State in small areas.

III. STREAM TERRACE SOILS

A. Gray surface, yellowish subsoil, mottled and generally poorly drained -- Tyler.

Tylor Silt Loam

This is yellowish-gray or gray friable and yellow silt loam 4 to 8 or more inches deep. The upper subsoil to a depth of 20 inches below the surface is light yellowish-brown slightly compact but friable heavy silt loam. The lower subsoil becomes more compact and heavier, ranging to light clay loam, light brown in color, and mottled with yellow, gray and rust brown. Iron concretions are commonly found within the soil mass.

Tyler is a second bottom or terrace soil, stream deposited at a time when the stream beds were at a much higher elevation than at present. It is derived mainly from wash from sandstone materials.

Not a fertile soil.

This soil comprises about 2,300 acres or 1.51% of the total Project area, 48% of it is on 4-12% slopes, 29% on 12-25% slopes, 21% has no apparent erosion, 46% has suffered slight erosion, 31% has lost 25-75% surface soil, and 2% has lost more than 75% surface soil.

Occurs along the larger streams which have received their wash from Sandstone areas.

Tyler Loam

This is similar in all respects to the Tyler silt loam except in texture. It consists of a light brown friable loam surface soil about 10 inches deep. The subsoil is a lighter brown, slightly compact gritty loam, ranging into more compact, deep loam, showing evidence of iron stains and mottles.

The type is associated with Tyler silt loam along the larger streams.

Slightly stronger than the Tyler Soils.

It comprises only a small part of the terrace formations.

Occurs in association with Tyler silt loam.

B. Light brown surface, yellowish subsoil -- Holston.

Holston Silt Loam

The surface soil is light brown to light yellowish-gray friable and mellow silt loam 3 to 8 inches deep. The subsoil is yellowish-brown friable silt loam to a depth of 18 or 20 inches below the surface. The lower subsoil is light reddish-brown heavy silt loam to silty clay loam. Drainage is usually good and mottles are usually absent.

Holston is a water deposited soil formed in the same manner as Tyler, mainly from the wash from sandstone material.

Rates favorably in fertility to the Tyler loam.

It is distributed mostly along the Little Kanawha River, comprising about 800 acres, or .52% of the total Project area, 10% of it is on slopes under 4%, 44% of Holston has lost up to 25% of its surface soil, 51% has lost 25-75% and 4% has lost more than 75% of its surface soil.

Occurs in association with Tyler soils but dominates in better drained positions.

IV. <u>FIRST BOTTOM SOILS</u>

A. Brown -- Pope

<u>Pope Silt Loam</u>

Pope silt loam is a recent deposition having no definite profile. It consists of a brown silt loam to a depth of 12 to 15 inches, grading into lighter brown and slightly more compact silt loam to the full depth of the soil mass. There is no decided change in structure or texture until a depth of about 4 feet is reached.

This type lies in narrow bands along the streams of the area, is derived from the wash from sandstone materials, is subject to frequent overflow, and is generally being added to by deposition.

Naturally fertile but usually acid in reaction. Responds to treatment.

It comprises about 7,000 acres, or 4.6% of the total Project area, 88% of it is practically flat, 12% is on slopes varying from 4-12%; 90% has no apparent erosion, and 10% has eroded slightly.

Occurs along streams which received their wash from Meigs and Dekalb areas.

<u>Pope Fine Sandy Loam</u>

This is identical with the silt loam of the same name except in texture. The texture is that of a fine sandy loam, brown in color, ranging with depth into lighter brown color and slightly more compact structure.

The deep subsoil contains enough clay to give it a sticky feel.

The material is non-calcareous wash, mainly from sandstones. It is associated with the Pope silt loam and is subject to the same conditions.

Occurs in association with Pope Silt Loam.

B. Red -- Moshannon.

Moshannon Silt Loam

The Moshannon is similar in all respects to the Pope Silt Loam except in color and derivation. To a depth of about 15 inches, the surface layer is a red silt loam. This grades into reddish-brown or brown, slightly more compact, silt loam. The surface sometimes bakes into clods if plowed in wet condition.

The soil is derived largely from wash from the red calcareous shale, and is itself apparently somewhat calcareous in character.

Naturally more fertile than the Pope Series. Less acid.

This type is usually associated with the Pope, occurs in narrow bands along the streams, and is subject to frequent overflow. It is relatively unimportant.

Occurs along streams which have received their wash from Upshur areas.

SECTION II

SOILS NOT OCCURRING IN THE REEDY CREEK SOIL EROSION CONTROL PROJECT #13 BUT FOUND IN OTHER PARTS OF WEST VIRGINIA.

I. UPLAND SOILS.

A. Limestone, or mixed limestone, sandstone, and shale land.

The Hagerstown soils are mainly silt loam and silty clay loam, with brown or reddish-brown surface soils, and reddish-brown friable clay subsoils. These are derived entirely from limestone and occur in Grant, Mineral, Jefferson, Berkeley, Morgan, Hampshire, Monroe, and probably in Greenbrier and Pocahontas Counties. The topography ranges from level to steeply rolling and the erosion is moderate to serious. These soils are considered naturally strong and productive.

The Frankstown series of soils are mainly silt loam and gravelly silt loam, having brown to yellowish-brown surface soils, underlain by yellowish-brown or yellow slightly compact silt loam to silty clay loam. They have been mapped in Grant, Mineral, Jefferson, Berkeley, and Morgan Counties. Mixed siliceous limestone and sandstone are the chief materials from which these soils are derived. The topography ranges from gently undulating to hilly. The soils have a high absorptive capacity and the erosion is moderate. In productiveness, these soils compare favorably with the Hagerstown soils.

The Frederick soils are light-gray to yellowish-brown silt loam, underlain by yellow or reddish-yellow compact silt loam or silty clay loam, becoming red clay in the deep subsoil. These soils are derived from cherty or flinty limestone, and are found associated with the Hagerstown and Frankstown soils in Jefferson, Berkeley, Morgan, and Mercer Counties. The topography is generally rolling and the erosion is moderate to severe. These are not considered to be quite as productive as the Hagerstown soils.

The surface soil of the Decatur clay loam is red to reddish-brown mellow clay loam, underlain by heavy red clay. Both surface and subsoil are mellow when dry but sticky and tenaceous when wet. It is derived from the weathering in place of massive blue limestone, and is confined to the eastern part of the Shenandoah Valley in Jefferson County. The topography is rolling, erosion is moderate, and the soil is considered to be very productive.

B. Sandstone and shale land.

The Tilsit series of soils have grayish-brown to yellowish-brown silt loam and very fine sandy loam surface soils, and brownish-yellow heavy silt loam or silty clay loam subsoils. Soft rust-brown iron concretions in abundance in the subsoil below 15 inches are characteristic of the series. The deep subsoil is mottled brown and gray, compact silty clay loam. These soils were mapped in Mercer, Monroe, and Summers Counties. The topography is smooth to undulating and the erosion moderate to severe. These are naturally poor and unproductive soils.

The Berks series of soils includes the shale loam and silt loam types. The surface soils are grayish or yellowish-brown silt loam containing varying quantities of partially disintegrated shale. The subsoil is light yellowish-brown or yellow, friable and slightly compact silt loam. These soils are derived from the weathering in place of Martinsburg shale and are found mainly in Jefferson, Berkeley, and Morgan Counties. The topography is smoothly rolling and the soil is moderately eroded. In productiveness, it ranges from fair to poor.

2. Stream Terrace Soils

Soils of the Monongahela series consist of silt loam and fine sandy loam types. The surface soils are grayish-brown or light-brown and the subsoils are light yellowish-brown to pale yellow. In all types, the subsoil ranges into mottled yellow, gray and rust-brown material of much heavier texture than the surface soil. These soils occupy terraces or benches at considerable elevation above the first bottoms bordering the streams. The topography is nearly level to gently rolling, and the erosion slight to moderate. The natural productiveness is fair. These soils have been mapped in Hampshire, Monroe, and Summers Counties.

The soils of the Wheeling series include the following types: gravelly loam, sandy loam, fine sand, fine sandy loam, silt loam, and silty clay loam. The surface soils are generally light-brown to brown, and the subsoils are yellowish-brown to yellow. All types are compact but friable in the subsoil, and frequently beds of gravel are encountered. These soils occur as second and third bottoms, or terraces, bordering the Ohio River wherever it contacts the state. The material is largely derived from wash from the glacial soils at the headwaters of the river. The topography is level to slightly rolling, erosion is slight, and the land is considered valuable for general and truck crops.

The Elk series have surface soils of light-brown or yellowish-brown silt loam or loam of friable and mellow structure, underlain by yellow, friable silt loam to silty clay loam, varying to sandy loam and gravelly loam in the different types. These are river terrace soils and frequently a part of the subsoil is of residual origin. It has been mapped in Monongalia County, principally in the Monongahela River Valley. The topography is gently rolling and the erosion is slight. Crop yields are fair.

3. Stream Bottom, or Recent Alluvial Soils.

The surface layer of the Huntington series of soils is dark-brown mellow silt loam or loam about 15 inches thick, underlain by lighter brown loam to clay loam. This is a first bottom soil, subject generally to overflow, but well drained. The material is derived principally from wash from soils which are derived in turn from limestone or mixed limestone and sandstone. The topography is usually flat and the erosion negligible. This is considered one of the richest soils.

The surface soils of the Holly series are gray silt loam, and the subsoils mottled gray, yellow, and brown heavy silt loam or silty clay loam. These are first bottom soils, subject to overflow and poorly drained. The material is derived from wash from sandstone and shale land. It has been mapped in McDowell County. The topography is level and the erosion negligible. The soil has a fair productive capacity, most of it being in pasture.

The surface soils of the Atkins series are dark grayish-brown heavy silt loam, over a subsoil of steel gray silty clay loam, ranging into mottled light-gray, yellow and rusty-brown sticky clay. It is poorly drained first bottom soil, associated with soils derived from the wash from sandstone and shale material. These soils have been mapped in Grant, Mineral, Hampshire, Barbour, Upshur, Summers, Monroe, Nicholas, Tucker, Mercer, and Webster Counties. The topography is flat and erosion is negligible. Most of the type is in pasture, being too poorly drained to farm successfully.

Other soils occurring within West Virginia, which are not of sufficient extent or agricultural importance to warrant more than mention here, are listed below.

Muck
Dunning Silty Clay Loam
Lowell Silty Clay Loam
Lowell Stony Silt Loam
Lickdale Silty Clay Loam
Lickdale Loam

Colbert Silt Loam
Clarksville Gravelly Silt Loam
Shelbyville Silt Loam
Summers Stony Loam
Summers Loam
Lindside Silt Loam
Elliber Gravelly Loam

SOIL CONSERVATION SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE

PROJECT #13 SPENCER, WEST VIRGINIA

P A R T   T H R E E

HYDRAULICS OF EROSION CONTROL STRUCTURES

CHAPTER VII

RUNOFF CONSIDERATIONS

In order to prevent the washing out of engineering structures it is necessary to provide adequate spillway capacity to take care of the runoff water for the drainage area above the dam in question. The rate of runoff from a drainage area depends upon the intensity and duration of the rainfall, shape and size of the area, slope, character of the soil, season of the year and type of vegetation covering the area.

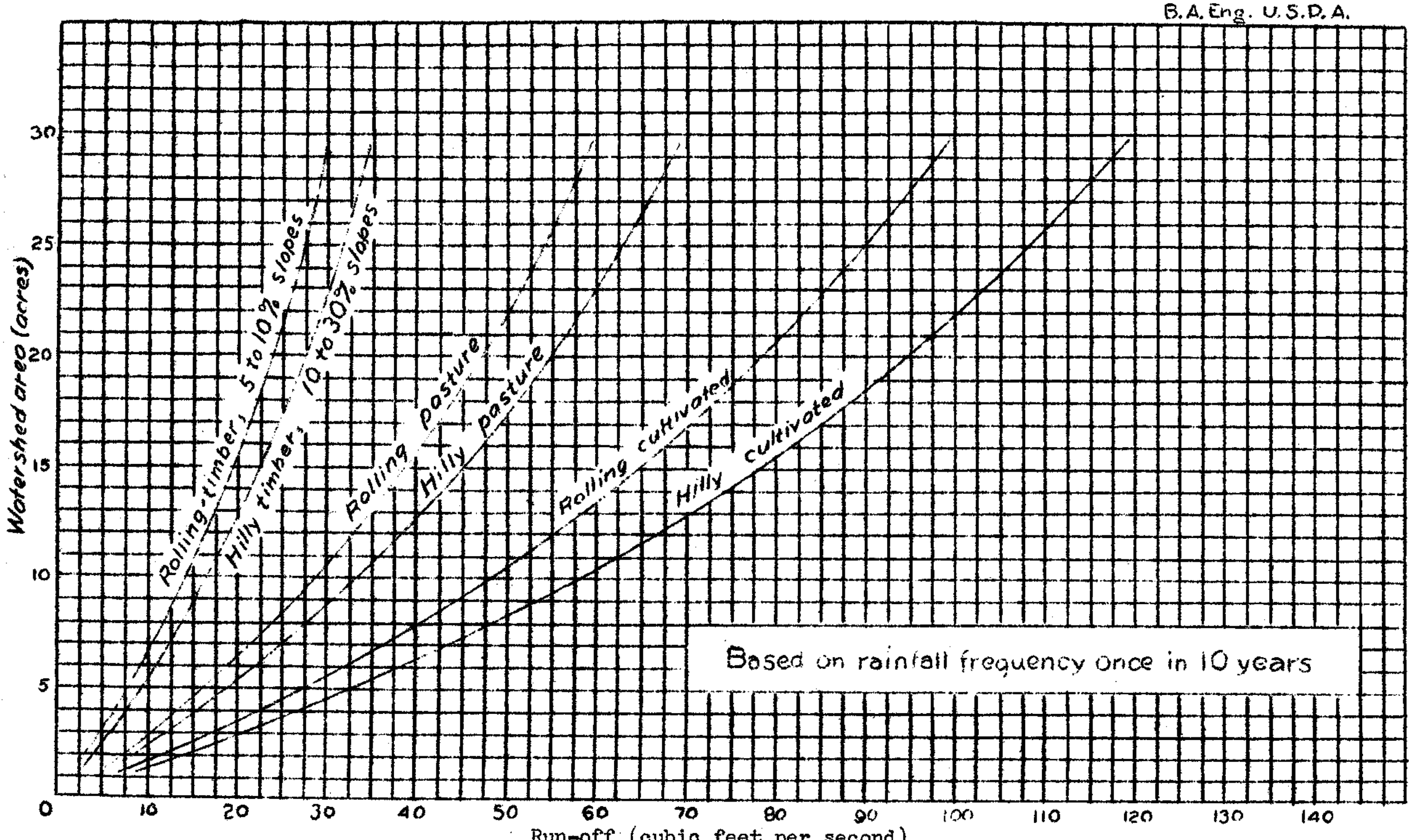
In a general way the intensity of precipitation varies inversely with the duration of the downpour or in other words very heavy showers do not last as long as rains of lesser intensity. For this reason the maximum flow of runoff water reaching a spillway area usually occurs when water from the most distant point of the drainage area reaches the dam spillway.

Probably the most reliable information concerning the runoff from agricultural areas has been compiled by C. E. Ramser, Senior Drainage Engineer, U. S. Department of Agriculture. His Runoff Chart from Small Agricultural Areas (based on a rainfall frequency of 10 years) gives the maximum rate of runoff in cubic feet per second that may be expected during a ten year period for these areas. This chart may be used in the design of dam structures of an expected life of ten years or less. (Chart #4, page 38).

The rates of runoff from Ramser's Charts are based on watersheds located in the area falling in group 3. (Chart #8, page 45).

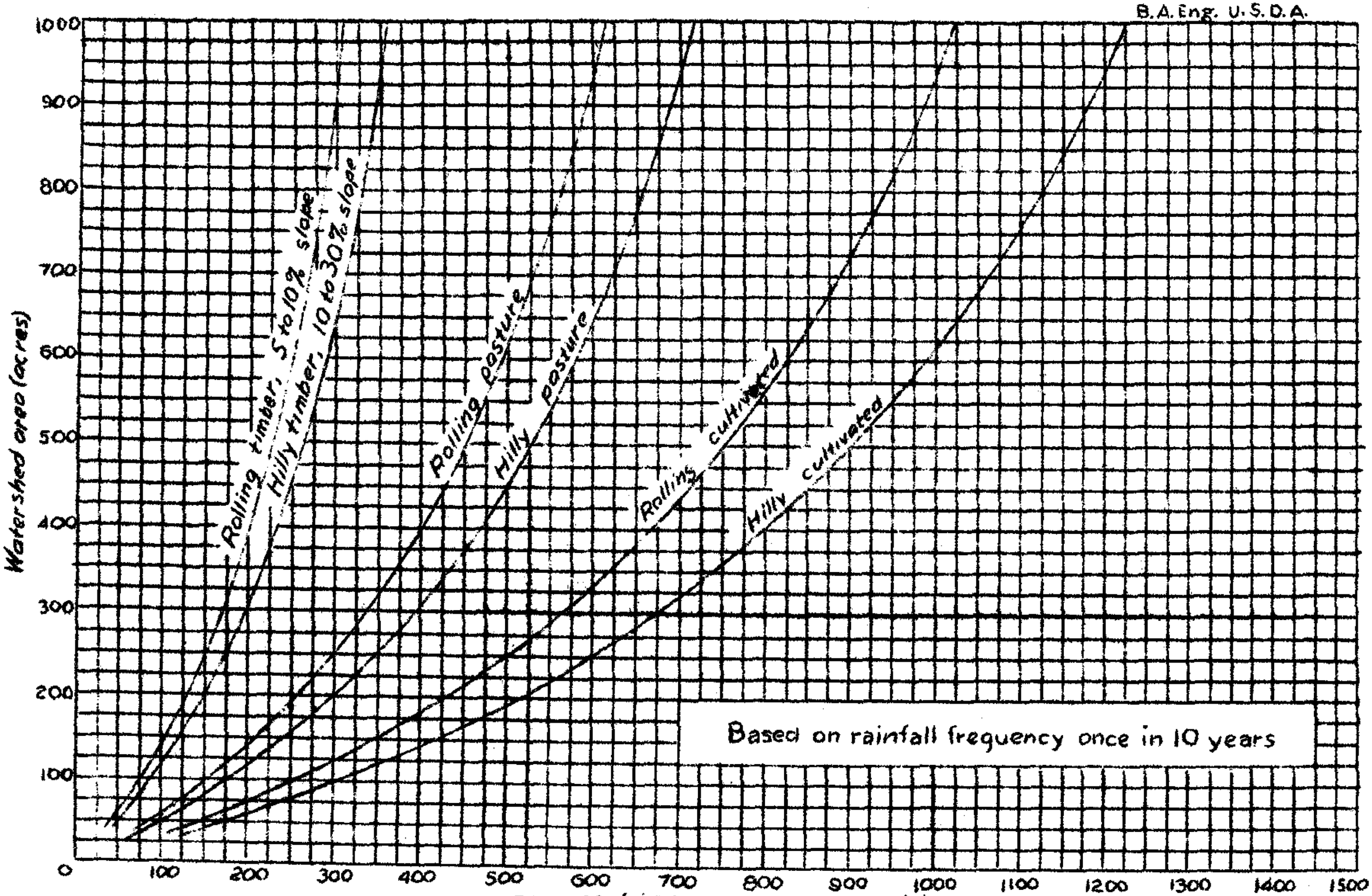
Other Ramser charts included in this Handbook for use in structure design are: Runoff from Large Agricultural Areas, Chart #5, page 39,(10 year frequency) and Runoff from Large Agricultural Areas, Chart #6, page 40, (50 year frequency. The curves based on a rainfall frequency once in 50 years should be used in the design of dam structures of a permanent nature.

In computing runoff for watersheds in West Virginia it should be kept in mind that much of the land has been cleared, is very steep, and has frequently been so heavily pastured as to be almost entirely denuded of vegetation. These conditions all contribute toward a very high rate of runoff. The shape of a watershed also materially affects the runoff. Under ordinary conditions we can assume that the charts by Ramser included hereunder are of sufficient accuracy in computing runoff for small areas wherein temporary check dams are being placed in erosion control. Where more permanent structures are to be placed and where the watershed is large it is recommended that the rational method of computing runoff be



Rates of run-off from timber, pasture, and cultivated watersheds for area group No. 3 shown

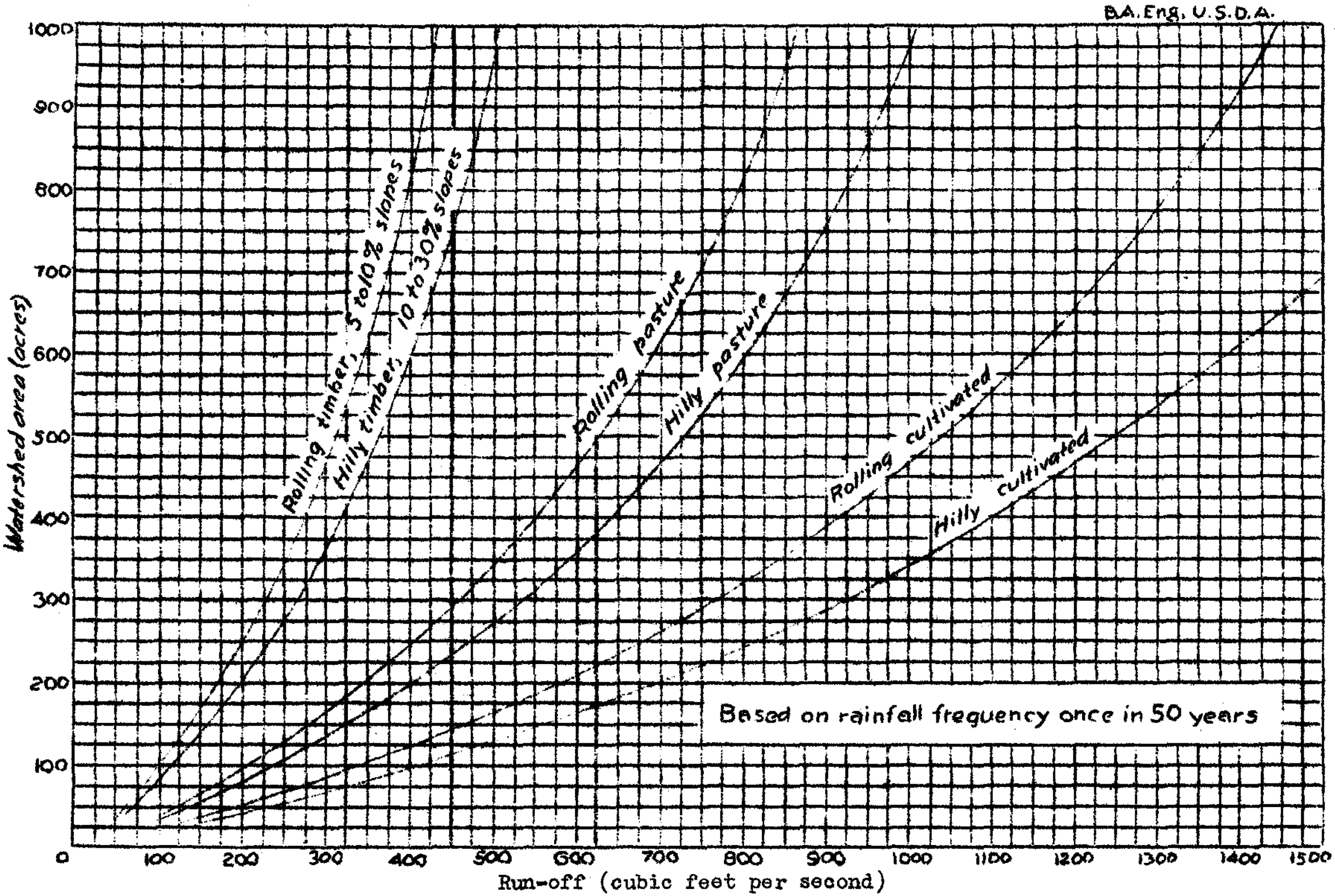
Chart 4



Run-off (cubic feet per second)

Rates of run-off from timber, pasture, and cultivated watersheds for area group No. 3 shown

Chart 5



Run-off (cubic feet per second)

Rates of run-off from timber, pasture, and cultivated watersheds for area group No. 3 shown

Chart 6

used. This method enables the engineer to apply judgment directly to specific allowances which are subject to analysis, measurement, and estimate. The rational method is based on the direct relation between the rainfall and runoff expressed by the formula,

$$Q = c\ i\ A$$

where Q = runoff in c.f.s. from the area
c = ratio of runoff to rainfall
i = intensity of rainfall in c.f.s. per acre (approximately the equivalent of inches of rain per hour)
A = drainage area in acres.

Of these factors, A can be measured directly but the others must be estimated. i depends on the curves developed for intensity of rainfall and on the time it takes to establish runoff and flow from the most distant point in the area to the place for which the runoff is being computed. Provision must be made for the greatest intensity of rainfall lasting for that time. A study can be made of the time frequency curves as indicated on Chart #7, page 42, which was compiled from data collected at Parkersburg, West Virginia. If data be available similar curves may be developed for local areas. Such data should cover a period of at least 20 consecutive years to be of much value. Once the curves for intensity of rainfall are available, an estimate of the time required to establish runoff must be made in order to arrive at the greatest intensity of rainfall lasting over that time. The estimate should be based on a well developed and carefully considered plan. All assumptions of necessity must be on the conservative side.

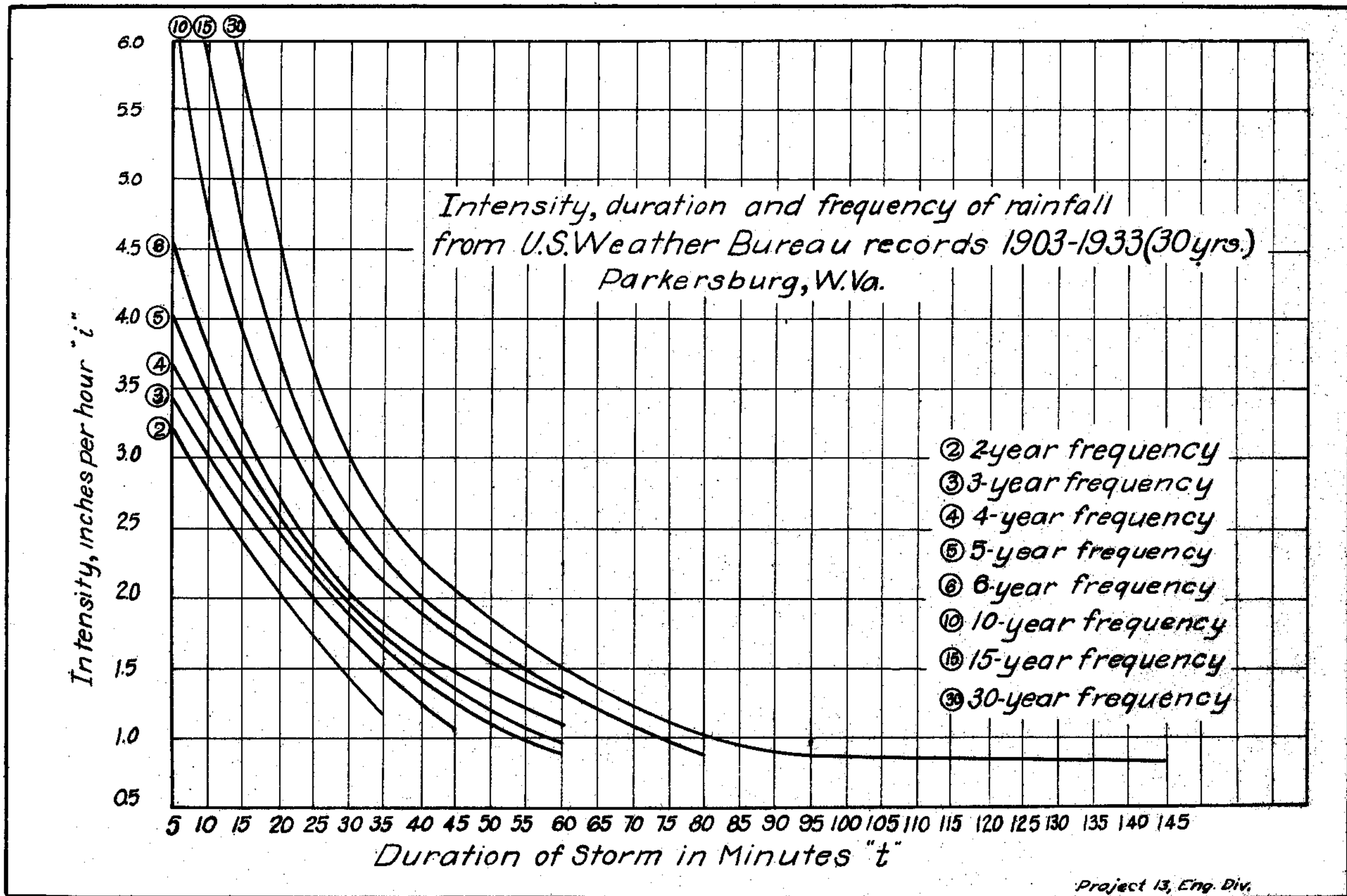
c- ratio of runoff to rainfall - must be determined from a study of soil, character of the surface, vegetation, slope, and probable future developments. The factors affecting runoff can well be grouped under two major heads:

1. Precipitation
2. Watershed characteristics

The effect of precipitation on runoff is much easier to evaluate, other things remaining constant. We know that the coefficient of rainfall distribution may deviate greatly from unity in large areas. Here we are on the safe side by assuming maximum or near maximum precipitation over the entire watershed.

In considering watershed characteristics it is well to consider that some factors tend to hasten and others to retard the flow of the water. It is almost impossible to rank them in order of their importance. The more important characteristics will be enumerated as far as they pertain to drainage sheds feeding the streams on which work may be done.

(a) Size of watershed - On large watersheds floods reach their crest slowly and subside slowly. The reverse is true for small watersheds,



Intensity, duration and frequency of rainfall
from U.S. Weather Bureau records 1903-1933 (30 yrs.)
Parkersburg, W.Va.
Intensity, inches per hour "i"
Duration of Storm in Minutes "t"
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145
② 2-year frequency
③ 3-year frequency
④ 4-year frequency
⑤ 5-year frequency
⑥ 6-year frequency
⑩ 10-year frequency
⑮ 15-year frequency
㉚ 30-year frequency
Project 13, Eng. Div.

Chart 7

as intense precipitation occurs over small areas only. Small watersheds may consist entirely of steep slopes and impervious soil, causing most of the precipitation to run off over the surface with resultant high concentration of flow. The ratio of runoff to rainfall will generally also be high where intense precipitation occurs.

(b) Shape of watershed - shape of watershed affects rate of runoff rather than ratio, though both are affected. A long narrow drainage area is likely to have a lower rate of runoff than one which is more compact. The tributaries will feed the main stream in a series of small flood crests. Generally the long watershed will not be entirely covered by intense precipitation at one time, which tends to keep down floods.

In the more compact watershed the tributaries will feed their crests into the main stream at more nearly the same time and they are also more apt to be covered entirely by intense precipitation at one time. It can further be stated that the ratio of runoff to rainfall will be higher under such conditions.

(c) Geology of watershed - the nature of the soil has marked effect upon both rate and quantity of runoff. A loose soil of sand, gravel, or loam will absorb a large proportion of the precipitation. More impervious soils like clay or even rock will have a very high runoff.

(d) Topography of watershed - it can generally be said that the greater the slope the greater the amount of runoff. Watersheds with steeply rolling slopes will produce more frequent and greater floods than the more level areas. Both rate and quantity of runoff are vitally affected by topography.

(c) Vegetation on watershed - vegetation increases percolation opportunity by opening up the soil and by retarding velocity of the surface flow. These factors tend to decrease the rate and quantity of runoff. Such is especially true for storms of comparatively short duration. After the ground has become well soaked or packed, however, vegetation does not exert so great an influence as is often thought. It will still continue to aid in preventing gully and sheet erosion but the quantity of runoff will not be so materially affected.

(f) Cultivation and artificial structures - it is known that runoff from a cultivated field on which the top soil has been well loosened and on which farming has been done along contours is frequently less than from an uncultivated field because the loose soil particles tend to retain moisture. Such is not true, however, after the humus in the soil becomes exhausted and where farming operations are so carried on as to induce erosion.

Any fair sized reservoir or pool created by a dam will tend to retard runoff for rains of short duration. Once a reservoir has been filled it will no longer equalize flood-crests.

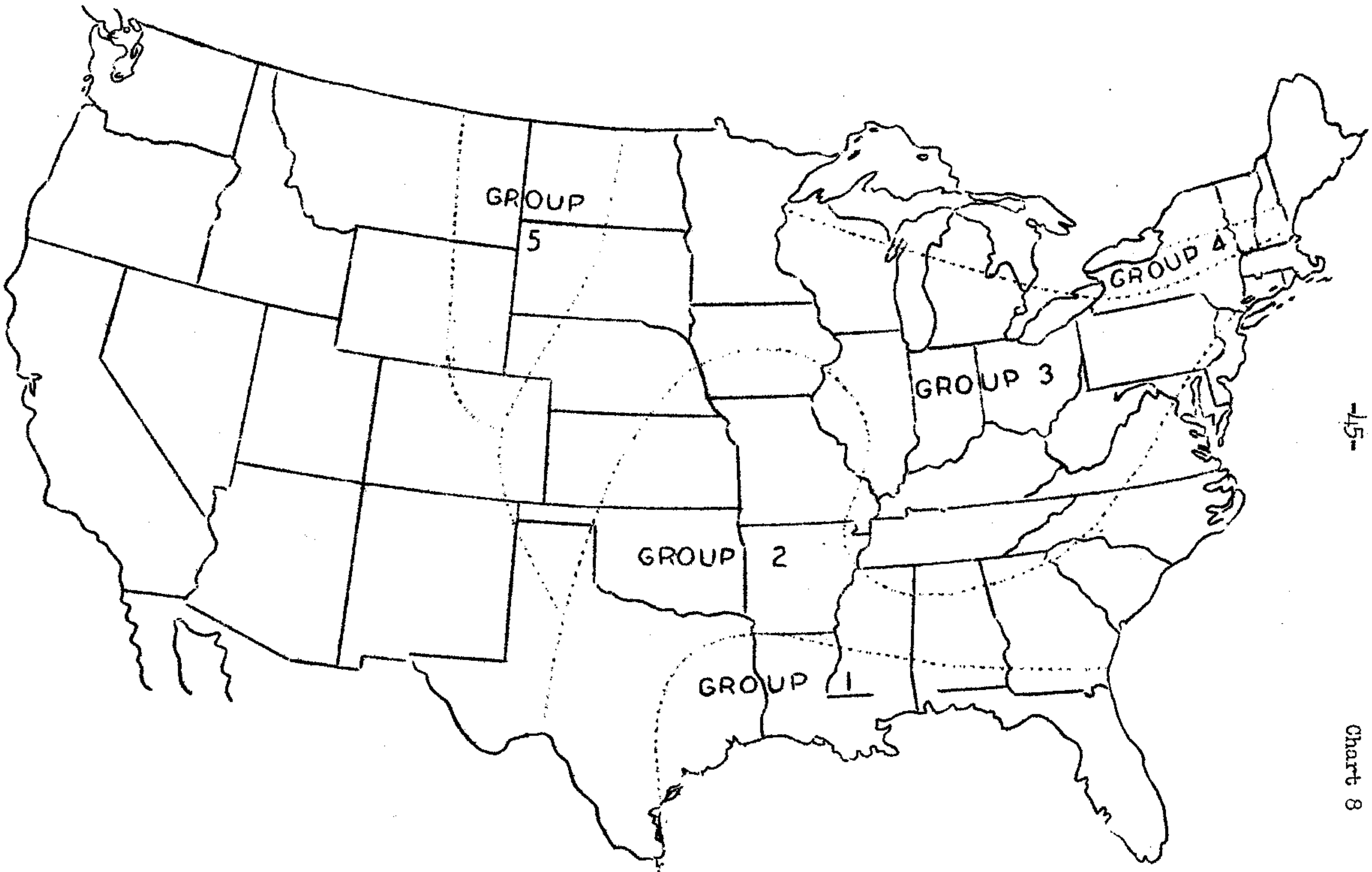
It should be kept in mind for the rational method of computing runoff that fairly accurate results cannot be obtained therefrom when extremely large watersheds are being considered. Too little as yet is known of the various runoff factors as applicable to extensive areas.

A word should also be said regarding future runoff. It is entirely possible that within a year, or two years, a watershed may have its surface covering changed from corn to close growing clover. Provision in design should be made for such possibilities to warrant future success. When examining rainfall curves in connection with design work on watersheds the size of the watershed should be kept in mind to assist in determining the character of storms. Intense precipitations lasting for less than a day are worthy of consideration on watersheds under 125 square miles. On larger drainage areas the storms lasting for several days are the more disastrous. Where no information of any kind is available the engineer must resort to high water marks or to a careful study of storms over similar watersheds. If such be done it is important that these watersheds be located as nearly as possible in areas having similar rainfall intensities. West Virginia would fall under group three. (Chart #8, page 45).

Mr. Ramser makes the following recommendations in regard to the watershed survey preliminary to using his charts:

"A reconnaissance survey should be made of the watershed to determine whether it should be classified as rolling or hilly, to determine approximate acreage of cultivated, pasture, and timber lands, and to determine the size of the watershed area in acres. The growing tendency is to place more land in pasture or timber so that ordinarily it would be safe to assume that the proportion of pasture and timber area would not be reduced. However, if definite information is available that it is the intention to clear for cultivation to pasture or to utilize as timber land, then proper consideration should be given this matter in classifying the lands of the watershed.

"The area of the watershed can often be closely determined from the location of land lines and by pacing any distances required. Where this is not possible, the area can be determined approximately by a compass traverse, using the pacing method to obtain distances. The traverse should be plotted with a protractor and the area computed with a planimeter. Where a transit is available, a quick stadia traverse survey can be made for a small watershed because the bearings and distance to points on the boundaries of the watershed area can be determined from one location of the transit."



BOUNDARIES OF AREAS OF SIMILAR RAINFALL INTENSITIES FOR SHORT PERIODS. (From Meyer's Hydrology)

Chart 8

Very frequently on a small watershed it will be possible to make a mental estimate as to extent of area. Where the area covers about 1 to 5 acres it should be possible to estimate the acreage to within 10% of the exact value which is close enough for ordinary purpose. Where such are available, use should be made of existing maps and previous surveys. These will often save a great deal of field work.

In all watershed surveys it is important that the entire area be covered in order that the topography become familiar to the surveyor. Where estimates are made of very small watersheds on steep slopes it is suggested that the actual surface on the slope be used rather than the horizontal projection of the same area. By doing this the engineer will have a conservative value on which to base runoff.

CHAPTER VIII

HYDRAULICS

To properly design erosion control structures a working knowledge of the theory and practice of hydraulics is required. Hydraulic principles are used in computing the runoff water from drainage areas, designing the weir notches in dam structures, computing the proper sizes for diversion ditch channels and outlets, and in designing adequate terraces with outlet channels sufficient to carry maximum runoff.

Mr. H. L. Cook, Hydraulic Engineer, Soil Conservation Service, has developed a very complete set of diagrams for use in hydraulic design of erosion control structures. These diagrams are included as part of this handbook and may be used in design problems. The uses of Mr. Cook's diagrams are explained by him on pages 47 to 51 inclusive. However, to facilitate their use in the field, type problems will be assumed and worked out according to Mr. Cook's diagrams and instructions. These type problems follow Mr. Cook's discussion and are found on pages 51 to 54 and 71 to 73 inclusive.

USE OF DIAGRAMS IN HYDRAULIC DESIGN

Figures 1, 2, 3, 4, Pages 58,59,61,63.

These diagrams are for use in the design of small open channels of trapezoidal cross-section. They are based upon the Manning formula:

$$Q = \frac{1.486}{n} A R^{2/3} S_b^{1/2}$$

Each figure is for a section of given side slope, thus:

Figure	Side Slope or Batter
1	Vertical sides
2	1 to 1
3	1.5 to 1
4	2 to 1

The notation employed is:

Q = rate of flow in cubic feet per second (CFS)
D = depth of water above bed in feet
b = width of bed in feet
A = area of cross-section of water in square feet

R = hydraulic radius or A divided by "wetted perimeter": feet
S_b= slope of channel bed
n = value of "roughness coefficient" in Manning formula
(See Table II, Page 55)

To use any diagram proceed as follows:

1. Having given Q, S_b and n, compute the quantity $\frac{nQ}{1.486\sqrt{S_b}}$

2. If a channel with a particular bed width - depth ratio is desired, find the intersections of a vertical line through the chosen b/D with a horizontal line through the computed value of $\frac{n\,Q}{1.486\sqrt{S_b}}$. The number on the curve lying nearest this intersection indicates the approximate depth at which the water will flow in a channel of the required proportions. If desired, interpolation between the curves may be used to establish the depth more closely.

3. If a channel of given depth is desired, find the intersection of the curve marked with this depth and a horizontal line through the value of $\frac{n\,Q}{1.486\sqrt{S_b}}$. The value of b/D vertically below the intersection gives the relative proportions of the channel.

Example: Side slope 1.5 to 1
Q = 10 CFS, S_b = .01, n = .04

$$\frac{nQ}{1.486\sqrt{S_b}} = 2.69$$

b/D (Assumed)	D	b	
0	1.53	0	(Triangular section)*
.61	1.50	.79	(Most efficient sec.)*
5	0.78	3.9	
10	0.60	6.0	(Widest section)

Anyone of the channels described above will carry 10 CFS. The final choice of dimensions would be based upon attendant circumstances.

To simplify the computations required in the application of the diagrams, Table III, Page 56, giving values of the quantity $1.486\sqrt{S_b}$, may be used.

It is recommended that channels designed for flood flows be proportioned so that b/D does not exceed 10.

*These sections to be used only where channel is lined.

Figures 2-A, 3-A, 4-A, pages 60, 62, 64

From these diagrams may be obtained the cross-sectional areas of the channels designed by use of Figures 2, 3 and 4, pages 59, 61 and 63.

It is necessary to have these areas to compute the velocity, V, that will exist in the designed channel. V is easily computed from

$$V = Q/A$$

Each area diagram immediately follows the design diagram for the same side slopes. An area diagram for rectangular channels is omitted, since the area is simply computed from $A = bD$.

Figure 7, page 65

This diagram provides approximate values of the weir coefficient, C, for rectangular weirs having broad, level crests. The standard formula used to calculate the discharge of such weirs is

$$Q = CLH^{\frac{3}{2}}$$

in which

H = head on crest of weir, in feet, measured about 6 feet upstream
L = length of crest of weir in feet
B = breadth of crest of weir in feet

The diagram should be used only for heads greater than 0.5 feet.

If the desired H and B for use in design are known, the ratio H/B is computed and the diagram entered to find C without further effort. If H is unknown it is necessary to employ a process of "cut and try". For the first trial a tentative ratio is estimated and C taken from the diagram. Using Figure 9, page 67, the value of H corresponding to the chosen C is found and the value of H/B recomputed. With this corrected ratio Figure 7, page 65, is again entered and C redetermined. After two or three trials H and C may be brought into sufficiently close agreement.

Figure 8, page 66

The values of C given by this diagram are to be used only for rectangular notches on the crests of vertical falls. The values of C given by the diagram are conservative, that is, slightly smaller than those that would probably be found by experiment. They apply only for values of H greater than 0.5 feet.

The manner of using this diagram is obvious. In design it is often necessary to proceed by "cut and try" in a manner somewhat similar to that described in discussing Figure 7.

<u>Figure 9 page 67</u>

Diagrams of this nature are called alignment charts or nomographs. They are used as follows:

> Having given two of the variables, they are located on their respective axes and a straight edge passed through them; the value of the unknown variable is read at the intersection of the straight edge with the third axis.

Figure 9 is used for the solution of the equation

$$Q_1 = CH^{\frac{3}{2}}$$

where Q_1 represents the discharge of a rectangular weir <u>per foot</u> of weir crest. To use the diagram divide Q by L to find Q_1, decide upon the proper value of C and determine H from the chart. To determine L it is best to proceed by trial, assuming several values of L and finding the values of H corresponding to each. The desired combination of H and L may be found by interpolating between these trial values. It should be remembered that

$$L = Q/Q_1$$

<u>Figure 10 page 68</u>

This is an alignment chart for the solution of the equation

$$Q = 3.33\ LH^{\frac{3}{2}}$$

When the weir coefficient C is in the neighborhood of 3.33 this diagram may be used to find L or H directly, and without recourse to Figure 9, page 67. The chart is also useful in preliminary design and in finding tentative values of H and L with which to enter Figure 9.

<u>Figures 15 and 16 pages 69 and 70</u>

On these diagrams are curves giving values of the culvert coefficient C_o in the formula

$$Q = C_o A\sqrt{2gh}$$

A sufficient number of curves are given to cover the types of culverts in ordinary use.

Values of C_o taken from these diagrams should be used only for <u>submerged culverts,</u> that is, for culverts operating with both ends under

1. Compute $\frac{nQ}{1.486\sqrt{S_b}}$ (Table III may be used) Page 56.

2. If a channel with a particular "bed width to depth" ratio (b/D) is desired, find the intersections of a vertical line through the chosen b/D with a horizontal line through the computed value of $\frac{n\,Q}{1.486\sqrt{S_b}}$

The number on the curve lying nearest this intersection indicates the approximate depth at which the water will flow in a channel of the required proportions.

3. If a channel of given depth is desired, find the intersection of the curve marked with this depth and a horizontal line through the value of $\frac{nQ}{1.486\sqrt{S_b}}$. The value of b/D vertically below the intersection gives the relative proportions of the channel.

4. After a b/D value is decided upon, the area of the channel may be determined from the area diagram following the dimension diagram for the various side slopes.

5. Divide the discharge by the cross sectional area to determine the velocity. $V = \frac{Q}{A}$

Computations for Type Problem No. 1 are given below:

Q = 10 (Ramser's Chart No. 4, page 38)

n = .04 (Table II, Page 55)

S_b = .014 (assumed)

$$\frac{nQ}{1.486\sqrt{S_b}} = \frac{.04 \times 10}{.1758} = 2.28$$ (use Table III Page 56).

b/D	D	b	Cross Section Area*	Velocity
1	1.13	1.13	2.6	3.85
2	.96	1.92	3.2	3.13
3	.85	2.55	3.3	3.03
4	.78	2.34	3.3	3.03

*Figure 3-A page 62.

Any of the above channels will carry 10 cubic feet per second. The final choice of dimensions will depend upon field conditions. However, a depth ratio b/D of 2 or 3 should prove satisfactory under ordinary conditions.

TYPE PROBLEM NO. 2

DESIGN OF A TERRACE OUTLET CHANNEL

STEPS IN THE DESIGN

1. Determine the drainage area of the terraces emptying into the outlet channel.

2. Determine the maximum rate of runoff from the area likely to occur during a ten year period by the use of the suitable Ramser 10 year frequency Runoff Charts (Chart #4 or #5, Pages 38 and 39).

3. Design a channel of sufficient capacity to pass this rate of runoff when the channel lining has attained its ultimate condition, by the use of Mr. Cook's tables for open channel design. This design will be similar to type problem No. 1 with the exception that a higher b/D value may be used. It is recommended that the maximum b/D value used does not exceed a value of 10.

4. Determine the velocity of flow that will exist in the channel so designed by the use of the proper Cook table. If the velocity is found to exceed 5 feet per second for channels protected by vegetation or 3 feet per second for unvegetated channels investigate the possibility of broadening the channel to reduce the velocity to an allowable figure. However, the maximum b/D value should generally not exceed 10.

5. In case no feasible broadening of the channel will bring about sufficient velocity reduction, permanent protection of the channel must be provided by suitable structures.

6. If permanent protection is not required after the channel has reached its ultimate condition a study should be made to determine the maximum velocity that could exist when the channel is new or in such condition as would cause the flowing water to attain its maximum velocity.

7. If the velocity in 6 above is found to exceed 3 feet per second, suitable temporary structures should be provided to protect the channel from excessive erosion until it has sodded over.

Example:

Rolling cultivated land

Drainage area = 12 acres

Referring to Ramser's Chart No. 4, page 38, we find the probable maximum runoff to be expected over a ten year period to be 55 cubic feet per second.

Slope S_b = .04 (4 feet in 100)

n = .04 (Table II, Page 55)

Ditch sides slopes $1\frac{1}{2}$ to 1

$$\frac{nQ}{1.486\sqrt{S_b}} = \frac{.04 \times 55}{.2972} = 7.41$$ (Use Table III, Page 56)

b/D	D	b	Cross Section Area*	Velocity
2	1.5	3.0	8	6.9
8	1.0	8.0	9.5	5.8
10	0.9	9.0	9.4	5.9

*Figure 3-A, Page 62.

In the above computations a b/D value of 2 was first used. This gave a velocity of 6.9 feet per second. The channel was then widened to a b/D value of 8 and 10. The widening of the channel reduced the velocities to 5.8 and 5.9 feet per second respectively. Since the velocity was not reduced below 5 feet per second, permanent protection of the channel must be provided by means of suitable structures.

TABLE II

COEFFICIENT n IN THE MANNING FORMULA

Description of Channel Lining	Value of n
LINED CHANNELS	
Planed plank	.012
Unplaned plank	.014
Concrete	.015
Good rubble masonry	.020
Rough rubble masonry or dry rubble (rip-rap)	.025
Rough rip-rap	.030
UNLINED CHANNELS IN EARTH	
In excellent condition; no weeds or debris	.02
Ordinary condition; low vegetation or gravel	.03
Poor condition; weeds, tall grasses or rough bottom	.04
Very poor condition; choked by weeds or willows	.05

TABLE III

Slope S_b	$\sqrt{S_b}$	$1.486\sqrt{S_b}$	Grade %
.0005	.0224	.0332	0.05
.0010	.0316	.0470	0.10
.0015	.0387	.0576	0.15
.0020	.0447	.0664	0.20
.0025	.0500	.0743	0.25
.0030	.0548	.0814	0.30
.0035	.0592	.0879	0.35
.0040	.0632	.0940	0.40
.0045	.0671	.0997	0.45
.0050	.0707	.1051	0.50
.0055	.0742	.1102	0.55
.0060	.0775	.1151	0.60
.0065	.0806	.1198	0.65
.0070	.0837	.1243	0.70
.0075	.0866	.1287	0.75
.0080	.0894	.1329	0.80
.0085	.0922	.1370	0.85
.0090	.0949	.1410	0.90
.0095	.0975	.1448	0.95
.010	.1000	.1486	1.00
.011	.1049	.1559	1.10
.012	.1095	.1627	1.20
.013	.1140	.1694	1.30
.014	.1183	.1758	1.40
.015	.1225	.1820	1.50
.016	.1265	.1880	1.60
.017	.1304	.1938	1.70
.018	.1342	.1994	1.80
.019	.1378	.2048	1.90
.020	.1414	.2101	2.00
.025	.1581	.2349	2.50
.030	.1732	.2574	3.00
.035	.1871	.2780	3.50
.040	.2000	.2972	4.00
.045	.2121	.3152	4.50
.050	.2236	.3323	5.00
.055	.2345	.3485	5.50
.060	.2449	.3639	6.00
.065	.2550	.3789	6.50
.070	.2646	.3932	7.00
.075	.2739	.4070	7.50
.080	.2828	.4202	8.00
.090	.3000	.4458	9.00
.10	.3162	.4699	10.00
.11	.3317	.4929	11.00
.12	.3464	.5148	12.00
.13	.3606	.5359	13.00
.14	.3742	.5561	14.00
.15	.3873	.5755	15.00
.16	.4000	.5944	16.00
.17	.4123	.6127	17.00
.18	.4243	.6305	18.00
.19	.4359	.6477	19.00
.20	.4472	.6645	20.00

TABLE VIII

TABLE OF $V = \sqrt{2gh}$

Value of h	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
0	0.00	2.54	3.59	4.39	5.07	5.67	6.21	6.71	7.17	7.61
1	8.02	8.41	8.79	9.14	9.49	9.82	10.14	10.46	10.76	11.05
2	11.34	11.62	11.90	12.16	12.42	12.68	12.93	13.18	13.42	13.66
3	13.89	14.12	14.35	14.57	14.79	15.00	15.22	15.43	15.63	15.84
4	16.04	16.24	16.44	16.63	16.82	17.01	17.20	17.39	17.57	17.75
5	17.93	18.11	18.29	18.46	18.63	18.81	18.98	19.15	19.31	19.48
6	19.64	19.81	19.97	20.13	20.20	20.45	20.60	20.76	20.91	21.06
7	21.22	21.37	21.52	21.67	21.81	21.96	22.11	22.26	22.40	22.54
8	22.68	22.83	22.97	23.11	23.24	23.38	23.53	23.65	23.79	23.93
9	24.06	24.19	24.32	24.46	24.59	24.72	24.85	24.98	25.11	25.24
10	25.36									

FIGURE 1

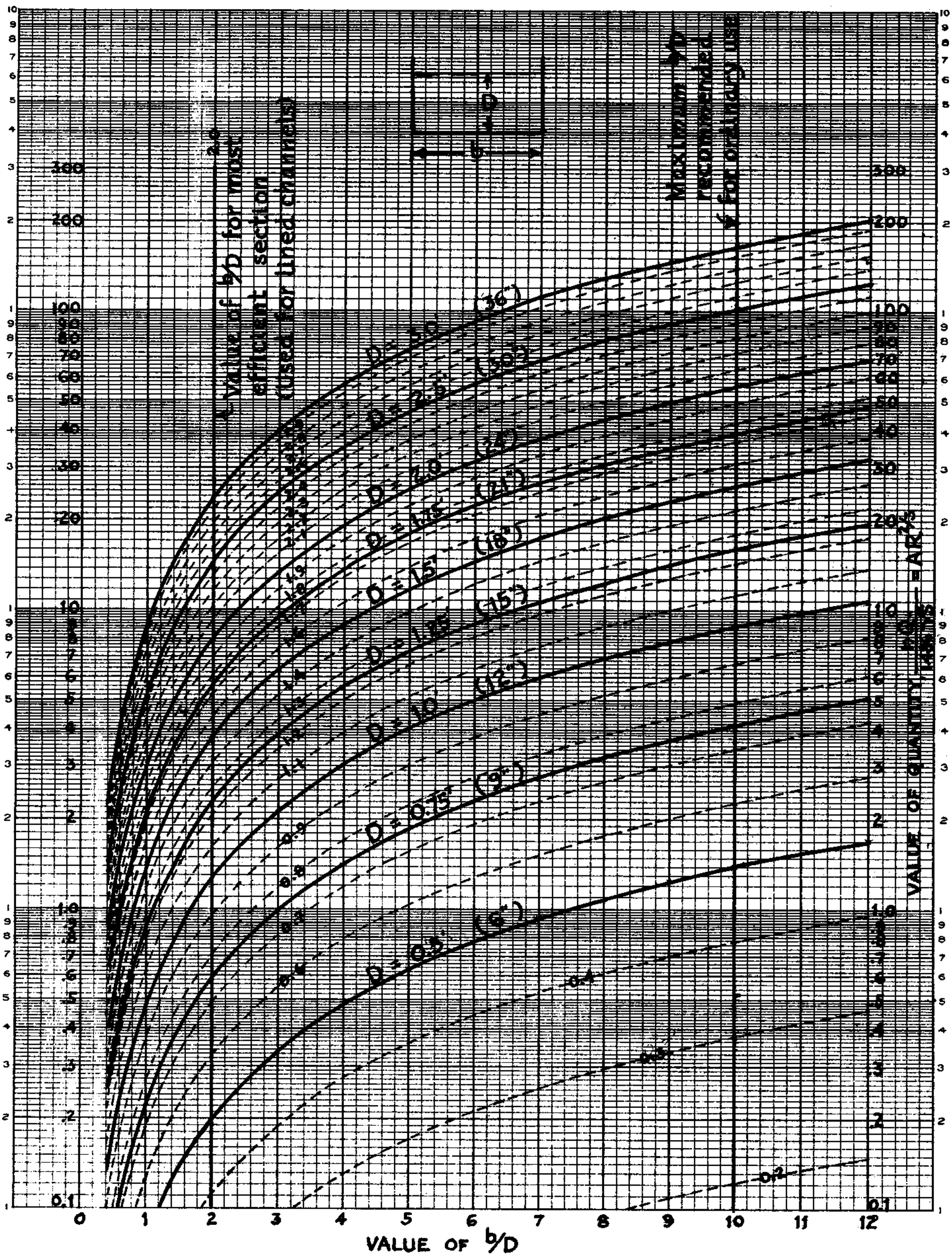


DIAGRAM FOR DETERMINING DIMENSIONS OF CHANNELS HAVING VERTICAL SIDES

FIGURE 2

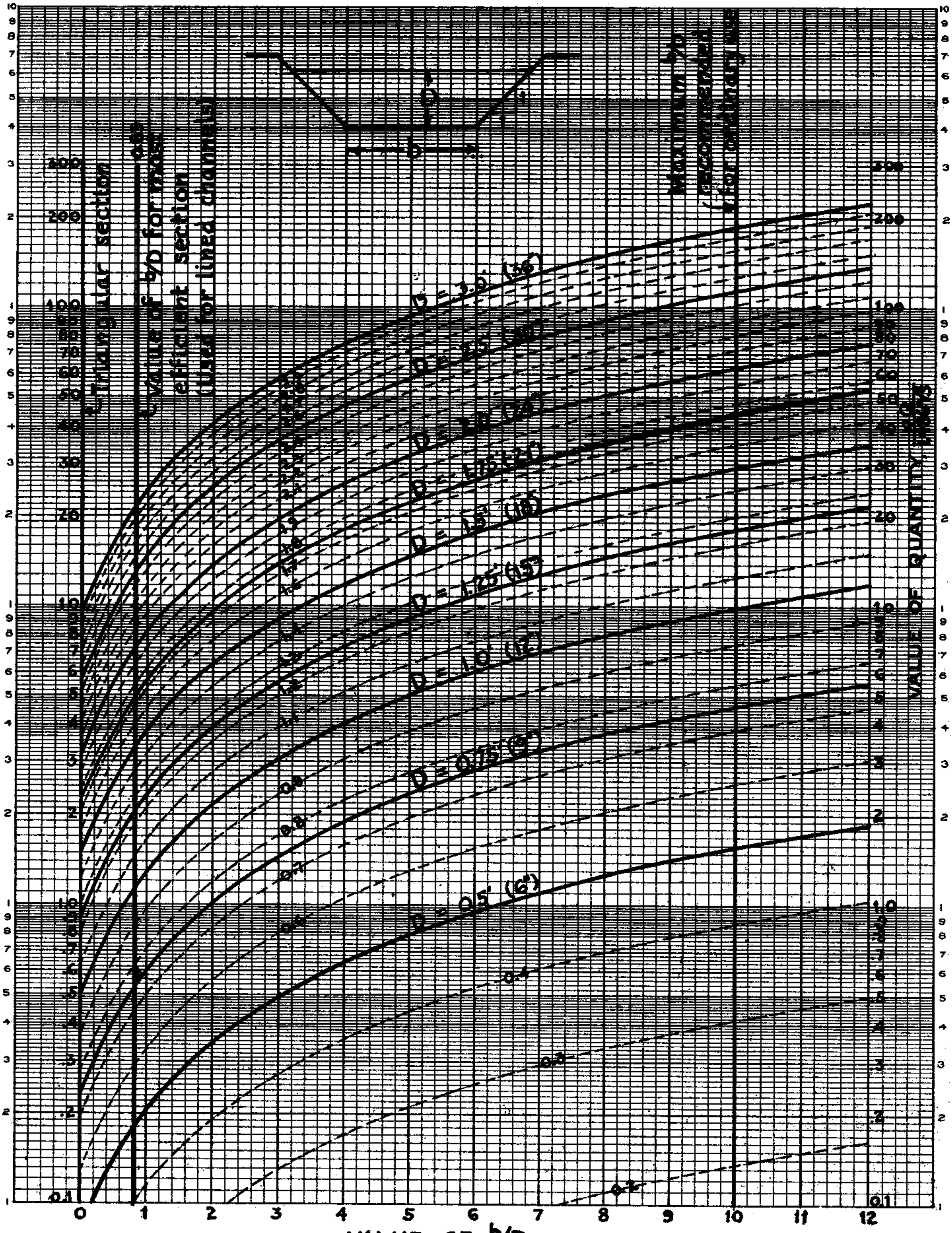


DIAGRAM FOR DETERMINING DIMENSIONS OF CHANNELS HAVING SIDE SLOPES OF 1 HOR. TO 1 VERT.

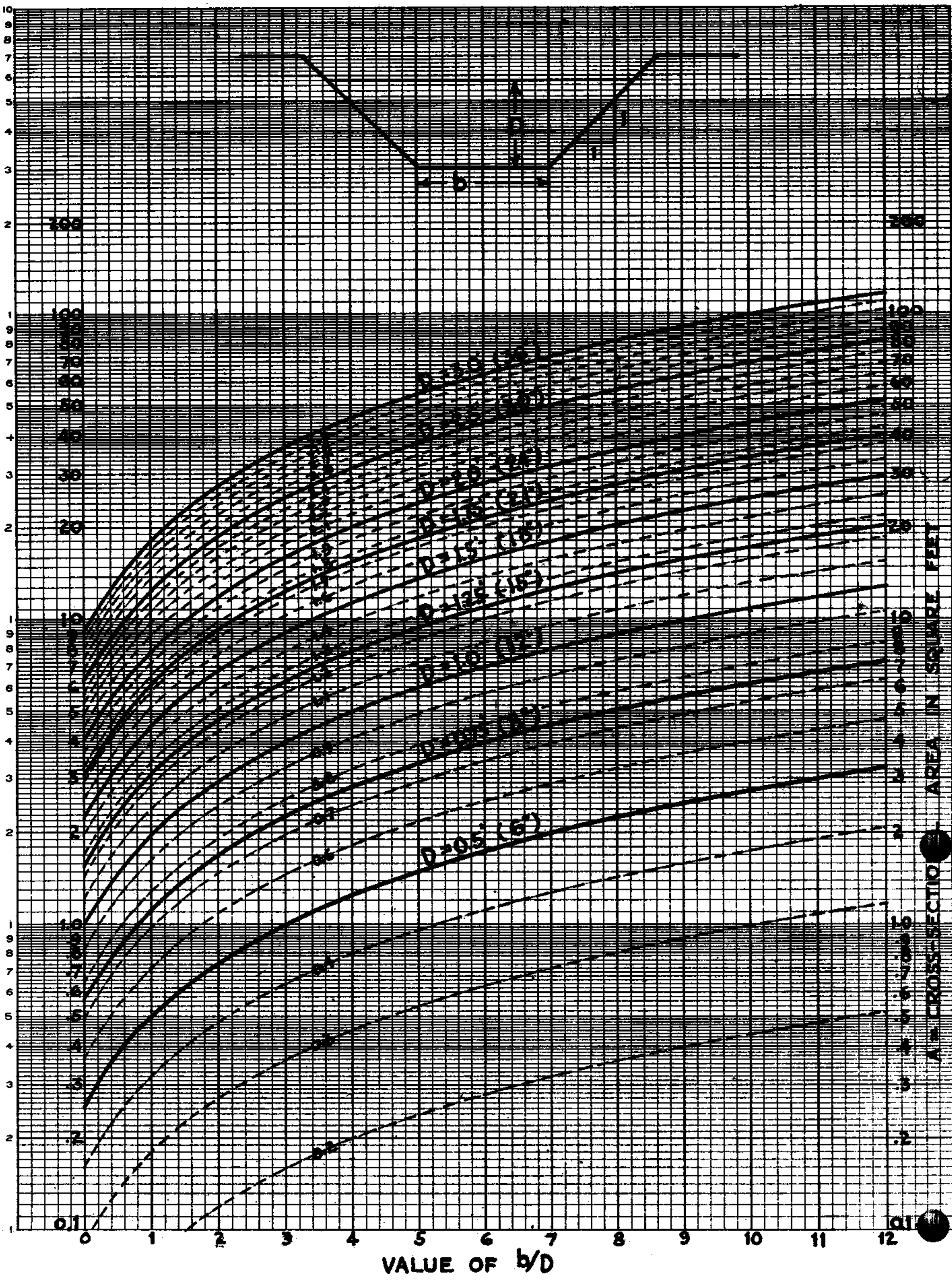


DIAGRAM FOR DETERMINING AREAS OF CHANNELS HAVING SIDE SLOPES OF 1 HOR. TO 1 VERT.

FIGURE 3

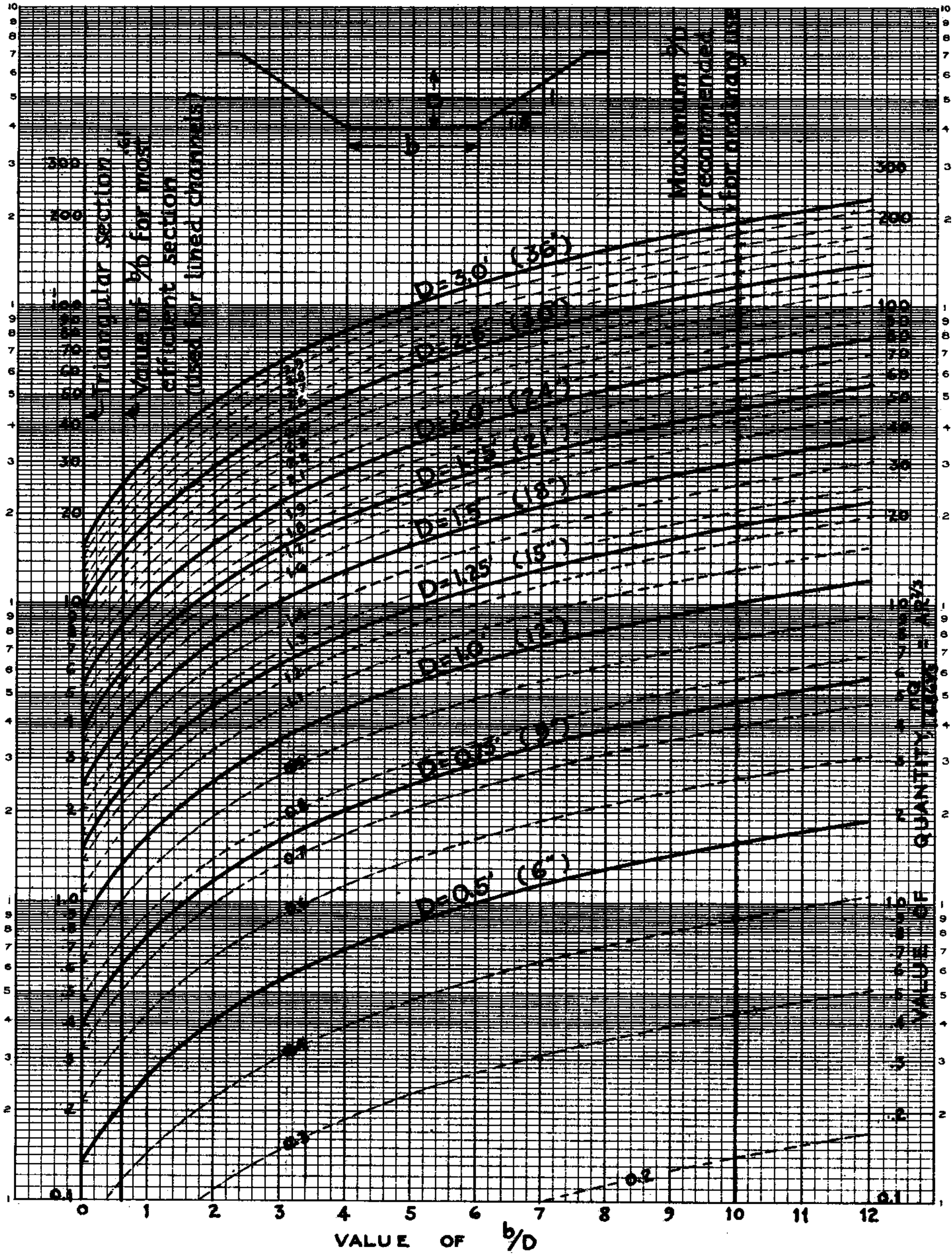


DIAGRAM FOR DETERMINING DIMENSIONS OF CHANNELS HAVING SIDE SLOPES OF 1.5 HOR. TO 1 VERT.

FIGURE 3-A

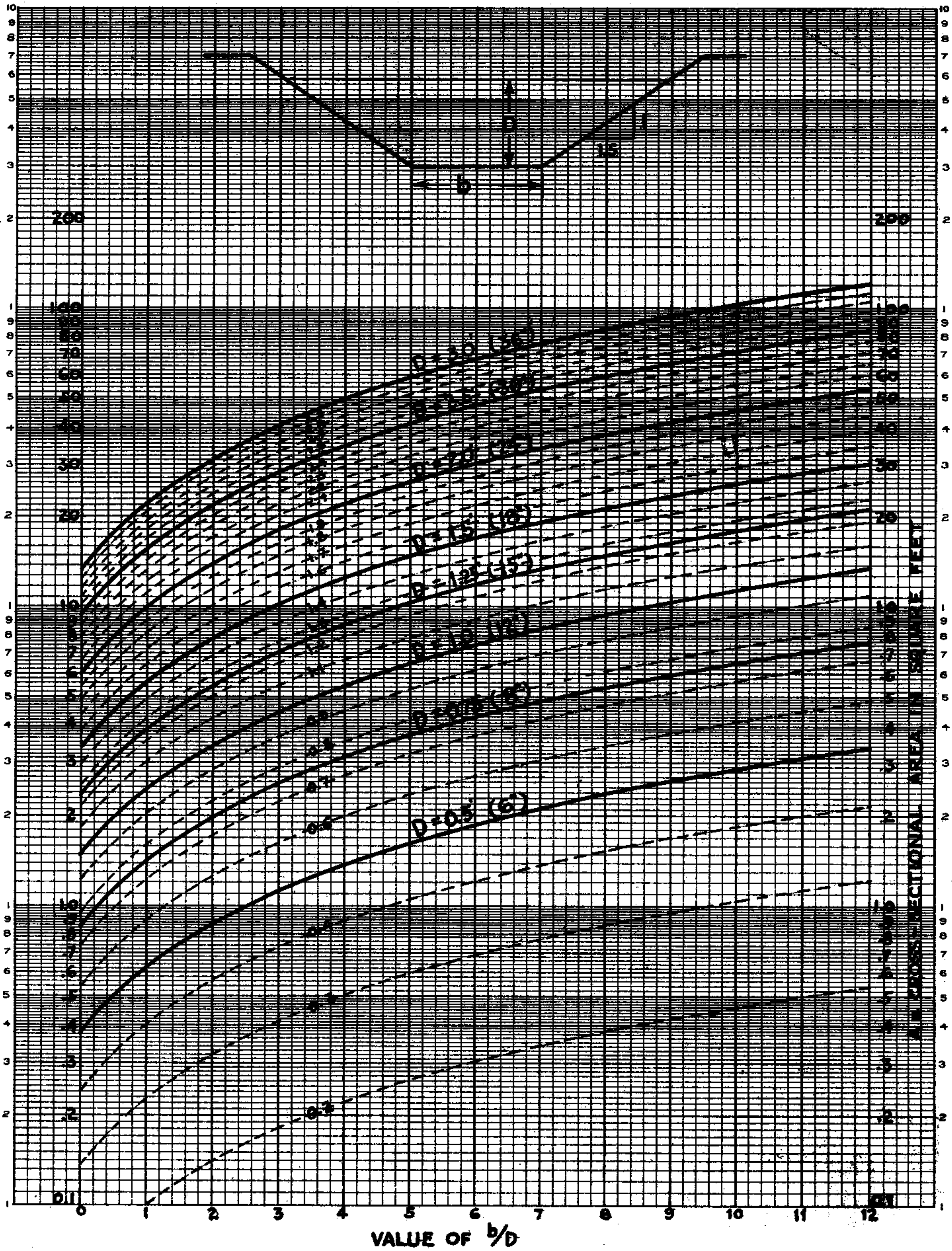


DIAGRAM FOR DETERMINING AREAS OF CHANNELS HAVING SIDE SLOPES OF 1½ HOR. TO 1 VERT.

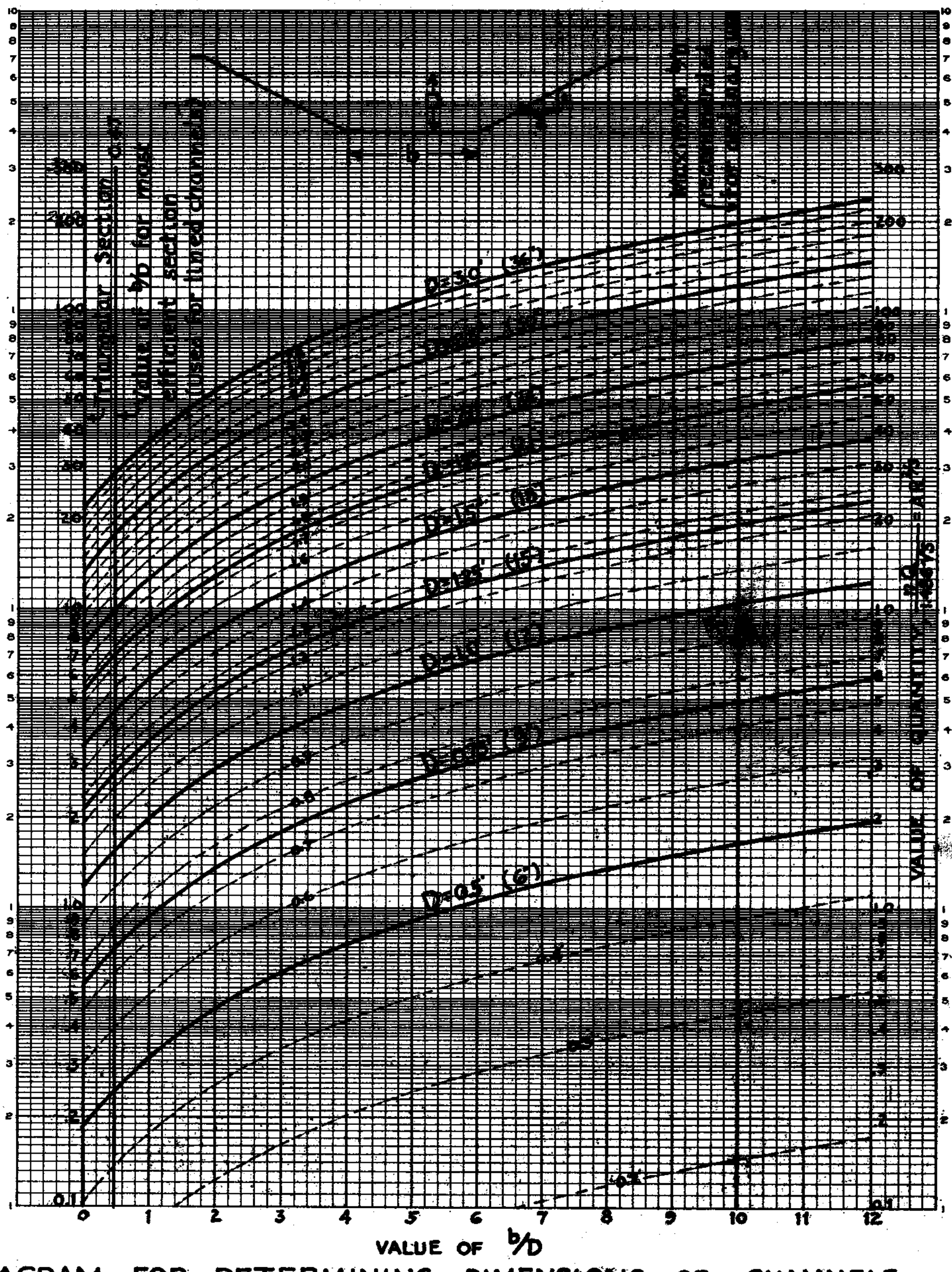


DIAGRAM FOR DETERMINING DIMENSIONS OF CHANNELS HAVING SIDE SLOPES OF 2 HOR. TO 1 VERT.

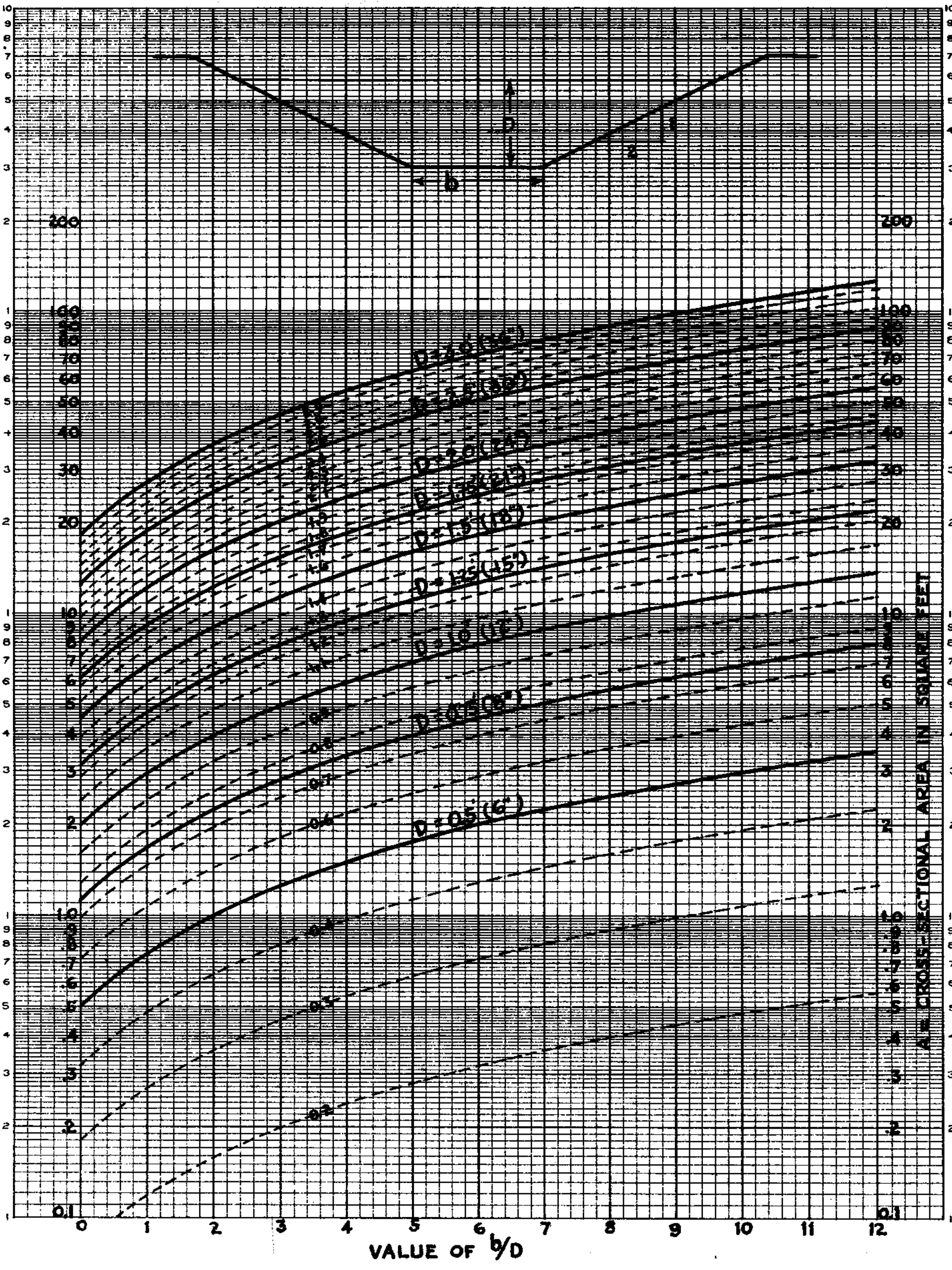
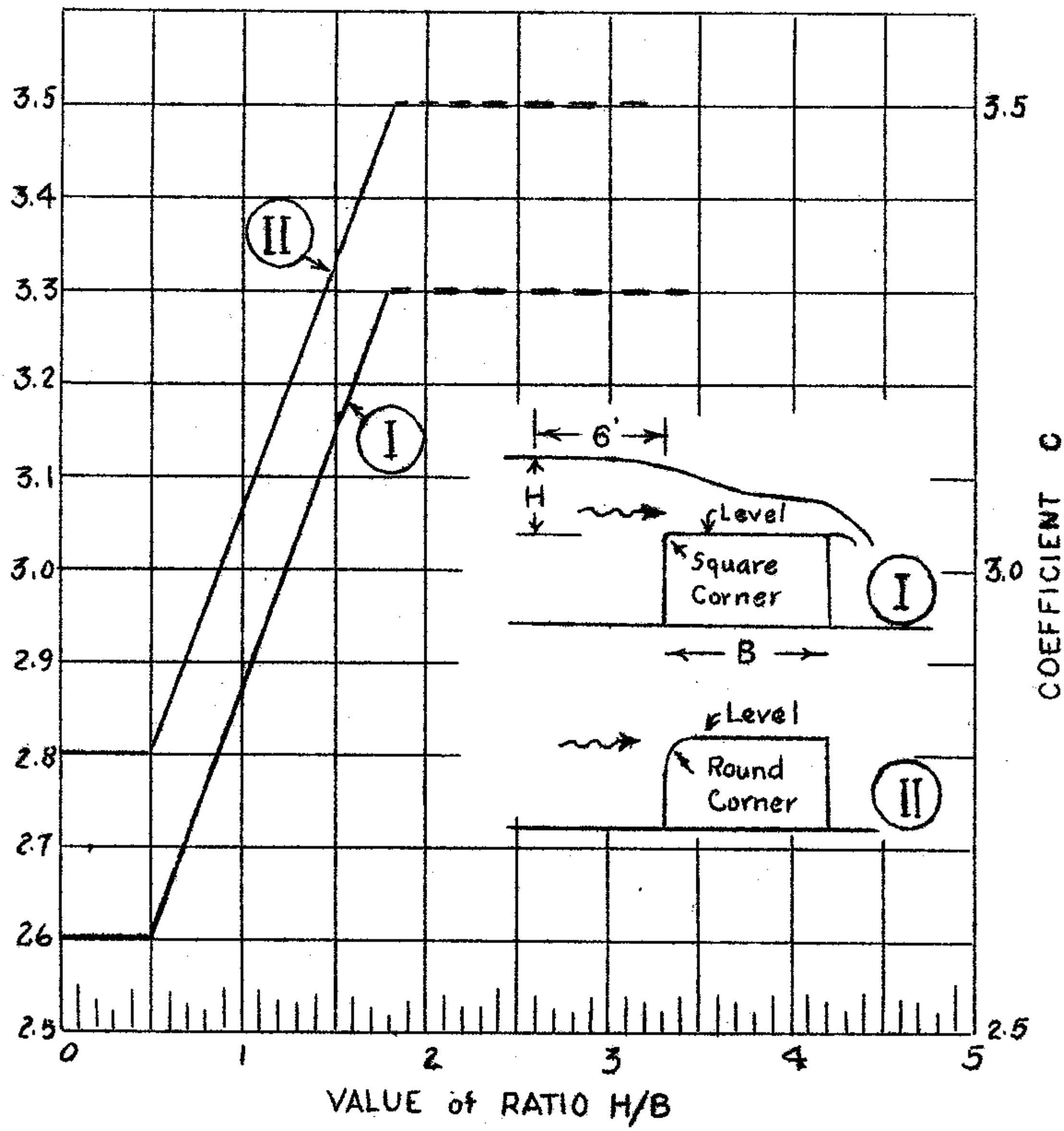


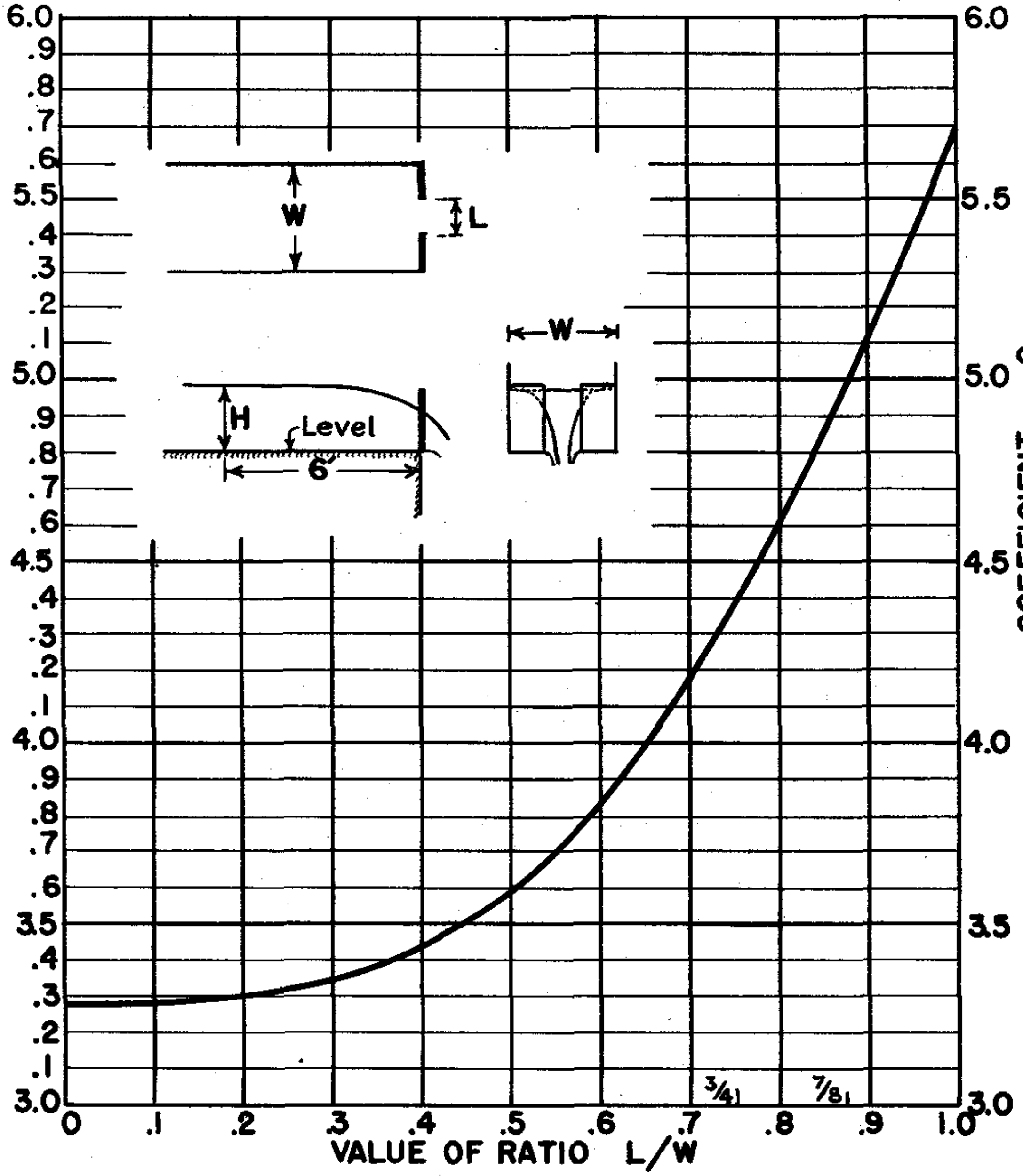
DIAGRAM FOR DETERMINING AREAS OF CHANNELS HAVING SIDE SLOPES OF 2 HOR. TO 1 VERT.

Fig. 7



COEFFICIENTS FOR BROAD CRESTED WEIRS
HAVING LEVEL CRESTS

Fig 8



COEFFICIENTS FOR RECTANGULAR NOTCHES ON THE CREST OF A VERTICAL FALL

Fig. 9

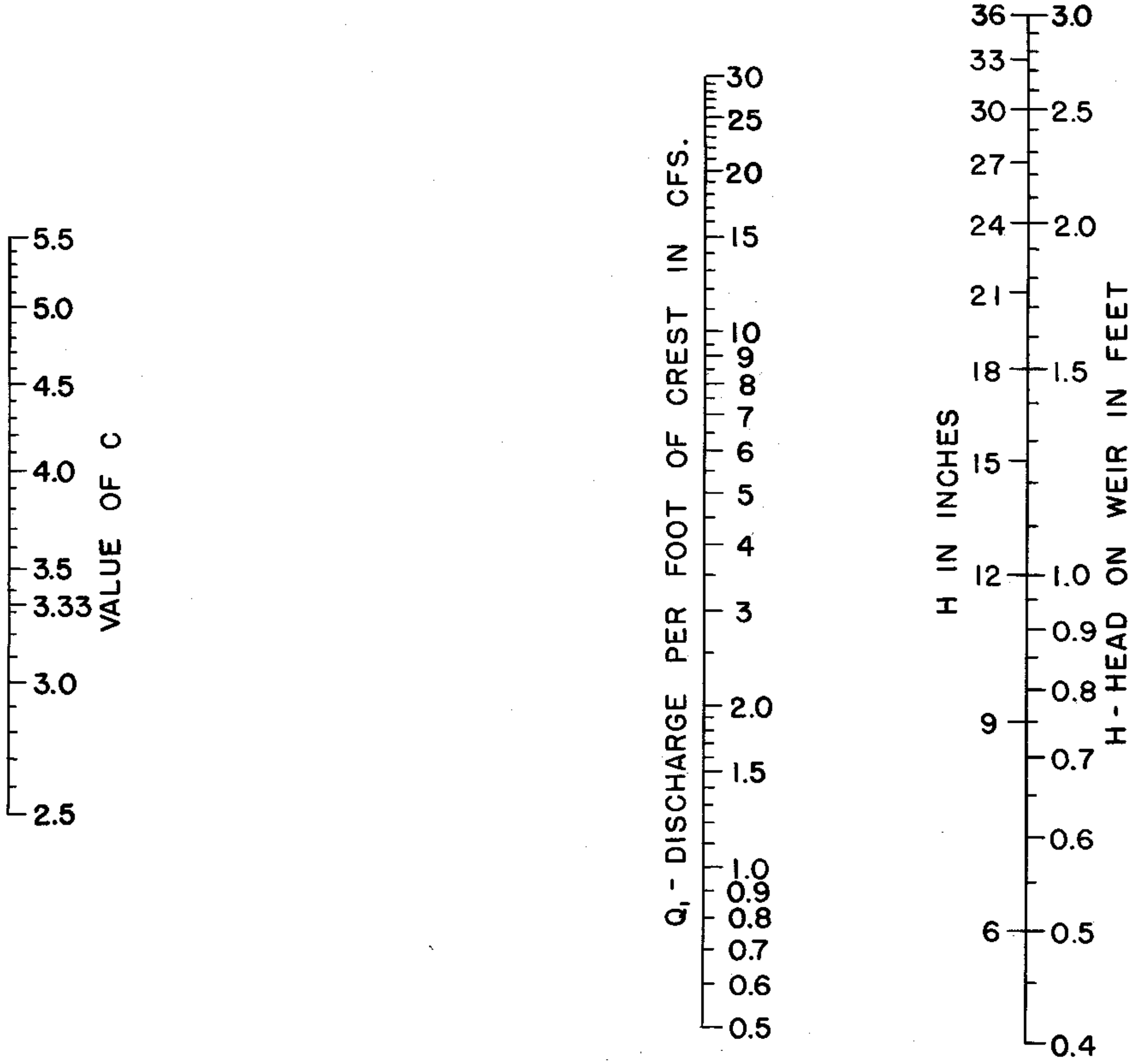
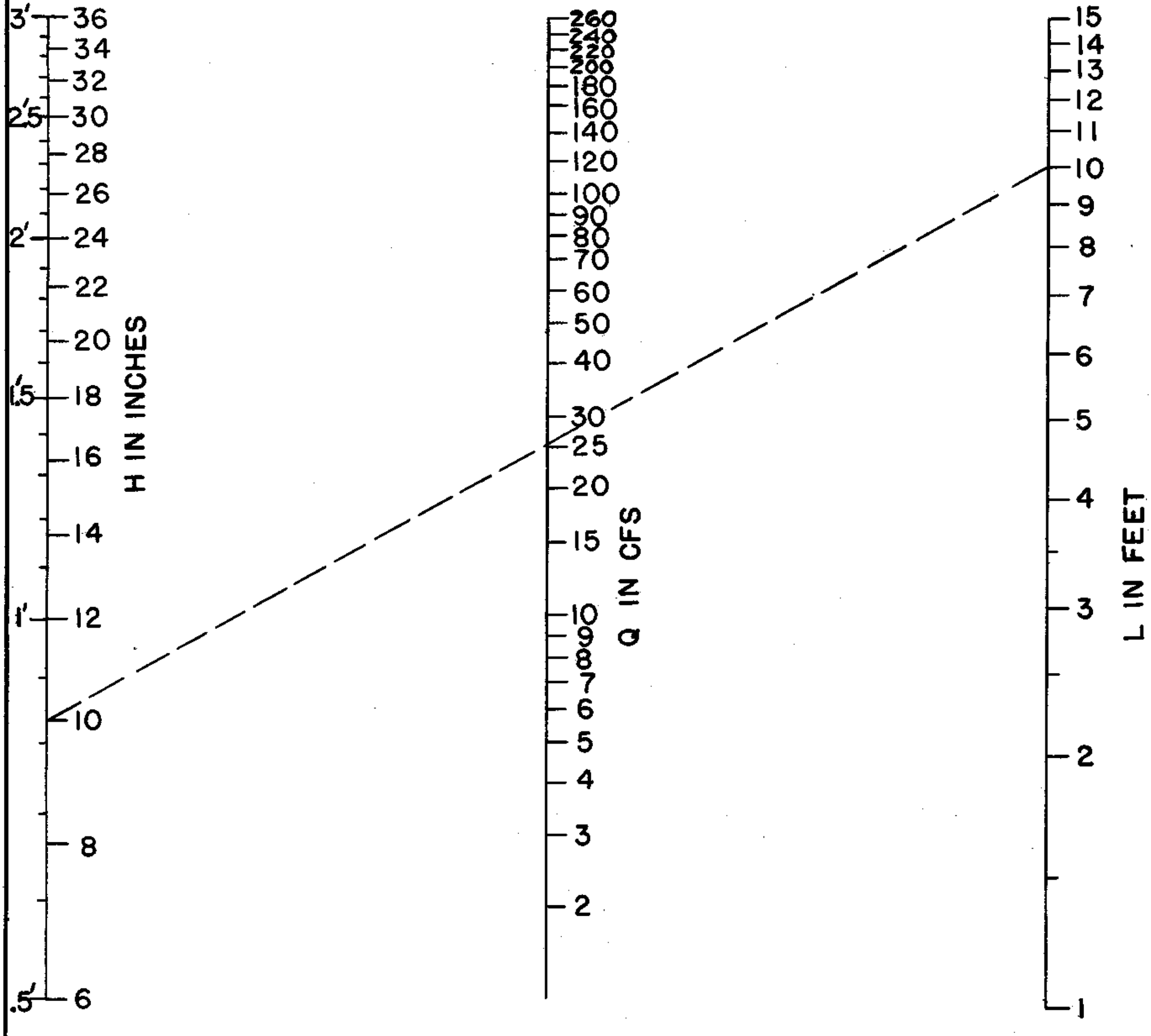


CHART FOR SOLUTION OF EQUATION

$Q_1 = CH^{3/2}$

Fig. 10



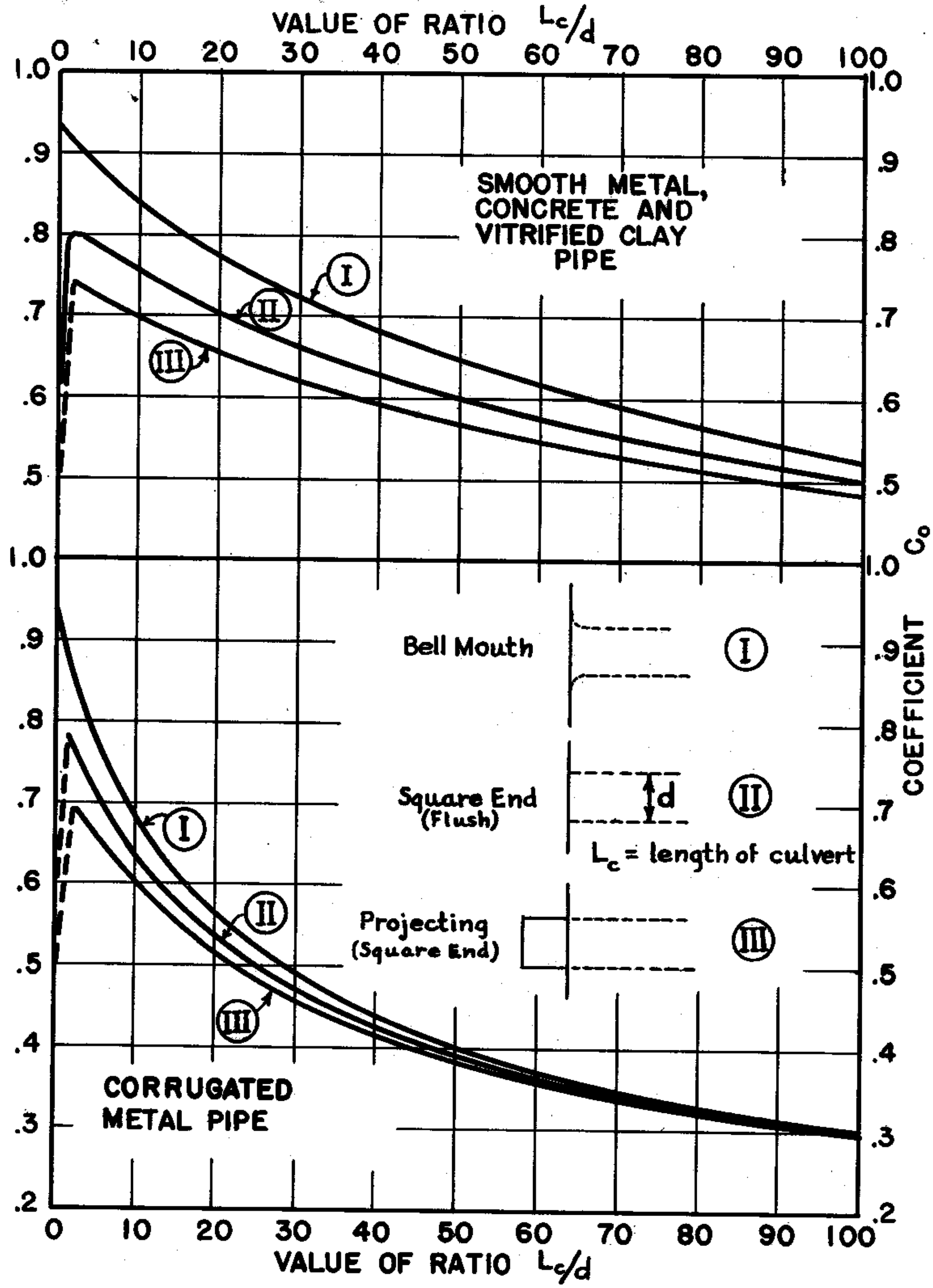
$Q = 3.33\, L H^{3/2}$

Q = CFS

L = FT.

H = FT.

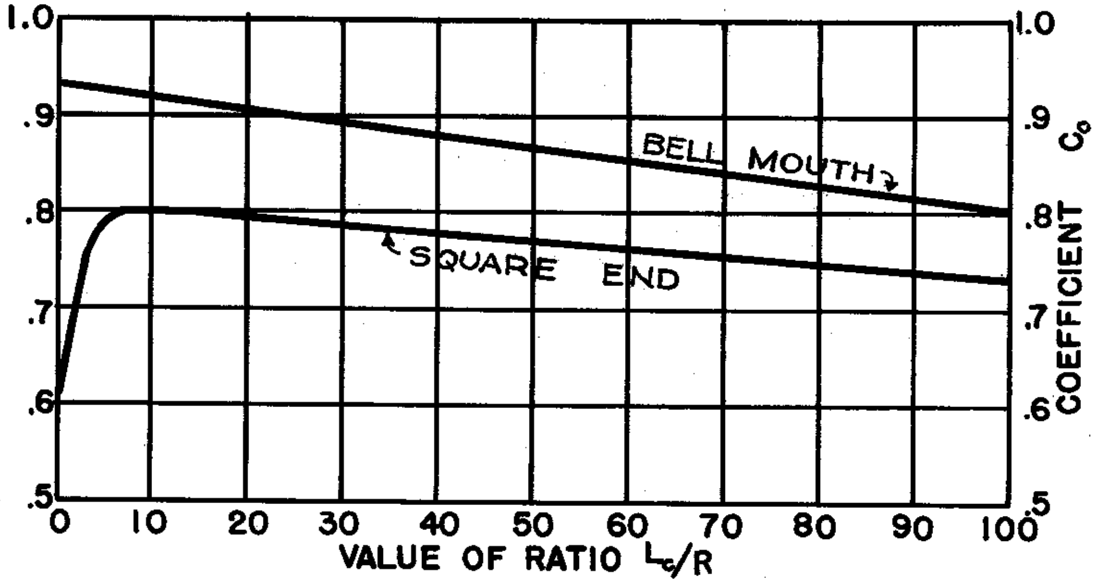
Fig. 15



COEFFICIENTS FOR

PIPE CULVERTS

Fig. 16



L_c = Length of culvert   R = Hydraulic radius

CULVERT DIMENSIONS	VALUE OF R
1 X 1 Feet	.250 Feet
1 X 2	.333
1 X 3	.375
2 X 2	.500
2 X 3	.600
2 X 4	.667
3 X 3	.750
3 X 4	.857
3 X 5	.938
4 X 4	1.00
4 X 5	1.11
5 X 5	1.25
5 X 6	1.36
6 X 6	1.50

COEFFICIENTS FOR

CONCRETE BOX CULVERTS

DESIGN OF WEIR NOTCHES IN DAMS:

The standard rectangular weir formula $Q = CLH^{\frac{3}{2}}$ may be used in the design of weir notches for dam structures.

Q = Discharge in cubic feet per second.

C = Coefficient of discharge usually varying from 2.5 to 3.5

L = Length of the crest of the weir in feet.

H = head of crest of weir in feet measured about 6 feet upstream.

The log and stone dams as used on this project have rectangular weir notches. The brush, wire, and stake dams have curved weirs somewhat in the form of a catenary. In many instances the loose rock dam is being built with the curved weir.

Type problems for both types of weir notches are given below.

TYPE PROBLEM NO. 3

DESIGN OF A RECTANGULAR WEIR NOTCH

Given a discharge of 10 cubic feet per second assume a trial value of C = 3.0; assume an H of 1.2 feet using Figure 9, page 67.

Pass a straight edge through an H of 1.2 feet and a value C of 3.0. Read the discharge per foot of weir width where the straight edge crosses the discharge line. In this case the discharge is 4 cubic feet per second. Divide 10 by 4 to get the tentative length of the weir. 10 ÷ 4 = 2.5 feet.

A correct value of C may now be determined by using Figure 7, page 65, and the weir notch redesigned to fit the value of C. In order to use Figure 7 it is necessary to know the breadth of the weir crest "B" and shape of the weir crest.

Assuming a round corner and a breadth of 1 foot for this problem we have a H/B ratio of 1.2 ÷ 1 or 1.2.

Referring to curve II of Figure 7, page 65, we find the correct value of the coefficient C to be 3.2.

Again using Figure 9, page 67, with the exact value of C we find the discharge per foot of crest to be 4.4 cubic feet per second. Dividing our given discharge of 10 cubic feet per second by 4.4 gives a length of crest of 2.27 feet.

Thus a weir notch 1.2 feet high by 2.27 feet long will handle a discharge of 10 cubic feet per second.

TYPE BROBLEM NO. 4

DESIGN OF A CURVED WEIR NOTCH AS USED ON WIRE, STAKE, BRUSH AND ROCK DAMS

No absolute formula for the discharge of curved weir notches of the catenary type is available for use at the present time. Until experimental data is available the curved weir notches will be designed by the approximate method that is used on Project No. 14, Zanesville, Ohio.

Their method is to multiply the estimated discharge by $1\frac{1}{2}$ and to use this value of discharge for computing the width and depth at the center point by means of Figure 9, page 67. A value of "C" of 2.5 is to be used.

Steps In The Design

1. Estimate the probable maximum runoff from the drainage area above the dam by the use of Ramser's 10 year frequency runoff chart, (Chart 4, page 38), and multiply that runoff by one and one-half.

2. By choosing a trial value of "H" at the center point of the weir determine the discharge per foot of weir width by the use of Figure 9, page 67. A value of "C" of 2.5 should be used.

3. Divide the runoff discharge obtained in 1. above by the discharge per foot of weir width obtained in 2. above.

This value will give the length of curved weir in feet necessary when the trial value of "H" is used. If the length is not satisfactory to use, increase or decrease the trial value of "H" until a satisfactory length and depth of weir is obtained.

Example

Q = 10 cubic feet per second. Assume a trial value of "H" of 1.0 feet.

In Figure 9, page 67, pass a straight edge through a value of "C" of 2.5 and a value of "H" of 1 foot. The straight edge cuts the Q_1 line at 2.5. 10 divided by 2.5 equals 4 feet.

Therefore, with a depth at the center of 1.0 feet a curved weir notch 4 feet long will discharge 10 cubic feet per second.

By using Figure 9, page 67, it is found that a curved weir 6 feet long with a depth of 9 inches will also discharge 10 cubic feet per second.

SOIL CONSERVATION SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE

PROJECT #13 SPENCER, WEST VIRGINIA

P A R T F O U R

EROSION CONTROL STRUCTURES

CHAPTER IX

STRUCTURE PLANS AND SPECIFICATIONS

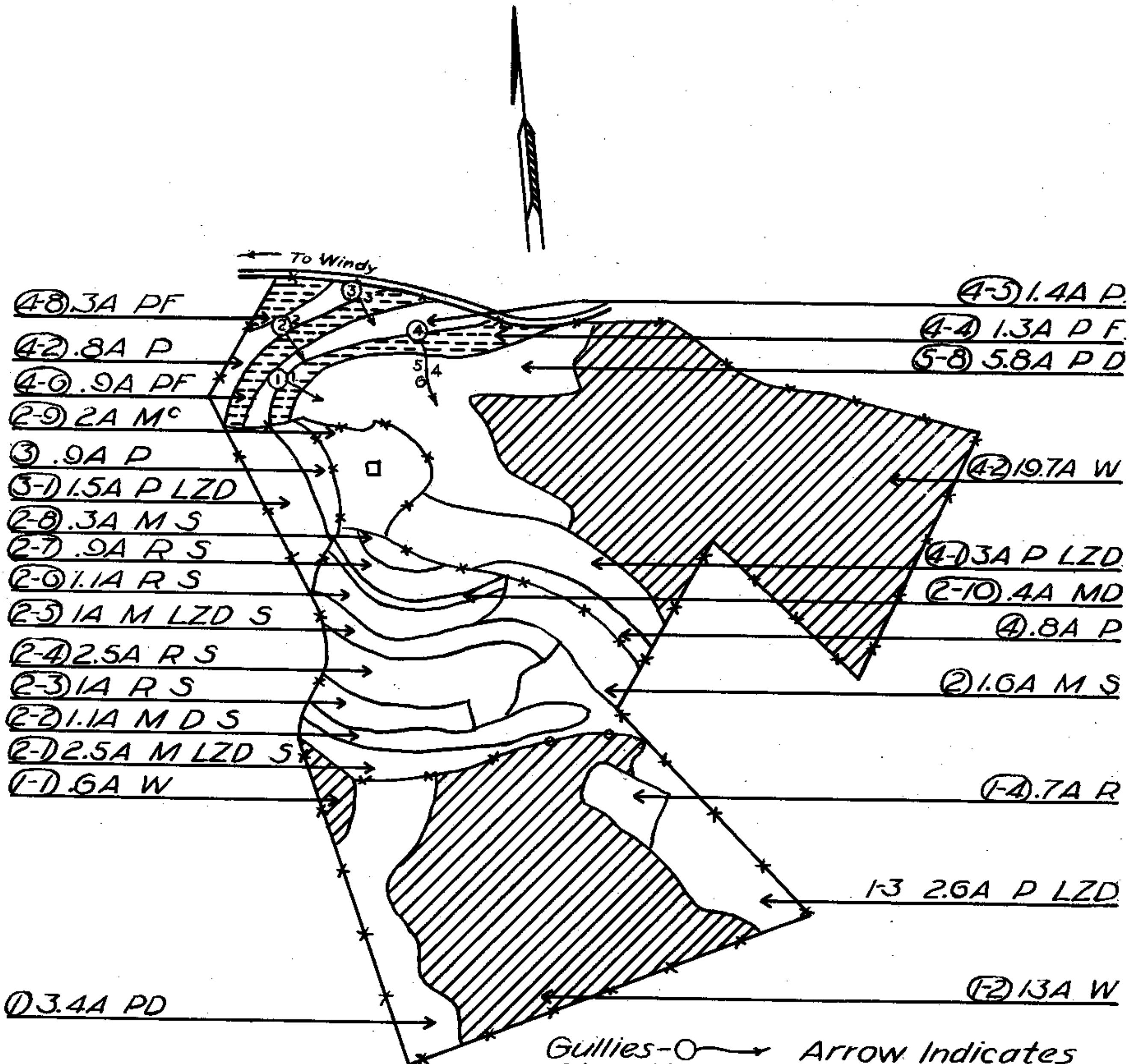
A

LOCATING, MAPPING AND RECORDING STRUCTURES

One of the most important duties of the engineer will be that of locating, staking out, and mapping the various structures to be used in erosion control. A great deal of reconnaissance is necessary to do the job well. The engineer should have in mind the extent of erosion on the farm being surveyed, the amounts of local material available, and the possible limits of work that can be done. Before leaving the office for the field it is well to locate on a map, for accessibility, the farm to be surveyed. The Agronomy and Soils maps pertaining to it should also be secured. A hand-axe, tally board, lumber crayon, pencils, clinometer, tape, field book, recording forms, runoff tables, and weir specifications are required. It is well to have a supply of stakes on hand. A 30 inch stake is recommended because it can be readily found even in fields with dense covering of vegetation. If necessary a small strip of red cloth may be tacked to the stake top.

Three-man survey parties are recommended for the location of gully structures. The engineer and his assistant can locate, measure and record the structures while the third man can stake and mark them. Upon entering a farm the engineer should first contact the farmer if possible because he is generally interested in what is going on and frequently has valuable suggestions to offer. A perusal of the agronomy and soils maps will indicate land-use program and erosion conditions. These should be utilized in marking gullies and in determining type of structure resorted to. The gullies are numbered as shown on the agronomy map, page 76. It is recommended that structures be numbered consecutively from #1 on clear through the entire farm rather than to start with number one for every gully. The structure number is marked on the stake with lumber crayon (blue is recommended, and it is also suggested that the stake be tilted with the number placed on lower side to preserve mark) and is recorded on Specification Sheet Form A as job number (give number of structure). The specifications are computed and set down in the proper column. This form is later turned over to the work foreman, who builds his structures from the information thereon. Form A is shown on page 78. Under Part B following will be shown manner of recording labor and materials for various structures.

~SAMPLE AGRONOMY MAP~



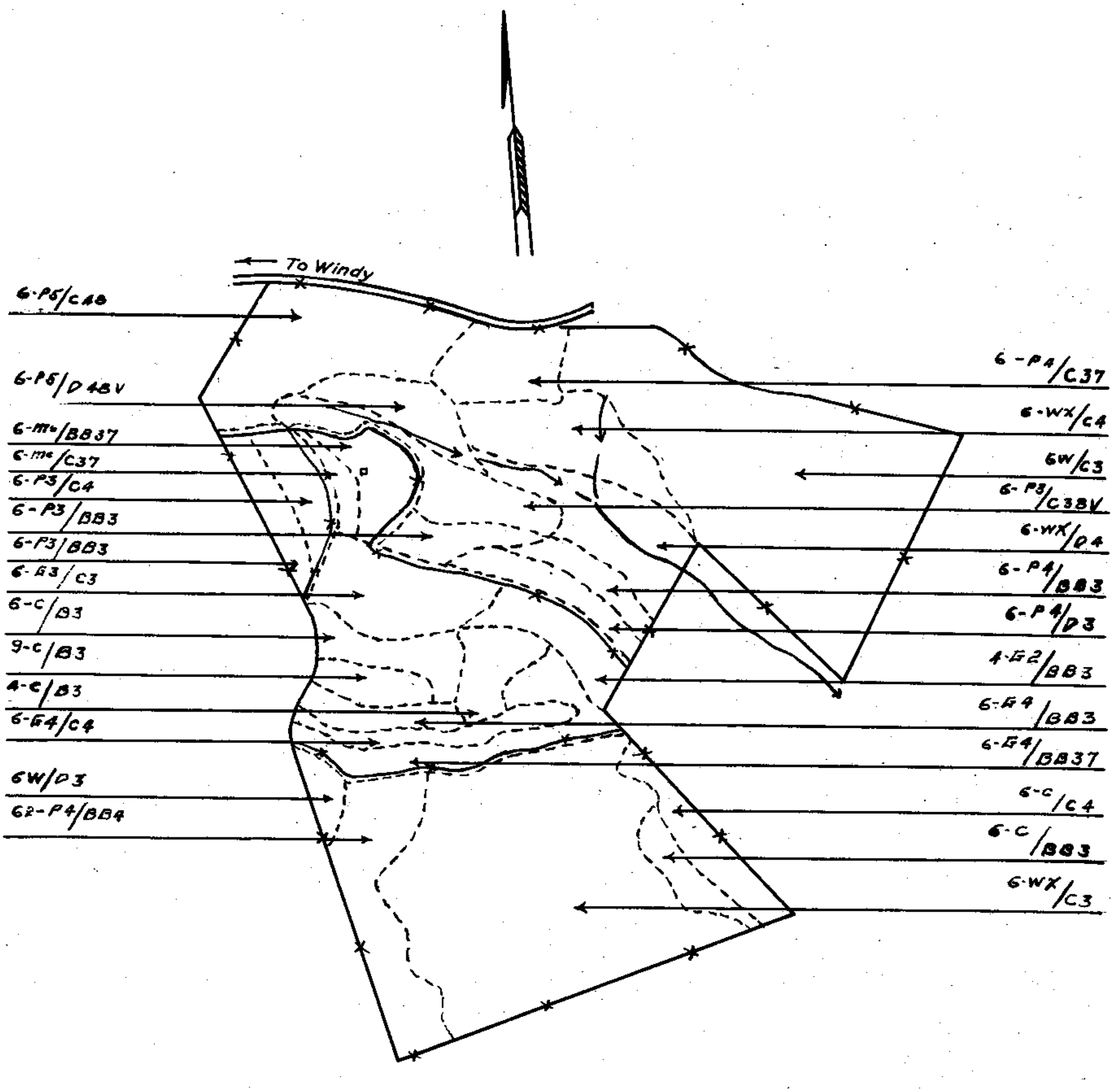
Gullies-O——> Arrow Indicates Direction of Flow. Gully Number in Circle. Structure Number Opposite Site of Structure.

FARM
Courtney Ridge, 1½ Mi. Palestine
2-232-A3
71.1A
Surveyor__________ Date________

Project 13, Eng. Div.

E-32

~SAMPLE SOILS MAP~



FARM
Courtney Ridge, 1½ Mi. Palestine
2-232-A3
71.1A
Surveyor__________ Date__________

Project 13, Eng. Div.

Form SCS-A

SPECIFICATION SHEET
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION

Sheet No. 1

West Va. Project # 13

Foreman Jones

Farm John Doe

Sub-Area No. 2

Date Surveyed 3/21/35

Location Courtney Ridge 1½ Mi. Palestine

Job No.	Type of Work	Strm. or Gully No.	Clas'f. No. on ECW-7	General Specif. L.	General Specif. W.	General Specif. D.	General Specif. Area or Vol.	Dam Specif. Crest Ht.	Dam Specif. Spwy Area H	Dam Specif. Spwy Area w	Materials Estimate	Acres D.A.	Acres G.A.	% Slope	Probable sounce of trouble, remarks, etc.
3	Rock Dam	1	305	10				2'-0"	1'-3"	2'-0"	1½ yds	3.0	.1	22	Haul Road
Total															

In the location of stream control structures it is recommended that a regular stadia traverse survey be made of the area including and adjacent to the stream problem. Once the area has been mapped it will be easy to place the structures required. If no survey is made the chances for making a blunder are much enhanced. The stream tangents and curves are very misleading to an observer in the field, especially on large jobs. The time used in making a detailed topography map of the problem area is time well spent and will generally assure a more complete and satisfactory stream job. A four man crew consisting of instrument man, recorder, and two rodmen is very satisfactory and efficient. In any kind of work it is desirable to have uniformity in all procedure. Map work is no exception, so there is included on page 80 a list of conventional signs to be used in mapping work where the type of structure must be indicated.

A method of estimating size of watershed has been discussed under "Hydraulics" so will not be repeated. The area of the watershed for any structure is included under Drainage Area (D.A.) in Form A, page 78. It should be given to the nearest one-tenth acre. The gullied area (G.A.) is obtained by estimating the actual area cut by gullies. It is well to include for width of such gullies an added ten foot strip on both gully banks to allow for lateral erosion. The total width multiplied by the length of gully will give gullied area. It should be recorded to the nearest one-tenth acre. Percent slope need not be carried to tenths of a degree. An average slope for the entire gully is sufficient unless there is a marked change between several consecutive structures.

Nothing should be placed in the column "Probable Source of Trouble" Form A, unless the cause is well determined. For example, on Project #13 a tabulation of "Probable Source of Trouble" for several thousand gullies surveyed indicated the following interesting data:

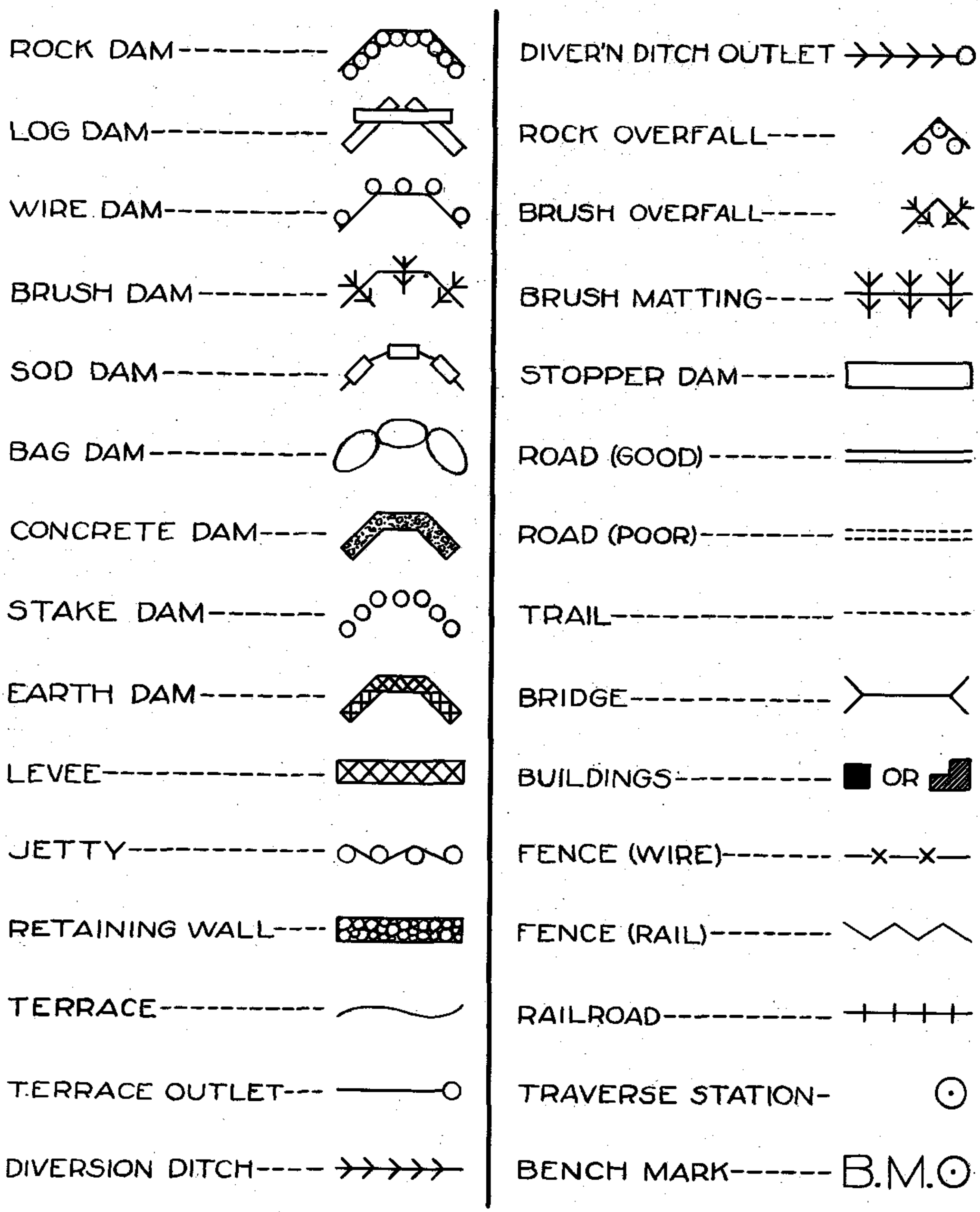
Causes of Gully Erosion

(a)	Livestock (trails, salt-licks, and feed lots)	21.7%
(b)	Slips	17.3%
(c)	Excessive grazing	15.5%
(d)	Haul roads (old logging trails, farm roads)	14.8%
(e)	Sub-surface erosion (underground seepage)	11.6%
(f)	Rodents (ground hogs, moles, etc.)	2.9%
(g)	Public Highways (improper drain placement)	2.0%
(h)	Springs (overflow and approaches)	1.1%
(i)	Miscellaneous	13.1%

Such information can be of great value in future planning and in concentrating control measures where they are most effective. Figures indicate that haul-roads cause almost 15 out of every 100 gullies, therefore they justify considerable attention.

~ CONVENTIONAL SIGNS ~

AS USED IN ENGINEERING WORK ON PROJECT #13
SPENCER, WEST VIRGINIA



Project 13, Eng. Div.

A key to reading the symbols as given on the Sample Soils map, page 77, has not been included because such can readily be obtained from the Soils Division of the Conservation Service, who may revise them from time to time. Suffice to say that symbols generally follow this definite plan:

$$\frac{\text{Soil type - Land use}}{\text{Slope - Erosion}}$$

The symbols and definitions for cultivated crops, field crops, pastures, and plantings as shown on the sample agronomy map, page 76, can be obtained from the Agronomy Division of the Soil Conservation Service. They may be subject to frequent revision, so were not included.

B

MATERIALS AND LABOR FOR STRUCTURES

In order to have a practical demonstration in erosion control it is necessary that the structures erected be built from material generally available on the average farm. Such material is usually classified as local and may include sand, gravel, brush, straw, rock, limestone, timber, and posts. Permanent structures could be used but ordinarily are not practical from an economic standpoint. Also the average farmer would be unable to extend on the erosion control program if he were expected to erect concrete or masonry dams that require a comparatively high outlay of cash. Temporary structures are usually long-lived enough to survive until vegetation has re-established itself, which is our ultimate objective.

The engineer conducting the structure survey should make an approximate estimate of the amounts of local material required and should inform the farmer as to these amounts and where they will be needed. The farmer can then commence at once to haul his materials to the site of construction before construction operations actually commence. Where a great deal of rock, brush, or timber is required it has been found to expedite construction efficiency to send out materials crews beforehand to assist the farmer in getting out his materials. Such advance crews of from 3 to 5 men can assist a great deal in assuring adequate supply of all materials.

In organizing gully control crews it has been found that the least man hours per structure resulted from crews not exceeding 8 men. Such small crews are not possible where camp labor is used. However, the crew should be held to not over 25 men per foreman if possible.

The foreman of a crew should be supplied with Specification Sheet, Form A, page 78, and Forms B and B-1, pages 82 and 83, respectively. All items included under these forms have been checked

Form SCS-B

LABOR, TRANSPORTATION, AND EQUIPMENT REPORT
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION

Sheet No. 1

West Va. Project # 13

Foreman Jones

Sub-Area No. 2

Farm John Doe

Location Courtney Ridge, $1\frac{1}{2}$ mi. Palestine

Job No.	Type of Work	Nature of Work: Const.	Maint.	Protect.	Labor: ECW: Supt.	Fore.	Enr.	SCS: Fore.	Oper.	Com.	Misc.	Donated: Kind	Hrs.	Transp.: Kind	Mi.	Equip.: Kind	Hrs.	Date
3	Rock Dam				½	½	8					Tm.	1	1½T	10			4/3/35
Total																		

Form SCS-B-1

Sheet No. 1

MATERIALS REPORT
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION

West Va. Project # 13

Foreman Jones

Sub-Area No. 2

Farm John Doe

Location Courtney Ridge 1 Mi. Palestine

Job No.	Type of Work	Materials Used											Earth		Date Comp.	Remarks
		Sand	Gravel	Cement	Lumber	Rock	W. Wire	S. Wire	B. Wire	F. Posts	Brush	Misc.	Exc.	Fill		
3	Rock Dam					1½									4/8/35	
Total																

Form SCS-B-2

Sheet No. 1

PLANTING AND SEEDING RECORD
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION

West Va. Project # 13

Foreman Jones

Sub-Area No. 2

Farm John Doe

Location Sourtney Ridge 1½ Mi. Palestine

					Materials Used													
	Type	Strm. or		Add.	Seed		Plants		Trees		Fert.		Lime		Sod	Date	Failures, repairs
Job No.	of Work	Gully No.	Job Area	Bank Sl. Sq. Yds.	Kind	lbs	Kind	No.	Kind	No.	Kind	lbs.	Kind	lbs.	Sq. Yds.	Compl.	Recommendations, etc
3	Rock Dam	1	10	5	Mix.	2					0-16-0	4	G.L.	8	1	4/28/35	No Repairs
Total																	

against the most recent recommendations as to classification. It is hoped that the forms are flexible enough to meet the various phases of work to be recorded. Form B, page 82, Labor, Transportation and Equipment is self-explanatory. Sample insertion has been made. The same holds true for Form B-1 page 83, Materials. It is to be remembered that if a dam is given a definite job number then that number should be used whenever any additional work is done on the structure, as for example, maintenance work.

Form SCS B-2, Planting and Seeding Record, page 84, should be turned over to the crew foreman at the time seeding operations are to be carried on, i.e. in seeding or planting season. At such time the foreman should also make all repairs necessary on the structure being seeded or planted.

When a farm has been completed the Forms should be attached to the farm map and sent into the central office for recording of data and for filing purposes. If seeding or planting is not to be done immediately following completion of structures it is suggested that all forms be sent to the central office. Form SCS B-2 can then be gotten, together with the maps, at such later date as needed for seeding or planting.

A complete record of all structures should be kept in order that failures and reasons therefor can be determined. Whenever man-hours per structure run consistently high it is recommended that manner of construction and efficiency of crews be investigated for the source or sources of trouble.

In all types of government work it is well to keep very complete records. By so doing it is possible to have available information on various phases of work completed.

C

SHEET EROSION CONTROL STRUCTURES

Under the discussion covering soils was classified the different types of erosion occurring in West Virginia. The classification covering sheet erosion will be repeated for convenience.

1. Sheet Erosion

    (1) Moderate
    (2) Severe
        a - Pockets
        b - Galled areas
        c - Slips

The type of structure utilized under each erosion class will now be taken up.

Sheet Erosion

Where sheet erosion is moderate no mechanical structures will be required. Proper field rotations and contour farming, furrowing and stripping will ordinarily suffice for positive control. Severe sheet erosion resulting in pockets, galled areas, or slips will need additional measures for control.

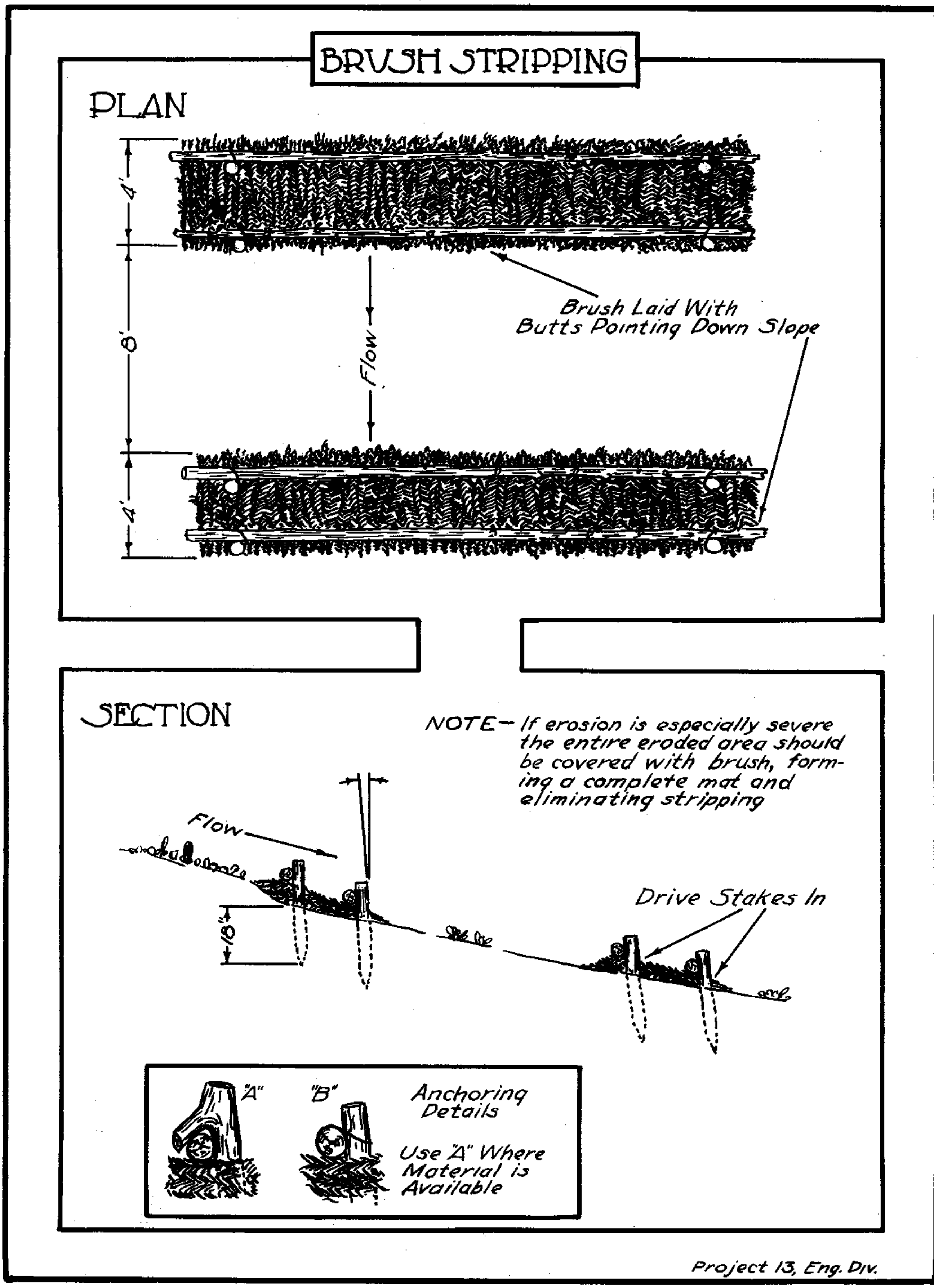
a - Pockets - These can be held by filling with mulch, brush, straw or rocks. Brush or straw should be tied in place. A pocket ordinarily has no watershed except for its own surface area. Stock frequently are the cause for such pockets to form. It is well to seed the area following the cover application.

b - Galled areas - These may be very severely eroded and should receive careful attention. Brush matting or strips may be laid as shown on page 87, Figure 17. Where the area is large and brush scarce there is a decided saving in materials by laying brush in strips. The strips serve as miniature bench terraces to collect soil and establish vegetation. It is well to lime, fertilize and seed a galled area before brush has been placed. A brush mat or strip may be defined as a man-made cover to control washing until vegetation can be established. It is a very economical and effective way of doing it as experience has already shown. The materials may be gotten from woodlots by removing scrub timber of no commercial value or by trimming scattered trees. Sprouts cut from old stumps are very desirable as is also the ordinary "filth" such as brush growing in pastures. In no case should shade trees be "butchered" or whole areas be depleted of trees.

The tools necessary include axes, pruning saws, hand-axes, climbers, wire cutting pliers, light sledges, mattocks and hammers. Brace wire (#9 galvanized) should be available. In no case should barb wire be used for anchoring brush mats because of danger to stock. Where possible it is better to use forked stakes to hold mats or weight down with rock and logs.

The brush is laid on the eroded area by starting at one of the upper corners and laying a strip across the top. In laying the mat the brush must be trimmed down and all high ridges on the area smoothed with a mattock. This will assure the mat clinging closer to the ground. The second strip is laid below and overlapping the first. In all cases the material is laid with the butt-end down hill. Fine brush is kept near the bottom. Strips are continued until the specified area is covered.

Figure 17


BRUSH STRIPPING
PLAN
4'
8'
4'
Flow
Brush Laid With
Butts Pointing Down Slope
SECTION
NOTE— If erosion is especially severe the entire eroded area should be covered with brush, forming a complete mat and eliminating stripping
Flow
18"
Drive Stakes In
"A"
"B"
Anchoring Details
Use "A" Where Material is Available
Project 13, Eng. Div.

The mat is fastened by laying poles across the brush and staking into position by a system of criss-cross stakes. If the ground is too hard for stakes the brush may be weighted down with heavy poles.

Where a galled area is too large to cover even with brush strips it is well to resort to fencing. A fenced area will reclaim itself in time. The process may be hastened by liming, fertilizing, and seeding. It is important that stock be kept out. Where hogs must be guarded against, woven wire is preferable. All fences should be well built and braced. The following specifications are suggested:

1. Posts must be of good quality, sound, not under 4 inches in diameter at the small end, 6 to 7 feet long. Not to be set over 12 feet apart.

2. Six strand fence to be used with the spacing as follows:

#1 - 4 inches from ground
#2 - 8 inches from ground
#3 - 14 inches from ground
#4 - 20 inches from ground
#5 - 30 inches from ground
#6 - 42 inches from ground

Corner and brace posts should of course be larger. Posts must be placed not less than 2 feet in the ground and well tamped. Corner posts should be set 3 feet down.

c - Slips - In general we can say that slips represent nearly total destruction. It requires complete reclamation to bring them back to normal. The cost of reclamation would make such work prohibitive ordinarily. The best practice is to recommend reforestation on and surrounding these areas. It is also possible to fence and seed them. Where topography permits in certain cases an interception ditch may be placed above the slip to carry away all head waters. Where this is done care must be exercised to discharge the water where it will not cause gullying.

D

GULLY EROSION CONTROL STRUCTURES

Type of erosion:

II. Gully Erosion
(1) Head Erosion
(2) Channel Erosion
(3) Lateral Erosion

In gully control there are two possible objectives, namely, Stabilization and Reclamation. Reclamation in general for large gullies would be too costly a process on a short time period, so will not be considered here. It is sufficient to indicate that stabilization may eventually produce complete reclamation. The minor gullies can of course be completely reclaimed by diverting head waters and plowing or filling in the channels, so the following discussion will refer primarily to stabilization of major gullies.

(1) Head Erosion - This is a very dangerous and active type of gully erosion because it progresses rapidly up a slope once it gets under way. It endangers good land and poor alike when started. Effort should be made to plug head erosion by placing gully head plugs and by stabilizing the channels to prevent the head plugs from undermining. Two structures, the brush and the rock overfall, pages 92 and 93, Figures 18 and 19 have been used for gully plugs. A year of experience has indicated that a high percentage of failure results from brush overfalls. For that reason their use has been largely discontinued on Project #13. Where it is impossible to make rock overfalls because of lack of materials the brush structure will have to be used, so specifications for it are included. The rock overfall is ordinarily recommended, but it is thought that in some types of soil the brush overfall may prove more successful than it has here.

The brush overfall is constructed by clearing away any loose material immediately below the break until the sod actually overhangs throughout the length of the original break. It is not necessary to bring the break to a straight line because the only object gained is greater ease in fitting brush later. A bunch of brush or litter is now selected and placed up and under the overhang and at right angles to the line of flow. Longer and heavier brush is placed over this on line with direction of flow. Butts are placed down slope. Poles are placed across this brush and the brush pushed firmly into the break. The poles should be short enough to follow the line of the break in order not to leave loose brush. Poles may be fastened with stakes. A properly constructed overfall extends at least twice as far down hill as the break is high. It provides a smooth path for water to flow over an abrupt fall in the ground.

The rock overfall, Figure 19, page 93, is similarly constructed. The important thing is to have suitable materials. Project #13 was fortunate in having available vast quantities of flag-rock which are easily laid up as structures. These were utilized to construct rock overfalls. Flag-rock, if well laid, makes a structure that approaches masonry in strength and yet is far cheaper. The secret of a strong structure is to lay the stones in such a manner that they "key together" and are held by weight from above. Where only boulders are available it is recommended that masonry be used because of the uncertainty of loose rock structures.

In laying the flag-rock a very shallow trench should be dug across the gully about as far from the crest as the break is high. The ditch should be curved upstream. In this ditch the first layer of flat stones is laid. On these are laid the second layer in such a manner that they overlap about half the surface of the first layer and so on up until the overfall is completed. The finished job should have a "shingled" appearance and should extend well up on each side of the gully. The structure should be flume-shaped.

(2) Channel Erosion - This is a type of erosion familiar to nearly everybody as ordinary gullies. Channel erosion may be either lateral or vertical, depending upon the condition of the bottom and the type of soil. It is also variable according to the soil strata in which it is cutting. Once a gully has cut into the C-horizon it will usually eat rapidly and frequently has vertical or even overhanging banks. If the gully channel is of hard bottom such as shale we will find a semi-lateral erosion occurring. It has been stated before that little is yet known of the many variables producing the conditions indicated.

The engineer has at his command a host of structures that may be used to control channel erosion. Final choice will depend upon severity of erosion, type of gully, slope of gully, extent of watershed, prevalent soil, available materials, locality, and permanency desired. He should be constantly on the alert for practical and economical ways of controlling erosion. It is a well established fact that a structure which has been successfully used in one section of the country may be a complete failure in another. A careful and critical observer can learn more from Mother Nature than he can from reading all the texts on erosion engineering ever written. There are many examples of natural check-dams that eclipse the best we can afford to build.

Channel erosion may be controlled by (a) diverting head waters, (b) by filling in the channel completely, or (c) by stabilizing the channel.

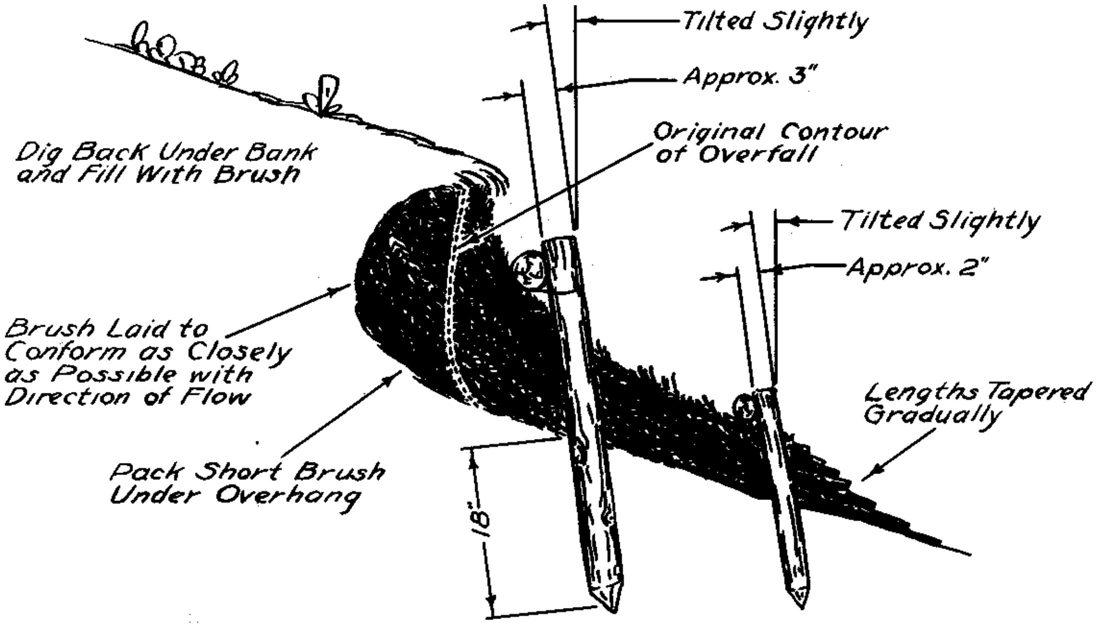
Where head waters are diverted it is frequently necessary to erect a fence around the gully to assist vegetation in healing the channel. The water can be diverted through the use of a diversion ditch, Figure 20, page 94. Before a diversion ditch is resorted to it is well to determine whether a suitable outlet is available. If an outlet appears doubtful it is wiser not to use a ditch at all. In staking out the ditch it is well to place grade stakes every 25 feet and offset from the center line up-slope in order to keep stakes clear of the dirt which later forms the lower side of the ditch. A large diversion ditch should be run in by level or transit rather than by clinometer. It is well to start the line at the point where the outlet is to be and run back. The ditch itself is cut with slopes as indicated on the diagram. The material for the fill should be well packed and then seeded. In ditches carrying much water it is well to place sod strips at definite intervals. It may even be necessary to place spreader boards instead of sod strips. A ditch should never be "run in" by eye alone as such practice will deliberately invite destruction.

No definite grade can be recommended but practice has indicated that for very erosive soils a 1% slope is satisfactory. The water should flow with sufficient velocity to carry its burden of sediment without excessive deposition and yet cutting should not take place. Velocities between 2 to 4 feet per second are ordinarily not dangerous. Much has been written regarding the carrying capacity of flowing water yet the subject is not very well understood. It might be well to mention here that the weight of objects which can be transported by water varies as the sixth power of the water velocity. Thus if velocity be doubled the transporting capacity of the water is 64 times as great. It should be kept in mind, however, that transporting capacity applies to the size and weight of particles moved by the water rather than to the total amount of material carried. Materials are transported by flowing water in three ways: (1) by continuous suspension; (2) by intermittent suspension; and (3) by rolling or skipping along the bed of the stream. Of course a great amount is carried in solution in addition to that in suspension but this is not being considered. If a solid whose density exceeds that of water is introduced at the surface of a stream it tends to settle gradually to the bottom under the action of gravity as it is carried along. The downward force is opposed by a greater or smaller upward force created by the irregularities on the channel bottom and thereby a certain amount of material is kept in suspension. The upward pressure of the deflected currents varies as the square of the velocity. Since the amount of material held in suspension is proportional to this upward pressure it also varies as the square of the velocity. The total quantity transported in suspension varies as the cube of the velocity. It may further be stated then, that as depth and velocity increase, the transporting power increases rapidly. The diameters of similarly shaped solids which the water is just able to move vary as the square of the velocity, and their weights theoretically as the sixth power of the velocity and actually as the fifth power.

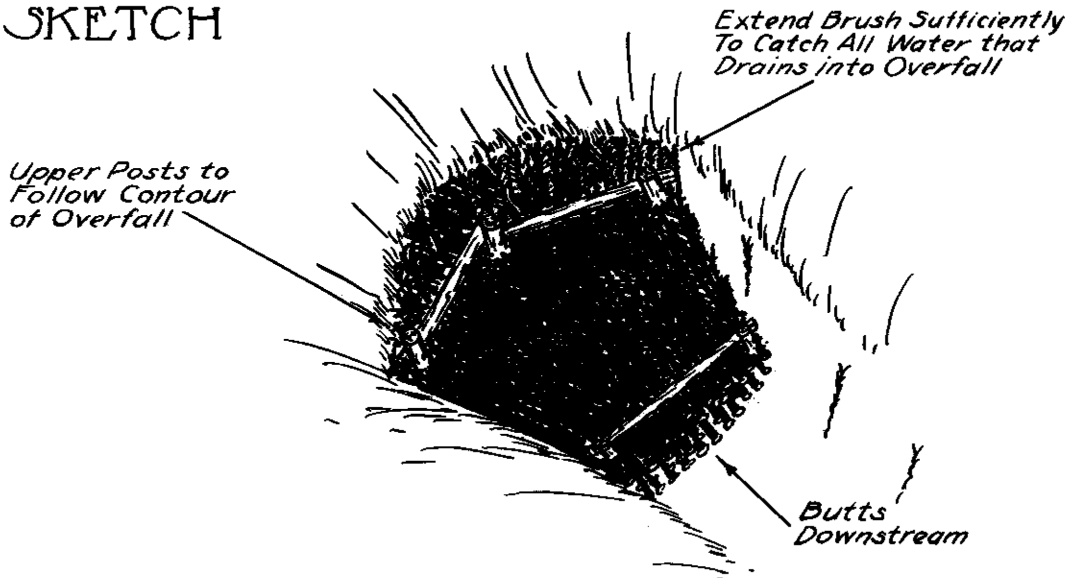
In ordinary diversion ditch design it will be impractical to make the above investigations but it will be necessary to design the ditch capacity for total runoff that might accumulate. Sufficient information to make such computation has been included under Hydraulics Part Three. There are indications that the variable grade diversion ditch may merit considerable attention. Where such a ditch is employed

BRUSH OVERFALL

SECTION



SKETCH



NOTE—Poles Wired to Anchoring Posts

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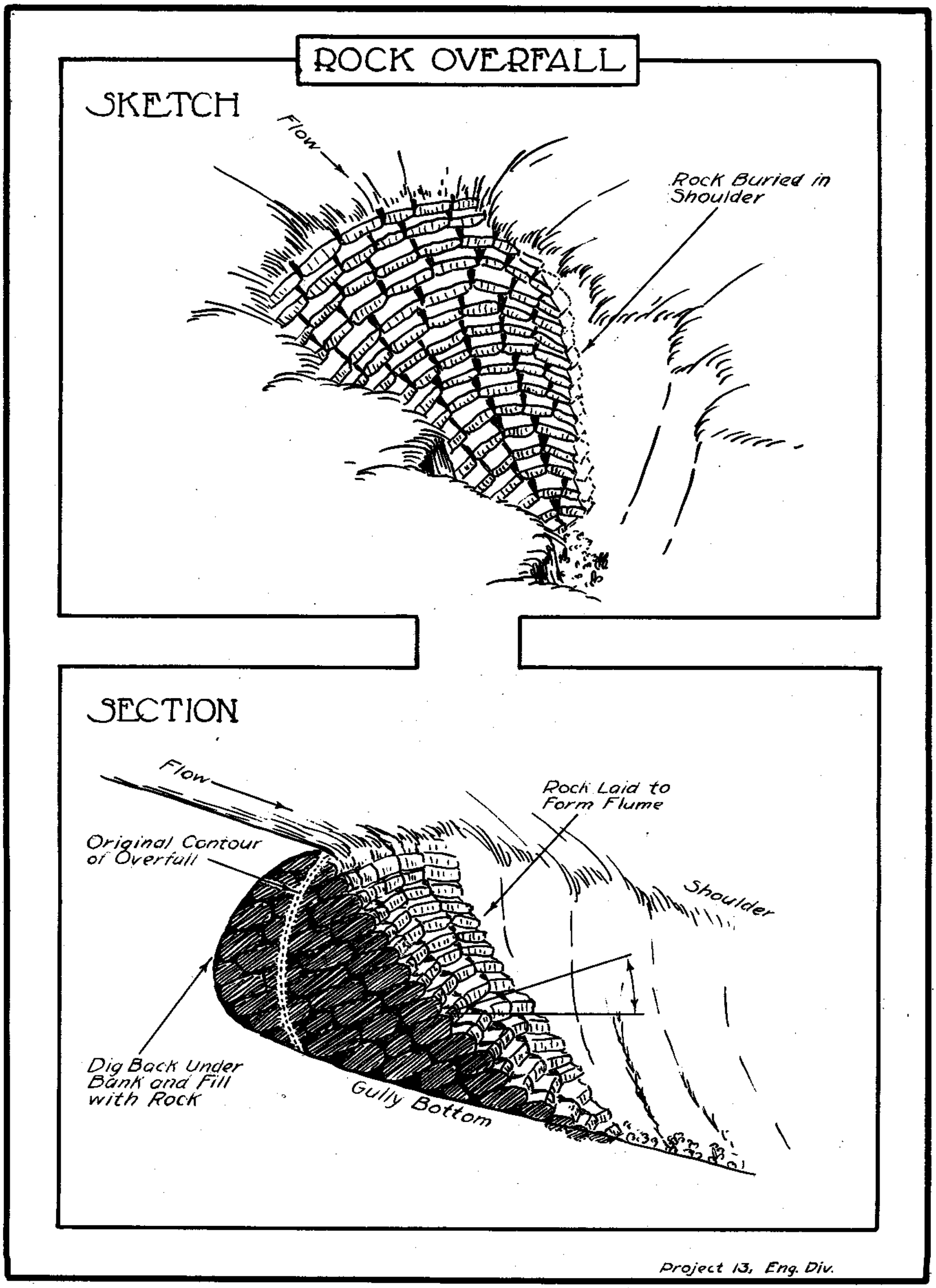
ROCK OVERFALL
SKETCH
Flow
Rock Buried in Shoulder
SECTION
Flow
Rock Laid to Form Flume
Original Contour of Overfall
Shoulder
Dig Back Under Bank and Fill with Rock
Gully Bottom
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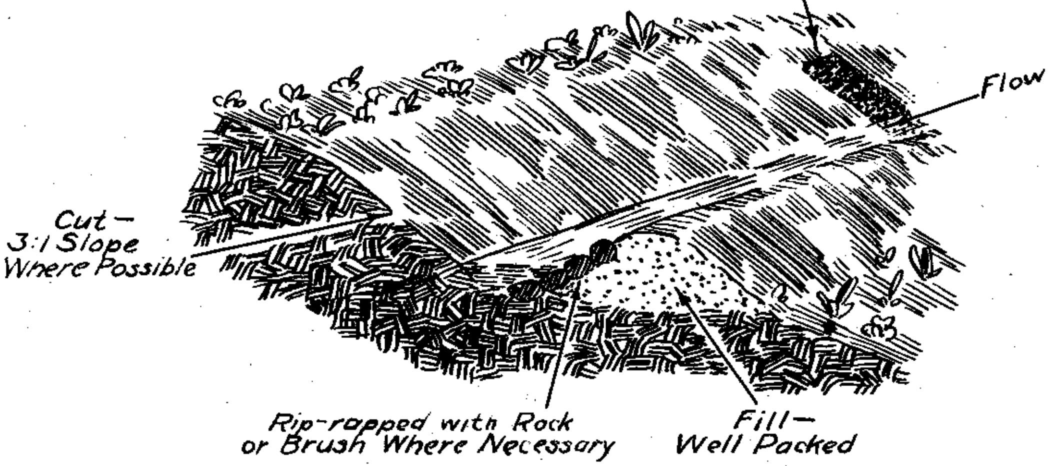
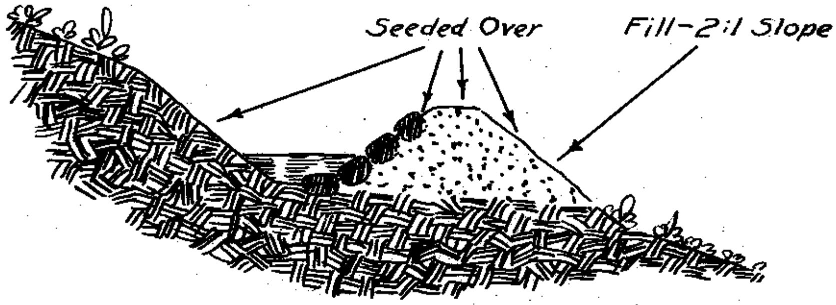
DIVERSION DITCH

SKETCH



SECTION



NOTE — Slope of Channel Not to Exceed 1% Ordinarily

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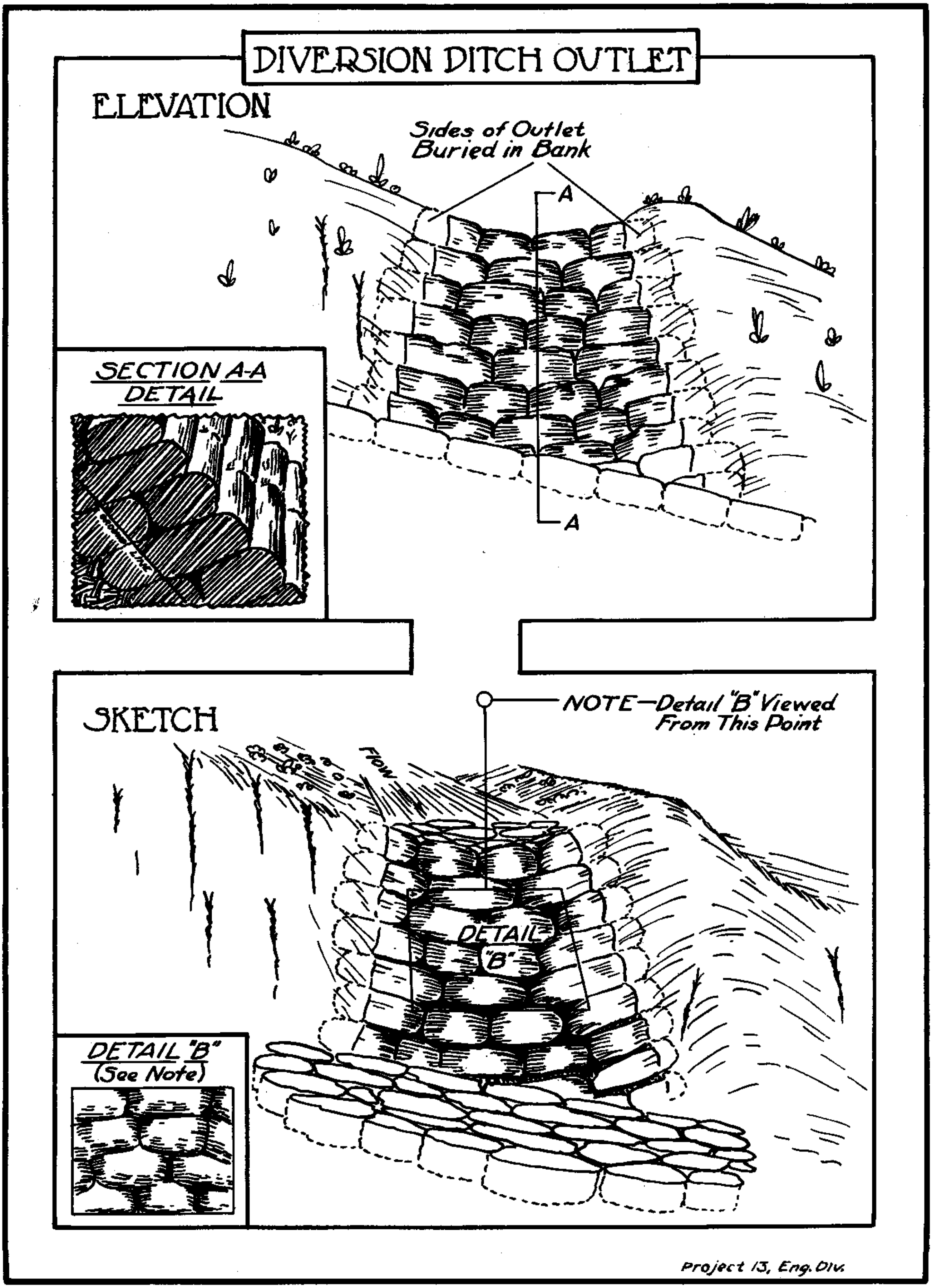
Figure 21


DIVERSION DITCH OUTLET
ELEVATION
Sides of Outlet Buried in Bank
A
A
SECTION A-A DETAIL
SKETCH
NOTE—Detail "B" Viewed From This Point
Flow
DETAIL "B"
DETAIL "B" (See Note)
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allowance should be made in the channel design.

Great care must be exercised in design of the ditch outlet (Figure 21 page 95). If flag-rock is not available a masonry outlet is recommended. In some cases it is possible to empty a diversion ditch direct without the use of a special outlet. Such is only possible where flow is very intermittent and a well sodded area is available. The outlet end of the ditch in such cases should be "flared".

Where a whole series of gullies has channeled out a large area, the diversion ditch may be used to advantage. All water may be guided into one channel by its use, and that channel protected by additional structures. The other channels can then be allowed to heal.

(b) By filling in channel - This method of control is effective on the smaller gullies only because it is in reality complete reclamation, which is far too expensive for average farm land. On the large gullies it has been found best practice to plow in the sides to a moderate slope, fence the gully and seed it. A bulldozer is very effective for cutting down gully banks. Powder could be used but is too expensive. Where a bulldozer is not available ordinary scrapers can be used. All headwater must of course be diverted.

(c) By stabilizing channel - This method of gully control involves the use of check dams. The following types are in common use and will later be considered in more detail:

1. Log Dam
2. Wire Dam
3. Brush Dam
4. Stake Dam
5. Rock Dam, rectangular spillway
6. Rock Dam, curved spillway
7. Bag Dam
8. Sod Dam

In the selection of the type of check dam to be used, the size and characteristics of the gully must be considered, the extent of watershed, the slope, probable runoff, materials available, permanency desired, soil character, and supplementary structures. Whatever type is selected involves almost identical fundamental construction principles. The basic rule as to general policy, namely, "where water can be controlled, concentrate it; where it cannot, disperse it" well applies here. Water is to be controlled by check dams, therefore its flow must be concentrated through proper weir notches and adequate channels. The structures must be built strong enough to care for heavy flows. The generally applicable features include:

(a) Base of structure placed well below channel bed to form cutoff wall.

(b) Wings to extend sufficiently into gully shoulders to avoid end cutting.

(c) Spillway of capacity sufficient to care for all floods covering the life of the structure.

(d) Apron to tie-in to the main structure and to extend well below it.

(e) Materials to be durable and well placed.

(f) Fill above main structure to extend back full distance specified and to be tamped.

(g) Immediate vegetative control measures.

(h) Adequate maintenance.

The hydraulic features in design of a dam have been covered under Part Three of this Handbook, including type problems for both a notched and curved spillway. Proper construction according to specifications will of course be the responsibility of the engineer and crew foreman. Drawings have been included to show construction features. Some changes have been recommended since the drawings were first made and these will be indicated in proper place. Before going into the field all required tools should be checked as many will be needed for this type of work. They should include cross-cut saw, post-hole digger, spud bars, pliers, pinch bar, hammer, shovels, mattock, tape, hand level, tamper, axes, hand-axe, stone hammer, cant hooks, spade, sod knife, hay fork, brush scythe, and sledge. Where seeding is done rakes should be taken along. Staples, various sized nails, brace and woven wire must be made available to the crews. When it is necessary to split logs or break rock the foreman should take along iron wedges and stone wedges as well as a striking drill where minor blasting becomes necessary.

Log Dam

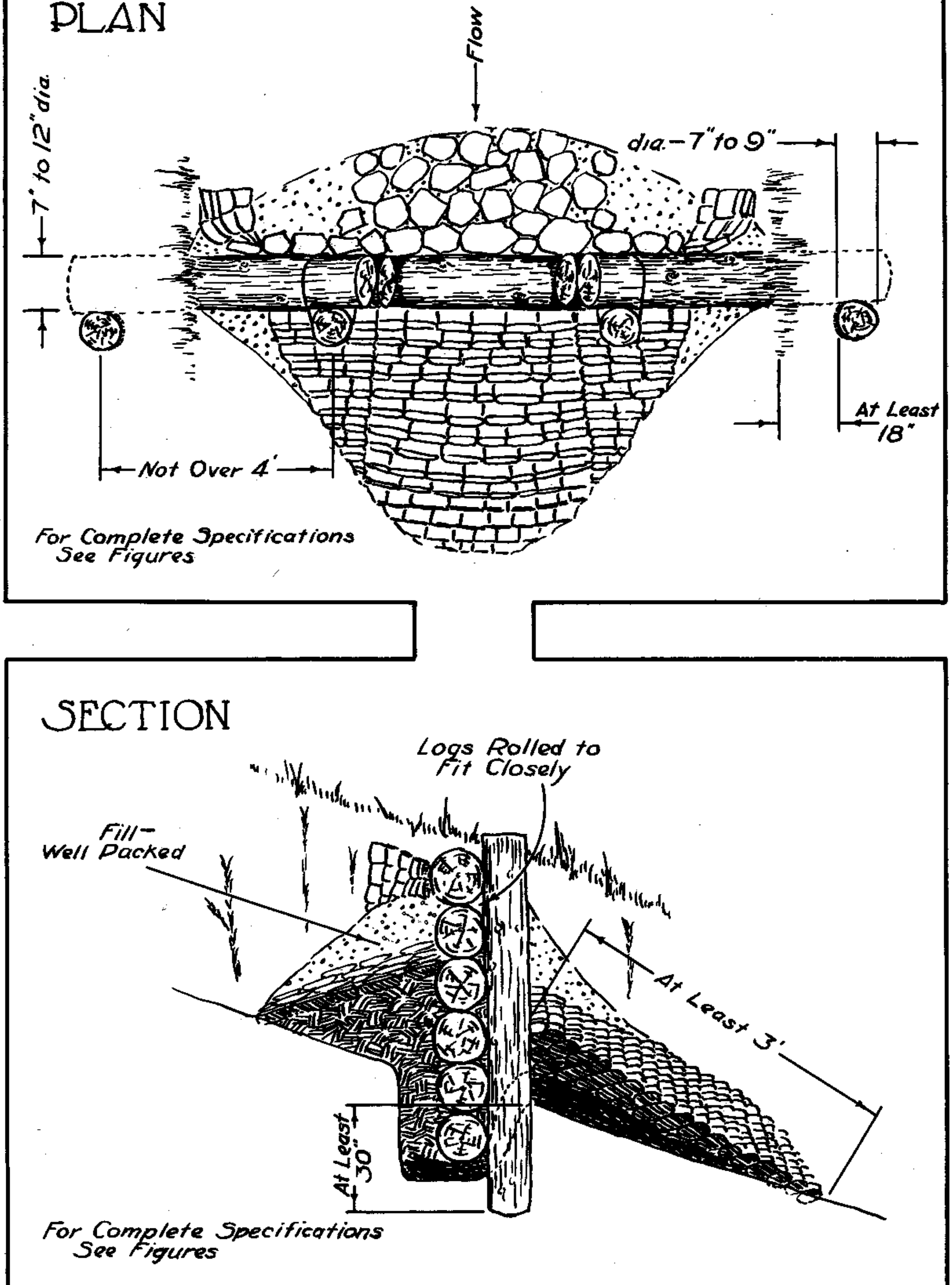
Refer to Figures 22 and 23, pages 99 and 100. This type of structure is very strong and durable. It is ideal to place in deep, narrow gullies having large drainage areas. Where possible, a log dam should be placed at such strategic points as, for example, the intersection of two or more gullies.

Right here in the beginning of the discussion on dams it might be well to state that ordinarily it will not be economical to place check dams so that the apron of one dam will be just slightly above the spillway crest of the dam below, allowing of course a natural gradient of 1% to 2% between the two structures. It is felt that dams should rather be placed strategically at vantage points along the gully where sites are suitable for a structure. Considerable saving can be accomplished through such practice and results obtained will be comparable to the other method. The placement policy applies to all types of check dams with the exception perhaps of the sod and bag dams.

Materials for a log dam should consist of logs cut 6 to 8 inches in diameter, smooth wire, and flag-rock. About a yard of flag-rock will be required to build a good apron and to slab the approaches. The logs used should have a uniform diameter and should be straight.

At the site selected a core trench is dug perpendicular to the center line of the gully. Specifications are shown on the figures. A large base log is placed in the trench. Posts are now placed along the downstream edge of the base log. They should be 4-8 inches in diameter and long enough to extend to the top of the gully bank. Spillway posts are set on each side of the proposed weir notch with about 6" clearance from the cut. A post is set at each end of the dam. Where the structure exceeds 20 feet in length, extra posts should be used. It is well to remember while digging the core trench to throw the excavated dirt up slope several feet in order to make it readily available for later use on the back fill. After the base log has been placed the other logs should be fitted. They are put one on top of the other until the height of the dam is reached. They should fit closely together, even at the expense of trimming out projections or snags. Often a good fit may be obtained by rolling the logs. About a #9 brace wire is used to tie the logs to the upright posts. If proper length logs are available the dam may be built to the height of the spillway crest and the shorter logs used to continue with the notch. Final dimensions for the dam spillway may then be obtained by sawing out the weir notch to proper size. A trapezoidal weir notch makes a very pleasing appearance and adds to the symmetry of the structure. It is very important that the spillway crest log be placed absolutely horizontal so that water flowing over the spillway will not concentrate in one corner of the notch, thereby endangering the apron. The Abney Level may be used to obtain a horizontal crest. After the dam proper is completed and the notch cut out the back fill is put in. Where a close fit was not obtained the chinks between logs should be stuffed with broomsedge, straw, or similar material such as leaves or mulch and the dirt placed against the dam layer by layer until the fill reaches the spillway crest. Each layer must be thoroughly tamped as it is put in. The fill should extend well up on the shoulders. It is recommended that fills be seeded. Experience

LOG DAM



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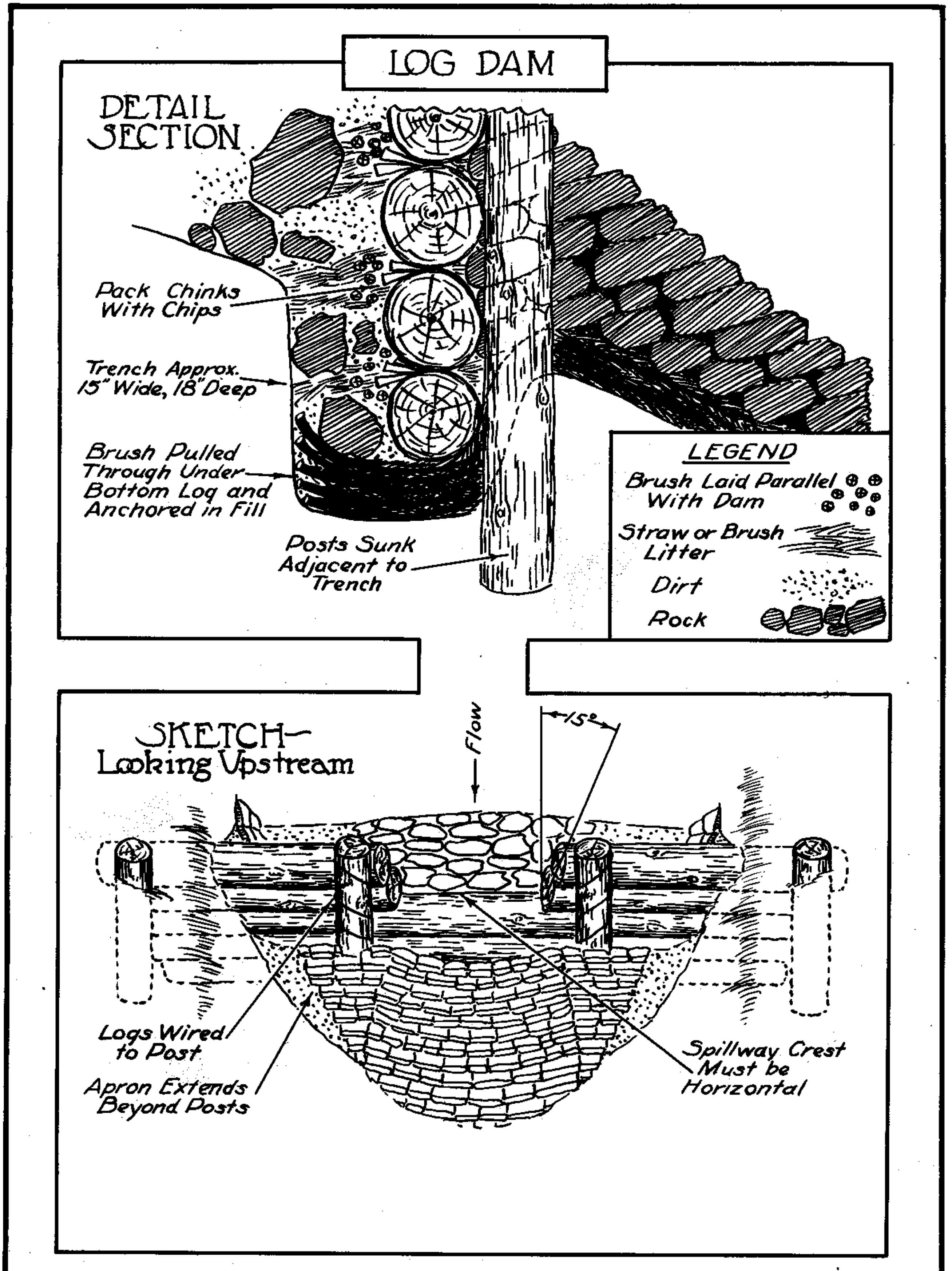

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has indicated on past structures that a sod crest placed on the spillway is very satisfactory. It has further been found that the flag rock crest indicated on the fills as per the drawings of log dams (pages 99 and 100) are not satisfactory and will undermine. Therefore it is recommended that the flag stone not be placed near the crest of the fill but rather be used only for the shoulders as a rip-rap and for apron construction. The banks above the gully should also be sloped and seeded. Reference should be made to Part Five which gives in detail the planting and seeding of structures.

The final feature of the dam will be the apron below the spillway. It is probably the most important single thing in the whole structure. It is best constructed by removing all brush and loose material from the bottom of the gully and then lining the channel with flag stone starting several feet below the dam. Immediately following the discussion on dams will be a description of apron construction which should be referred to. The apron indicated will be applicable to the log dam. From the type of material that goes into temporary dams we know that the life of the structure will be limited. Therefore the whole unit must be so planned and placed that a wash-out will not result when the structure rots away. For this reason we are advocating building an adequate rock apron that will act as a semi-dam even after the main structure is gone. This can very well be done by building the apron up to within two-thirds the spillway height of the dam and laying it in a flume shape so that it will always act as a waterway and still will retain soil above it. It is, of course, assumed that by the time the structure has decomposed sufficiently to be of no further value vegetation will have established itself sufficiently to prevent further erosion, with the help of the rock apron remaining.

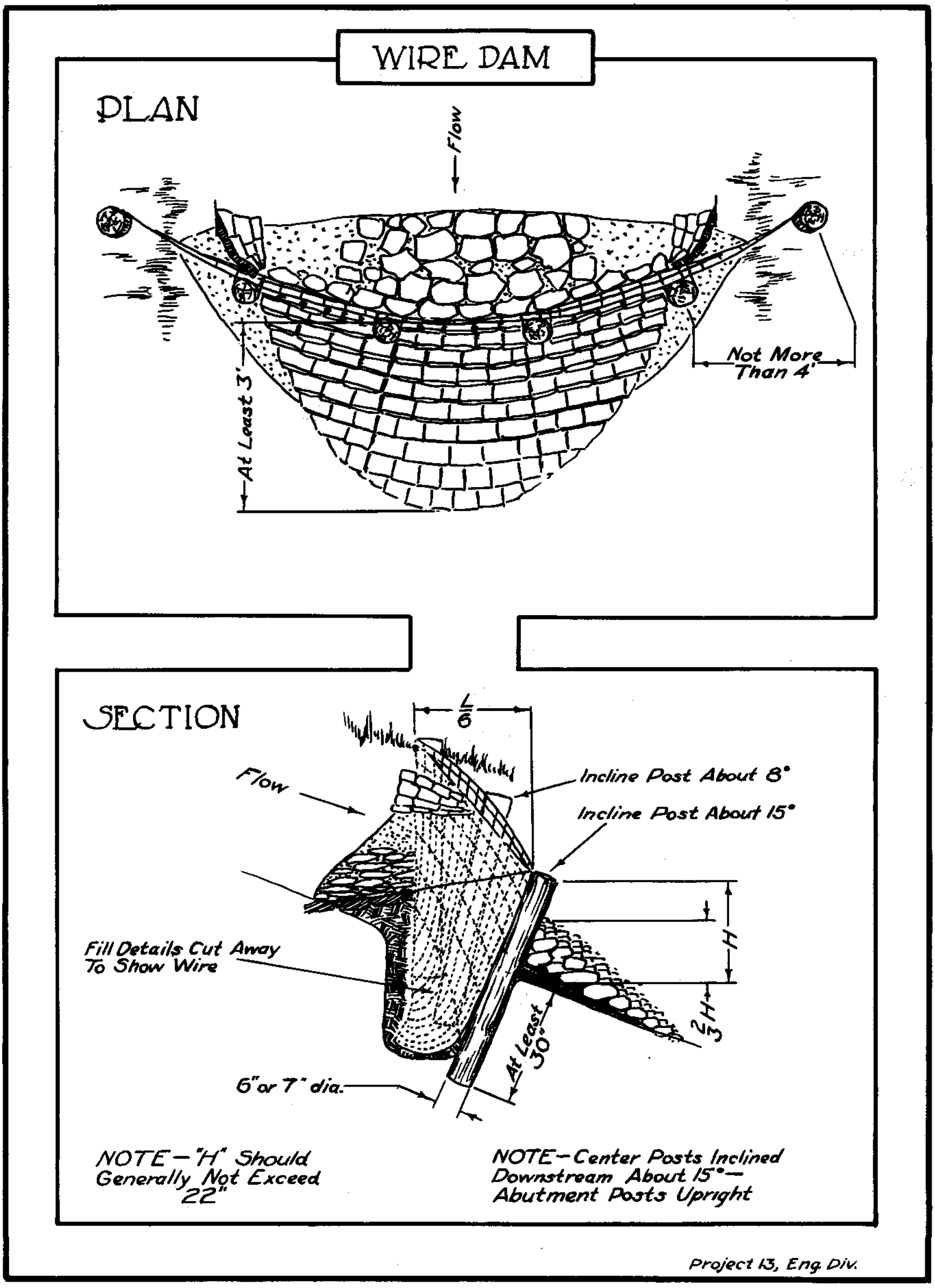
The log dam is expensive so must be used in places where it can collect considerable soil and where the land it protects has economic value. As before stated it is suited to narrow, deep gullies. As a final precaution before leaving a structure the foreman should make a careful inspection to see that specifications have been followed and the unit is complete. The little added effort necessary to make a well appearing dam is worth while. All waste material that is left should be neatly piled or should be placed in the gully above the structure. Never leave an untidy work site.

Wire Dam

Refer to Figures 24, 25, 26, pages 102, 103, and 104.

The woven wire check dam has proven to be a very satisfactory structure because of its low cost and ease of construction. It is suited to broad, shallow gullies with small watersheds. On the Spencer

Figure 24



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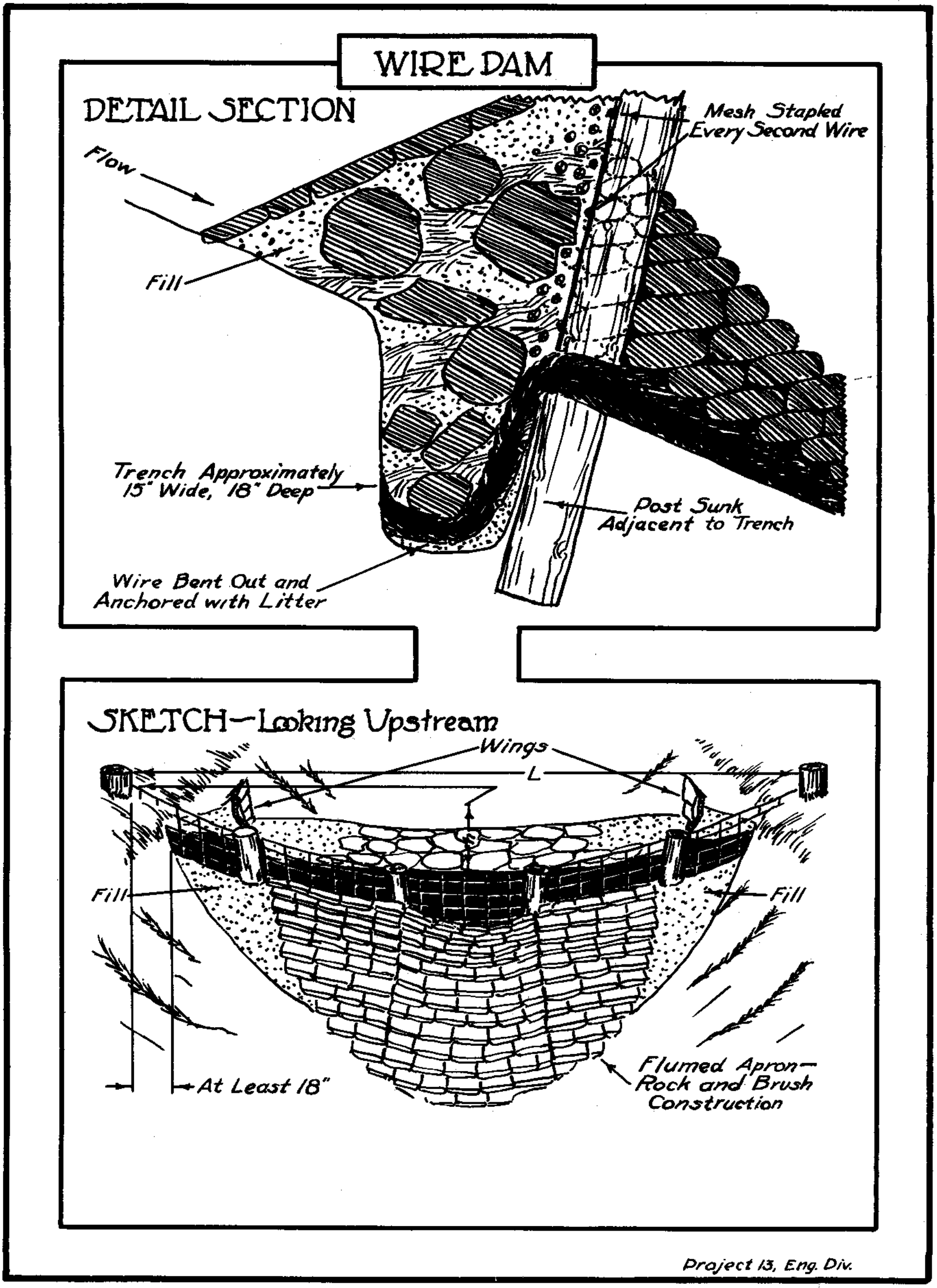
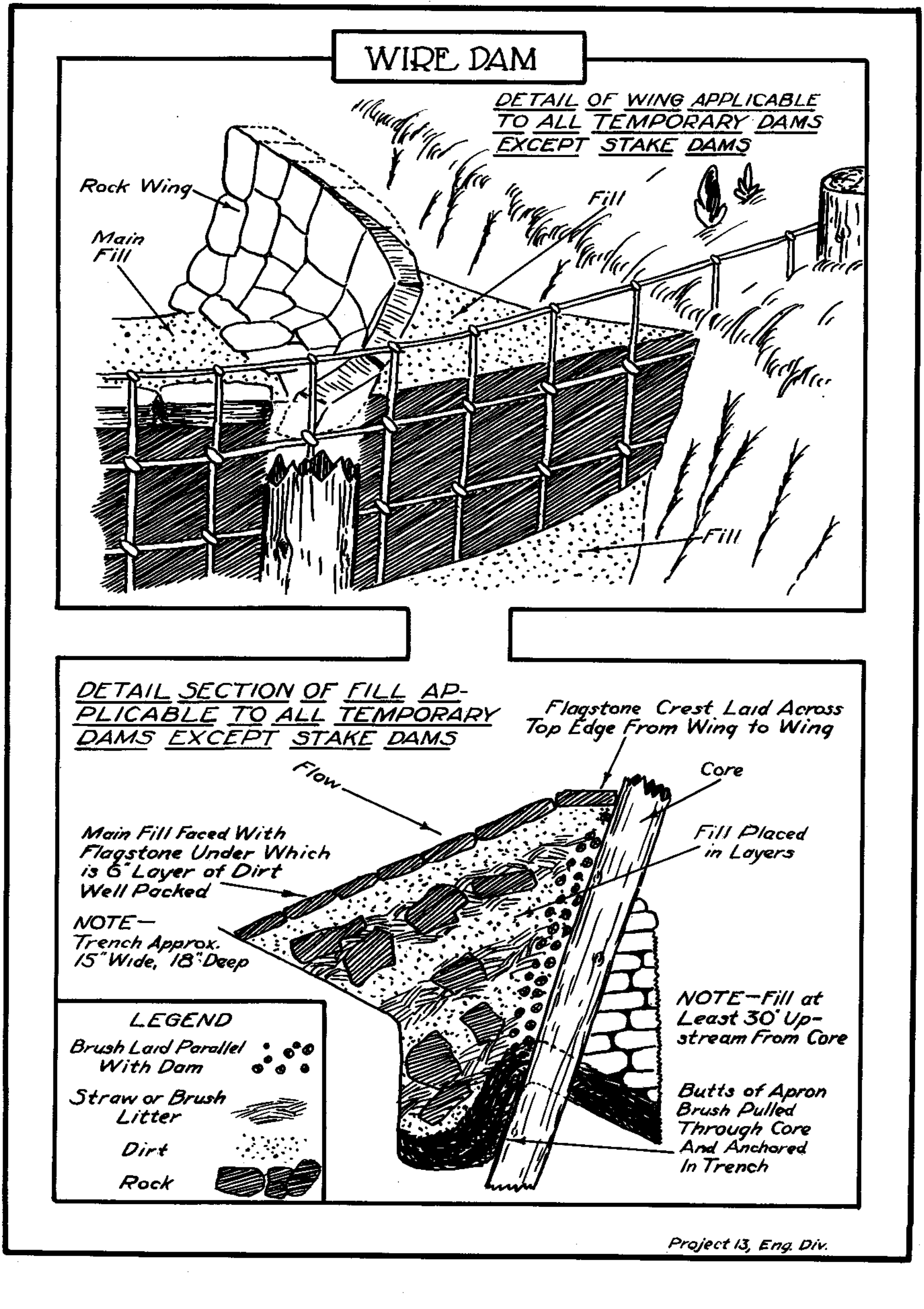

WIRE DAM
DETAIL SECTION
Flow
Fill
Mesh Stapled Every Second Wire
Trench Approximately 15" Wide, 18" Deep
Post Sunk Adjacent to Trench
Wire Bent Out and Anchored with Litter
SKETCH—Looking Upstream
Wings
L
Fill
Fill
At Least 18"
Flumed Apron—Rock and Brush Construction
Project 13, Eng. Div.


WIRE DAM
DETAIL OF WING APPLICABLE TO ALL TEMPORARY DAMS EXCEPT STAKE DAMS
Rock Wing
Main Fill
Fill
Fill
DETAIL SECTION OF FILL APPLICABLE TO ALL TEMPORARY DAMS EXCEPT STAKE DAMS
Flagstone Crest Laid Across Top Edge From Wing to Wing
Flow
Core
Main Fill Faced With Flagstone Under Which is 6" Layer of Dirt Well Packed
Fill Placed in Layers
NOTE— Trench Approx. 15" Wide, 18" Deep
NOTE—Fill at Least 30' Upstream From Core
Butts of Apron Brush Pulled Through Core And Anchored In Trench
LEGEND
Brush Laid Parallel With Dam
Straw or Brush Litter
Dirt
Rock
Project 13, Eng. Div.

Project a 39 inch woven wire was used, which proved adequate. Many engineers recommend chicken mesh for the wire dam. The heavier galvanized wire will, of course, be the more permanent of the two and should be used where possible.

The dam is laid out by stretching a tape from stake to stake straight across the gully. From the center of the tape a distance equal to one-sixth of the length of the dam is measured down stream and marked. This point determines the curve of the wire dam. A ditch is now dug along a curve joining the shoulder stakes, with the point marked out at the distance previously given. The dirt from the ditch should, of course, be thrown up stream to be used later as a fill.

Posts are now placed on the lower side of the trench. They should be slanted down stream, especially those in the center third of the dam. The post interval should not be more than four feet. For the spillway area the two center posts should be placed at equal distances from the center of the gully. After the posts are in place and well tamped in the ground the wire is stretched across and in the trench. A good practice in placing the wire is to invert it so that the small mesh will be at the top. All wire should be well stapled so that it will not pull loose. Care should be taken that the wire forms a symmetrical curve, especially in the part used as a spillway. It is good practice to bend up the bottom of the wire that is in the trench; by so doing the wire will be held by the soil and fill above it. The fill is made by placing fine brush against the wire. Brush should be laid longitudinally and alternated with layers of dirt. This process is continued until the trench has been filled. From this point the apron of the dam can be built at the same time as the fill is being continued by ramming brush through the wire with butts laid up stream. The brush so placed as part of the apron will be well anchored to the fill. The fill should now be continued until the crest of the spillway is reached. The final layer of any fill must, of course, be well packed dirt. No flag-stone rock should be placed on the crest of the dam as this has proven unsatisfactory. The rock has been shown in the figures, which were drawn before time had proven such practice unsatisfactory.

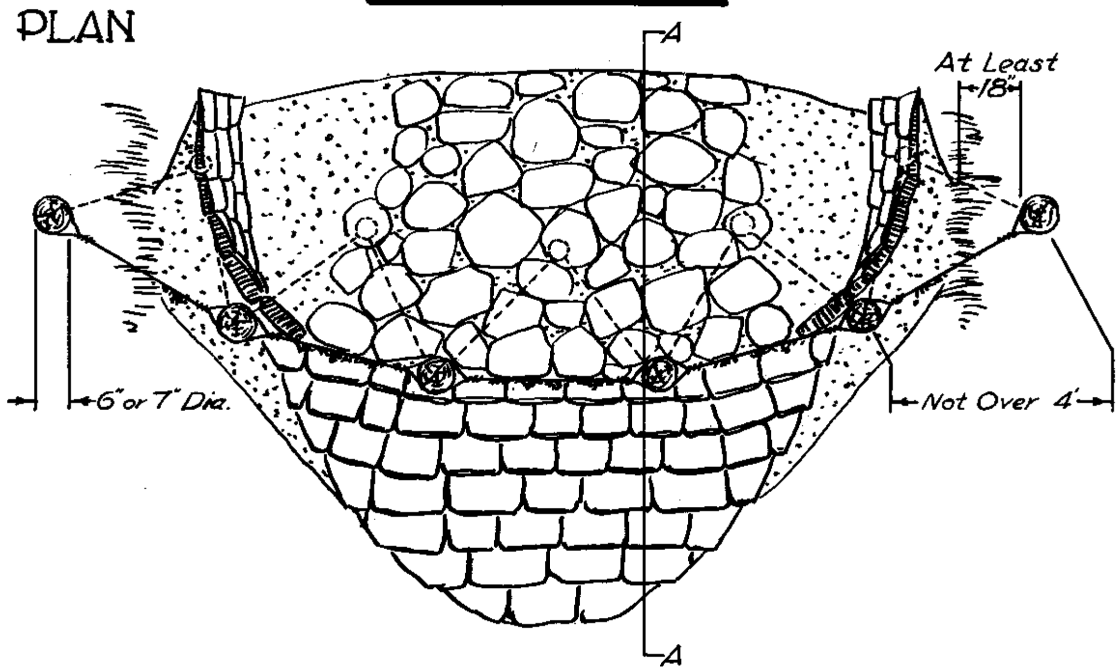
The apron should next be built; same procedure will be followed as for the log dam in conformity with specifications immediately following the discussion on dams. The apron on the wire dam will have to be very wide and should be built to two-thirds of the effective height of the spillway.

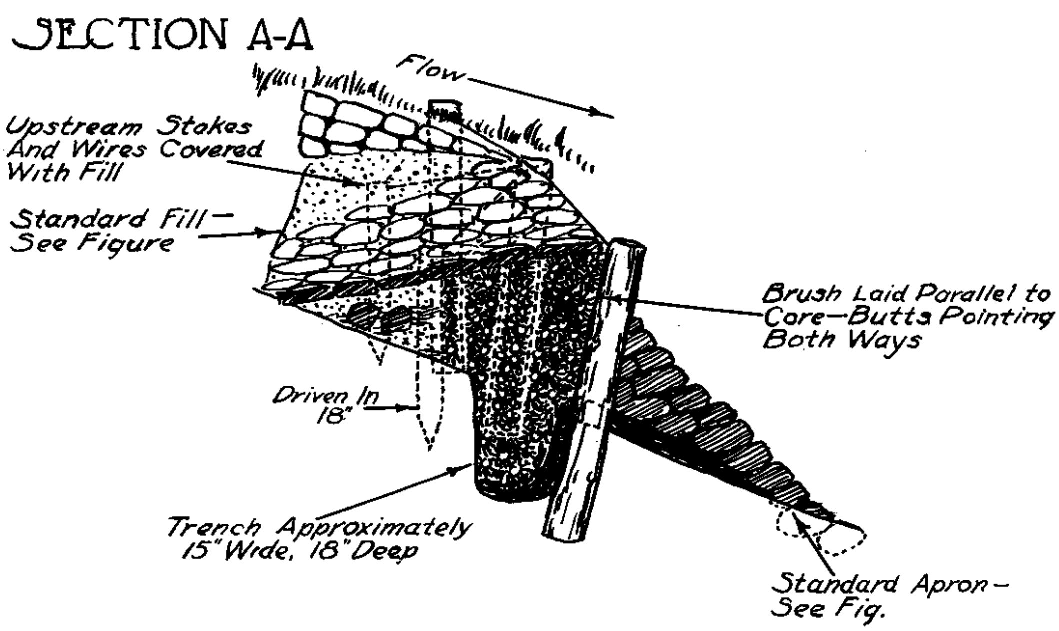
Brush Dam

Refer to Figures 27 and 28, pages 106 and 107.

A brush dam is built in gullies similar to the type in which wire dams are placed. It may be used where wire is not available and where the

BRUSH DAM





NOTE — Wings and Fill Extend Farther Upstream Than In Other Temporary Dams

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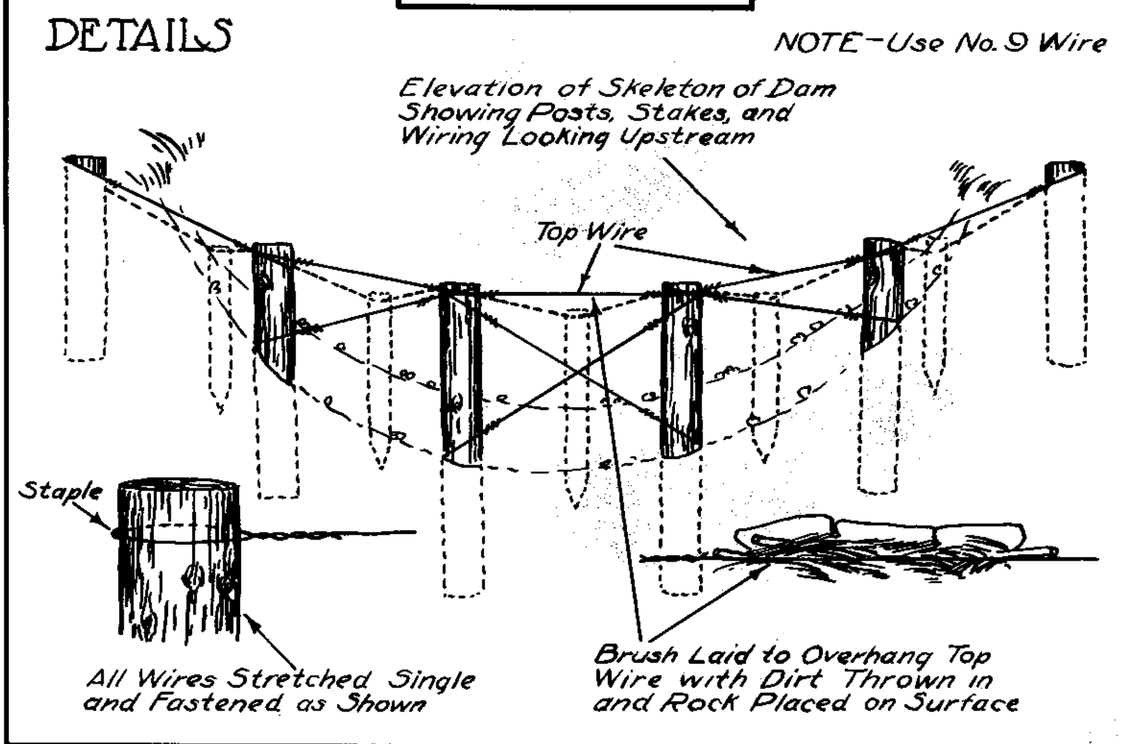
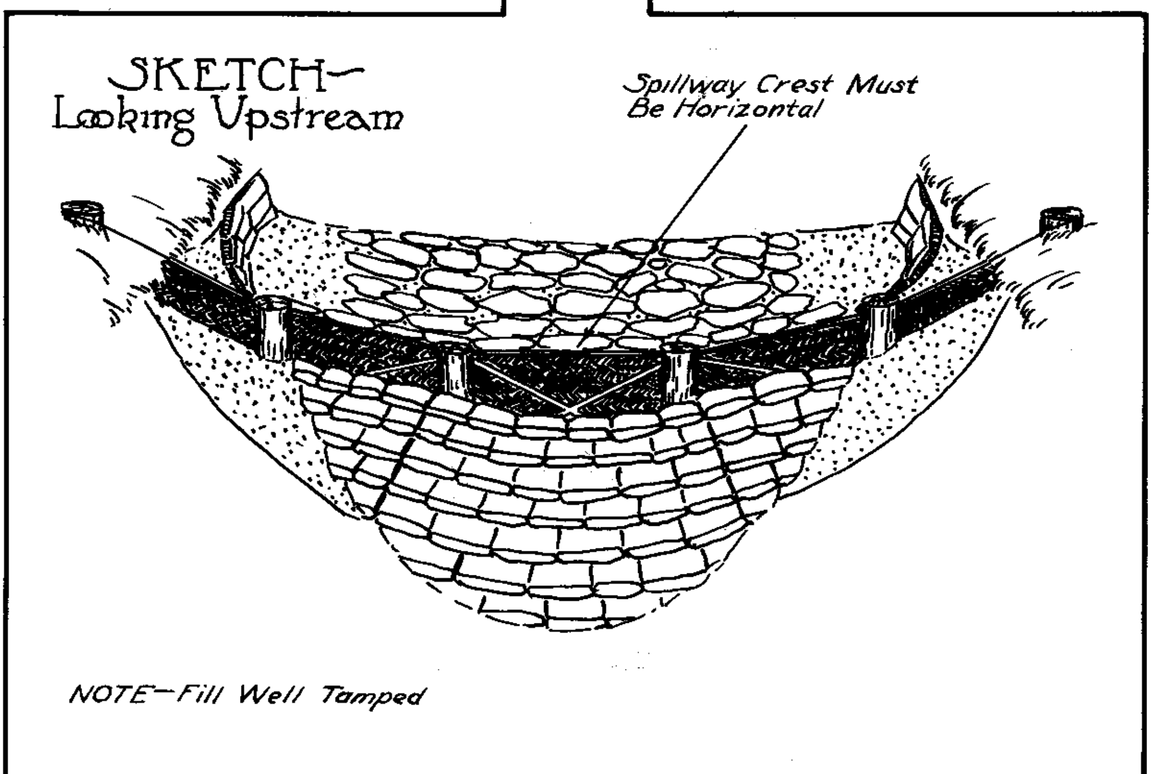
Figure 28

BRUSH DAM





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watershed is larger than that used for wire dams. The structure is strong and if well built will last for years depending, of course, upon the type of material used. A durable and tough brush is recommended.

The structure is staked out similar to the method used for the wire dam, with wings extending up stream approximately one-sixth of the length of the dam. The trench is dug on the curve thus laid out according to the specifications indicated on the diagram. Posts are placed on the lower side of the ditch and are tilted as shown. The posts should not be spaced more than three feet apart. In placing the brush for the fill, which in reality comprises the main part of the structure, the material should be placed in alternate layers, namely one layer running longitudinally the length of the trench and the next layer running longitudinally at right angles to the trench. On this latter layer the material should be laid with butts down stream and the tops extending well over and across the trench. When near the top for desired height the material is tied down with brace wire which has been diagonally placed and staked on the up stream side of the fill. A final layer of earth is then tamped in place. On the fill no flag rock should be placed, which is contrary to the specifications shown, but as before stated, the rock was indicated on the drawings prior to the time it was actually found that such practice was detrimental to the life of the structure.

The foremen should be cautioned in placing the brush for the body of the dam. This brush must be well picked and should be rammed into place. When finally tied down with brace wire it should fit snugly and be solidly packed into place. No unusually large material should be used for such a fill because it makes the structure subject to undue seepage, with resultant failure. Refer to Part Five of this Handbook as to manner of seeding and planting the structure. Where possible it is recommended that sod strips be placed along the crests of the dam, especially over the length that serves as spillway.

Final construction will be the apron. Please refer to discussion covering apron construction which follows the specifications for dams. The apron on the brush dam should be built wide, as in the wire dam, and should equal two-thirds of the total height of the spillway.

It is recommended that the brush dam be used as little as possible, because indications are that it requires considerable man hours in construction.

Stake Dam

Refer to Figures 29 and 30, pages 109 and 110.

The stake dam is applicable to very shallow gullies that have a small watershed and a gentle slope. The dam is in reality merely an

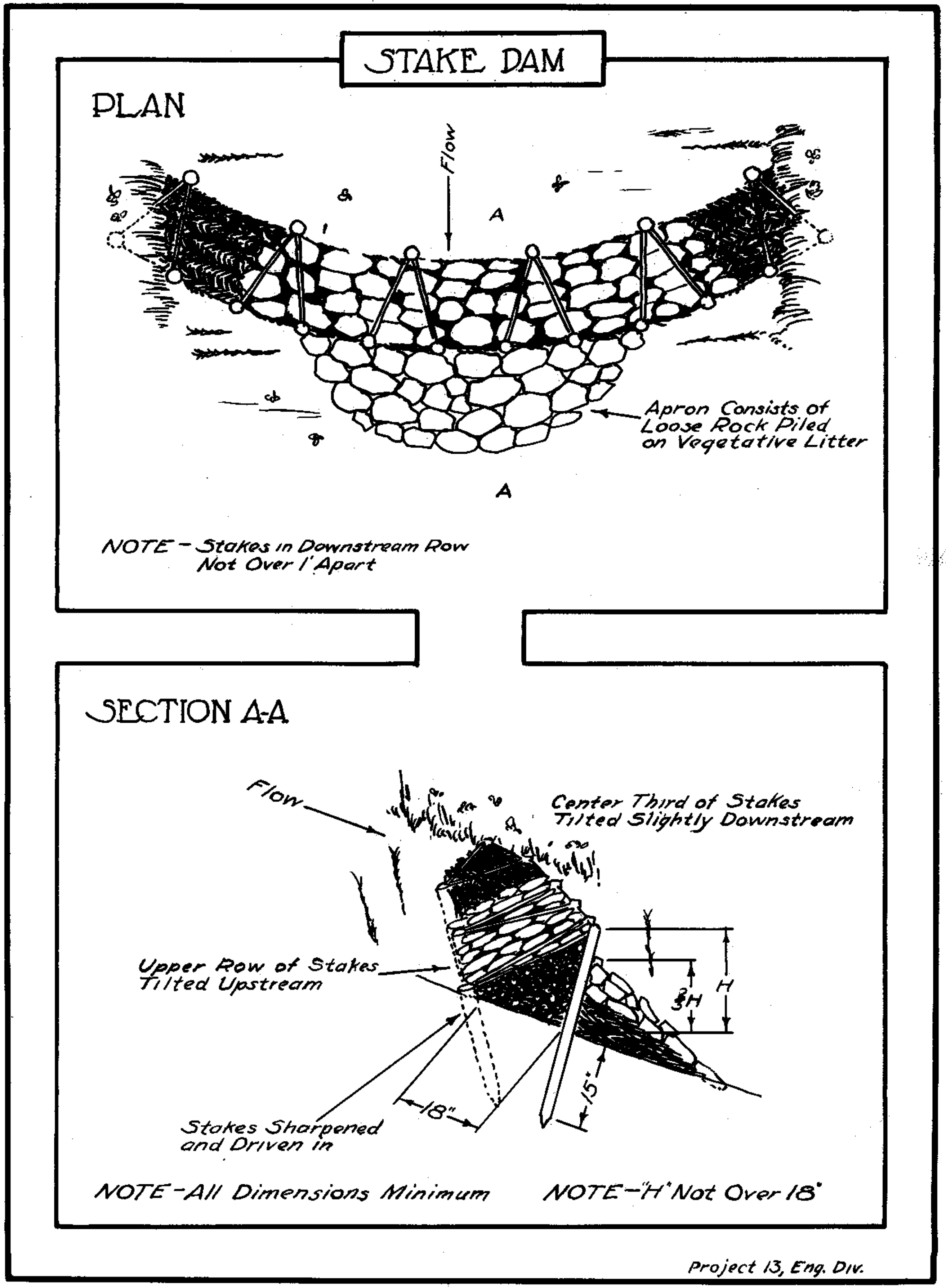
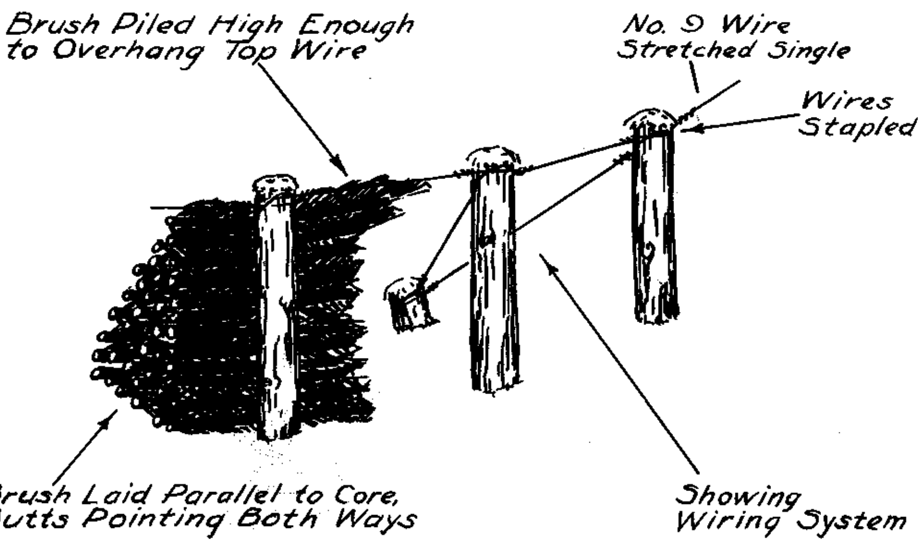

STAKE DAM
PLAN
Flow
A
Apron Consists of Loose Rock Piled on Vegetative Litter
A
NOTE - Stakes in Downstream Row Not Over 1' Apart
SECTION A-A
Flow
Center Third of Stakes Tilted Slightly Downstream
Upper Row of Stakes Tilted Upstream
H
2/3 H
15"
18"
Stakes Sharpened and Driven in
NOTE - All Dimensions Minimum
NOTE - 'H' Not Over 18"
Project 13, Eng. Div.

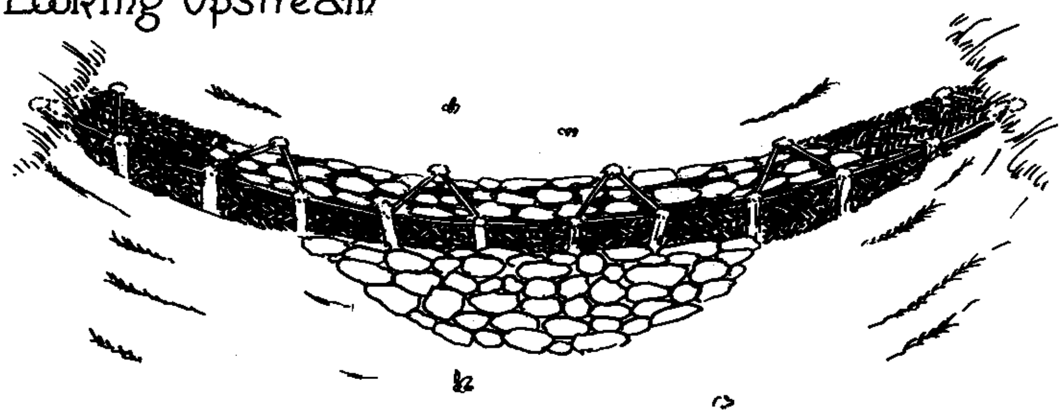
Figure 30

STAKE DAM

DETAILS



SKETCH– Looking Upstream



NOTE – Ends of Dam Buried About 6" Under Surface at Shoulder

NOTE – Excess Dirt From Abutments Thrown on Brush in Core

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obstruction placed to build a small bench and yet capable of confining water flow.

The dam requires no trench. It is sufficient to merely clean off the loose dirt on the site. The structure is marked out similar to the method used for the wire and brush dams. The wings are placed up stream about one-sixth of the length of the dam. It is not to be assumed that because the structure is small it should not receive the most careful attention in construction. If improperly built the dam may cause a great deal of damage to the gully channel. The accompanying figures indicate clearly the method of construction. It will be noted that fine brush is used for the body of the dam and that this brush is held in place by stakes driven into the ground.

Special mention should be made of the apron construction. In this type of dam the specifications given under apron construction following the discussion on dams is not applicable. Fine brush is interwoven with the material comprising the body of the dam. It is placed at right angles to the line of the dam or in other words parallel to the gully channel. The branches of this fine brush are allowed to extend below the lower row of stakes and thereby form the apron. It is well to cover the apron with loose rock as indicated in Figure 29, page 109. For assurance against washing a thin layer of dirt should be removed from the site of the apron in order that the material used will fit snugly to the channel bed.

No flag rock should be placed on the crest of the dam. This is not in conformity with the figures. In building the body of the structure, be sure that the brush is firmly packed before it is anchored. The final layer for the fill should consist of earth tamped into place.

The stake dam will be found very useful in construction work. The man hours required are small and ordinarily supervision will be at a minimum.

Rock Dam - Rectangular Spillway

Refer to Figures 31 and 32, pages 113 and 114.

The rock dam as a structure is highly recommended for use in erosion control in West Virginia. It is a permanent type of structure, very durable, and is easy to construct. The material entering into its construction is ordinarily available on every farm. The structure may be built of loose rock entirely if flag rock be available. Where boulder type stone must be used it is recommended that masonry structures be built, because experience has indicated that loose rock of a circular or semicircular shape will not withstand action of running water for any length of time without toppling or sliding. If the flag rock can be obtained and is laid properly, a loose rock dam will last indefinitely. It is, of course, important that the flag rock be so placed that all joints are broken and that the whole structure will key together with each unit being held in place by weight from above. On very large gullies with an extensive watershed the rock dam is not recommended, nor is it advisable to use it on a broad shallow gully.

The first process in construction is the digging of a ditch for a cut-off wall. The ditch is to be dug according to specifications indicated on the diagrams. Rock is then placed in the ditch and a base provided for the top layer. As soon as the top of the trench has been reached a layer of rock is placed several feet down stream and at right angles to the stream bed. From this toe layer, which is dug down, additional layers are added, with each succeeding layer placed two or three inches up stream according to the sizes of the rock. The layers are continued until the desired height forming the crest of the spillway is reached. From then on layers are placed on each side to form the weir notch. All rock should be laid at an angle to the horizontal, as indicated in Figure 31, page 113. In so tilting the rock the structure will be held in place by dirt deposited. Also the tilt will take care of any settling down stream that may take place.

It will be noted that the apron in the rock dam is an intregal part of the structure itself. In other words the entire dam including apron is built as a unit. The final tilt to the rock dam should be in the vicinity of 45°. This will allow the water to walk down the dam instead of splashing over in a vertical drop. Not enough emphasis can be placed on careful placement of the rock to form alternate layers comprising a unit that will be held together by the weight of water and dirt above and behind it. The laying of the rock is very similar to the construction employed on the rock overfall.

The fill for the dam should consist of earth and brush well tamped into place. Where fine brush is not available use broomsedge, straw, or similar materials. The whole fill should be well tamped, and sod strips placed along the crest and wings of the structure will aid materially in preventing failures. It is again mentioned that the apron construction of the rock dam is not according to that indicated for the other dams. The apron here comprises the body of the dam itself.

Time spent in looking for suitable rock to be placed in the structure will be well spent. A stone hammer should be on hand at all times to be used in breaking rock to suitable size.

There are records available which indicate that this type of structure will last for fifty years or more, so it is still a worth while structure in erosion control. As a precaution it is to be noted that where it is necessary to haul rock long distances for the dam it may be more economical to construct other types of dam.

Figure 31

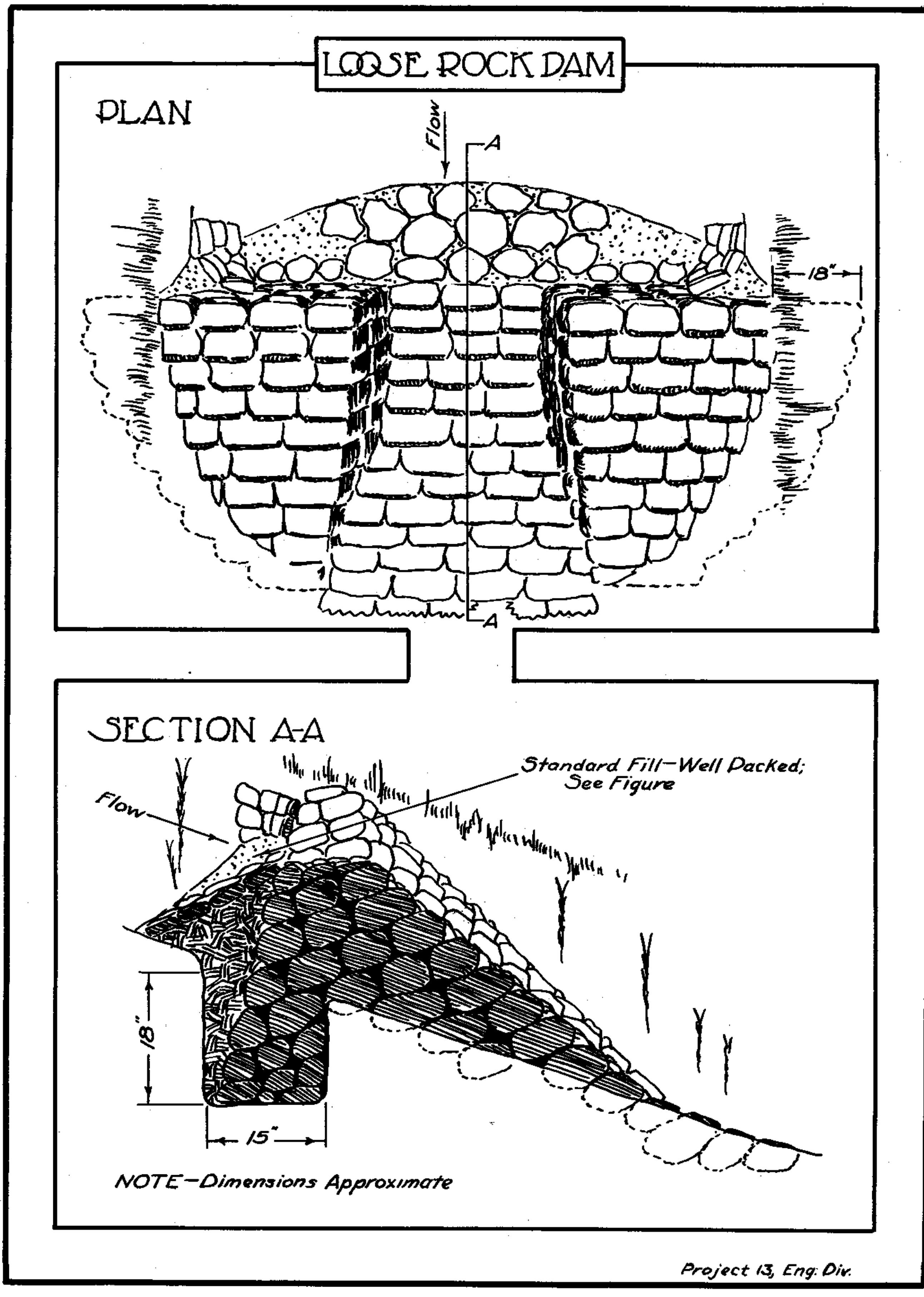
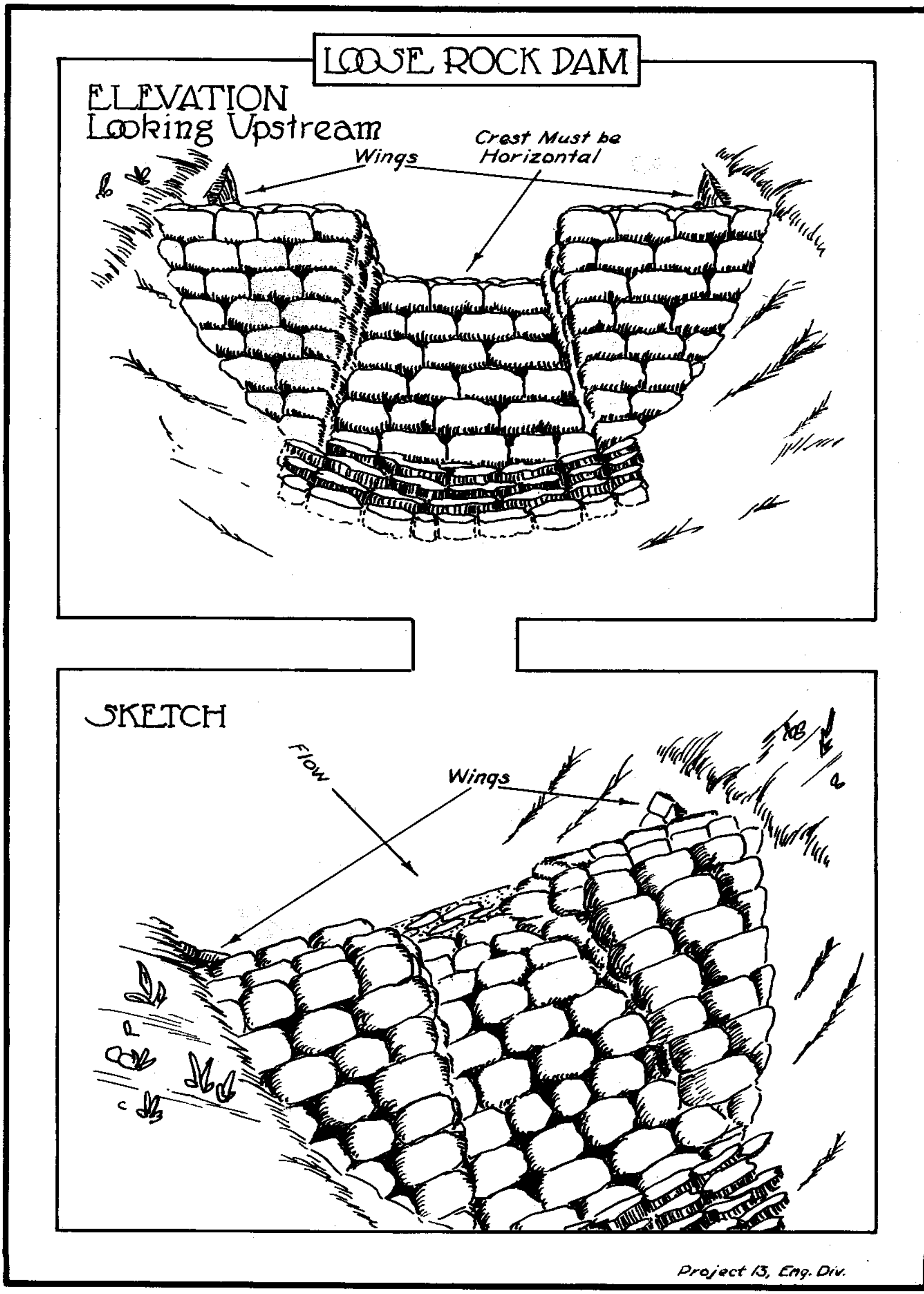

LOOSE ROCK DAM
PLAN
Flow
A
18"
A
SECTION A-A
Flow
Standard Fill—Well Packed;
See Figure
18"
15"
NOTE—Dimensions Approximate
Project 13, Eng. Div.

Figure 32


LOOSE ROCK DAM
ELEVATION
Looking Upstream
Wings
Crest Must be
Horizontal
SKETCH
Flow
Wings
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Rock Dam - Curved Spillway

Refer to Figure 33, page 117.

In many cases it is preferred to use a rock dam with a curved spillway in preference to the notch weir employed by some engineers. The curved spillway gives the advantage of spreading the water rather than concentrating it and would be desirable in a broad gully.

The curved spillway dam has almost similar construction principles as were employed for the weir notch type. The only difference is that the spillway is formed by building the wings of the dam higher than the middle as the dam progresses. Upon completion the spillway will be a part of the structure. In order to produce a more symmetrical spillway it is suggested that the rock used toward the center of the curve be smaller than those placed on the wings. It will take considerable practice before men become proficient in laying a rock dam, but once the art is learned work progresses rapidly.

It is not possible to give a written description of the exact method to lay rock. Experience must be the teacher. If suitable materials are not available it will be impossible to turn out a good job, so another type of structure should be selected or masonry be employed. The curved spillway rock dam requires no separate apron, the apron being built into the main structure as indicated in the previous discussion for the rectangular weir dam. It is recommended that the fill for the rock dam consist of earth well tamped. Sod strips should be placed along the crest and wings of the structure. Please refer to planting and seeding instructions under Part Five for detailed instructions.

Bag Dam

Refer to Figure 34 page 118.

The bag dam is to be used in very shallow swales. It is merely an obstruction to catch silt and debris and to establish a strip of vegetation. The bags are to be partly filled with earth well limed, fertilized and seeded and are then to be placed in a very shallow trench dug at right angles to the line of flow in the small gully being treated. It is important that the bags be fitted closely together and that the center bag be placed lower than those in the shoulders in order to concentrate flow of water in the center of the gully. Where such is available it is suggested that the bags be treated with some material that will prevent immediate decomposition of the burlap.

The bag dam is easily constructed and should be widely used wherever gully erosion is still moderate. If it is felt that considerable water will flow over the center bag, it is suggested that an empty sack or two be placed down stream from the spillway for an apron. These sacks could be staked down and would be entirely adequate to care for average flow.

Sod Dam

Refer to figure 34, page 118.

The sod dam is utilized in conjunction with the bag dam. Ordinarily it will not withstand as large a flow as will the bag dam. Extremely shallow gullies form an ideal site for the use of sod strips.

Material for this dam consists of sod strips cut into lengths which may readily be handled by workers. The strips can be rolled into a bundle and transported to the site of construction. Such strips should be carefully cut. It is important that no sod be cut from an area where such operation might induce further erosion. The depth to which the sod is cut will vary with the type of sod used. Sod dams should preferably be built during early spring when rainfall is sufficient to re-establish the sod.

Where the sod dam is used it is important that the distance between successive dams be small, otherwise channelling will occur in the gully. The strips should follow each other about fifteen feet, depending of course on the slope of the gully.

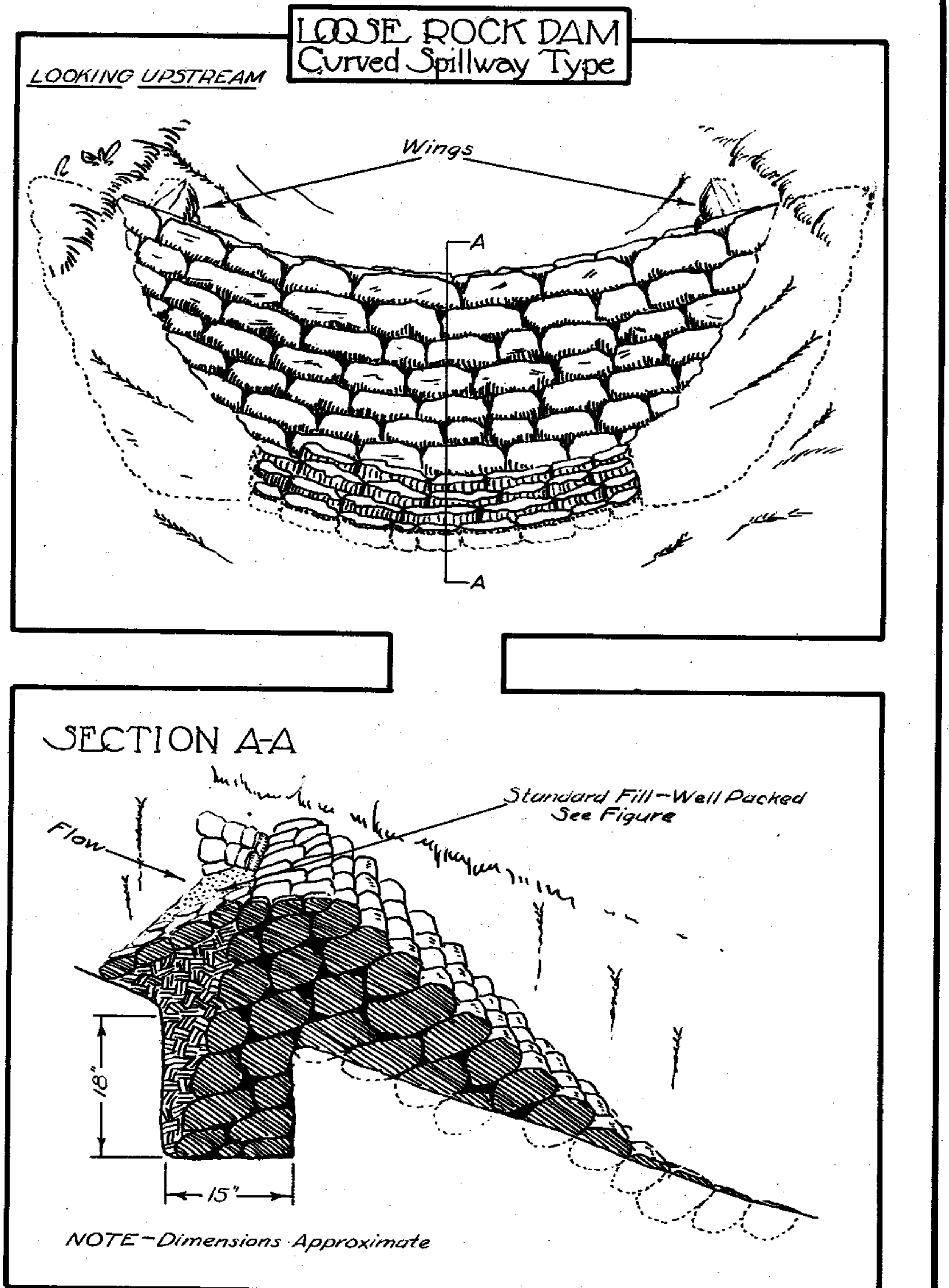
Apron Details

Refer to Figure 35 page 119.

There is included herewith a drawing of an apron indicating general construction features applicable to all temporary dams discussed excepting the stake, rock, sod and bag dams.

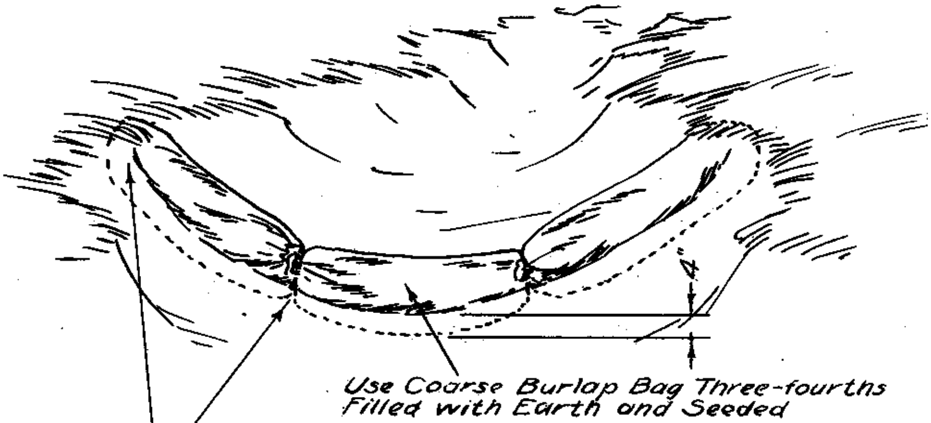
It was felt that, due to the relatively short life of the temporary structures, provisions should be made to care for the gully channel after the structure has rotted away. A rock apron was decided upon, to be so built that it would permanently hold the fill above the dam even after the dam was gone. It is, of course, assumed that vegetation will have become established at such a time.

As indicated in the figure, the apron should be built of flag rock placed in alternate layers and extending to at least two-thirds the height of the spillway. The whole apron should be built in a flume shape, thereby affording a definite channel for stream flow. The toe rocks on the apron are to be dug flush with the bed of the channel.


LOOSE ROCK DAM
Curved Spillway Type
LOOKING UPSTREAM
Wings
A
A
SECTION A-A
Standard Fill—Well Packed
See Figure
Flow
18"
15"
NOTE—Dimensions Approximate

BAG DAM

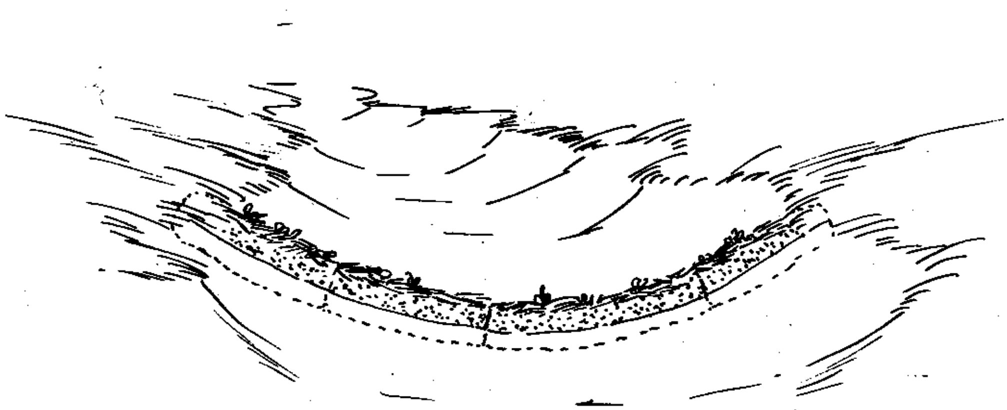
SKETCH
Looking Upstream



NOTE--Lay Bags to Fit Closely, with Ends Buried in Gully Shoulders. Fill Interstices with Earth, Well Tamped. Dam Suited to Shallow Gullies with Small Drainage Areas.

SOD STRIP DAM

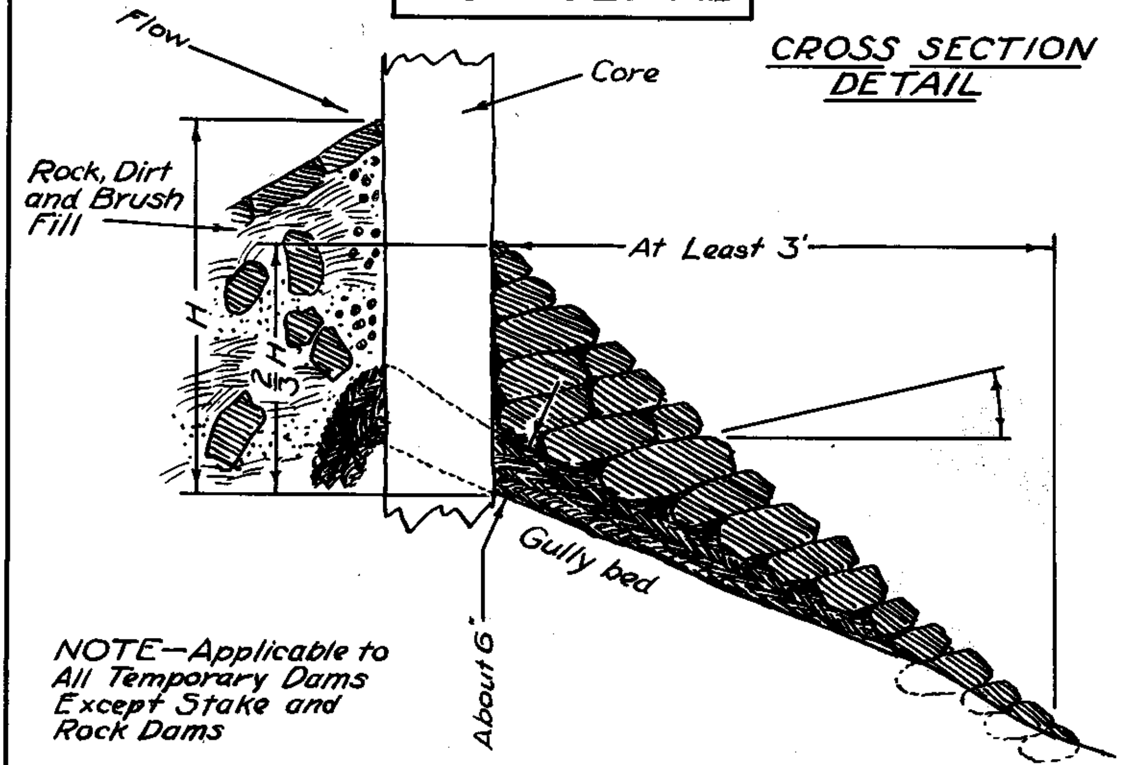
SKETCH
Looking Upstream

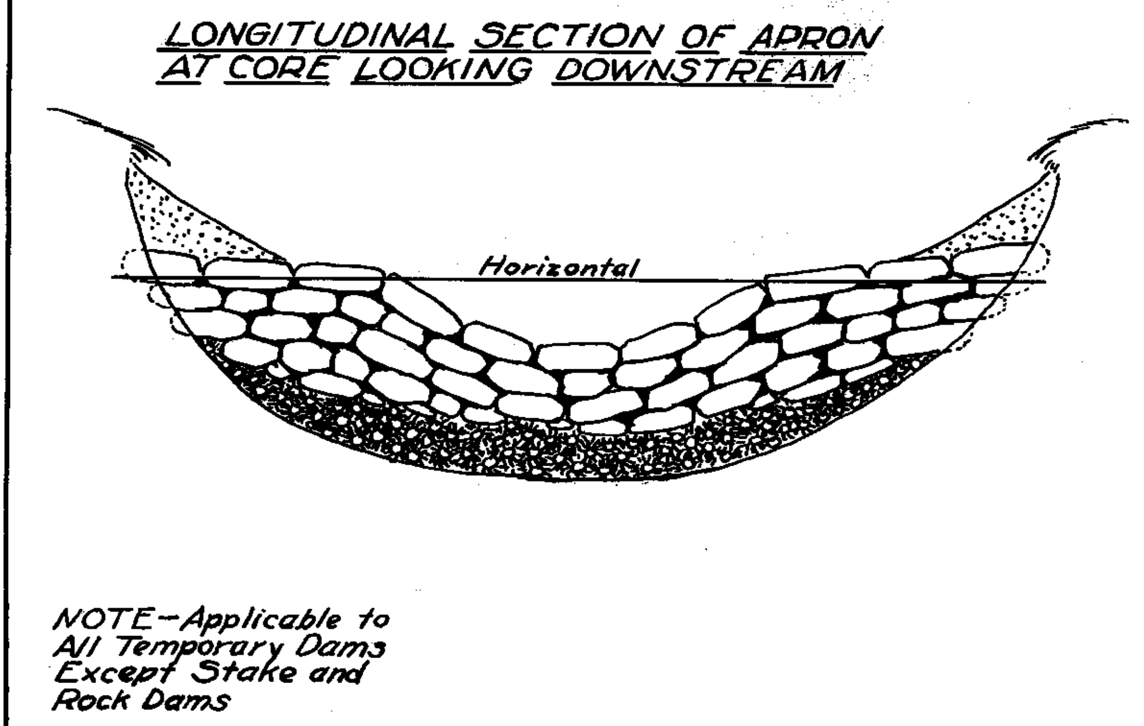


NOTE—This Type of Dam is Suitable Only for Small, Shallow Gullies. Sod is Cut in 8" to 15" Strips, to the Depth of 2" to 4", and Laid Across Gully, Being Packed Well into the Gully Bed

Project 13, Eng. Div.

APRON DETAILS





Project 13, Eng. Div.

Wherever a continuous flow of water is encountered it will be necessary to make the apron of masonry construction.

When placing rock in the apron it is important that all joints be broken and that the rock be tilted slightly in order to "key" the structure.

(3) Lateral Erosion - This type of erosion is prevalent wherever we have channel erosion and is found to a greater or minor degree, depending upon the soil characteristics, slope of gully, extent of watershed, etc. It appears that when the gully bed reaches a hard layer lateral erosion begins to take its toll. Very frequently the small shoe string type gullies comprising lateral erosion evolve into primary gullies and their control is therefore of great importance.

Ordinarily proper stabilization of a gully channel with adequate vegetative protection will prevent lateral erosion to any marked degree. Where lateral erosion appears to have gotten a good start other means will have to be used. In many instances a small rock retaining wall will be adequate. The wall will catch enough silt to form a small bench or silting reservoir upon which vegetation can establish itself. Of course where lateral erosion has developed into regular gullies the ordinary methods of gully control as covered under (2) will have to be used. The rock retaining wall, (Refer to Figure 36 page 121) may be easily constructed and ordinarily may be of a loose rock type. It is important that the wall be extended well below the surface of the ground to prevent undermining. Adequate vegetative control must be resorted to as a supplemental control measure. Part Five takes up in detail this angle of work. Please refer to it for further discussion.

Under certain cases of extreme lateral erosion it has been necessary to use diversion ditches to cut off head water as well as to fence in the area. Diversion ditch construction has been previously covered, so will not be undertaken again.

-E-

Subsurface Erosion Control Structures

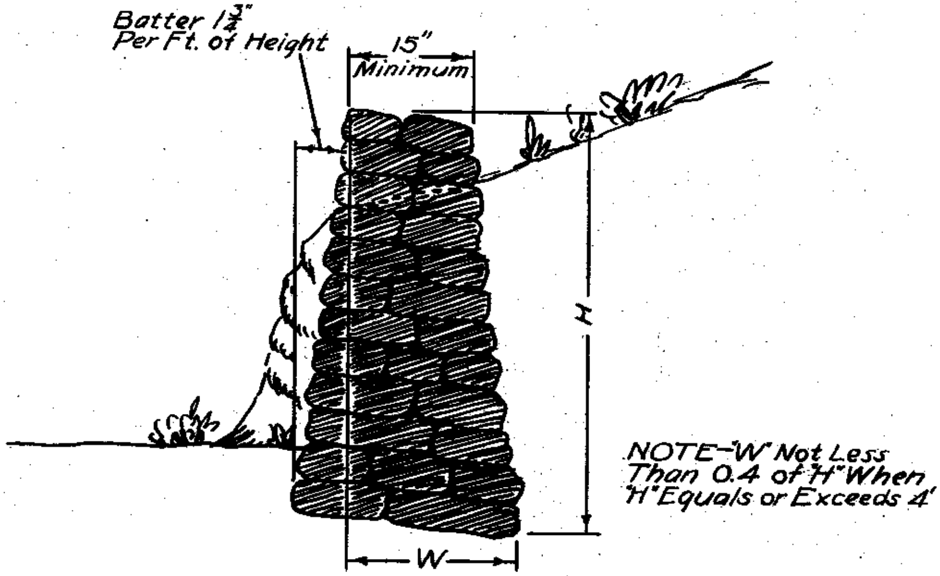
Subsurface erosion was previously defined under Part Two covering soil considerations. It will be reclassified for clarity.

III. Subsurface Erosion
  (1) Sheet Erosion
  (2) Channel Erosion

This type of erosion still requires a great deal of study before

ROCK RETAINING WALL
Gravity Type

SECTION



ELEVATION

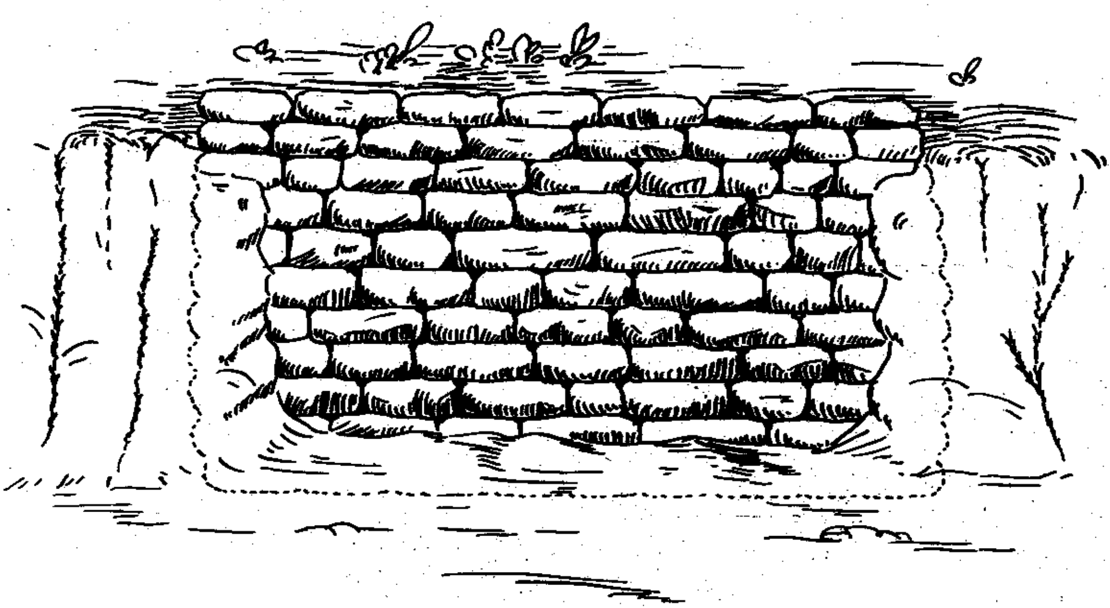


Figure 37

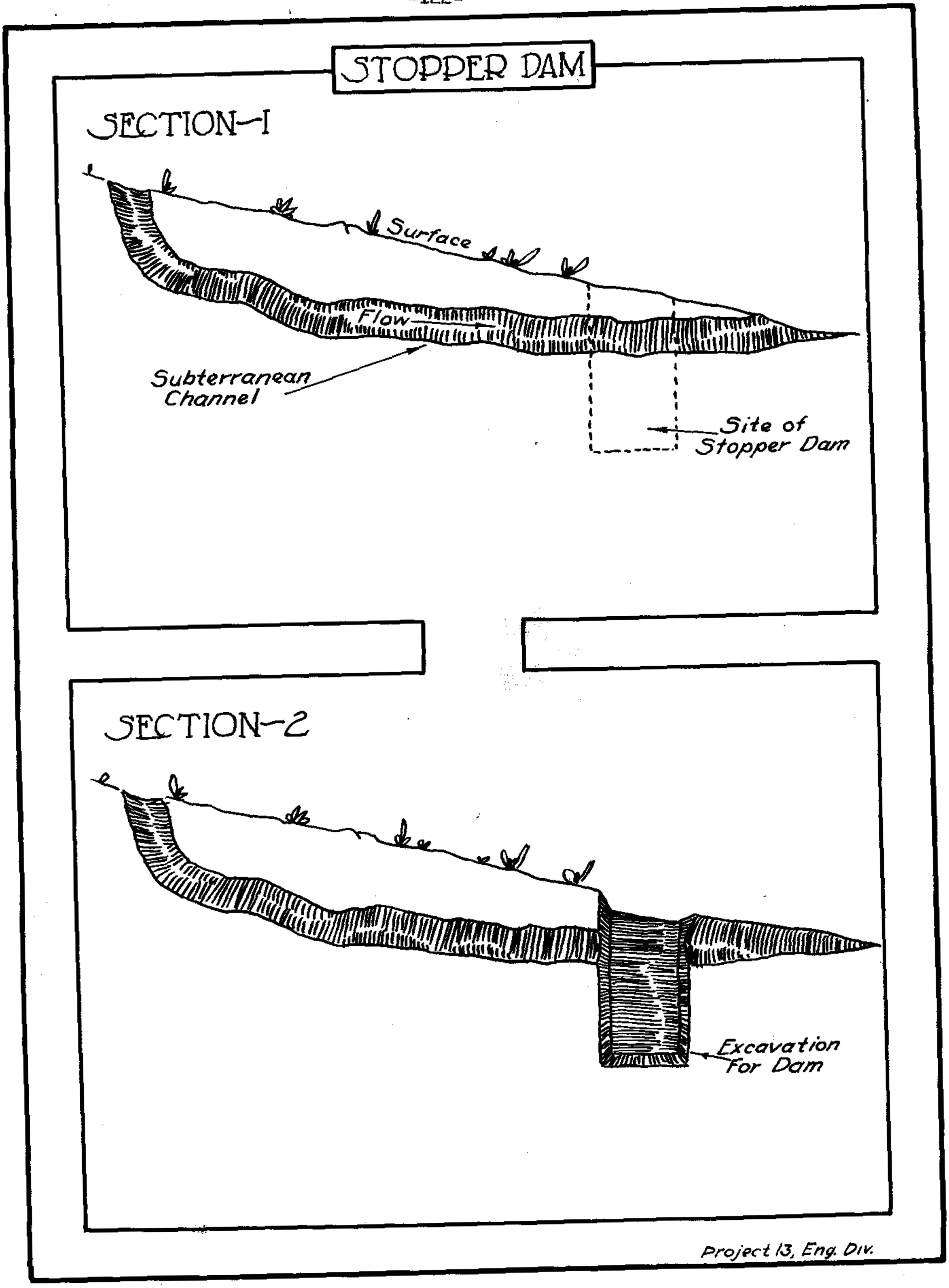
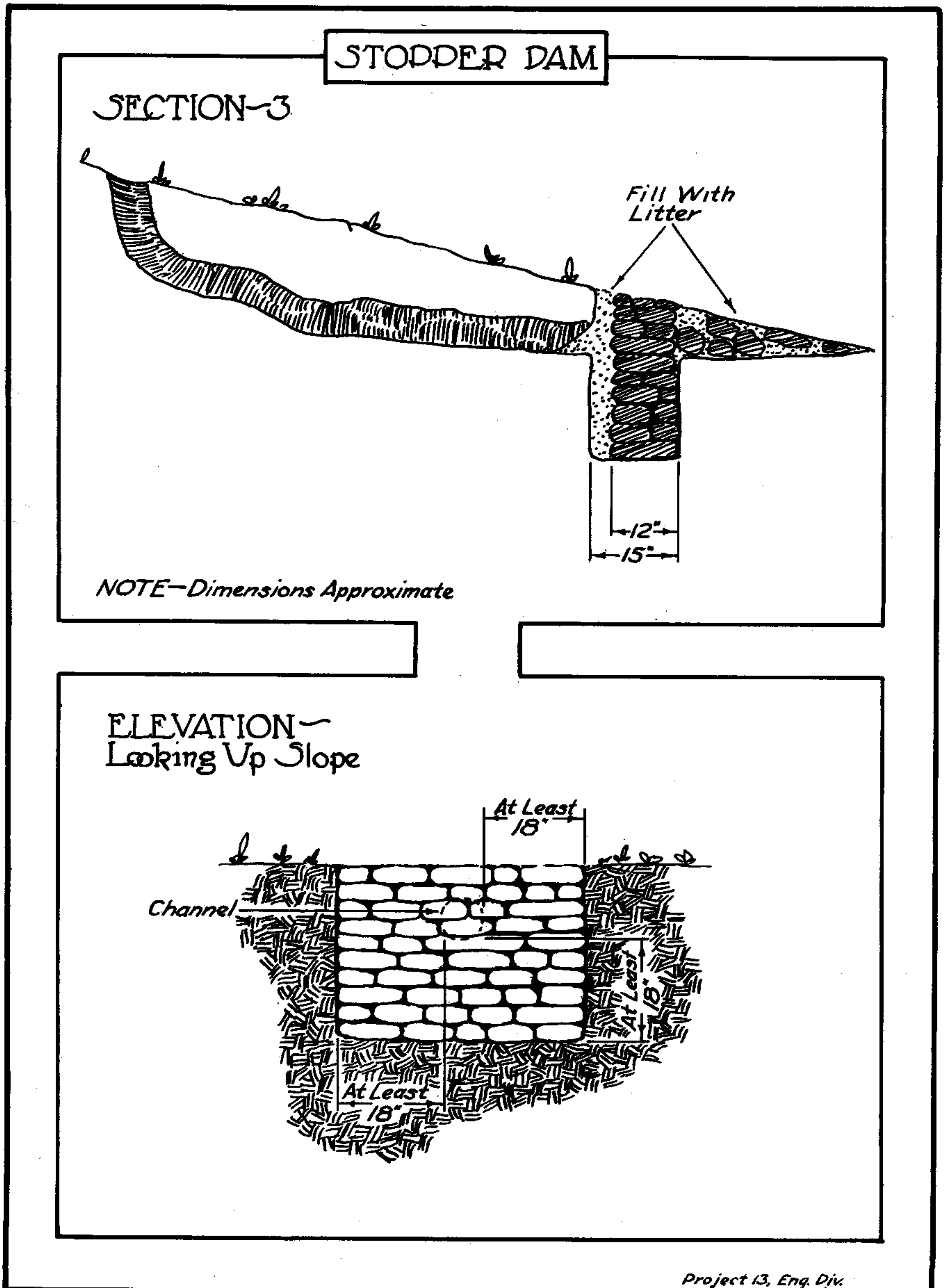

STOPPER DAM
SECTION-1
Surface
Flow
Subterranean Channel
Site of Stopper Dam
SECTION-2
Excavation For Dam
Project 13, Eng. Div.

Figure 38


STOPPER DAM
SECTION-3
Fill With Litter
12"
15"
NOTE—Dimensions Approximate
ELEVATION— Looking Up Slope
At Least 18"
Channel
At Least 18"
At Least 18"
Project 13, Eng. Div.

adequate control can be formulated. The sheet erosion in severe cases will result in large slips. It would appear that such could be prevented by intercepting ground water above the impending slip or by tiling for proper drainage. Ordinarily such procedure will be far too costly. Reforestation on such areas frequently solves the difficulty.

Subsurface channelling, though difficult of control, has far greater possibilities than has sheet erosion. Refer to Figures 37 and 38, pages 122 and 123. Subsurface erosion can readily be determined by a critical observer. It is, of course, difficult to arrive at positive control measures because most of the work must of necessity be underneath the ground. The rock stopper dam shown in the drawing will serve to bring the subsurface water to the surface of the ground, where it can be more readily controlled. Also if the structure is properly placed it will tend to silt the channel eroded above. It must be remembered, however, that frequently these underground channels extend for several hundred feet up slope and thereby build up a tremendous hydrostatic and hydrodynamic water head. The ordinary rock wall will not withstand a head of more than three or four feet. Greater head will only result in failure through seepage.

When "digging in" the dam it is important that the structure be extended far into solid ground on either side to prevent wing washing. The upstream face of the dam must be very well packed with fine material such as straw and finished off with a layer of earth packed solidly against the other fill. In case the subterranean channel extends far up slope its length should be broken by digging through from the surface and placing a structure.

Cases have been recorded where old gullies originally filled with logs placed longitudinally have eroded into subsurface channels, caused by the rotting of the logs.

As additional information is obtained it will be possible to develop structures that will more materially control the type of erosion referred to in this article. The engineer should be continuously on the alert for new devices that will afford practical control.

-F-

Stream Control Structures

Because of the fact that some stream control work has been and is being undertaken by the Soil Conservation Service it was thought advisable to include some information relative to the structures that may be utilized in such work. Ordinarily what should be done is to place temporary or semi-permanent structures at vantage points along stream banks. The structures utilized by Project #13 include (1) wing dams, (2) jetties, (3) levees, and (4) earth dams.

(1). The wing dams (refer to figures 39 and 40, pages 127 and 128) are shown in detail on the drawings. They have proven very satisfactory on smaller streams with watersheds below 25,000 acres. Of course a great deal depends on the size and density of the rock available for the bulk of the dam. Of equal importance is the proper placement of the cribbing, which should be well anchored in the stream bed. The size of structure to be used must be determined by the engineer in conformity with the stream to be worked. The wing dam is very useful in conjunction with jetties to silt wide pockets along stream channels. Great care must be taken in locating the site for a wing dam. The structure should be placed in such a manner that it will deflect stream flow where desired and protect the stream bank without cutting. A map of the area to be worked should be available before a final site is chosen. Where possible the timber utilized should be creosoted in order to preserve it a greater length of time.

(2). The jetty is a device which has proven of great value in preventing excessive erosion on stream banks and in helping to facilitate depositing of silt. Jetties should be used in conjunction with wing dams. The construction principles involved are shown on Figure 41, page 129. Ordinarily jetties need not extend very far into the stream to be effective. They have maximum efficiency when placed at right angles to the main current flow, which generally places them perpendicular to the stream bank. The posts used in construction must be well anchored, otherwise the jetty will be washed away by floating trash.

(3). In many cases the construction of levees will represent a very worth while outlet for a work program. They are the oldest known form of flood protection and have been used more effectively for this purpose than any other form of either flood protection or flood prevention. On the lower reaches of rivers they assure the only sure means of flood control. A levee is in reality nothing more than a small earthen dam placed at a varying distance from the banks of a stream to serve as artificial banks during flood periods, in order to protect bottom land from over-flow. Construction features are indicated on Figure 42, page 130. Before either construction or design is undertaken it is well to make an extensive study of the problem and to become familiar with best engineering practices. It is useless to undertake levee construction without adequate equipment.

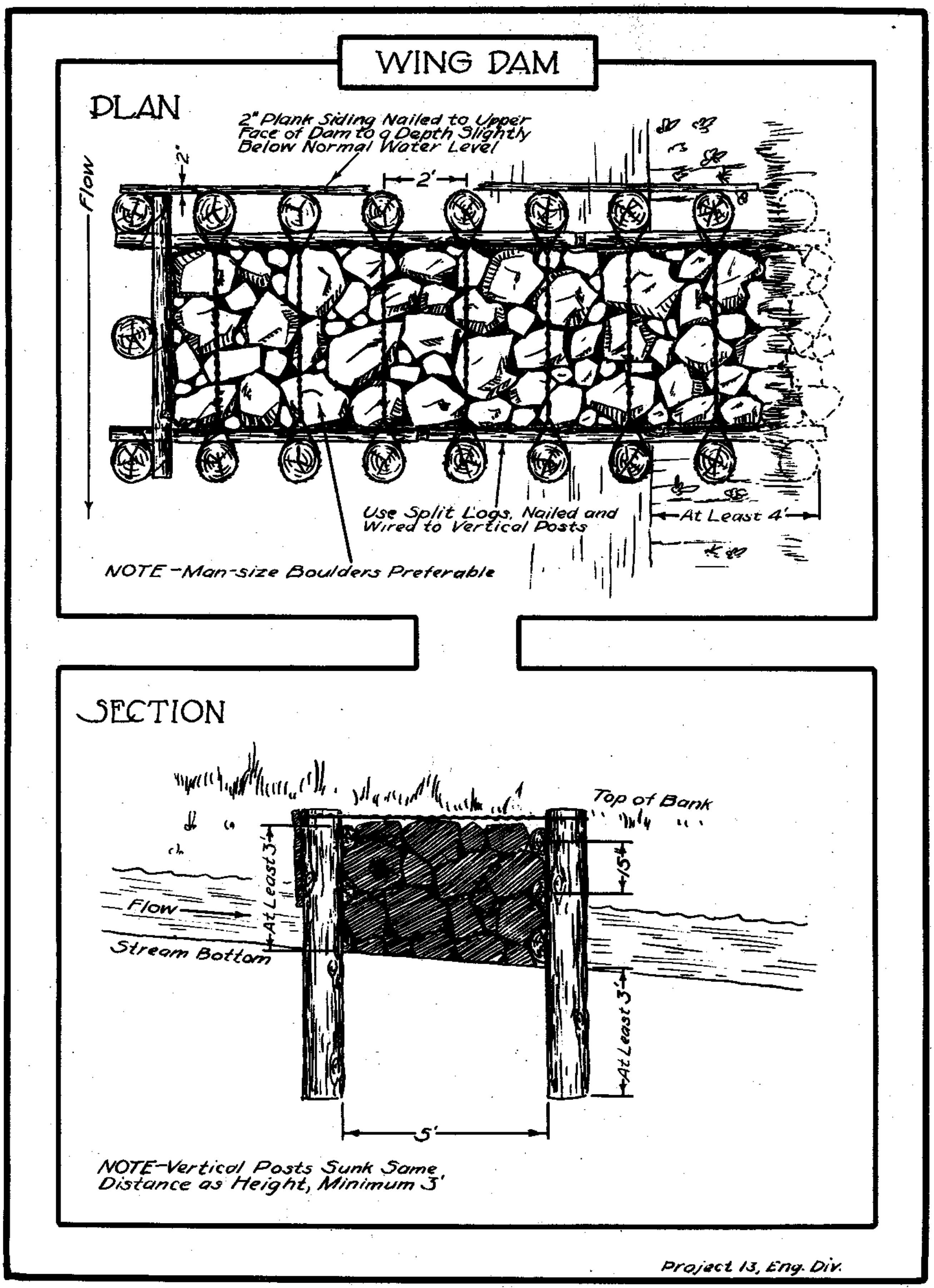
The spacing and height of levees are inter-dependent. Levees can be made low and far apart or high and close together. From an economic standpoint the location would depend upon the value of the land reclaimed by flood prevention. The engineer should compute by the rational method where possible the amount of runoff that must be taken care of before he makes final decision as to height and location of the levee. During construction the engineer should supervise carefully the building of the embankment in order that seepage will not later take place. It is important that the site of the levee be well cleaned before any dirt is placed. In staking out a levee, sufficient allowance must be made for settling which will take place as the levee is completed. The amount of settling will depend on the nature of the material, degree of saturation, method of construction, and bearing power of the foundation. In general, it is safe to assume settlement of from twenty to twenty-five percent. For continued success it is important that maintenance of levees be carefully watched. Frequent inspections are necessary.

(4). Earth dams afford a variety of uses because when properly designed, built, and maintained, they are entirely safe and will last indefinitely. They are little affected by extremes of temperature and are economical where suitable materials for their construction are close at hand. Most failures for earth dams occur because of inadequate and improperly drained foundations, imperfect bond between fill and the surface on which it is placed, poor materials with improper segregation or consolidation of materials, insufficient bulk to provide against sliding, poor protection of side slopes against erosion, placing of extraneous material in the dam. In making a fill the engineer should specify a material that will give suitable mixture, especially in the core wall if one be used. A recommended mixture would include ten parts of coarse gravel, three parts of fine gravel, four parts of sand gravel, and two parts of clay gravel.

Earth dams may be used for reservoir sites or for impounding streams. The engineer should make a careful study of all conditions involved similar to that undertaken for a levee. He should personally supervise the construction of the dam. A very important point to remember is that the foundation should be carefully and conscientiously prepared. All extraneous growth must be removed to a depth of four or five inches to obtain adequate bond. Please refer to Figure 43, page 131, for additional construction pointers. It is important that adequate equipment be available before such large construction is undertaken.

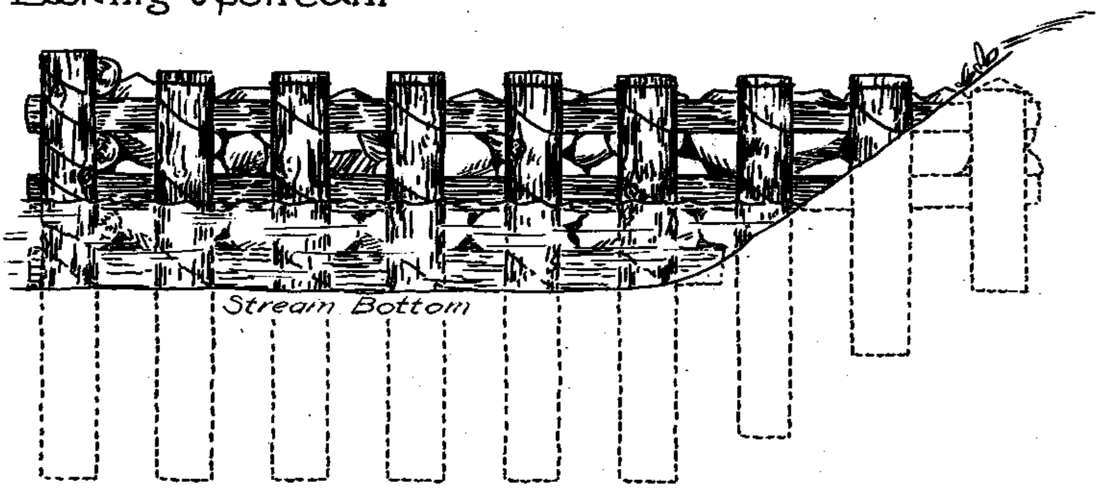
Some stream control has been undertaken through channel improvement. Such work is generally costly and results are doubtful unless a very detailed study is made of the problems involved. Ordinarily, channel improvement as a sole means of flood protection is applicable only to smaller streams. The straightening of a portion only of a stream will benefit the land above the improvement and most of the land along the improvement itself. The land at the lower end will generally be damaged instead of benefitted. The elimination of ox-bow bends through the use of cut-offs is generally not justifiable in larger streams. Only the small streams should be worked if this method of flood protection be

Figure 39


WING DAM
PLAN
2" Plank Siding Nailed to Upper Face of Dam to a Depth Slightly Below Normal Water Level
Flow
2'
2'
Use Split Logs, Nailed and Wired to Vertical Posts
At Least 4'
NOTE - Man-size Boulders Preferable
SECTION
Top of Bank
At Least 3'
1.5'
Flow
Stream Bottom
At Least 3'
5'
NOTE - Vertical Posts Sunk Same Distance as Height, Minimum 3'
Project 13, Eng. Div.

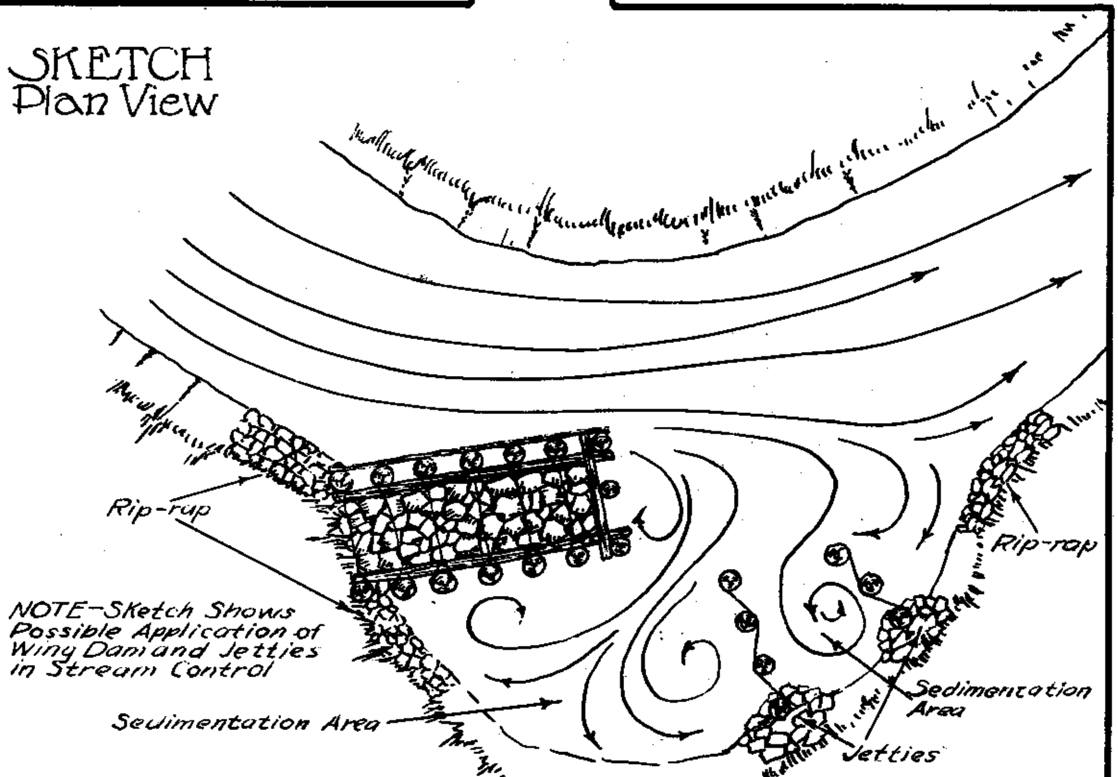
WING DAM

ELEVATION
Looking Upstream



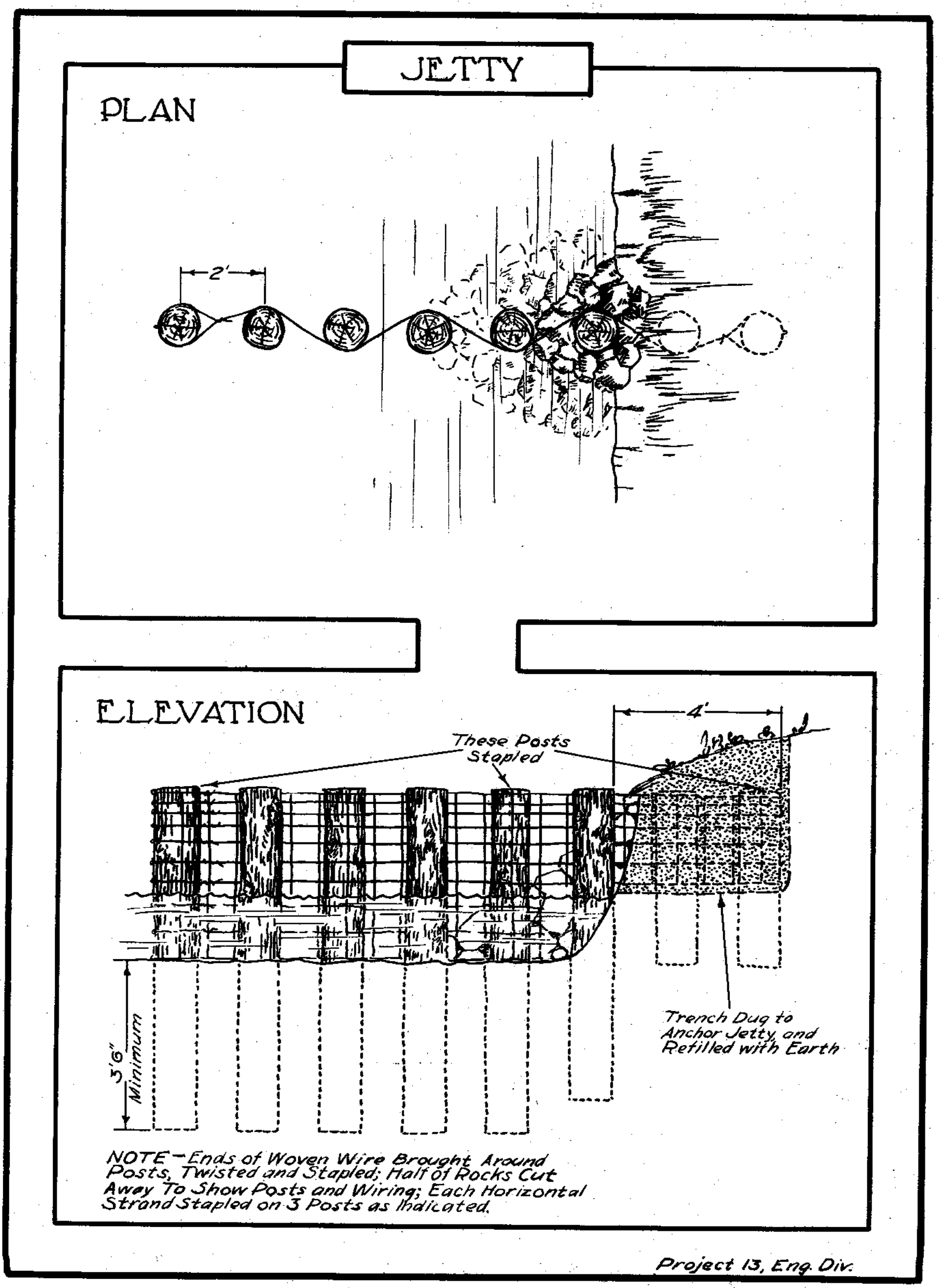
NOTE—All Timber Creosoted.
Use No. 9 Two-strand Galvanized Brace Wire

SKETCH
Plan View

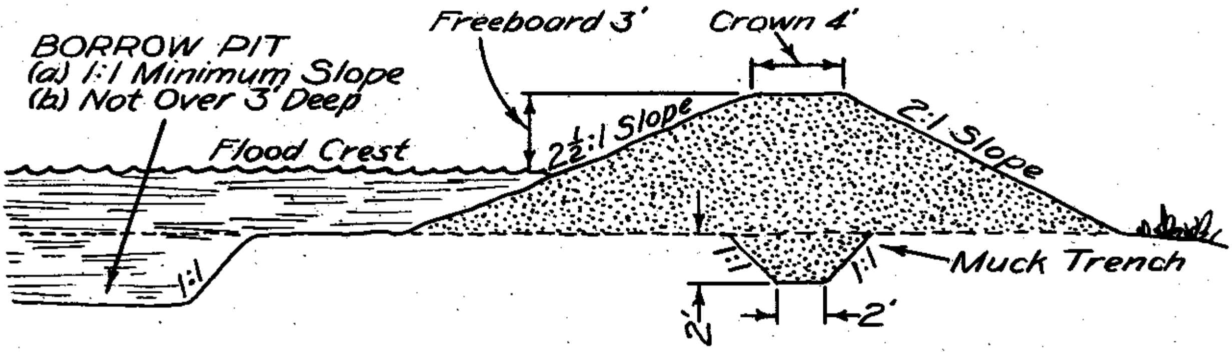


NOTE—Sketch Shows Possible Application of Wing Dam and Jetties in Stream Control

Project 13, Eng. Div.


JETTY
PLAN
2'
ELEVATION
4'
These Posts Stapled
3'6" Minimum
Trench Dug to Anchor Jetty and Refilled with Earth
NOTE—Ends of Woven Wire Brought Around Posts, Twisted and Stapled; Half of Rocks Cut Away To Show Posts and Wiring; Each Horizontal Strand Stapled on 3 Posts as Indicated.
Project 13, Eng. Div.

~LEVEE~
AS USED ALONG SMALL STREAMS
SECTIONAL VIEW



FEATURES ESSENTIAL TO A LEVEE

1.– Sufficient Floodway Between Levees to Provide for Maximum Floods for Specified Levee Height

2.– Levee Alignment Such as to Eliminate Sinuosities of Stream and to Avoid Sharp Curves

3– Enough Freeboard to Allow Margin of Safety Against Unusual Floods and Wave Action.

4.– Side Slopes Such as to Prevent Sliding of Superincumbent Material. 2½:1 is the Steepest Slope That Should be Used on the Stream Side

5– Use of Cut-off Ditches to Prevent Seepage Along Foundation

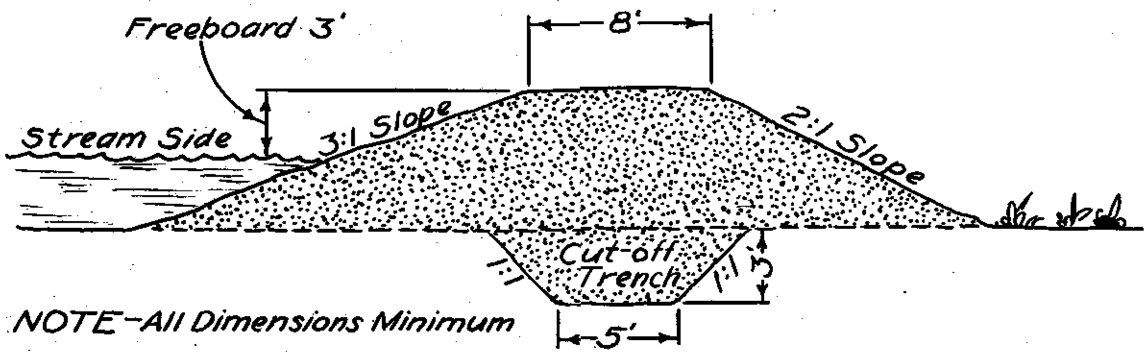
6– Good Material Well Tamped for Bulk of Levee

7.– Adequate Erosion Protection by Seeding of Slopes

8– Borrow Pits Located on Stream Side of Levee.

Project 13, Eng. Div.

~EARTH DAM~
FOR FARM RESERVOIRS AND SMALL STREAMS
SECTIONAL VIEW



NOTE–All Dimensions Minimum

FEATURES ESSENTIAL TO AN EARTH DAM

1.– Sufficient Spillway Capacity to Eliminate Danger of Overtopping

2.– Upstream and Downstream Slopes Stable

3.– Enough Freeboard to Prevent Overtopping by Wave Action and Leakage Through Frost Checks

4.– Sufficient Weight to Provide Safety Against Sliding. Crown Not Less Than 8' For Small Dams.

5.– Properly Drained Foundation

6.– Clear-cut Line of Cleavage Between Structure and Foundation. Use of Core-wall to Prevent Seepage Along Foundation.

7.– Dam Site Cleared of All Extraneous Material to a Depth of 5 or 6 Inches. This is Usually Waste Material

8.– Good Material Well Tamped to Form Body of the Dam. Slopes and Crown Seeded

Project 13, Eng. Div.

employed. The highest percentage of effectiveness on stream control for the small streams is obtained by cleaning out the channel itself, i.e. removing material that is choking the stream bed, cutting out trees and willows jutting into the stream, etc. It has been reported that in the case of small streams it frequently happens that the efficiency of the channel can be increased from one-third to one-half by clearing the banks and removing fallen trees, snags, and sand bars.

The discussion on stream control will be closed with this final suggestion that before any problem be undertaken, a complete survey should be made and the various factors entering be carefully considered and weighed.

-G-

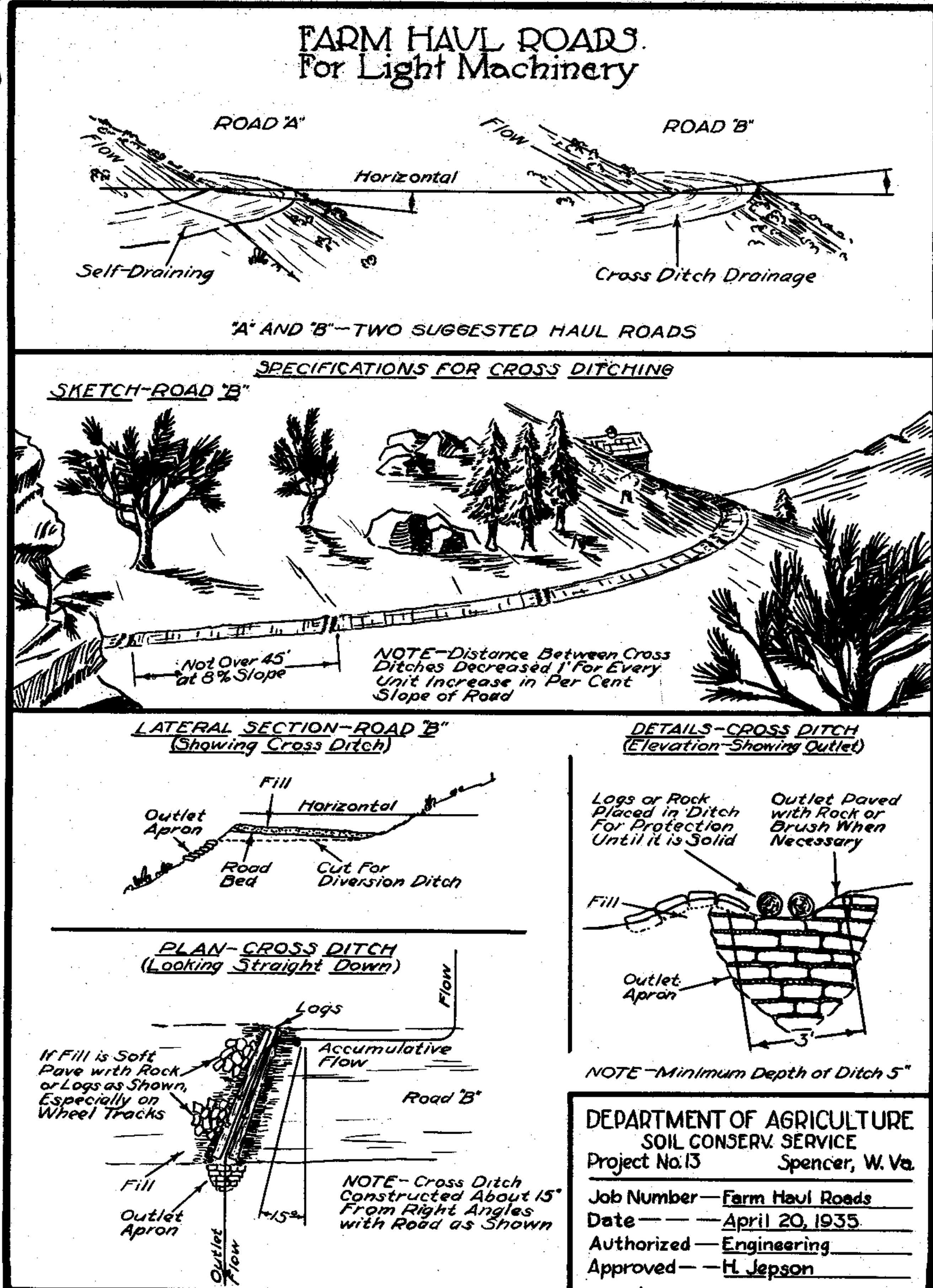
Farm Haul Roads

Poor management in the placement of haul roads for light machinery has resulted in a great deal of unnecessary erosion. Almost every farm in West Virginia has indications of such erosion. In many cases acres upon acres of land have been abandoned just because a haul road was placed where maximum erosion resulted. Practice has been to use a haul road or skid road until it was so deeply cut down that another road had to be placed alongside. The other road was then used until it, too, had to be eventually abandoned. These old roads, of course, continue to erode, some to the extent of forming gullies many feet in depth.

A little judgment in placing the haul road will ordinarily forestall effective erosion. The secret of road building is adequate drainage and the principle applies to haul roads as well as to a Class A pavement. There has been given on Figure 44 page 133, two methods for controlling erosion on a haul road. The method used will be determined by the general conditions of the soil and terrain. The soil conservation engineer can well afford to spend considerable time instructing farmers on proper road building because he will thereby prevent many times more work in the future. Almost any reconnaissance survey in the field will bring to light to a critical observer examples of short stretches of haul roads that appear to be in A-1 condition. Upon careful scrutiny it usually becomes apparent that those stretches of road were so placed that water could not accumulate in any large amounts, and thereby channelling was eliminated.

The figure above mentioned is self-explanatory so no further detail will be given. The engineer must solve the major number of his problems in the field, because generally they vary with the area in which they are located.

Figure 44


FARM HAUL ROADS
For Light Machinery
ROAD "A"
Flow
Horizontal
Self-Draining
ROAD "B"
Flow
Cross Ditch Drainage
"A" AND "B"—TWO SUGGESTED HAUL ROADS
SPECIFICATIONS FOR CROSS DITCHING
SKETCH—ROAD "B"
Not Over 45' at 8% Slope
NOTE—Distance Between Cross Ditches Decreased 1' For Every Unit Increase in Per Cent Slope of Road
LATERAL SECTION—ROAD "B"
(Showing Cross Ditch)
Fill
Horizontal
Outlet Apron
Road Bed
Cut For Diversion Ditch
DETAILS—CROSS DITCH
(Elevation—Showing Outlet)
Logs or Rock Placed in Ditch For Protection Until it is Solid
Outlet Paved with Rock or Brush When Necessary
Fill
Outlet Apron
3'
NOTE—Minimum Depth of Ditch 5"
PLAN—CROSS DITCH
(Looking Straight Down)
Flow
Logs
Accumulative Flow
If Fill is Soft Pave with Rock or Logs as Shown, Especially on Wheel Tracks
Road "B"
Fill
Outlet Apron
15°
Outlet Flow
NOTE—Cross Ditch Constructed About 15° From Right Angles with Road as Shown
DEPARTMENT OF AGRICULTURE
SOIL CONSERV. SERVICE
Project No. 13
Spencer, W. Va.
Job Number—Farm Haul Roads
Date—April 20, 1935
Authorized—Engineering
Approved—H. Jepson

H

Spring Improvement

Refer to Figure 45, page 135.

On Project #13 livestock raising is the most important agricultural enterprise at the present time. Approximately 50% of the area is in permanent pasture and every available water supply for livestock is a paramount factor in livestock raising, because an abundance of good pasture grass is of no use for grazing without a water supply. Drought years have indicated that well developed spring water supplies for sheep and cattle would be very beneficial.

Water supplies have been reduced to their present status by removal of forests, by drainage of land, and by injury to springs caused by stock trampling. Frequently during past years stockmen have been compelled to drive their stock for a considerable distance to water, or to pump it from wells. It is not uncommon for a farmer to possess around twenty head of cattle and when it is considered that the average cow drinks about twenty gallons of water per day it may readily be seen why the average undeveloped spring is deficient in amount of water produced.

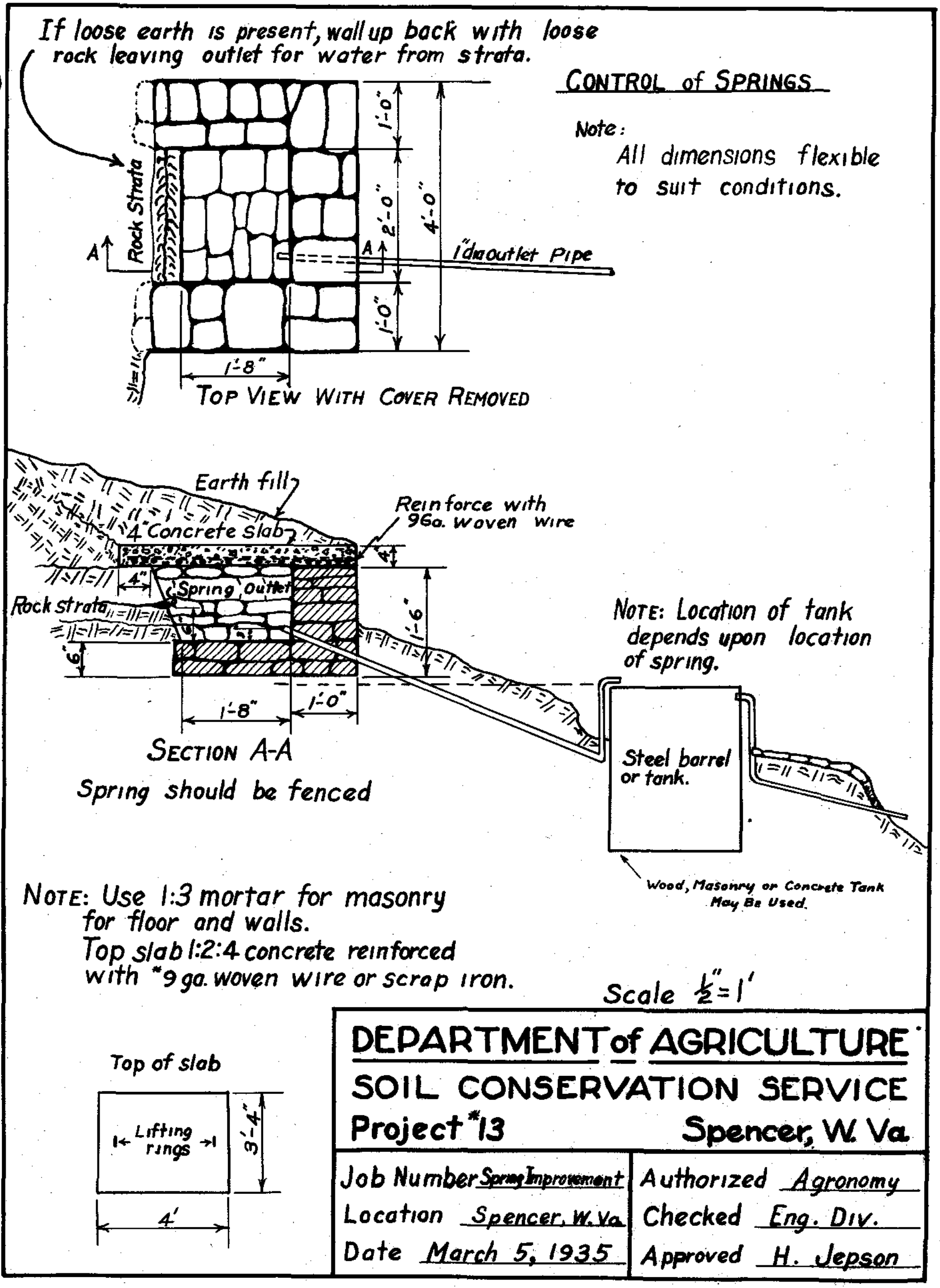
From the above consideration it would appear justifiable to do considerable spring improvement on the farms needing it. Such improvement need not necessarily require a large outlay of cash where rocks, posts, and poles are available. A few sacks of cement, a steel barrel or tank, and several lengths of pipe will usually suffice. Where a more expensive concrete job is desired the initial cost is greater, but a permanent job is had that is dependable for twenty or thirty years.

No definite rule can be made for construction, as each spring will be a separate problem due to slope, type of soil, location of rock strata and amount of water. The following recommendations are made for rock structures where large expense is not involved but where water supply will be satisfactory:

1. The banks should be dug out far enough to determine the spring outlet - approximately four feet. The natural rock strata should be used for the basin if possible and building rock and masonry to protect all sides of the spring.

2. Where there is danger of the soil caving in on the spring at the outlet a rock retaining wall should be included.

3. A large rock or slab of concrete should be placed over the top of the structure to keep the basin clear.


If loose earth is present, wall up back with loose rock leaving outlet for water from strata.
CONTROL of SPRINGS
Note:
All dimensions flexible to suit conditions.
Rock Strata
A
A
1" dia outlet Pipe
1'-0"
2'-0"
4'-0"
1'-0"
1'-8"
TOP VIEW WITH COVER REMOVED
Earth fill
4" Concrete Slab
Reinforce with 9Ga. woven wire
4"
4"
Spring outlet
Rock strata
1'-6"
6"
1'-8"
1'-0"
SECTION A-A
Spring should be fenced
NOTE: Location of tank depends upon location of spring.
Steel barrel or tank.
Wood, Masonry or Concrete Tank May Be Used.
NOTE: Use 1:3 mortar for masonry for floor and walls.
Top slab 1:2:4 concrete reinforced with *9 ga. woven wire or scrap iron.
Scale 1/2" = 1'
Top of slab
Lifting rings
3'-4"
4'
DEPARTMENT of AGRICULTURE
SOIL CONSERVATION SERVICE
Project *13
Spencer, W. Va.
Job Number Spring Improvement
Location Spencer, W. Va.
Date March 5, 1935
Authorized Agronomy
Checked Eng. Div.
Approved H. Jepson

4. The structure should be completely covered over with soil to prevent livestock from being attracted to the spring.

5. Where stock trails lead across and above the spring, a pole or wire fence should be used to exclude the area from pasture.

6. The outlet pipe should be buried or protected to prevent stock from breaking it down and to forestall freezing.

7. The area stirred up should be seeded to close growing cover grasses.

Wherever dynamite is resorted to for opening a spring it should be remembered that utmost caution must be used. Dynamiting frequently completely ruins springs for further use by sealing the water bearing strata.

Please refer to the figure on spring improvement as a nucleus for construction.

- I -

Farm Reservoirs

The construction of small reservoirs for farm usage appears to be a very worth while endeavor. Such reservoirs have an intrinsic value which is hard to evaluate in dollars and cents. The reservoir will serve many purposes, among which may be included:

1. Water for stock during dry periods
2. Irrigation (in some cases)
3. Recreational facilities
4. Wild life conservation.

The engineer making a survey should use the utmost care in determining and evaluating the many factors entering into such a construction unit. The factors involved parallel closely those for earth dam and levee construction. No reservoir should be placed where it will endanger life in case of failure. Utmost care must be utilized in the selection of the reservoir site because soil characteristics, run-off, impervious strata, materials available, equipment available, yearly evaporation, and demands, all must be considered.

Please refer to Figure 43, page 131, under F (Stream Control Structures), which takes up in detail the construction of earth dams which ordinarily are utilized to create reservoirs.

Terraces

Terraces, generally speaking, are flat bottom ditches with broad ridges of soil below, placed nearly horizontally around cultivated hill-sides and slopes, to catch runoff water before it can build up destructive velocity. Each successive terrace carries its share of the water which has accumulated between the terrace lines. Size, length and grades of terraces and proper distances between terraces and terrace outlets are matters of engineering design and depend upon the type of soil, amount of rainfall, slope of fields, cropping practices and types of farming machinery used.

Terracing has been employed in the south for many years. It has been gradually developed to suit modern field cultivation and is regarded as one of the essential field practices used to control erosion on sloping fields during the months when intense rains fall on a soil loose from cultivation.

According to reliable authority, "A good job of terracing costs approximately the same as a good job of plowing. Once correctly done the maintenance cost adds but little to the annual plowing cost. Terracing as a field practice should be accompanied by contour plowing, planting and cultivation and the use of such soil-building and soil-holding crops as can be grown most satisfactorily in a rotation".

Up to the present time no terracing work has been attempted on Project #13 because of unsuitable terrain. However, since some terracing work is planned in West Virginia it was felt that tentative recommendations should be made in regard to terracing operations in order to be prepared to design and lay out terraces when and where needed. A general discussion and recommended practices follow:

Terrace Cross Section

The mangum or broad base terrace has the following characteristics and is recommended for this area:

1. It must be high enough to hold its certain amount of runoff water from the heaviest rains with reasonable safety.

2. It must be broad enough so that farm tools can be worked over it without undue strains on the tools or damage to the terrace.

3. There must be ample ditch capacity in the channel on the upper side of the terrace to take care of the runoff water.

The mangum terrace cross section gives the requirements and is tentatively adopted for use in the State of West Virginia.

Diagrams 1 and 2 on pages 139 and 140 give approximate dimensions and construction steps to be followed in making the terrace on lands under 12% and on those with slopes in excess of 12%. The dimensions given are, of course, tentative but have been carefully selected and should therefore form the starting point from which further developments may be made. The cuts indicated in the diagrams are for about a nine foot terracer blade and not for small equipment. It is believed that the more economical and satisfactory method of terrace construction will be through the use of heavier equipment. When small plows and slip scrapers are used the tendency is to hold up the job and inadequate terraces result. More terrace failures have been recorded from the small unit job than from any other. A terrace must have a broad ridge to withstand excessive waters and such a ridge is hard to build with small equipment.

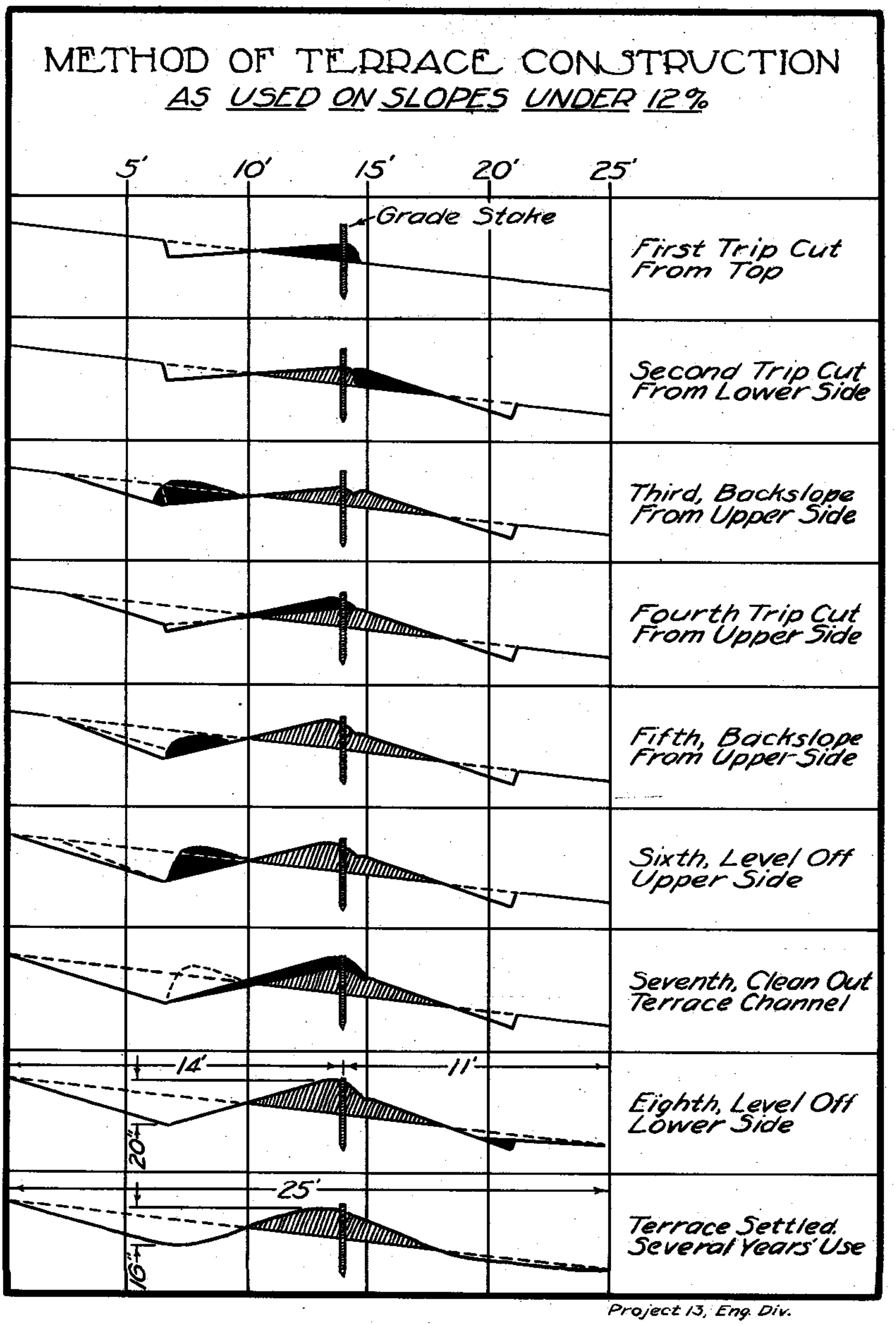
Terrace Grades

In order to carry excess runoff water a terrace must have a grade or drop toward the terrace outlet. The grade of a terrace refers to its drop in 100 feet of length and may be flat, uniform or variable, depending upon the section of the country. A variable grade terrace is adapted to this area, with the grade varying from flat to a maximum of four inches per hundred feet at the outlet, depending upon the length of terrace.

The following recommendations made by C. E. Ramser, Senior Drainage Engineer, U. S. Department of Agriculture, will be used on this project:

Table -9-

Length of Terrace	Grade in inches per 100 ft.	Grade in feet per hundred feet.
0-300	½	0.042
300-600	1	0.083
600-900	2	0.169
900-1200	3	0.250
1200-1500	4	0.334



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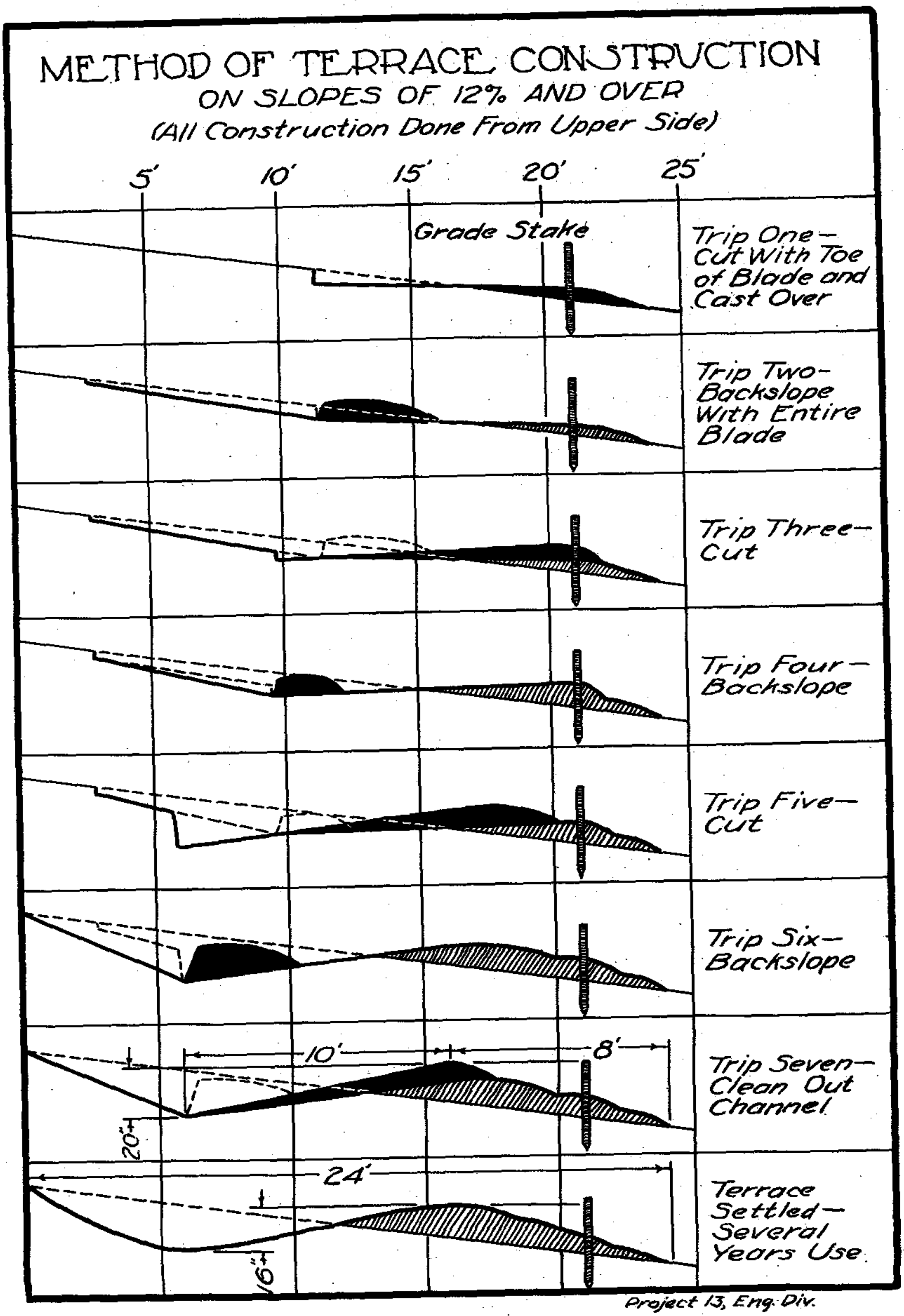
METHOD OF TERRACE CONSTRUCTION
ON SLOPES OF 12% AND OVER
(All Construction Done From Upper Side)
5'
10'
15'
20'
25'
Grade Stake
Trip One— Cut With Toe of Blade and Cast Over
Trip Two— Backslope With Entire Blade
Trip Three— Cut
Trip Four— Backslope
Trip Five— Cut
Trip Six— Backslope
10'
8'
20"±
Trip Seven— Clean Out Channel
24'
16"±
Terrace Settled— Several Years Use
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Terraces longer than 1500 feet should ordinarily not be used. Where it is necessary to have terraces longer than this it is best to have an outlet at both ends of the terrace. Long terraces give better conservation of moisture, less runoff and require fewer outlets. However, there is a limit to length because of channel capacity in regard to runoff water.

It has been recorded that soil losses for a 6" terrace grade are five times as great as for a level terrace and three times as great as for a 2" grade. In conformity with this, higher soil losses have been recorded for a uniform grade terrace than for a variable grade terrace.

Terrace Spacing

Terraces must be spaced close enough so that each terrace will take care of the water that falls on the area it protects. The vertical distance, or drop, between terraces depends principally upon the slope of the land. If the terraces are too far apart, runoff water moving down the hillside between them will develop sufficient volume and velocity to cause washing.

Recommendations as to vertical and horizontal spacing are as follows:

Table -10-

Drop or vertical distance between terraces

Slope of land per 100 ft.	Horizontal distance between terraces	Vertical distance or drop between terraces
Less than 1 foot	190 feet	1'0"
1 foot	180 "	2'0"
2 feet	140 "	2'6"
3 feet	100 "	2'9"
4 feet	80 "	3'0"
5 feet	70 "	3'3"
6 feet	63 "	3'6"
7 feet	57 "	3'9"
8 feet	53 "	4'0"
9 feet	50 "	4'3"
10 feet	47 "	4'6"
11 feet	45 "	4'9"
12 feet	43 "	5'0"
14 feet	40 "	5'6"

In general, the terracing of slopes greater than 12% or a drop of 12 feet in 100 feet is not recommended. When fields are badly riddled with small gullies it may be feasible at times to terrace on slopes up to 20%. However, in general, slopes greater than 12% should be taken care of by close growing crops or reforestation. The diagram included in Figure 46, page 143, indicates proper method for determining terrace interval slopes.

Terrace Outlets

Probably the biggest problem in terracing work is providing suitable outlets for the terraces. In laying out a terrace system the outlets should be decided upon before the system is built. Natural water courses are best and should be used whenever possible. Woods or permanent pastures are very good terrace outlets where vegetation is sufficient to hold the soil. Sod ravines in fields may be used if they are wide enough. However, in most cases it will be necessary to use artificial outlets. If the slope of the artificial channel is such as to produce a velocity of over $2\frac{1}{2}$ feet per second the channel must be protected by structures or seeding, or both. As far as seeding the outlet ditches is concerned, the ideal situation would be to construct and seed the outlet channels a year or two previous to the terrace construction. This, of course, is impossible in the majority of cases. In outlets protected by vegetation the velocity should never exceed 5 feet per second. On steep slopes where permanent protection is required cost estimates covering feasible methods of protection should be made in order to determine the most economical methods to use.

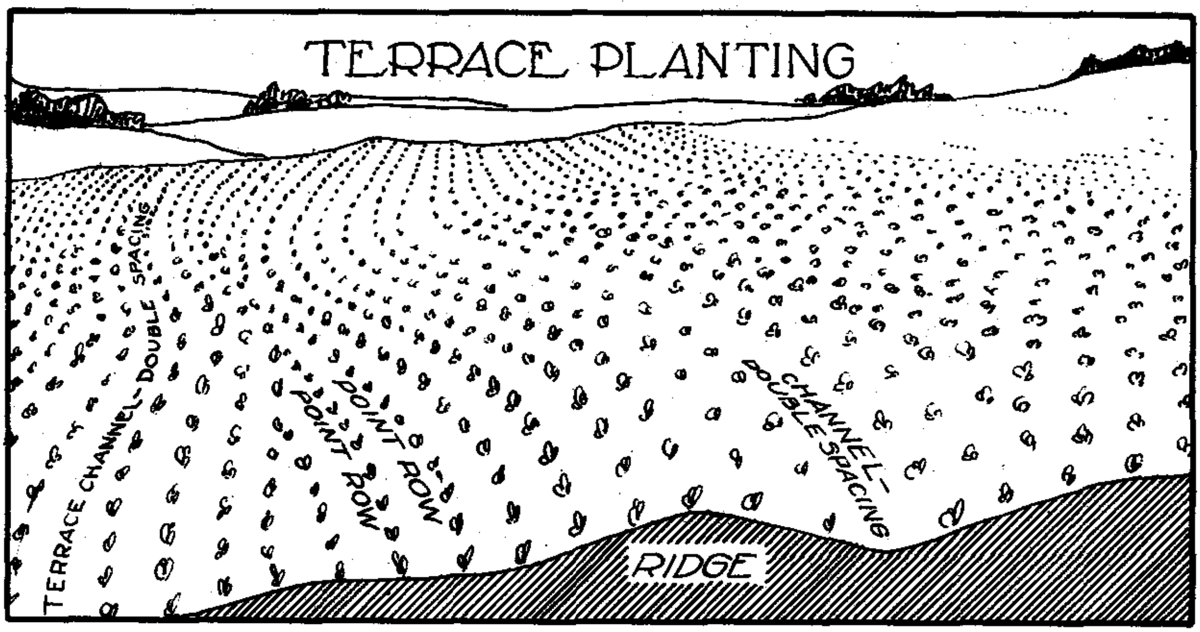
Steps in the design of a terrace outlet are given under Type Problem No. 2, page 53.

Figure 47, page 144, shows methods of holding terrace outlet ditches by use of spreader boards. The spreaders may also be built of masonry. In some cases it is necessary to build outlet ditches in a series of steps, through the use of masonry checks. Adequate aprons must be provided if this is done.

Maintaining Terraces

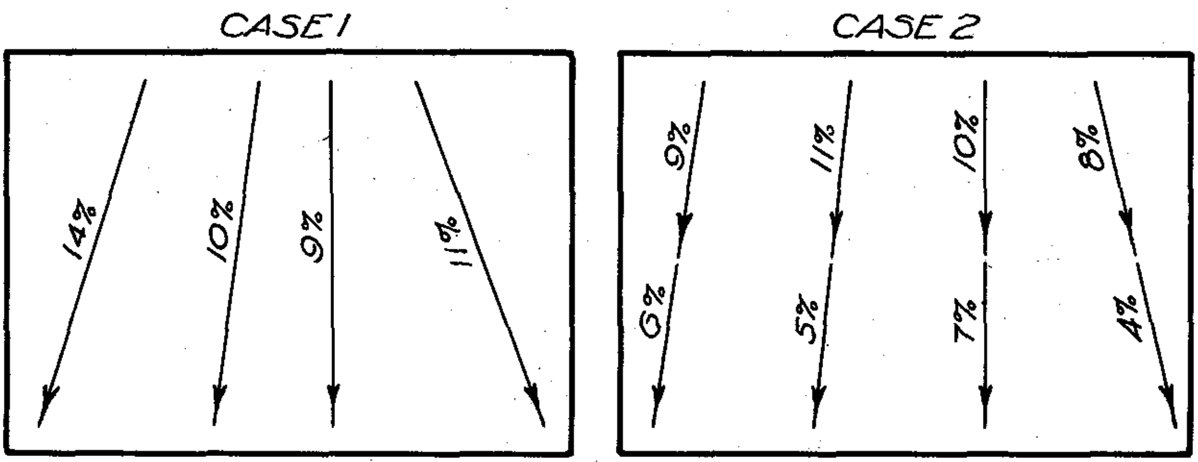
Refer to Figure 46, page 143 and Figure 48, page 145.

Terrace maintenance is an important phase of successful terrace operation. All cultivation should preferably be done parallel to the terrace. Whenever low places are found in a terrace they should be filled at once. All breaks should be repaired immediately as they are discovered. It is important that periodic inspection be given terraces in order to keep them in good working condition. Planting and cultivation of crops should be carried on with the following point uppermost in mind, namely, preserve the terrace.



NOTES—
(a)—Best practice is to plant on contour.
(b)—Wider spaced rows should straddle terrace channel.
(c)—Point rows are accumulated between terraces.

TERRACE INTERVAL SLOPES



NOTE—In spacing terraces on slopes of varying degree it may be necessary to determine the average slope to arrive at the proper terrace interval.

(a) Case 1—Here the vertical terrace interval to be used should correspond to the 11 percent grade.

(b) Case 2—Here the average slope of the benches must be determined and the corresponding interval used. A vertical interval to correspond to a 9½ per cent slope should be used on the upper bench and an interval corresponding to a 5½ percent slope should be used on the lower bench for best results.

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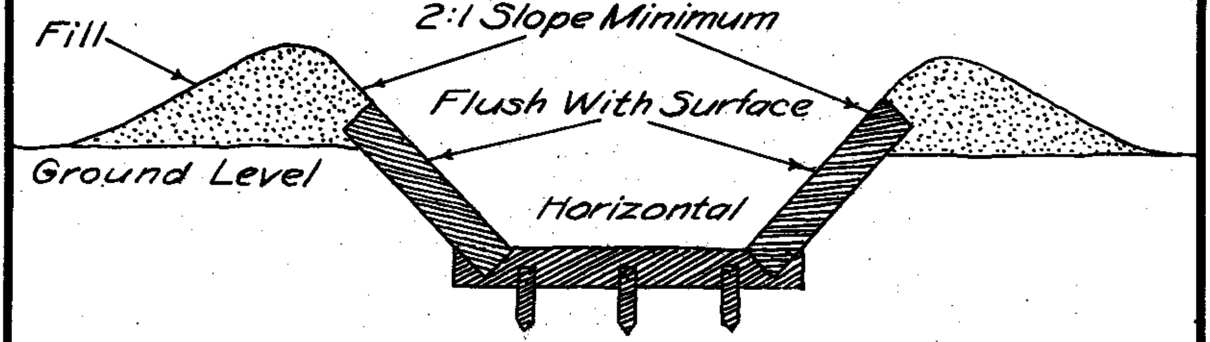
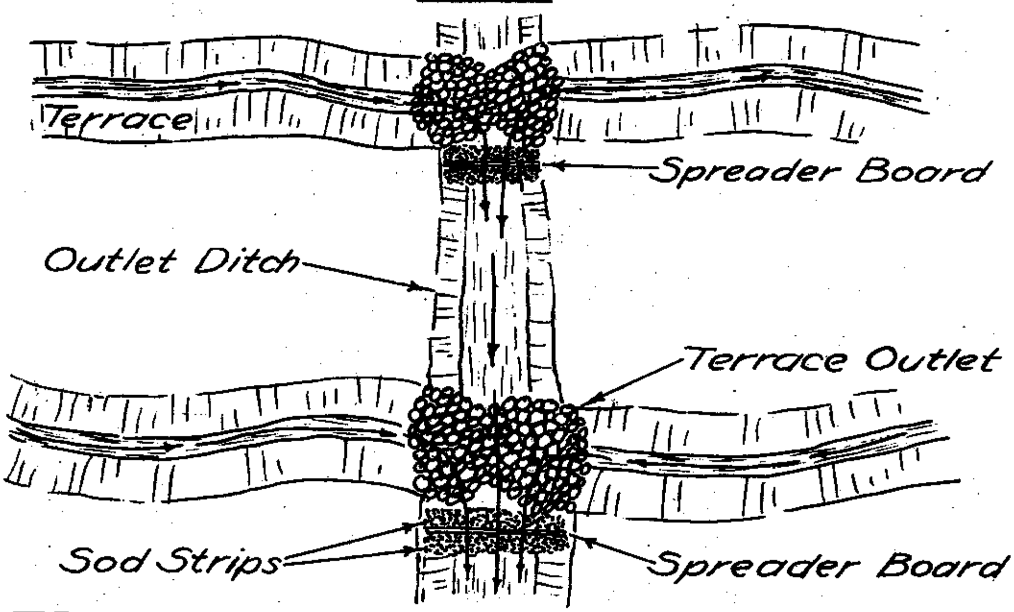
TERRACE OUTLET DITCHES
SPREADER BOARD CONSTRUCTION
SECTIONAL



NOTE-(a)-Use 2 x 12" Material Creosoted.
(b)-Place Sod Strip Above and Below Spreader Board and Extend Strip Into Shoulders.
(c)-Other Types of Spreader Boards May be Used.

WHERE TO PLACE SPREADERS
(PLAN)



NOTE-(a)-Allow at least 6" Drop from End of Terrace to where it Enters Outlet Channel.
(b)-If Distance Between Terraces is Great Place Spreader Boards in Intermediary Points.

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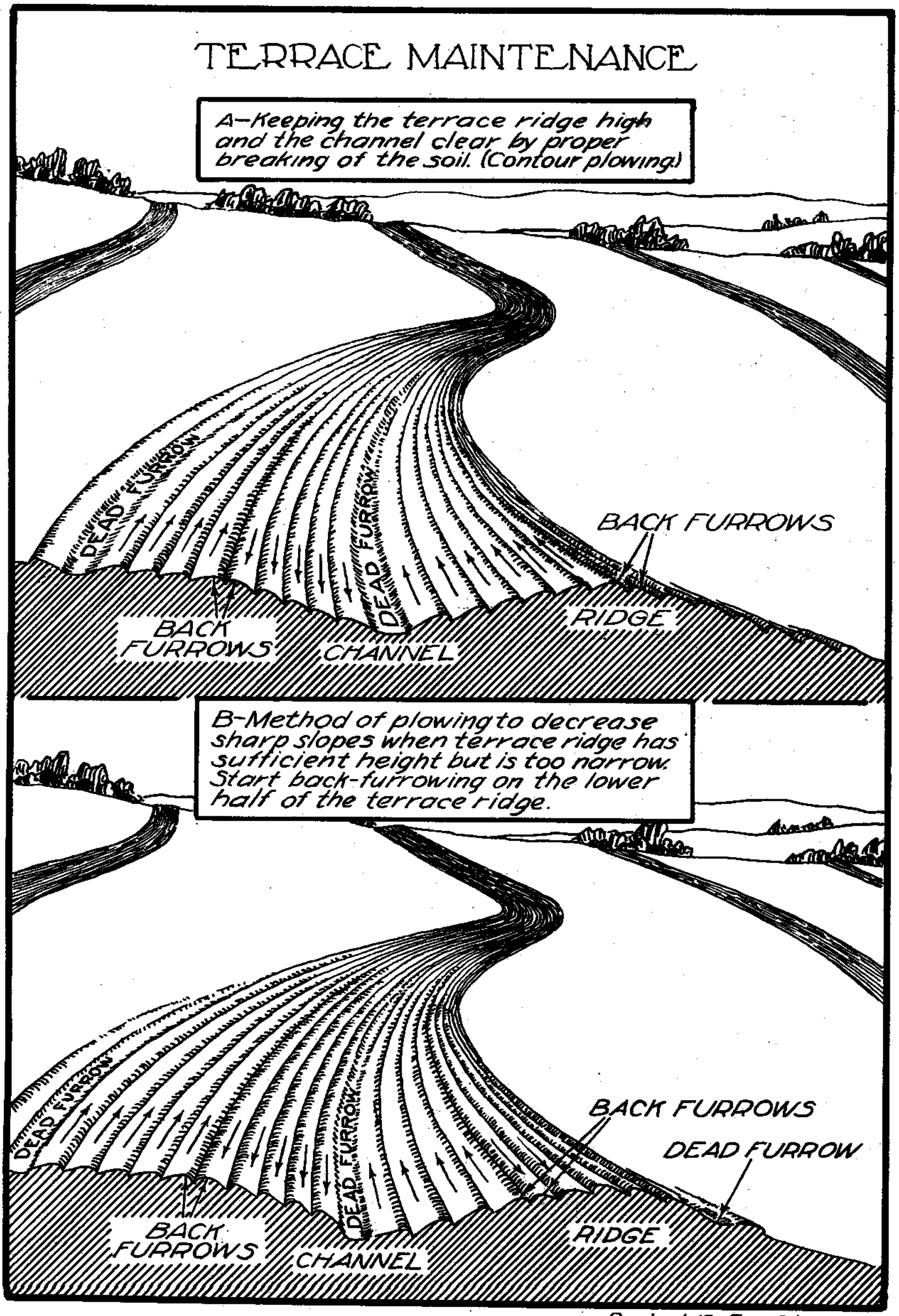

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Laying Off Terraces

The following procedure in laying off terraces is that given in Farmers Bulletin No. 1669, Department of Agriculture, with slight modifications:

"In laying off a system of terraces it is first necessary to provide for suitable outlets. Where necessary, outlets should be placed at both ends of the terraces. This divides the water of the field and gives each terrace the minimum quantity to handle. Short terraces are less likely to break than long ones and are, therefore, more desirable. Yet it is conceded that outlets are responsible for a great deal of erosion. Their number should be kept at a minimum as they are always costly.

When a draw or depression occurs near the middle of the field it is desirable to begin the terraces in the draw, so as to avoid building a high embankment such as would be required for carrying the water across it. Of course, the possibility of doing this depends upon the size of the draw. Sometimes it is found necessary to use such a draw as a terrace outlet where suitable outlets are not available at the border of the field.

It is always best to lay out the uppermost terrace first. A starting or reference point for this terrace should first be fixed by measuring down the proper vertical distance from the top of the hill or the highest point in the field. If a terrace midway down the slope is laid out first, and a point from which to start is selected at random without respect to the top of the hill, the chances are that the upper terrace will drain either too large or too small an area. If it is made to drain too large an area - which is a very common mistake in terracing - the excessively large volume of drainage water generally breaks the upper terrace, and usually all of the terraces below are then broken in turn. If the upper part of a hill belongs to a neighbor an effort should be made to induce him to terrace it. Otherwise it will be necessary to dig a hillside diversion ditch or an embankment along the upper side of the field to intercept the water draining from the neighboring farm above.

The field work required in laying off a system of Mangum terraces with variable grade is as follows: Set the leveling instrument about midway between the ends of the uppermost terrace, and high enough so that when it is level the line of sight will be above the highest point in the field. Have an assistant hold a level rod on this highest point, and read the rod there and also at a point 50 feet directly down the slope. Twice the difference between the rod readings obtained is the slope of the land in 100 feet between those two points. From Table 10, page 141, find the recommended vertical distance, or drop, between terraces for that slope.

Example:	Rod reading at top of field	1 foot
	Rod reading 50 feet down the slope	5 feet
	Difference in rod readings	4 feet
	Twice the difference in rod readings or slope of land in 100 feet	8 feet

According to Table 10 the vertical distance, or drop, between the top of the field and the first terrace in this case should be 4 feet.

Set the target on the rod at 5 feet (which is 4 feet above the rod reading at the top of the hill). Have the rodman move the rod down the hill until the line of sight through the telescope strikes the center of the target. The point thus located is 4 feet below the top and therefore is the starting point on the first terrace, provided an outlet is available at each end.

From this point locate the line of the terrace in both directions, giving it the grade shown in Table 9. To do this, the rodman sets the target at 5 feet plus one-fourth inch (in the example above), moves 50 feet along the side of the hill, and is directed up or down the slope by the man at the instrument until the line of sight through the instrument strikes the center of the target. The point on which the rod rests is one-fourth inch below the starting point. The rod is now carried 50 feet farther and the third point located in the same manner. In accordance with Table 9, after the first 300 feet of terrace has been located the target should be raised one-half inch (instead of one-fourth inch) for each 50 feet; after 600 feet, 1 inch; after 900 feet, 1½ inches; and after 1,200 feet, 2 inches, to the end of the terrace. A terrace should not carry water more than 1,500 feet in one direction if it can be avoided. If a longer terrace is necessary the grade should not be increased above 2 inches in 50 feet, but instead the lower end of the terrace should be built to extra height to take care of the excess water.

After the uppermost terrace has been located from the middle of the field toward one outlet, the next step is to locate the other half of this terrace in exactly the same manner.

Sometimes it is impossible to provide an outlet at each end of a divided terrace; it is then necessary to carry all the water to an outlet at one end. Under such conditions the terrace should not exceed 1,500 feet in length unless the lower end is given an extra height as before mentioned. In the above example the rod reading on the first point located on the terrace line was 5 feet. Use this as a reference point, although it may not prove to be exactly on the terrace line because in this case locating starts at the edge of the field. Lower the target 4 inches and have the rodman carry the rod to the edge of the field at the upper end of the proposed terrace and move it up or down the slope until the line of sight through the instrument strikes the center of the target on the rod. This is the starting point for the terrace and is 4 inches higher than the reference point. The purpose of starting the terrace 4 inches higher than the reference point in the middle of the field is to insure that the terrace line shall pass close to the reference point in the middle of the field. It is evident - since the terrace line continually falls - that if it were started at the same elevation as that of the reference point, the line would fall below the reference point by the time the middle of the field is reached. The terrace can now be laid off by raising the target each 50 feet exactly as described in the previous example.

Before starting to locate the second terrace, the slope of the land should again be measured. Read the rod at a point on the first terrace about midway between its ends. Measure 50 feet directly down the slope and read the rod at this point. It will sometimes be necessary to reset the instrument farther down the hill before this can be done. If the instrument is moved, both readings must be taken from the new position. Having determined the slope of the land, refer again to Table 10 to find the proper vertical drop between the terraces for the new slope and proceed in the same manner as with the first terrace.

In terracing work distances are measured by pacing. In pacing the distances the rodman should try to estimate as nearly as possible where the next point will be, and when directed up or down the hill by the levelman should keep the proper distance from the last point. To avoid mistakes the rodman should always change the target before starting to pace off the distance. If the field has been cultivated in ridges, the points should be so located by setting the rod either always on top of the ridges or always in the depressions between them. If after the proper distance between points on the terrace line has been determined it is found that the rod is too low when set in a depression between the ridges and too high when set in the next depression above, then the proper location for the line of the terrace lies between the two positions of the rod.

A man should accompany the rodman and set stakes at points on the proposed terrace lines. A plowman should follow immediately and lay out the first furrow. Care should be taken to see that no abrupt turns are made with the plow. All changes in direction should be made by smooth, regular curves. Where gullies or draws are crossed, stakes should be set on each side and the terrace run directly across.

Long sights with the level (exceeding 500 or 600 feet) should be avoided. Much more accurate results are obtained where short sights are taken. When it becomes necessary to move the level so as to avoid taking long sights or in order to see around a hill, the rodman should remain holding the rod exactly on the last point located. When the level is set up at the new position the rodman raises or lowers the target so that the new line of sight of the level passes through the center of the target and the work proceeds as already described.

NOTE

A few pointers regarding terraces and terrace construction are given because it is felt they are important.

1. Always construct and complete the top terrace first.

2. Cross gullies directly and build up the terrace to grade. Such fills should be made first and should be slightly higher than the rest of the terrace in order to allow for settling. A 20% settling factor is not excessive.

3. It is good practice to construct outlet channels for terraces first, rather than to put them in after the terrace is complete and ready for service.

4. Leave at least a 6 inch drop from terrace to outlet channel. In case the channel silts up the terrace will still be able to operate.

5. On slopes up to 4% build terraces from both sides; from 4% to 12% build mostly from upper side of terrace gradually increasing the ratio of upper to lower as the slope increases. From 12% on build from upper side.

6. Avoid sharp turns in the terrace.

7. Check height, grade and width of terrace before leaving it.

8. Give all terraces periodic inspections.

Up to the present time nothing has been said regarding contour furrowing. A demonstration of contour furrowing was placed on a farm in Project #13 to determine its advantage and disadvantage. The demonstration was put on a pasture field which has slopes below 20%. The furrows were placed at 20 foot intervals horizontally measured on the slope. The depth averaged about 9 inches. The furrows were placed on exact contour. All low places crossed were left in sod. Another feature employed was to leave baffles in the furrow by jerking out the plow occasionally. Not enough information has been gathered on this type of erosion control to warrant further discussion.

SOIL CONSERVATION SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE

PROJECT #13 SPENCER, WEST VIRGINIA

P A R T F I V E

ESTABLISHMENT OF VEGETATION TO SUPPLEMENT EROSION CONTROL STRUCTURES

CHAPTER X

PLANTING OF EROSION CONTROL STRUCTURES

A sound engineering policy of erosion control necessitates the use of vegetative cover in conjunction with the various structures. Consequently, in the preparation of an engineer's handbook it is necessary to include a chapter dealing with the establishment of successful plantings of trees and shrubs.

Any written work dealing with this subject must of necessity be comprehensive and flexible so that it may be used by the layman and technician alike. Presentation of the subject matter from this viewpoint has been a perplexing and difficult problem, which for simplicity has been divided into the following parts.

Part I	General Planting Information
Part II	Gully Plantings
Part III	Stream Control Plantings
Part IV	Diversion Ditch Plantings
Part V	Terrace Outlet Plantings
Part VI	Road Side Planting

PART ONE

GENERAL PLANTING INFORMATION

A general knowledge of the principles involved is essential to the proper use of trees and shrubs in conjunction with erosion control structures. It must be borne in mind that many factors enter into the planting of trees and shrubs, any one of which will often determine the success or failure of the plantation. Consequently, each factor must be duly considered and given full weight throughout the entire operation.

Probably the most important single factor to be considered is the planting site in relation to the vegetative cover it will support.

General site classifications with a list of adaptable species of trees and shrubs are:

	Common Name	Scientific Name
DRY SITES:	Black Locust	Robinia Pseudoacacia
	Shortleaf Pine	Pinus Echinata
	Osage Orange	Toxcylon Pomifera
	Red Cedar	Juniperus Virginiana
	Black Jack Oak	Quercus Marilandica

Dry sites con't:

Common Name	Scientific Name
Scrub Oak	Quercus Ilicifolia
Chestnut Oak	Quercus Montana
Cedar	Juniperus Ashei
Pitch Pine	Pinus Rigida
Red Pine	Pinus Resinosa
Table Mt. Pine	Pinus Pungens
Scrub Pine	Pinus Virginiana
Aspen Pine	Populus Tremuloides
Pig-nut Hickory	Hicoria Glabra
Hornbeam	Ostrya Virginiana
Hazel Nut	Corylus Americana
White Oak	Quercus Alba
Post Oak	Quercus Stellata
Red Mulberry	Morus Rubra
Sourwood	Oxydendrum Arboreum
Thorns	Crataegus Species
Sumach	Rhus Copallina
Sassafras	Sassafras Variifolium
Ailanthus	Ailanthus Glandulosa
Dogwood	Cornus Florida
Black Gum	Nyssa Sylvatica
Silk Tree	Albizzia Julibrissin
Indigobush	Amorpha Fruticosa
Heartleaf Ampelopsis	Ampelopsis Cordata
Virginia Creeper	Ampelopsis Quinquefolia
Bearberry	Arctostaphylos uva-ursi
Groundselbush	Bacchan's Halmifolia
Siberian Pea-Tree	Cacagana Arborescens
Jersey Tea	Ceanothus Americanus
Scotch Broom	Cytisus Scoparius
Woodwaxen	Genista Tinctoria
Shrubby St. Johnswort	Hypericum Prolificum
Winter Jasmine	Jasminium Nudiflorum
Common Juniper	Juniperus Communis Depressa Plumosa
Creeping Juniper	Juniperus Horizontalis
Shrub bush Clover	Lespedeza Bicolor
Everblooming Honeysuckle	Lonicera Heckrotti
Japanese Honeysuckle	Lonicera Japonica
Hall Honeysuckle	Lonicera Halliana
Wax Myrtle	Myrica Carolinensis
Southern Wax Myrtle	Myrica Cerifera
American Wild Plum	Prunus Americana
Chickasan Plum	Prunus Angustifolia
Beach Plum	Prunus Maritima
Shining Sumach	Rhus Copallina

	Common Name	Scientific Name
Dry Sites Con't:		
	Smooth Sumach	Rhus Glabra
	Staghorn Sumach	Rhus Typhina
	Meadow Rose	Rosa Blanda
	Pasture Rose	Rosa Humilis
	Virginia Rose	Rosa Lucida
	Japanese Rose	Rosa Multiflora
	Bristly Rose	Rosa Nitida
	Carolina Rose	Rosa Palustris
	Rugosa Rose	Rosa Rugosa
	Wichuriam Rose	Rosa Wichuriana
	White Flowering Raspberry	Rubus Parviflorus
	Northern Dewberry	Rubus Procumbens
	Himalaya Blackberry	Rubus Thrysanthus
	Kashmir False Spirea	Sorbaria Aitchsoni
	Japanese Snowball	Styrax Japonica
	Chenault's Snowberry	Symphoricarpos Chenaulti
	Corralberry	Symphoricarpos Vulgaris
	Prickly Ash	Zanthoxylum Americanum
MOIST SITES:	White Pine	Pinus Strobus
	Scotch Pine	Pinus Sylvestris
	Red Spruce	Picea Rubra
	Norway Spruce	Picea Abies
	Southern Balsam	Abies Fraseri
	Hemlock	Tsuga Canadensis
	Arbor Vitae	Thuja Occidentalis
	Red Cedar	Juniperus Virginiana
	Black Willow	Salix Nigra
	Beaked Willow	Salix Rostrata
	Large Toothed Aspen	Populus Grandidentata
	Cottonwood	Populus Deltoides
	Butternut	Juglans Cinera
	Black Walnut	Juglans Nigra
	Shell Bark Hickory	Hicoria Ovata
	Big Shell Bark Hickory	Hicoria Laciniosa
	Mocker Nut	Hicoria Alba
	Yellow Birch	Betula Lutea
	Black Birch	Betula Lenta
	Beech	Fagus Grandifolia
	White Oak	Quercus Alba
	Bur Oak	Quercus Macrocarpa
	Pin Oak	Quercus Palustris
	Scarlet Oak	Quercus Coccinea
	Laurel Oak	Quercus Imbricaria
	Slippery Elm	Ulmus Fulva
	American Elm	Ulmus Americana

	Common Name	Scientific Name
Moist Sites Con't:	Hackberry	Celtis Occidentalis
	Osage Orange	Toxylon Pomifera
	Red Mulberry	Morus Rubra
	Cucumber	Magnolia Acuminata
	Yellow Poplar	Liriodendron Tulipifera
	Papaw	Asimina Triloba
	Witch Hazel	Hamamelis Virginiana
	Sweet Gum	Liquidambar Styraciflua
	Wild Black Cherry	Prunus Serotina
	Choke Cherry	Prunus Virginiana
	American Crab Apple	Pyrus Coronaria
	Mountain Ash	Pyrus Americana
	Shad Bush	Amelanchier Canadensis
	Sycamore	Platanus Occidentalis
	Kentucky Coffee Tree	Gymnocladius Dioica
	Honey Locust	Gleditsia Triacanthos
	Black Locust	Robinia Pseudoacacia
	Red Bud	Cercis Canadensis
	Tree of Heaven	Ailanthus Glandulosa
	American Holly	Ilex Opaca
	Large Leaved Holly	Ilex Monticola
	Loblolly Pine	Pinus Taeda
	Striped Maple	Acer Pennsylvanicum
	Mountain Maple	Acer Spicatum
	Sugar Maple	Acer Saccharum
	Silver Maple	Acer Saccharinum
	Red Maple	Acer Rubrum
	Box Elder	Acer Negundo
	Buckeye	Aesculus Glabra
	Sweet Buckeye	Aesculus Octandra
	Basswood	Tilia Americana
	Dogwood	Cornus Florida
	Black Gum	Nyssa Sylvatica
	Mountain Laurel	Kalmia Latifolia
	Persimmon	Diospyros Virginiana
	Catalpa	Catalpa Bignonioides
	White Ash	Fraxinus Americana
	Fringe Tree	Chionanthus Virginica
	Purple Azalea	Azalea Hinodegiri
	Sheep Laurel	Kalmia Angustifolia
	Pinxterbloom	Azalea Nudiflora
	Amur Privet	Ligustrum Amurense
	California Privet	Ligustrum Ovalifolium
	Spice Bush	Benzoin Aestivale
	Japanese Barberry	Berberis Thumbergi
	Everblooming Honeysuckle	Lonicera Heckrotti

Moist Sites Con't:

Common Name	Scientific Name
Japanese Honeysuckle	Lonicera Japonica
Jersey Tea	Ceanothus Americanus
Hall Honeysuckle	Lonicera Japonica Halliani
Chinese Red Bud	Cercis Chinonsis
Wax Myrtle	Myrica Carolinensis
Evergreen Spurge	Pachysandra Terminalis
Pink Dogwood	Cornus Florida Rubra
Carolina Rhododendron	Rhododendron Carolinianum
Alternate Leaf Dogwood	Cornus Racemosa
Great Laurel	Rhododendron Maximum
Leather Wood	Direa Palustris
Fragrant Sumach	Rhus Canadensis
Winter Creeper	Euonymous Radicans
Vernal Witch Hazel	Hamamelis Vernalis
Carolina Hemlock	Tsuga Caroliniana
High Bush Blueberry	Vaccinium Corymbosum
Ivy	Hedera and Varieties
Low Bush Blueberry	Vaccinium Pennsylvanicum
English Ivy	Hedera Helix
Deerberry	Vaccinium Stamineum
St. Johnswort	Hypericum Calysinium
Mapleleaf Viburnum	Viburnum Acerifolium
Common Periwinkle	Vinae Minor
Glossy Abelia	Abelia Grandiflora
Alleghany Service Berry	Amelanchier Laevis
Mountain Currant	Ribes Alpinum
Golden Currant	Ribes Odoratum
American Bittersweet	Celastrus Scandens
Winter Currant	Ribes Sanguineum
Cornelian Cherry	Cornus Mas
American Elder	Sambucus Canadensis
Red-Osies Dogwood	Cornus Stolonifera
European Elder	Sambucus Racemosa
Gray Dogwood	Cornus Paniculata
Chenault Snowberry	Symphoricarpos Chenaulti Racemosus
Hazelnut	Corylus Americana
Corralberry	Symphoricarpos Vulgaris
Scotch Broom	Cytisus Scoparius
Arrow Wood	Viburnum Dentatum
Nannyberry	Viburnum Lentago
American Creeper	Euonymous Americanus
European Burningbush	Euonymous Europaeus
Inkberry	Ilex Glabra
Kudzu	Pueraria Thunbergiana

	Common Name	Scientific Name
WET SITES:	American Larch	Larix Laricina
	Black Spruce	Picea Mariana
	Southern Balsam	Abies Fraseri
	Balsam Fir	Abies Balsamea
	White Cedar	Chamaecyparis Thyoides
	Arbor Vitae	Thuja Occidentalis
	Red Cedar	Juniperus Virginiana
	Black Willow	Salix Nigra
	Shining Willow	Salix Lucida
	Glaucous Willow	Salix Discolor
	Downy Poplar	Populus Heterophylla
	Cottonwood	Populus Deltoides
	Bitternut Nut Hickory	Hicoria Cordiformis
	Paper Birch	Betula Alba Papyrifera
	Yellow Birch	Betula Lutea
	Red Birch	Betula Nigra
	Blue Beech	Carpinus Caroliniana
	Smooth Alder	Alnus Rugosa
	Swamp White Oak	Quercus Bicolor
	Pin Oak	Quercus Palustris
	Willow Oak	Quercus Phellos
	Laurel Magnolia	Magnolia Virginiana
	Umbrella Tree	Magnolia Tripetala
	Papaw	Asimina Triloba
	Poison Sumach	Rhus Vernix
	American Holly	Ilex Opaca
	Red Maple	Acer Rubrum
	Box Elder	Acer Negundo
	Black Gum	Nyssa Sylvatica
	Swamp Black Gum	Nyssa Biflora
	Tupelo Gum	Nyssa Aquatica
	Great Laurel	Rhododendron Maximus
	Catalpa	Catalpa Bignonioides
	Black Ash	Fraxinus Nigra
	Red Ash	Fraxinus Pennsylvanica
	Green Ash	Fraxinus Pennsylvanica Lanceolata
	Fringe Tree	Chionanthus Virginica
	Sweet Viburnum	Viburnum Lentago
	Water Elm	Planera Aquatica
	Swamp Privet	Forestiera Acuminata
	Button Bush	Cephalanthus Occidentalis
	Speckled Alder	Alnus Incana
	Red Chokeberry	Aronia Arbutifolia
	Spirebush	Benzoin Aestivale
	Summersweet	Clethra Alnifolia
	Tatarian Dogwood	Cornus Alba

	Common Name	Scientific Name
Wet Sites Con't:	Silky Dogwood	Cornus Amomum
	Bloodtwig Dogwood	Cornus Sanginea
	Red Osies Dogwood	Cornus Stolonifera
	Leatherwood	Dirca Palustris
	Common Winterberry	Ilex Verticillata
	European Larch	Larix Europaea
	Sweet Gum	Liquidambar Styraciflua
	Sycamore	Platanus Occidentalis
	Beach Plum	Prunus Maritima
	Carolina Rose	Rosa Carolina (Humilis)
	Weeping Willow	Salix Babylonica
	Pussy Willow	Salix Caprea
	Bay-Leaved Willow	Salix Pentandra
	American Elder	Sambucus Canadensis
	European Red Elder	Sambucus Racemosa
	Bald Cypress	Taxodium Distichum
	Hemlock	Tsuga Canadensis

The foregoing list of trees and shrubs is a very broad and general one and it should be used as a handy guide by foresters and engineers in determining the kind of planting stock to be used on different sites. It should be kept in mind that there is no substitute for good sound judgment. The individual must analyze the conditions as they exist and act accordingly.

Naturally the above table of trees and shrubs is limited by the amount of stock available and whether or not the plant sites fall within the range of the species.

No suggested combinations have been listed for the simple reason that each area presents a particular planting problem which can best be solved by the individual in charge, unhampered by definite recommendations and suggestions.

Of equal importance, perhaps, is the care of planting stock. Young trees and shrubs in the seedling stage are very tender and sensitive to abnormal conditions. Consequently, every possible precaution should be taken to prevent any damages to them after their removal from the nursery until such time as they are replanted. It is very important that the roots be well covered with wet spagnum, burlap or similar materials during the time they are out of the ground, and at no time should the roots of planting stock be exposed to the drying effect of the sun and wind. At the close of each day's work the planting stock should be carefully heeled-in in good moist soil for safe keeping until the next day.

Planting foremen should receive careful instructions relative to the care of planting stock and should constantly check on the field crews to see that the stock is being properly cared for.

The matter of proper mixture and spacing of trees and shrubs has long been a controversial point among foresters. Needless to say the writer does not hope to solve this much debated point but rather to offer some suggestions that may be of value. By all means the individual on the ground, with the facts before him, is the only one in a position to judge, and the proper mixture and spacing for any particular area rightly rests with him. The planting of trees and shrubs in mixtures should by all means be encouraged at every opportunity.

Spacings that have been used at various times are:

Spacing (Ft.)	No. trees per Acre	Spacing (Ft.)	No. trees per Acre
2 x 2	10,890	6 x 6	1,210
2 x 4	5,445	6 x 8	907
3 x 3	4,840	7 x 7	890
4 x 4	2,722	7 x 8	778
4 x 5	2,275	8 x 8	680
5 x 5	1,743	10 x 10	436
4 x 6	1,814	12 x 12	302

The methods of planting come in for serious consideration and should be carefully worked out. There are a number of recommended methods of planting, each of which has its place. Good results may be secured, irrespective of the method used, providing the individual planters have a clear knowledge of certain basic principles which are:

1. Remove all sod or debris from the spot where tree is to be planted.

2. Make the hole large enough to accomodate the entire root system without crowding.

3. Be sure that well pulverized mineral soil is firmly packed around the roots.

4. Do not under any circumstances pack trash or sticks around the roots.

5. Be sure the seedling is firmly held in an upright position.

6. On exposed barren sites a few handfuls of surface soil will aid materially in getting the seedlings started.

7. The area immediately adjacent to the planted seedling should be mulched with leaves, broomsedge, grass or inverted sod.

The center-hole, mattock slit, and dibble bar methods of planting, using one, two, or three man crews are adaptable to almost any area or condition that may be encountered.

On badly gullied or galled areas it may be worth while to use some fertilizer. From the data available it seems that a complete fertilizer gives the best results. For example, experiments with 4-12-4 fertilizer have proven very satisfactory. It is felt however, that until such time as more accurate data is available only experimental plantings should be fertilized.

As a yardstick to measure results, staked rows of 100 trees or shrubs should be established on many of the plantations, these staked rows should be carefully selected in order to give much needed information on site, spacing, mixtures, and growth under varying degrees of erosion and exposure.

Vigorous, well balanced, nursery stock is ideal for planting in connection with erosion control structures, and the practice of using wild stock or seed spotting should be resorted to only when nursery grown stock is unavailable.

PART TWO

GULLY PLANTING

Gullies are the only form of erosion readily recognized by average individuals and for that reason any control measures undertaken are immediately subjected to the critical eye of the general public. Hence, any successful control measures used are important, in that they serve to convince the general public that erosion can be controlled, in addition to the many other values resulting from such control.

It is not feasible or sound to assume that gullies should be filled in, revegetated and forgotten on the basis that once they have been worked the problem has been solved.

Gullies are usually formed as the result of concentrated and accelerated surface drainage and it must be borne in mind that in many cases the only solution is to stabilize the main gullies and let them serve as the natural drain for the area involved. This is particularly true of any area where the slopes are excessive. Gully control planting as suggested herein will be made for the purpose of stabilizing existing gullies to enable them to serve as natural drains without further destructive action, and in addition will be so placed as to reinforce and bind gully control structures, making them of a more permanent value in our erosion control program.

For the purpose of brevity and clearness, sketches are shown to illustrate where and how gully control plantings should be made.

Sketch No. 1, page 161, Planting the Vertical Sides.

1. Should be some species that will develop into a tree.

2. Should be some species of shrub or small tree.

3. Should be a thrifty and hearty species of shrub or vine.

Slope banks as shown. Usually a 2:1 slope will suffice. Intermediate barren spaces to be seeded to lespedeza, grasses, or small grain.

Sketch No. 2, page 162, Spacing Gully Plantings.

Note staggered spacing. Spacing should be 2' x 2' near the bottom of the gully and increased as you approach the top. Plantings should extend back from the top to a distance equal to the depth of the gully and farther if possible. In most cases plantings should never be made in the gully bottom.

Sketch No. 3, page 163, Using Sod Strips.

Sod may also be planted in continuous strips like miniature terraces along the gully sides. Sod strip should be from 8" to 12" wide and from 2' to 3' long. Spacing should be closer on the lower section of the sides. Lespedeza, grasses, or small grain may be sown on the bare spots.

Sketch No. 4, page 164, Using Loose Rock Retaining Walls to Establish Shrubs, Briars or Vines near Bottom of Gully.

Rocks should be laid in a horizontal arc forming a pocket in which enough topsoil can be placed for planting purposes. If pockets are built well in advance of the planting crew they will usually collect enough soil for planting purposes.

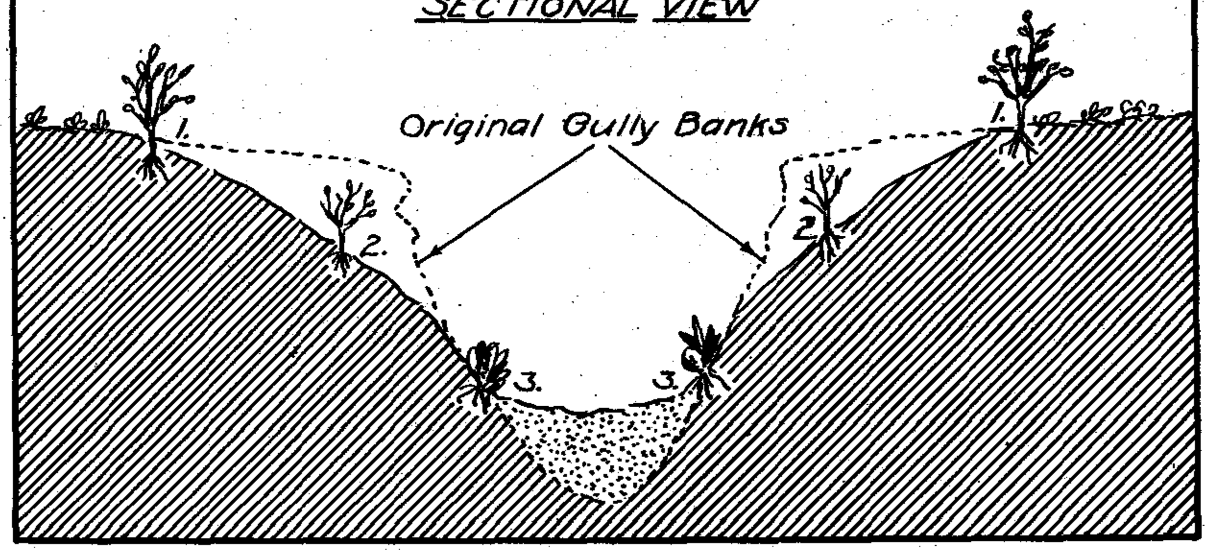
Sketch No. 5, page 165, Holding Brush or Straw on Badly Galled Areas Until Vegetative Cover Becomes Established.

Forked stakes are driven into the ground to hold poles in place. The poles hold the brush, straw, or similar material. Burlap may be used when its use can be justified from an economic standpoint. Trees, shrubs, grasses, briars and vines can be established on badly galled areas by this means.

SKETCH NO. 1

PLANTING THE VERTICAL SIDES

SECTIONAL VIEW



SPECIFICATIONS

1.-Should be Some Species that will Develop into a Tree Within a Few Years.

2.-Should be Some Species of Shrub or Small Tree.

3.-Should be a Thrifty and Hardy Species of Shrub or Vine.

Banks Sloped as Illustrated Above. Usually a Slope of About 2:1 Will Suffice.

Intermediate Barren Slopes to be Seeded to Lespedeza, Grasses, or Small Grain.

Trees Should be Planted Back from Shoulders – a Distance at Least Equal to the Depth of the Gully and Farther if Possible.

Species Planted will be Governed by the Location of the Gully in Addition to the Factors Ordinarily Considered.

All Plantings to be Mulched with Any Suitable Material Which May be Available.

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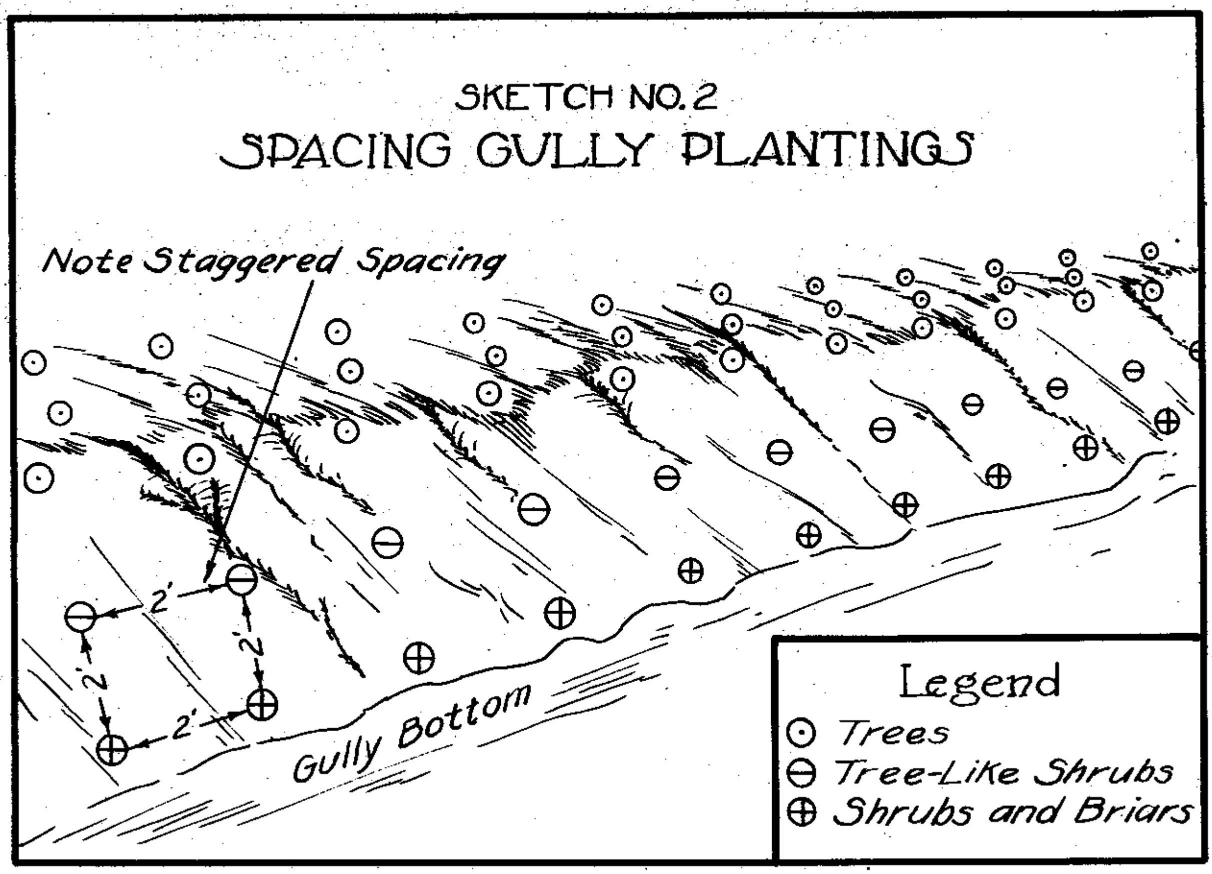

SPECIFICATIONS

Spacing Should be 2x2 Near the Bottom of the Gully and Increased as the Top is Approached.

Plantings Should Extend Back from the Top to a Distance Equal to the Depth of the Gully and Farther if it is Possible.

In Most Cases Plantings Should Never be Made in the Gully Bottom.

Suggestions Pertaining to Planting in General Should be Rigidly Adhered to.

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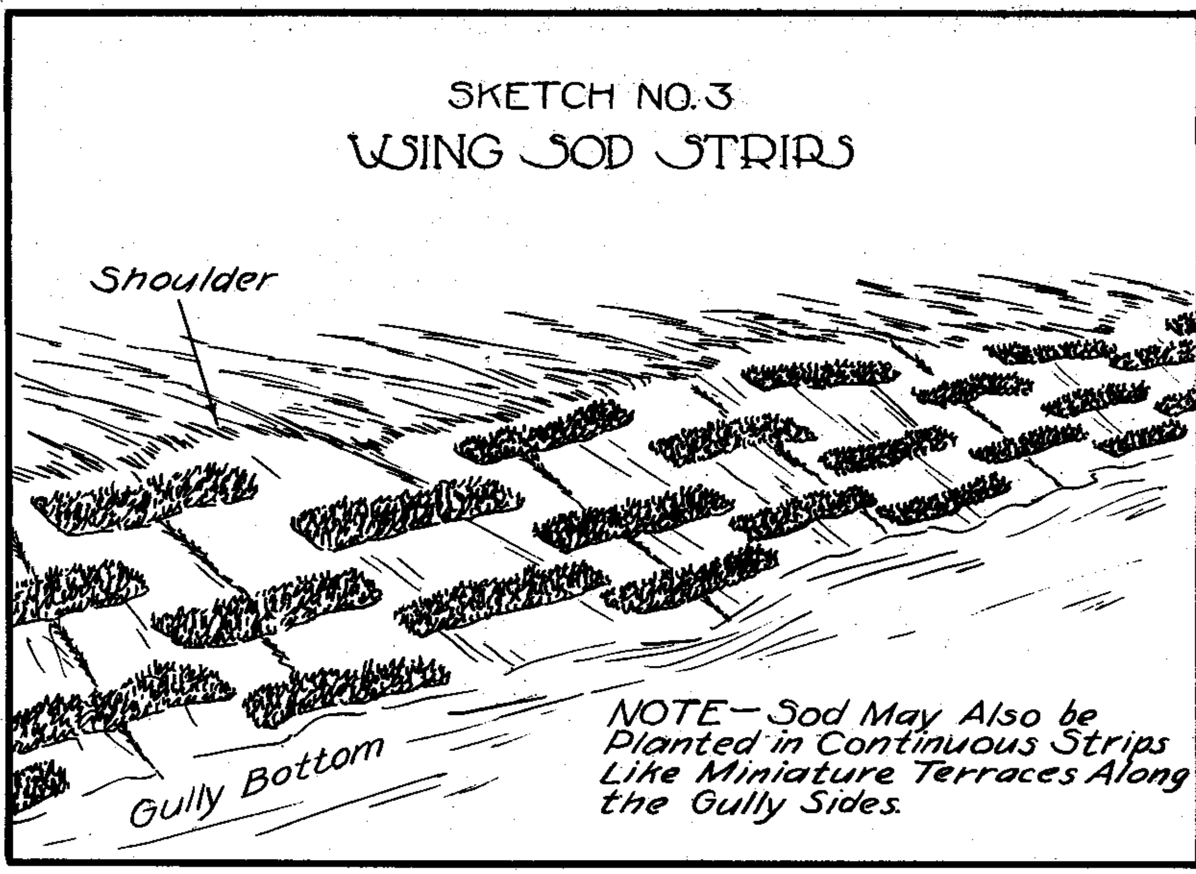

SPECIFICATIONS

Sod Strips Should be from 8" to 12" Wide and from 2' to 3' Long.

Strips Should be Placed in Shallow Trenches Just Large Enough to Receive Them Without Crowding.

On Badly Exposed Areas, Good Top Soil or Fertilizer Placed in the Trench, Beneath the Sod, Will Aid Materially in Getting it Started.

Spacing Should be Closer on the Lower Section of the Sides.

Lespedeza, Grasses or Small Grain May be Sown on the Bare Spots.

Sod Planted in this Manner Will Serve as Miniature Terraces and be of Particular Value in Facilitating the Growth of Other Vegetation.

Can be Used in Combination with Trees and Shrubs.

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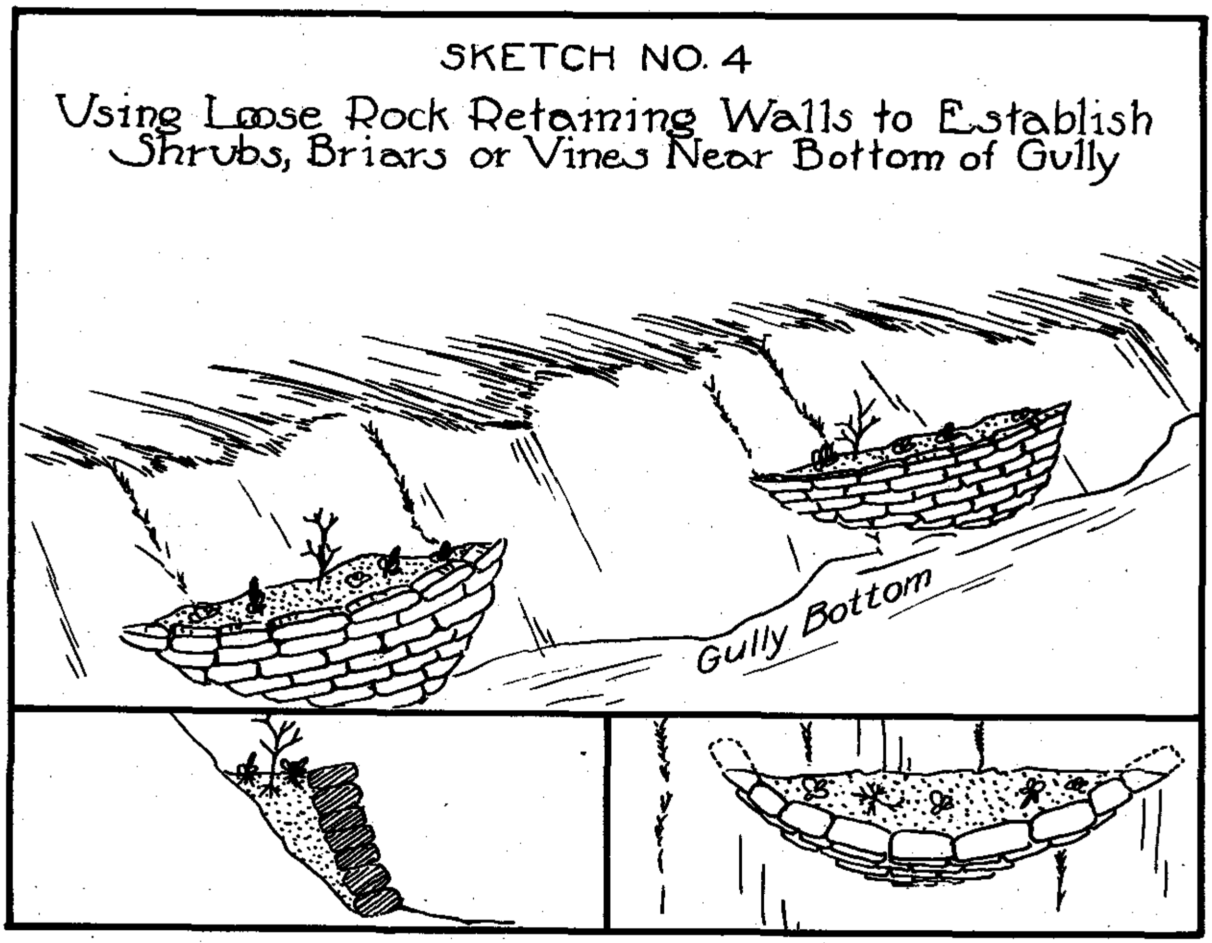

SPECIFICATIONS

Rocks Should be Laid in a Horizontal Arc Forming a Pocket in Which Enough Topsoil Can be Placed to Facilitate Planting.

If Pockets are Built Well in Advance of the Planting Crew They Will Usually Collect Enough Soil for Planting Purposes.

These Pockets are Best Adapted to Areas Where it is Not Justifiable to Spend the Time or Money to Revegetate the Entire Area.

Especially Adapted to Areas Where Rocks are Plentiful and Easily Obtainable.

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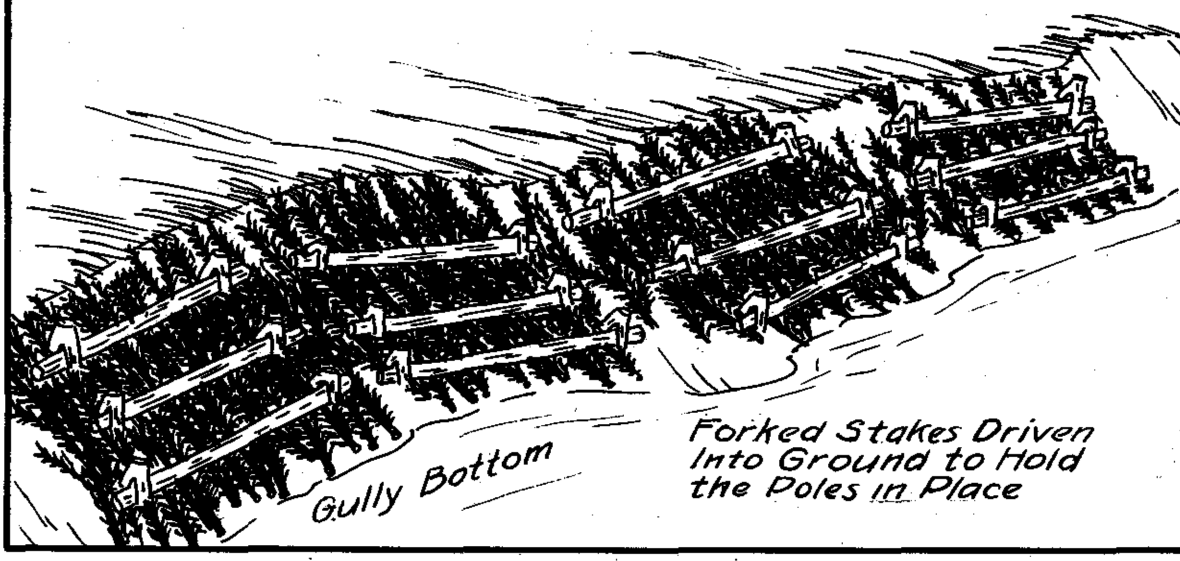
SKETCH NO. 5

Holding Brush or Straw on Badly Galled Areas Until Vegetative Cover Becomes Established



SPECIFICATIONS

Poles are Used to Hold Down the Brush, Straw or Similar Material Used in Preventing Further Inroads of Erosive Action.

Burlap may be Used When its Use can be Justified From an Economic Standpoint

Trees, Briars, Shrubs, Grasses and Vines can be Established on Badly Galled Areas by this Means.

Tops of Brush Should Point Up the Slope.

Brush Should Overlap—Like Shingles on a Roof.

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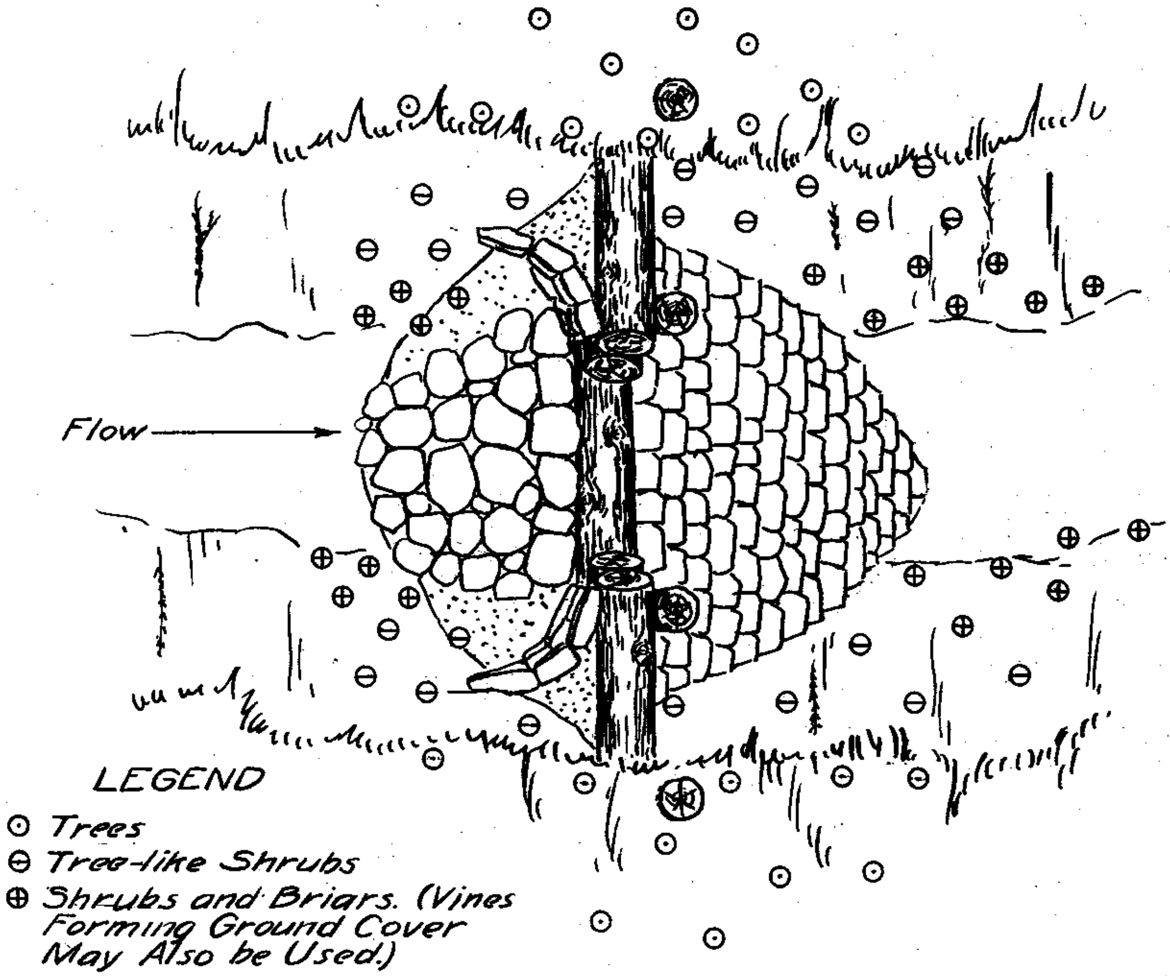
SKETCH NO. 6
PLANTING TO REINFORCE A STRUCTURE



SPECIFICATIONS

Arrangement, Species and Spacing to be Determined by Size of Gully, Structure, Soil Type and Other Physiographic and Climatic Conditions.

Planting Should Extend Well Back on Each Side—Depending Upon the Size of the Structure.

Always Work toward the Objective of Stabilizing the Structure by Means of the Plantings Being Made.

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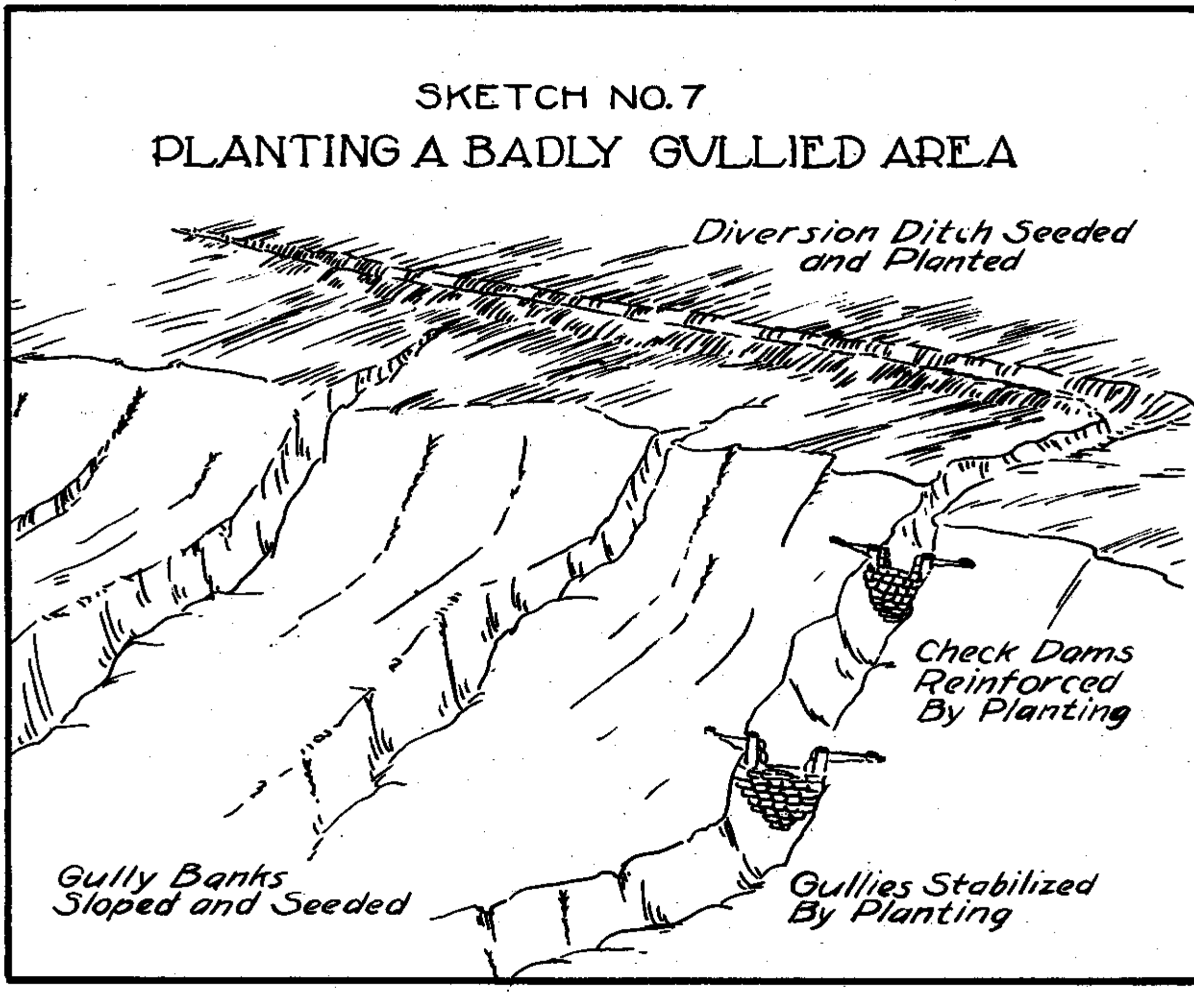

SPECIFICATIONS

This Method of Using Planting in Conjunction with Erosion Control Stabilization is Advisable on Areas of Value as Agricultural Land on Which Numerous Gullies Have Formed Parallel to Each Other.

By the Above Method One Gully is Selected to Serve as a Natural Stabilized Drain, While the Water from the Other Gullies is Diverted into the Main Gully by Means of a Diversion Ditch.

The Other Gullies Should be Filled in and Seeded. The Diversion Ditch Should be Adequately Supported by Planting.

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Sketch No. 6, page 166, Planting to Reinforce a Structure.

Trees, tree-like shrubs, shrubs, briars, and vines may be used. Arrangement, species, and spacing to be determined by size of gully, structure, soil type, and other physiographic and climatic conditions. Planting should extend well back of each side, depending upon the size of the structure.

Sketch No. 7, page 167, Planting a Badly Gullied Area.

Diversion ditch seeded and planted as shown with check dam reinforced by plantings. The gullied banks are sloped and seeded. This method of using planting in conjunction with erosion control structures is advisable on areas of value as agricultural land on which numerous gullies have formed parallel to each other. By the above method one gully is selected to serve as a natural stabilized drain while the water from the other gullies is diverted into the main gully by means of a diversion ditch. The other gullies may be filled in and seeded. The diversion ditch should be adequately supported by planting.

PART THREE

STREAM CONTROL PLANTINGS

The problems presented by stream control planting are similar in many respects to those encountered under gully planting. Stream control plantings logically fall into two classes, namely, (a) plantings for bank protection, and (b) plantings to reinforce and protect stream control structures. The same general method of mixture and spacing as discussed under gully control can be used for stream control plantings with some modification. The attached sketches illustrate general methods that can be used and which will give good results.

Sketch No. 1, page 169, Stream Bank Plantings.

Lower part of bank up to maximum water level should be rip-rapped with stone, or brush held in place with woven wire and stakes.

Sketch No. 2, page 169, Brush Matting or Rip-rap Reinforced by Planting.

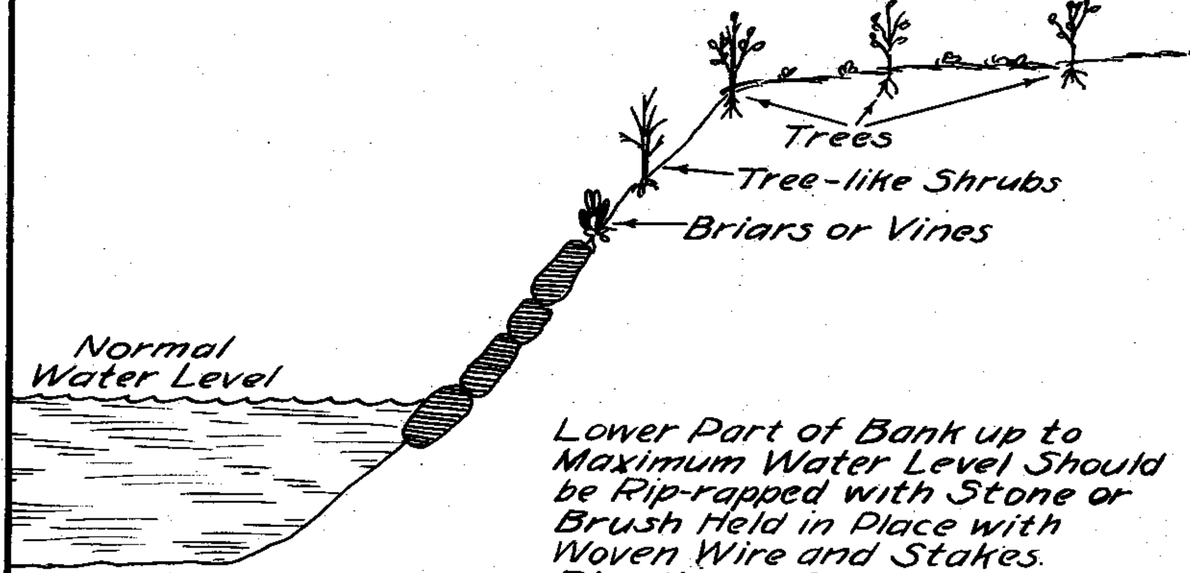
Sketch No. 3, page 170, Dam Reinforced by Planting.

Sketch No. 4, page 171, Planting to Reinforce Wing Dams, Levees and Similar Structures.

The sedimentation areas indicated are to be planted as rapidly

SKETCH NO. 1

STREAM BANK PLANTINGS

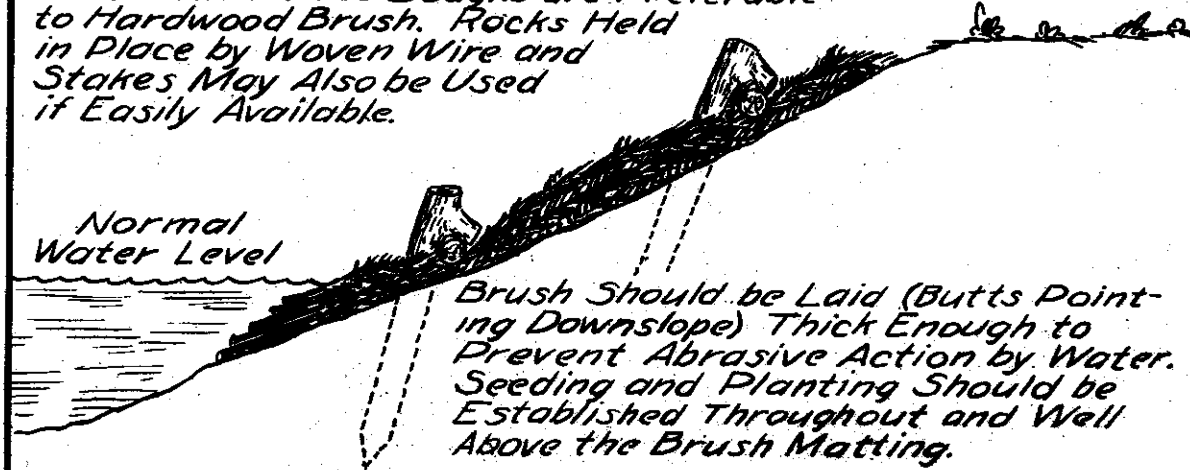


Lower Part of Bank up to Maximum Water Level Should be Rip-rapped with Stone or Brush Held in Place with Woven Wire and Stakes. Planting is Arranged as Shown in Sketches 1 and 2, Part 2.

SKETCH NO. 2

Brush Matting or Rip-rap Reinforced by Planting

Brush May be Held Down by Poles or Galvanized Woven Wire. Pine Boughs are Preferable to Hardwood Brush. Rocks Held in Place by Woven Wire and Stakes May Also be Used if Easily Available.



Brush Should be Laid (Butts Pointing Downslope) Thick Enough to Prevent Abrasive Action by Water. Seeding and Planting Should be Established Throughout and Well Above the Brush Matting.

NOTE—Strategic Plantings Such as Shown Above Should be Similarly Employed Where Rip-rapping is Used.

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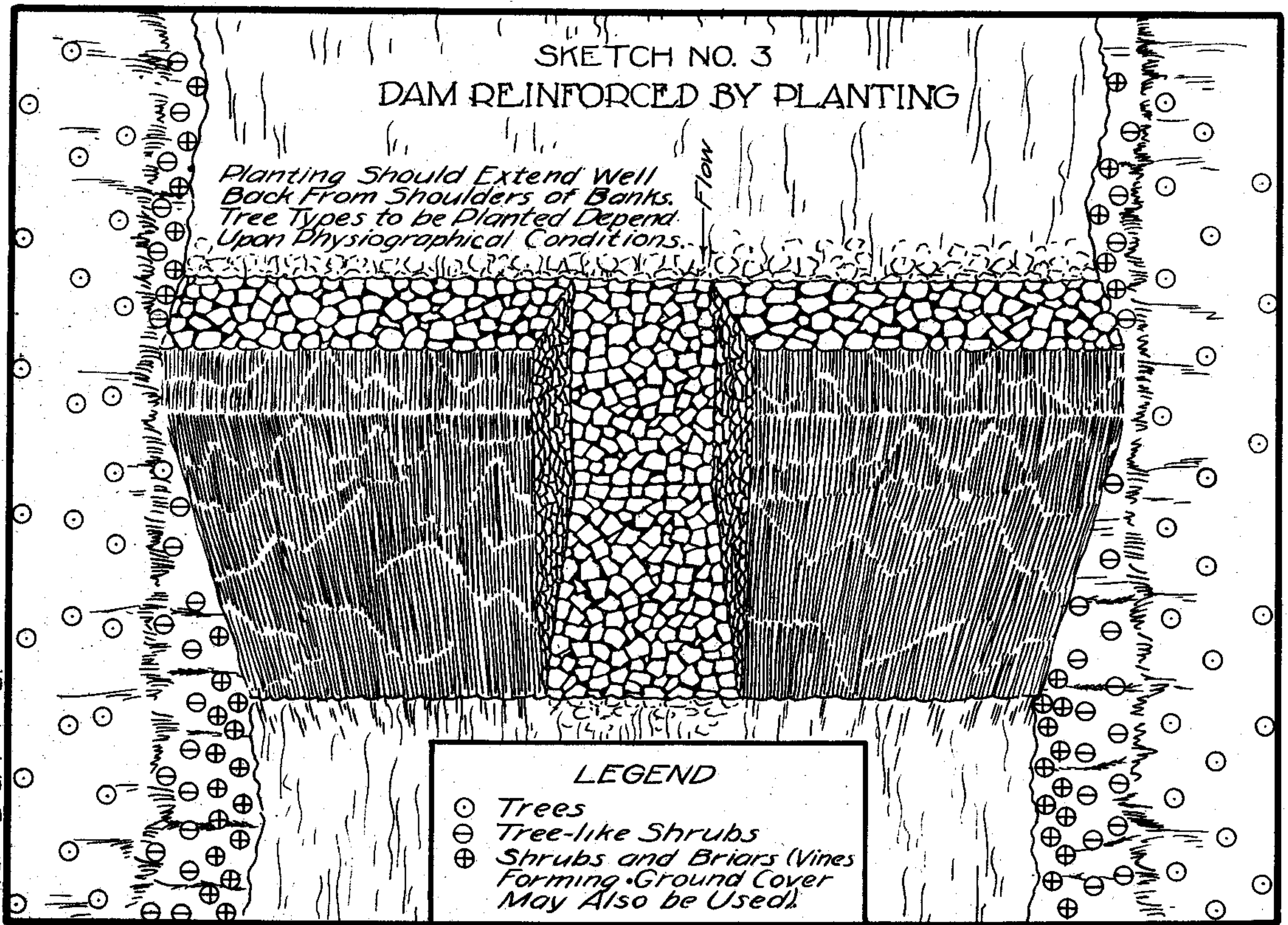

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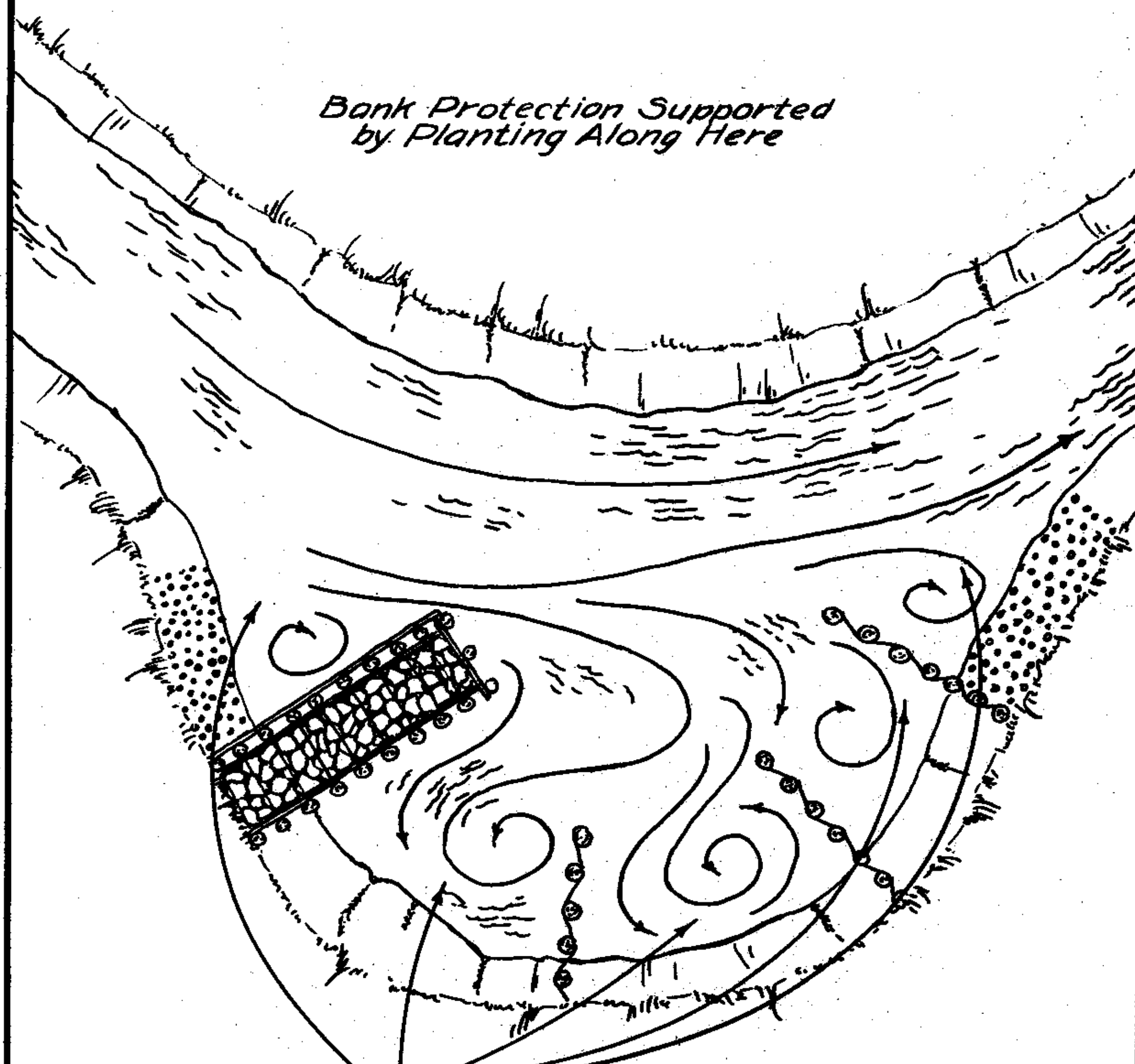
SKETCH NO. 4

Planting to Reinforce Wing Dams, Jetties, Levees and Similar Structures



These Areas to be Planted as fast as They Silt in. This Means that the Planting Work Must Lag Behind the Engineering Work.

It Usually Takes a Period of From 5 to 10 Years to Complete the Planting

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as silting occurs. Five or ten years is usually required to complete the planting on these areas.

In all stream control work the individual action and characteristics of the stream must be carefully studied and the information obtained should be used as a guide in formulating the plan of control.

PART FOUR

DIVERSION DITCH PLANTINGS

On many projects the planting of diversion ditches is very important. It is a problem of simple solution if we keep in mind first, that the ditch must present a smooth unobstructed surface for carrying the water and second, that the lower shoulder must be maintained unbroken. A sketch to illustrate a method that can be universally applied is included.

Sketch No. 1, page 173, Diversion Ditch Planting.

The entire area to be seeded to grass and kept in sod. Part of the area to be planted to trees or shrubs. Care must be exercised to prevent planting of species that will interfere with farm practices.

Sketch No. 2, page 173, Planting Diversion Ditch Outlets.

PART FIVE

TERRACE OUTLET PLANTINGS

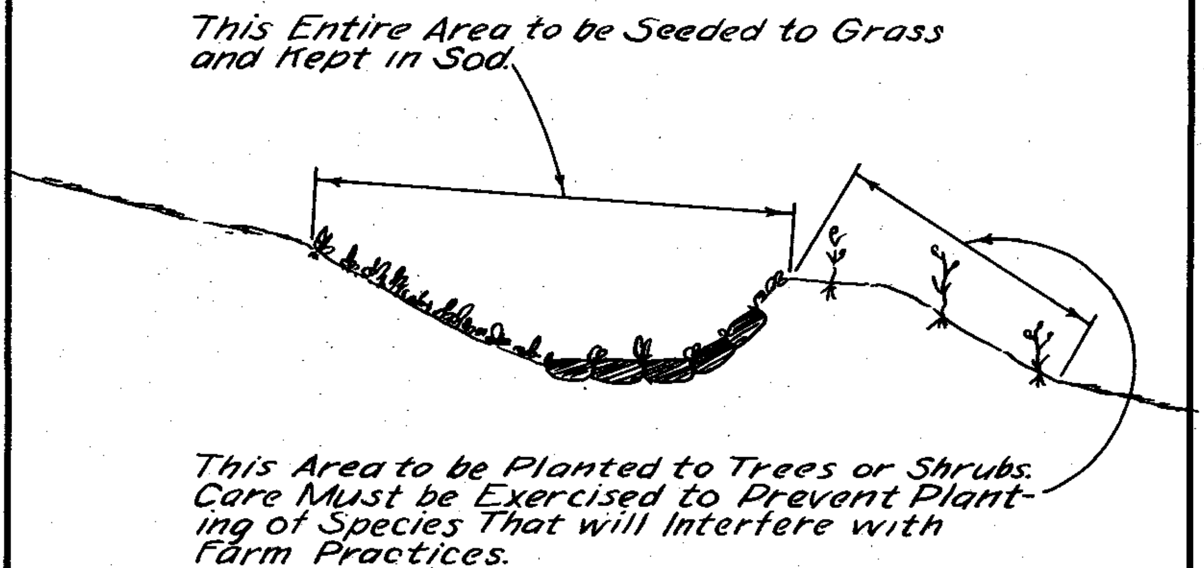
Many gullies are caused by terrace outlets that are not properly protected. If a natural, stabilized channel is not available to act as an outlet for the terrace, by all means one should be provided and should be supported by vegetative cover.

The terrace outlet is constructed on the same general principle as the diversion ditch outlet, and vegetation may be placed in much the same way. Note planting around outlet shown in Sketch No. 2, page 173. Where trees or shrubs cannot be used, substitute sod strips and seeding as shown in Sketch No. 1, page 173. Both sketches refer to diversion ditch outlets but the terrace outlet requires similar control.

SKETCH NO. 1

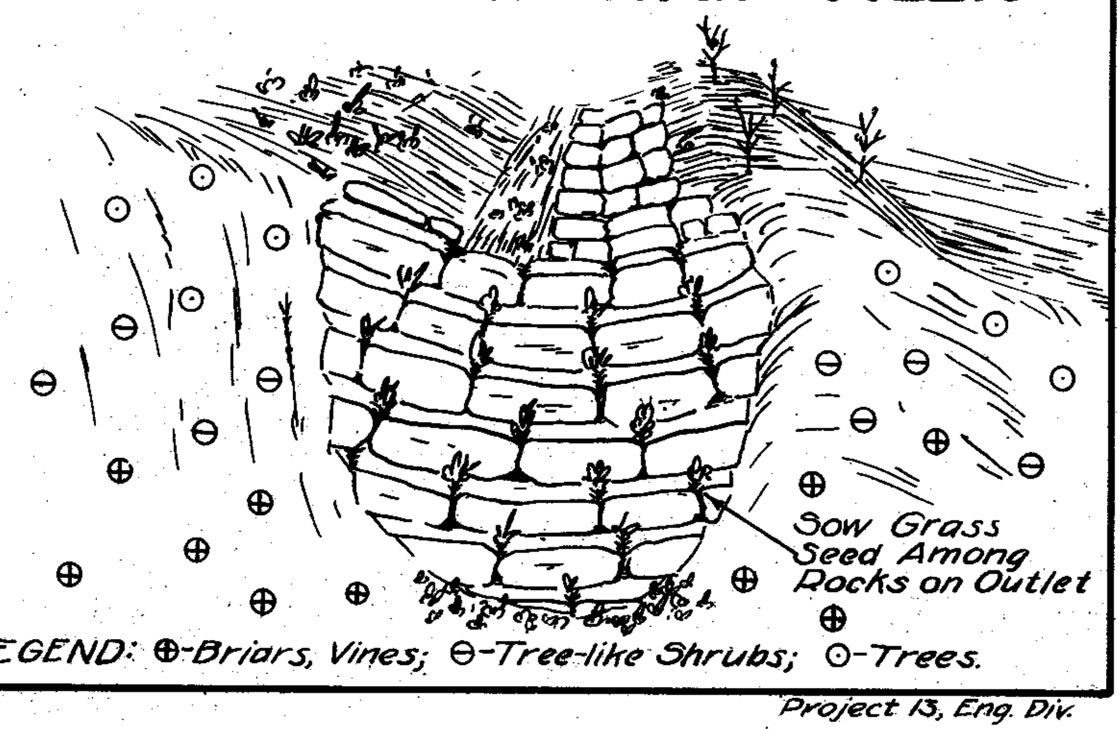
DIVERSION DITCH PLANTINGS

SECTIONAL VIEW



SKETCH NO. 2

PLANTING DIVERSION DITCH OUTLETS



LEGEND: ⊕-Briars, Vines; ⊖-Tree-like Shrubs; ⊙-Trees.

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PART SIX

ROADSIDE PLANTING

Much serious erosion has resulted from improper handling of the cut and fill banks along highways and roads. This has resulted in not only extremely high maintenance cost to the Highway Commission but thousands of acres of valuable farm land have been affected as well.

Much of the loss could have been prevented if a procedure as illustrated had been followed. It is with the hope that this type of erosion control will be expanded that we offer these suggestions.

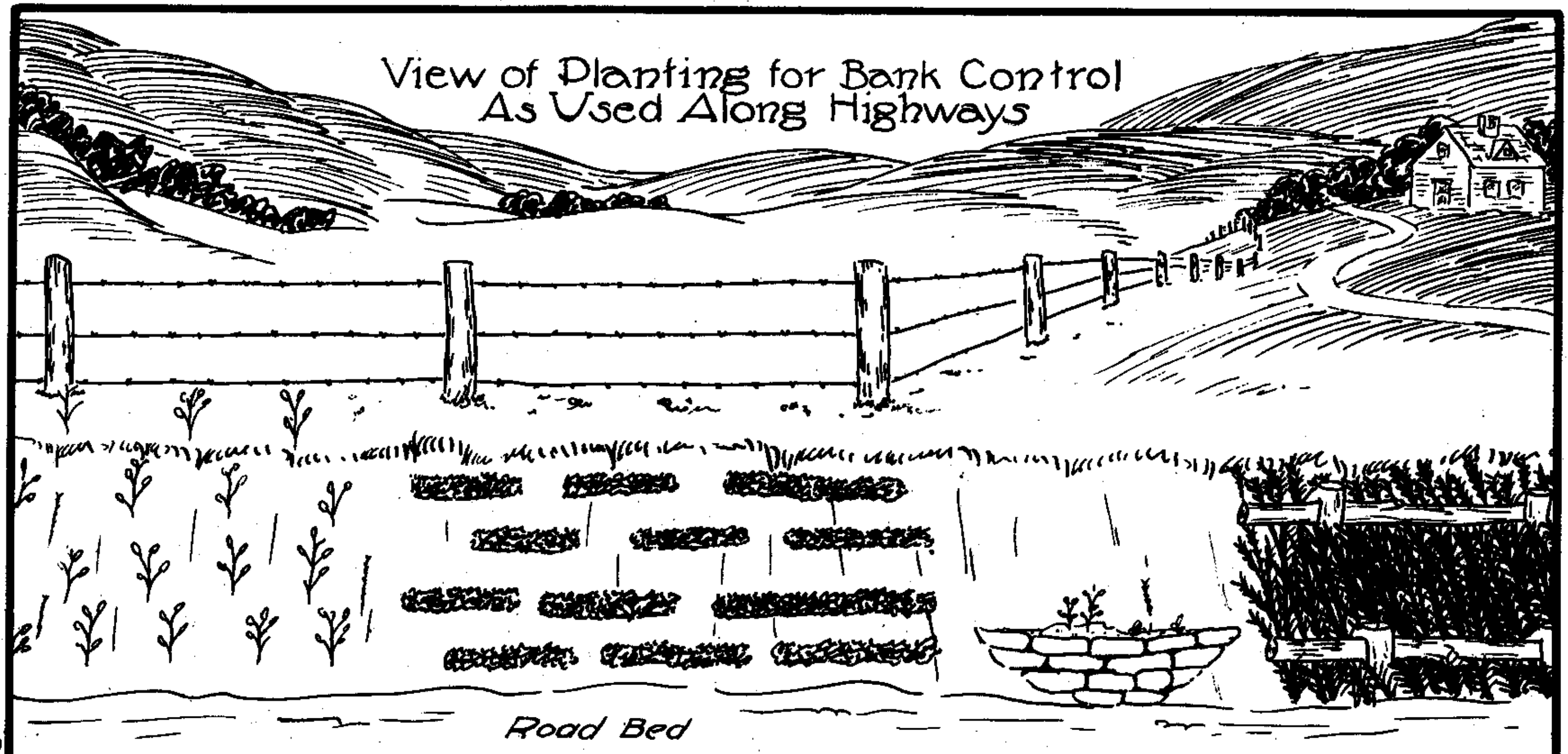
Sketch No. 3, page 175, View of Planting for Bank Control.

Sketch No. 4, page 176, Planting in Conjunction with Culvert Outlets.

It should be kept in mind in making roadside plantings that small flowering shrubs or vines should always be planted adjacent to either or both sides of the highway in order to prevent obscuring the vision along the highway and to beautify the scenery.

As the plantings recede from the highway different species may be used and by proper selection they can be made to harmonize with the existing background.

The foregoing concludes a very elementary discussion on the use of trees and shrubs in conjunction with engineering structures designed for controlling erosion.



Trees Planted Along Here to Protect Bank. Spaced and Arranged as Illustrated in Sketch 2, Part 2.

Sod Stripping Placed Here to Establish Vegetative Growth. Arranged Same as Shown in Sketch 3, Part 2, Gully Plantings.

Rock Retaining Wall Built Here to Start Vegetation. See Part 2, Sketch 4, Gully Plantings.

Brush Matting Laid Here and Seeded as Illustrated in Sketch 5, Part 2, Gully Plantings

NOTE—These Methods May be Used Either Singly or in Combination as Determined by Physical Conditions of Bank.

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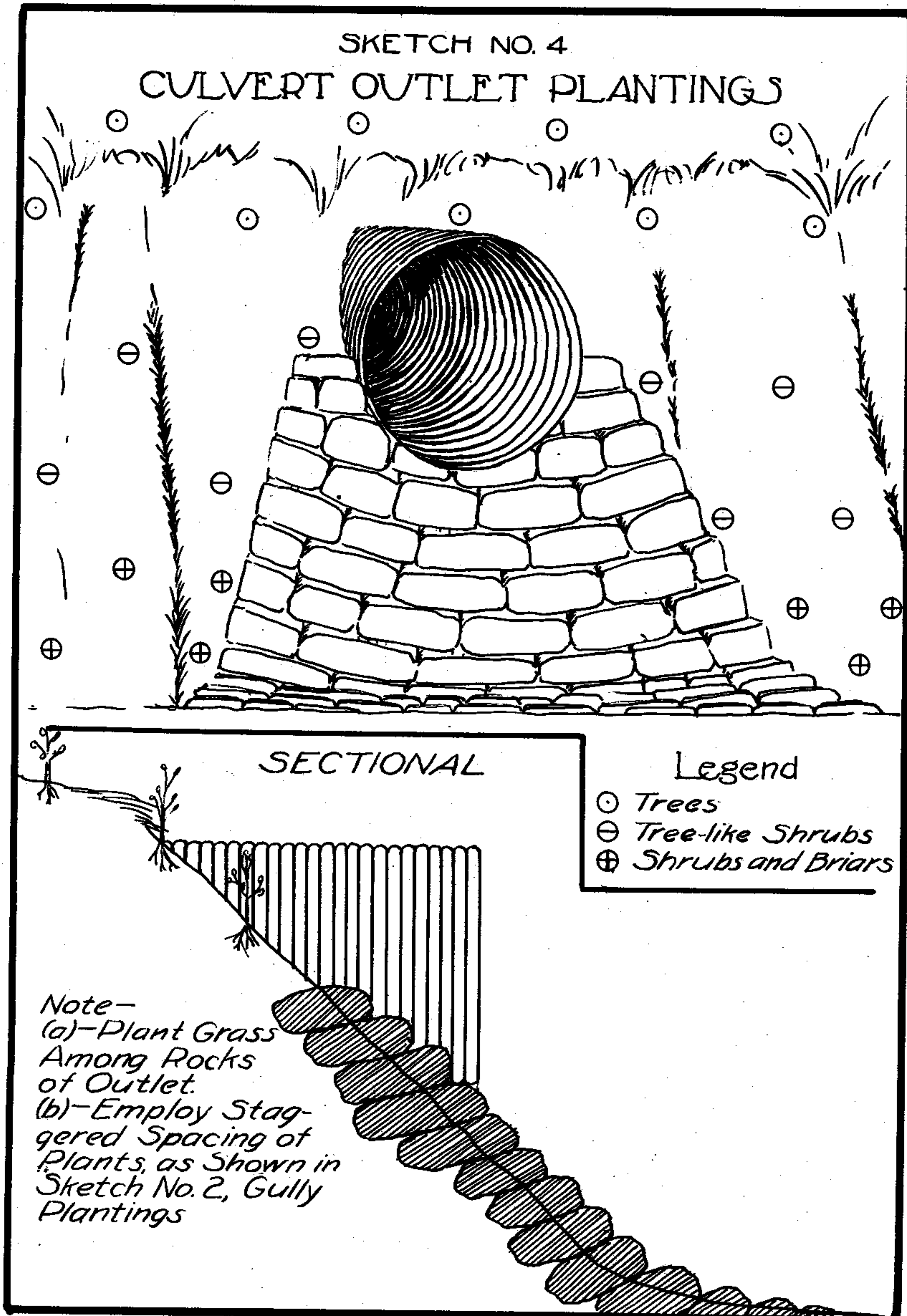
Sketch 3



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CHAPTER XI

SEEDING OF EROSION CONTROL STRUCTURES

Erosion control structures are not intended to control erosion unaided. In most cases they are used to check the flow of water until vegetation can become established. In a few cases they are necessary as a permanent protection in order to establish and hold vegetation. Ordinarily, vegetation should be used with all erosion control structures.

To make a satisfactory seeding, in connection with erosion control structures, a number of factors must be taken into consideration, including soil, slope, time of year and seed available. Under the best of conditions it is difficult to establish a cover on the raw subsoil and shale so prevalent around erosion control structures. The lack of organic matter causes the soil to dry rapidly and difficulty will be encountered in securing a good vegetative cover. However, a little vegetation is better than none and every sprig established aids in reproduction of additional vegetation. Whenever a plant establishes itself on the side of a gully bank, it immediately begins to build up organic matter. It also forms a shade which serves as protection to other plants from the hot sun, preventing the soil from drying so rapidly. The fine roots hold the soil. Leaves, twigs and other organic matter have a tendency to lodge against the plant stems, all helping to form a protective covering. If the plant propagates by rhizomes or stolons, a spreading of the plant begins to take place as soon as it has become well established.

In making seedings, it is better to use several different kinds of seeds rather than just one or two. Sometimes the soil is suitable to one and sometimes to another plant. It is also important to remember that, in nature, plants live in communities and the success or failure of one depends, in a large way, upon other plants in the immediate vicinity. A very good seed mixture to use under average conditions, is as follows:

Korean lespedeza	25 pounds
Common "	20 "
Redtop	10 "
Orchard grass	20 "
Timothy	10 "

Where the lespedezas are used, it is well to keep in mind that they are legumes and support on their roots bacteria capable of taking nitrogen from the air and fixing it in the soil. For this reason, it is necessary that the suitable bacteria be present. The supplying of these bacteria is called inoculating. Inoculation can be accomplished by securing soil from a field where the legume in question has been grown successfully or by using commercial inoculant. The main thing to keep in mind in inoculating seed is that some of the bacteria must come in contact with each and every seed. Where the soil method of inoculation is used, enough fine dirt should be used so that there is little doubt but that the bacteria is in contact with all of the seed. It is preferable to use commercial inoculants. When this is done, directions for their use will be found on the container. Both Korean and common lespedeza are annuals; both produce seed in abundance and start reasonably early in the spring. They are in the height of their growth during the hot, dry, summer months when the growth of most of the perennial grasses is retarded. They have a good root system and, although they die in the fall with the first frosts, the roots remain in the soil over winter and not only serve as a protection against erosion, but serve materially in building up the organic matter of the soil. Their nitrogen fixing habit, explained above, causes them to be beneficial to other plants grown in the vicinity.

Redtop is a perennial, has a fine fibrous root system, will grow on relatively poor, acid and damp soils and serves a very definite place in controlling erosion in moist gullies and under acid conditions.

Orchard grass is a perennial, grows in bunches, and on account of its dense growth and fine fibrous and extensive root system, is very effective in controlling erosion. It does fairly well on poor soils, but responds rapidly to fertilization.

Kentucky blue grass is a perennial, does not do well on poor, acid soils, but when properly fertilized, makes a dense turf over the soil. Its habit of propagation by under-ground rhizomes causes it to spread very rapidly under favorable conditions.

Timothy, used extensively as a hay crop, is a perennial and under favorable conditions will live many years. It will grow on fairly poor soil, but responds readily to fertilization.

The mixture mentioned above, planted at the rate of 20 to 30 pounds per acre, makes a fairly good seeding. It will depend upon the time of year as to whether this mixture should be adhered to closely or not. The mixture is recommended for late winter and spring. It is not recommended that seeding be attempted during the summer months on account of the hot, dry weather, February and March are recommended as the best time for spring seeding, but seeding may be continued until the first of May with fairly good results from April seeding, depending upon the weather conditions. Fall seeding is recommended and, in many cases, may be expected to give more satisfactory results than spring seeding. However, fall seeding should generally not be attempted after November first. A mixture for fall seeding can be made by leaving the lespedeza out of the mixture recommended for spring seeding. When fall seeding is followed, the lespedezas can be sown the following spring in late February or early March.

It is quite common to find enough lime in some of our subsoils and shales to cause sweet clover to grow well. Where this is the case, it is advisable to seed some sweet clover in addition to the previously mentioned seed mixture. The sweet clover can be seeded separate from the seed mixture if desired. (Sweet clover should be properly inoculated.)

Whenever it is possible to fence the structures from grazing, it is well to use some rapidly growing small grain such as barley, wheat or oats for a nurse or cover crop. Winter wheat or winter barley may be used in the spring as well as in the fall. These small grains grow more rapidly than do the grasses mentioned in the seed mixture and will aid immensely in holding the soil until the permanent grasses can become established. However, it is not advisable to use small grains in areas where livestock is left to graze, as the luscious green of the small grain will cause the livestock to concentrate just where it is not wanted.

Bermuda grass has the possibility of becoming an important erosion control plant in West Virginia, especially in connection with controlling erosion on badly eroded areas and in connection with erosion control structures. Bermuda grass is a perennial and propagates itself mainly by running stems known as stolons. These stolons have nodes or joints which are able to take root and send up aerial branches at each node, thereby forming a new plant. While Bermuda grass is a southern plant, so to speak, it has been known to grow as far north as Canada. Its value in West Virginia is still questionable, but because of its erosion resisting qualities it should be given a trial.

Kudzu is a vinous legume, introduced into this country from Japan. It has been found to do quite well in the southern states, producing runners as long as 70 feet in one year. In the Piedmont section of the south, it is being used extensively to control erosion in the larger gullies. Its use in West Virginia as an erosion control plant may still be questionable but, from observations made of its growth, it is felt that it will play an important part in controlling erosion in the low altitudes of the state. It is propagated by allowing the long vines to take root at the nodes or by taking the runners in the fall, cutting them up, leaving one node to the piece, and planting them in a nursery until a good root system has been established. Transplanting should not be done until the plant is at least two years old, as the larger the root system the greater its chance for living. The rate of planting will vary from 500 to 1000 crowns per acre, depending upon conditions such as soil, vegetative cover already present, and other seeding or planting done.

Fertilization is very necessary in connection with the establishment of vegetation in gullied areas and on erosion control structures. It is best to use a complete fertilizer, but if such is not available, a fertilizer containing phosphorus and nitrogen will probably give satisfactory results. Application should be made at the rate of 400 to 500 pounds per acre of the equivalent of 4-12-4. As mentioned before in this article, the soil in many gullied areas has been found to contain enough lime for the proper growth of sweet clover. However, in many others the soil is found to be very poor and much in need of lime. In those cases, it is advisable to apply lime at the same time the fertilizer is applied. The rate of application will depend upon the requirement, but the average will be around two tons per acre.

In making seedings the different types of engineering structures must always be kept in mind as well as the erosion problem which the engineer is trying to solve. Since it is impossible to cover all of these problems in a general discussion, they will be discussed under separate headings as follows:

1. GULLIES

<u>Temporary Dams</u>

Temporary dams are built to check the flow of water and to hold the soil until vegetation can become established and take care of the situation. Fertilizer should be applied and lime, if necessary. This can be done by spreading the fertilizer and lime by hand over the structures and raking in with a hand rake. The recommended seed mixture should be used according to the earlier discussion. This mixture can be sown at the same time the fertilizer is spread and raked in under one operation. However, if the seeding is done in the early spring before freezing weather is over, it is not necessary to rake the seed in, as alternate freezing and thawing will work the seed into the ground. If the structure is fenced from grazing, it is advisable to use one of the small grains in addition to the seed mixture.

Bermuda sod is used very effectively in the south in making a vegetative cover for temporary structures. It can be placed below the dam and between the logs in case the temporary structure is a log dam. It will grow readily between the logs on the lower side of the dam and will make a complete covering of vegetation that will go a long way in controlling erosion when the life of the structure is over. It is probable that it will give satisfactory results in West Virginia.

Again, if the structure is fenced from grazing, kudzu is a very desirable plant to use. It will develop a luxuriant growth in from three to four years, or in plenty of time to take care of the situation before the temporary structure rots out. In the planting of Kudzu on areas of this nature, locations should be made where there is still sufficient soil for proper growth. The planting of kudzu can be made three to four feet back from the edge of the gully itself and can be expected to vine over into the gully in time and form a complete covering over the gully and structure.

Permanent Dams

Permanent dams do not present such an immediate vegetation problem as do temporary dams. Since permanent dams are expected to last more or less indefinitely, it is not so important to have as rapidly growing plants as were required for the temporary dams. The exposed surface in connection with permanent dams should be seeded with the previously recommended seed mixture and in the same manner as described under temporary dams. However, Bermuda grass or Kudzu can probably be used to advantage. Fertilizer and lime is just as necessary in connection with permanent dams as with temporary dams.

Gully Banks

Gully banks present a somewhat difficult problem because they are usually fairly steep and have nothing on which to establish vegetation except subsoil and shale. A good way to begin establishment of vegetation on gully banks is to cut off any overhanging sod, let it slide down the bank and hold it somewhere on the slope. This is easy to accomplish when the worker is operating from below with an instrument such as a hoe or mattock. The sod can be allowed to slide down to the selected location and may then be stamped firmly into the ground. After the overhanging sod has been removed and located as described, fertilizer and lime may be applied along with the recommended seed mixture. If the soil contains lime in sufficient quantity, sweet clover can be added in addition to the recommended mixture. Since gully banks take up very little water, they dry soon after a rain. For this reason every precaution should be taken to get some sort of vegetation that will maintain itself under such conditions.

A number of native lespedezas are able to maintain themselves on steep gully banks. Workers should always be careful in repairing and seeding gullies and gully banks not to destroy any more vegetation than is absolutely necessary, since vegetation found growing under these conditions has usually adapted itself to its surrounding. If the area is fenced from grazing, the use of Kudzu should not be overlooked. It can be planted in the better locations back of the gully bank and, as described above, can be expected to vine over the entire gully.

Gully Beds

It is usually easier to establish vegetation in gully beds than on the banks. The tendency to dry out is less rapid and any obstructions have a tendency to collect sediment and debris. These aid materially in conserving the moisture and protecting the plants. The recommended seed mixture should be used. Vegetation can also be established in gully beds by placing some soil, fertilizer and seed in a cheap burlap bag and placing dam fashion, in the bottom of the gully. This method has been found to work exceptionally well on the Spencer project.

Diversion Ditches

Diversion ditches present a somewhat different problem than do gullies and gully structures. Since, in a great many cases, there is still some topsoil on the sides of the diversion ditches an effort should be made to establish vegetation along the sides and bottom of diversion ditches. Bermuda grass has been used very effectively on southern projects and it is felt to have its place for such work in West Virginia. Where there is sufficient soil to support it, a good blue grass sod is very effective in controlling erosion. The idea is to have some sort of close growing grass that will prevent erosion in a diversion ditch and, at the same time, not fill it up to the point of obstructing the flow of water. The recommended seed mixture can be used, or a mixture of Redtop and Common Lespedeza. Fertilizer should be applied if it is possible to get it worked into the soil so as to be helpful.

II. SHEET EROSION

Brush Matting

Brush matting serves two important purposes. First, it checks erosion itself, because of the protection afforded from the beating rain and because the flow of water is retarded over eroded areas. Second, it conserves moisture and protects young plants from the heat until they have become established. Seedings that have been made on areas of this kind have been found to be very successful. The recommended seed mixture should be used and, if the area is fenced, small grain can be used. Since brush matting is more or less temporary and since in large numbers of cases where brush matting is used, the entire topsoil and part of the subsoil is gone, it is felt that some plant, such as kudzu should be used in the immediate vicinity since it will vine over the area and aid materially in controlling erosion after the brush matting has gone.

Brush Strips

Brush strips can be handled very similarly to the brush matting, except that seeding should be made between the strip with the recommended seed mixture, and lime and fertilizer used and raked in with the seed.

III. TERRACES

Terrace Outlets

Some sort of vegetation should be established in terrace outlets that will permit the free flow of water and, at the same time, form a complete covering over the sides and bottom of the terrace outlets. If the soil is sufficiently fertile, blue grass will do a very effective job. Redtop can also be used along with common lespedeza. Better still, probably Bermuda grass, since it will grow on fairly unfertile soil in the form of a complete covering. Natural grass waterways should be used wherever possible.