WATERSHED WORK PLAN

WILLIS RIVER WATERSHED

Buckingham and Cumberland Counties, Virginia

Prepared Under the Authority of the Watershed Protection and Flood Prevention Act (Public Law 566, 83d Congress, 68 Stat. 666) as amended.

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Prepared by: Robert E. Lee Soil and Water Conservation District

Buckingham County Board of Supervisors

Cumberland County Board of Supervisors

With assistance by:

U. S. Department of Agriculture, Soil Conservation Service

U. S. Department of Agriculture, Forest Service
in cooperation with the Virginia Division of Forestry

August 1964

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SUMMARY OF PLAN

This watershed work plan for the Willis River watershed was sponsored and prepared by the Robert E. Lee Soil and Water Conservation District, the Buckingham County Board of Supervisors, and Cumberland County Board of Supervisors. Technical assistance was provided by the Soil Conservation Service and Forest Service of the U. S. Department of Agriculture cooperating with the Virginia Division of Forestry of the Department of Conservation and Economic Development. Other State and Federal agencies assisting were the Agricultural Stabilization and Conservation Service, Virginia Department of Highways, the Agricultural Extension Service, the Virginia Commission of Game and Inland Fisheries and the U. S. Fish and Wildlife Service.

The Willis River watershed as set forth in this plan drains 176,700 acres of which approximately 50 percent is in Buckingham County and 50 percent in Cumberland County. Its headwaters originate near the Appomattox County line and it flows in a northern direction to its confluence with the James River. The watershed is bisected near its mid-point by U. S. Route 60 which runs in an east-west direction.

This is primarily an agricultural watershed which is subject to frequent damaging floods. Portions of the flood plain are inundated numerous times each year. In some sections the flooding is so frequent that the landowners have very limited use of some of their most productive land. The area is served by a good road network but numerous stream crossings make road and bridge damages a problem. The erosion of the uplands and scouring and deposition on the bottom lands also present a problem to landowners in the watershed.

The problems will be solved largely through the application of an overall watershed management plan. This plan will consist of land treatment measures in the upland areas designed to increase moisture absorption and reduce runoff, 11 floodwater retarding structures and 14.91 miles of stream channel improvement. With the project installed the acres flooded by the 5-year frequency flood will be reduced by 2,039 acres; the 3-year event by 2,142 acres and 2-year event by 2,435 acres.

The average annual monetary value of the damages will be reduced 88.2 percent by the accelerated land treatment program in

combination with the structural measures. The average annual benefits from all of the structural measures planned are estimated to be $53,402 (Ref. Table 6). The estimated annual cost will be $42,836. This will result in a favorable benefit-cost ratio of 1.2 to 1.0 for all structural measures.

It is anticipated that the project will be completed in 5 years at a total cost of $1,919,736 with Public Law 566 bearing $1,289,567 and others bearing $630,169 of the cost. The land treatment measures proposed in this plan will cost $795,460 with $214,943 being furnished from Public Law 566 funds for accelerated technical assistance and others furnishing $580,517 for installation. They will augment existing land treatment measures costing $597,936. The structural measures are estimated to cost $1,124,276 with Public Law 566 bearing $1,074,624 and others $49,652. Of this $49,652 to be supplied from other than Public Law 566, $48,172 represents the easements and rights-of-way cost and $1,480 the cost of administering the contracts. These costs will be primarily the responsibility of the Robert E. Lee Soil and Water Conservation District.

The Robert E. Lee Soil and Water Conservation District will be responsible for operating and maintaining all of the works of improvement. The estimated total annual cost for the maintenance of all structural measures is $6,005.

DESCRIPTION OF THE WATERSHED

Physical Data

General - The Willis River watershed drains an area of 176,700 acres. The acreage is about equally divided between Buckingham and Cumberland Counties, Virginia. The watershed is somewhat wedge shaped, being approximately 32 miles long and having an average width of about 8.5 miles. The Willis River flows in a northernly direction from its headwaters near the Appomattox County line to the James River. The James River flows in an easternly direction to the Chesapeake Bay.

Willis River proper is formed by the convergence of three rather large tributaries near the mid-portion of the watershed. The stream gradient is rather flat as is typical for most streams in the Piedmont section of Virginia. There is a swamp covering nearly 400 acres in the vicinity of the confluence of the three forming tributaries and a large mill pond approximately three miles downstream from the swamp. The mill pond is used as a private recreational area and the swamp is considered to be a wildlife refuge of some value. The lower portion of the main stem flows through the Cumberland State Forest.

Geology - The area drained by the Willis River watershed is underlain by igneous, sedimentary and metamorphic rocks of uncertain age. The generally accepted ages of the majority of the rocks in

Physical Data

this watershed are Pre-Cambrian but differences of opinion exist which date some of the metamorphosed sediments as early Paleozoic in age. The southeastern portion is underlain by Triassic sediments of the Newark group. There are also numerous diabase dikes found cutting the Triassic and older rocks. The ages of the rocks are unimportant where foundations for dams are concerned so it will suffice to say that the Willis River watershed is underlain by old igneous, sedimentary and metamorphic rocks. Some of the rock types present are granite, granodiorite, diorite, diabase, gabbro, hornblende gneiss, schist, phyllite, quartzite, kyanite-quartzite, sandstone, shale and conglomerate. The total number and variety of rock types present cannot be thoroughly covered but the above list should be considered representative of the watershed.

The youngest rocks present as mentioned above are diabase dikes and sills of Triassic age. The intrusions are scattered throughout the watershed with a greater concentration in the south central portion; although these intrusions are relatively unimportant to the watershed as a whole, their importance on an individual damsite could be great.

Willis Mountain located in the lower central part of the watershed is one of the largest mineable deposits of kyanite in the United States. Kyanite is an aluminum silicate used in the manufacture of high temperature ceramics such as spark plug porcelain.

Soils - There are five main soil areas in the Willis River watershed. The character of the soils in four of the areas is determined by the underlying bedrock and the fifth comprises the flood plain and adjacent terraces.

Bottomland and terraces occupy 7 percent of the watershed. Congaree, Chewacla and Wehadkee soils comprise the majority of the flood plain. Terraces adjoining the flood plain are made up of Altavista, Wickham, Turbeville and Masada. These highly productive soils have been developed from old alluvial deposits. Areas not subject to frequent overflow are well suited to the production of corn, small grain, truck crops, grasses and clovers. Runoff is slow on the flood plain where the slope is 0 to 2 percent and medium on the 2 to 12 percent slopes adjacent to the flood plain.

Granitic type rocks underlie about 43 percent of the watershed. This area covers most of the eastern half of the watershed. The major soils of the granitic area are Cecil and Appling, with lesser amounts of Colfax, Worsham, Madison, Wilkes, Enon, Helena and Vance. Slopes range from 2 to more than 25 percent.

Serecite schist soils occupy about 20 percent of the watershed and are found along its entire western edge. The predominant

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Several [illegible] found along [illegible]

soil is deep Tatum associated with Nason and to a lesser degree Manteo. Soils derived from other associated rocks are Lloyd, Orange, Wilkes, Fluvanna, and Iredell. Slopes range from 2 to over 25 percent. Runoff varies from medium on the gentler slopes to rapid on the steep slopes.

Soils underlain by basic rock types occupy about 10 percent of the watershed but are found in scattered relatively small areas. The major soils include Enon, Helena, Iredell and Wilkes. Minor soils are Orange. and Lloyd. Slopes range from 2 to over 25 percent. Runoff is medium on the gentler slopes and rapid on the steep slopes.

The Triassic rocks underlie about 20 percent of the watershed and occur in the southeastern part. The major soils are Mayodan, Creedmoor, and White Store. Minor soils include the Wadesboro, Penn and Granville soils. The slopes are mostly 2 to 15 percent. Runoff is medium on Mayodan, Wadesboro, Granville, Creedmoor and, where protected, White Store and Penn soils. Runoff is rapid on unprotected White Store and Penn soils.

Climate - The average temperatures in the area vary from 37 to 76 degrees with a maximum of 108 and a minimum of -16. The last killing frost in the spring usually occurs about April 17 and the first killing frost in the fall usually occurs about October 21, allowing a growing season averaging 187 days. The average annual rainfall for the area is 42.3 inches.

Land Use and Cover Conditions - The economy of this area is and has always been primarily dependent on agriculture, timber and related industries. Early agricultural and logging practices resulted in excessive erosion, however, changes in techniques have lessened this problem in recent years. Present land use consists of cropland, 15,836 acres; pasture, 18,810 acres; idle land, 3,053 acres; and miscellaneous land, 2,644 acres. There are 136,357 acres of forest land. These forest lands are well suited for the production of timber products and under protection and management improvement of forest hydrologic conditions is expected.

Economic Data

There are an estimated 5,000 people living within the watershed occupying holdings that vary from rural residencies to a 1500 acre farm operation. There are 664 farms in the watershed, 339 being full time operations and 325 part time operations. There are no towns within the boundaries of the watershed other than the typical rural post offices. The area is well served by a number of primary and secondary roads and highways. Foremost among these is U. S. Route 60 which crosses the middle portion of the watershed in an east-west direction.

The flood plain of the watershed contains 7,528 acres and represents all or part of 120 farms and woodland tracts. The present flood plain use is 7 percent cropland, 4 percent improved pasture, 7 percent native pasture, 13 percent idle, 2 percent miscellaneous use and 67 percent woodlands. Most of the cropland is devoted to corn and hay crops as the soil conditions are not the most desirable for small grains. Pasture is the most common use made of the flood plain under present conditions. Much of the land classified as woods, brush and idle is grazed intermittently.

Forests covering 136,357 acres consist of the following: hardwood stands 39 percent, mixed hardwood and softwood stands 39 percent and softwood stands 22 percent. Principal hardwood species include chestnut, white, Northern red, Southern red, black and scarlet oak along with yellow poplar, hickory, red maple, black gum, sweet gum, sycamore, beech, white ash and river birch. Softwood stands consist of Virginia and shortleaf pine with scattered pitch and Eastern white pine with scattered loblolly pine plantings. A small amount of Eastern red cedar is also present.

Approximately 46 percent of the forest land supports stands of sawtimber size, having more than 1500 board feet per acre; 25 percent has pole size timber; and 29 percent has stands of seedlings and saplings.

There is a good demand for quality sawlogs and other forest products at nearby sawmills and concentration yards. Most of the timber area is readily accessible by a network of state and county roads.

Of the forest land, 18,152 acres is in public ownership, including all of the Cumberland State Forest and approximately 2,046 acres of the Buckingham State Forest. The balance of the woodland is in private ownership consisting of small farm holdings and forest industry holdings.

Forest fire protection is provided by the Virginia Division of Forestry through the Clarke-McNary Cooperative Forest Fire Control Program, assisted by local volunteer fire companies. Other going Federal-State cooperative forestry programs include: Cooperative Forest Management (CFM), Cooperative Forestation (C-M4) and Cooperative Forest Insect and Disease Control.

Given protection, care, and management, the forest stands are expected to contribute to the future overall economy of the watershed.

WATERSHED PROBLEMS

Floodwater Damages

This area is subject to damaging floods any season of the year; however, records indicate that nearly 70 percent of the floods

occur during the cropping season. Floods resulting in major losses occurred in 1928, 1935, 1940, 1944 and 1955. The 100-year event inundates an estimated 7,528 acres of flood plain land the majority of which either is or has been in agricultural production. In more recent years the constant flooding has forced the landowners to remove higher income crops from these productive bottom lands. This has resulted in nearly 80 percent of the flood plain presently being classified as woodland and idle providing only periodic poor grazing. Much of this land was once in cultivation as is apparent from the outlines of the fields and drainage measures.

As the farmers are forced to remove their cultivated crops from the flood plain, they clear and plow the uplands for a replacement. This becomes an expensive operation for the farmer. The uplands require heavier fertilizer applications, greater tillage and harvesting cost and more extensive erosion control measures. These factors combined with the fact that the uplands have less inherent fertility and tend to be drouthy, results in considerably less return per acre than from a protected flood plain acre.

The more frequent floods are not small in the area affected. The 2-year event inundates 57 percent of the flood plain and the 10-year event floods 86 percent of the bottom land acreage.

The Willis River flood plain use is uniform throughout with a few exceptions. Reach V contains a swamp area of approximately 300 acres which will be left unchanged to serve as a refuge area for wildlife. Reaches II and III are adjacent to the Cumberland State Forest. As this holding of public land reduces the concentration of farmers in the immediate area, the agricultural use of the adjacent flood plain is somewhat restricted.

Fixed improvements in the flood plain are limited primarily to fences, water gaps, roads and bridges. There are also some old mill dams in the lower reaches of the watershed, which are now used primarily for recreational purposes, that will not be altered in stream channel improvement work. The major portion of damages to fixed improvements stem from roads and bridges. There are 24 different locations where damages occur to portions of the road network, which include one section of U. S. Route 60. Not only are road and bridge foundations and surfaces destroyed but the floodwaters often block highways, disrupting traffic for hours. Some sections of the watershed are completely isolated until the water recedes.

Sediment Damage

The frequent flooding of the main stream deposits fine grained sediment over a large portion of the flood plain and coarser sediments at localized areas. The coarse infertile splays damage agricultural land directly through the loss of production. Natural

levees are formed by the finer sediments causing a lesser amount of damage to productivity. An additional effect is the impairment of natural drainage which constitutes a portion of the swamping damage.

Erosion Damage

There are several factors which, when coupled together, make erosion in the upland portion of the watershed a problem. Among these are the road cuts and fills, the sheet erosion from the idle lands, the practices involved in harvesting timber products and the increasing amount of upland being used for cultivated crops. However, with the continued establishment of more and better conservation practices this problem is being reduced.

Problems Relating to Water Management

There are no major water management problems in the Willis River watershed. Since the area is primarily agricultural with no urban areas there is little need for public water facilities. There may be a need for irrigation water some time in the future but there is no immediate interest in this type of storage. Existing natural facilities are deemed adequate to meet the needs for recreational purposes.

PROJECTS OF OTHER AGENCIES

There are no existing or proposed projects for water resource development within or outside the watershed area which will be in conflict with these proposed works.

BASIS FOR PROJECT FORMULATION

Project formulation considerations were based on the objectives agreed upon with the sponsoring local organizations. Inasmuch as there are two separate and distinct problem areas in the watershed, the project was tailored to meet the needs of these areas. The upper portion of the watershed, primarily that area above U. S. Route 60, and the Hatchers Creek tributary is where most of agriculture is concentrated. This is also the area with the most severe flooding problem. It was mutually agreed that a minimum of three year protection was needed in this area. The lower portion of the watershed, primarily that area below Route 60, has less agricultural development. This lack of agricultural development results from the flood plain being relatively narrow and the public land holdings in the Cumberland State Forest. The flooding does not seem to be a serious problem through most of this area. Based on these facts, the sponsors decided that an attempt to obtain three year protection in this area would be uneconomical and thus should not be sought.

Land treatment measures included in this plan are those which will be effective in reducing erosion damage to existing cropland; reduce runoff and sediment production that would adversely affect the operation, maintenance and the life of proposed structural works of improvement; and will increase the efficiency of land use on existing farm land.

Structural works of improvement were selected to meet the objectives of the sponsors consistent with physical characteristics of the watershed, Service policies and engineering criteria. The maximum utilization of floodwater retarding structures plus necessary channel enlargement and improvements required to meet the project objectives were discussed with and approved by the sponsoring local organizations after alternative systems had been considered and evaluated.

WORKS OF IMPROVEMENT TO BE INSTALLED

Land Treatment Measures

Land treatment measures included in this plan were considered as the basic element in formulating the watershed project. They are necessary and justified for the conservation, development and improvement of agricultural tracts of land, and assurance of the continuing effect of proposed structural works of improvement. These measures will be planned and applied in cooperation with the Robert E. Lee Soil and Water Conservation District. Technical assistance for planning and installation will be provided by the Soil Conservation Service. The Virginia Division of Forestry, in cooperation with the U. S. Forest Service, will provide technical assistance for installing the forestry measures.

Open Land Measures - The following open land measures have been developed by the local people:

Cropland - Conservation cropping systems, stripcropping and the use of cover crops will reduce the amount of sediment being deposited in the stream channels and on the flood plain. The rate of moisture storage will be increased by stripcropping and the proper use of crop residue. Open drains and tile drainage will remove excessive runoff water and seep water from the uplands. The installation of irrigation systems will enable the landowners to more fully utilize their most desirable croplands.

Grassland - The reduction of sediment and erosion on the grasslands will be accomplished by planting and renovating pastures and haylands, practicing rotational grazing, proper use of pastures and installing diversion and grassed waterways. Water troughs and tanks will be installed to provide greater latitude in the use of pastures and thereby reduce over grazing.

Miscellaneous Land - Farm ponds, spring developments and wildlife habitat improvement practices will be applied to portions of the miscellaneous land. Also critical areas, mainly on road banks, will be treated to reduce sediment production. The net results will be improved cover conditions, increased soil infiltration and reduced runoff and erosion.

Forest Land Measures - The following program for private forest land has been developed by the local people from a statement of land treatment needs prepared by the Virginia Division of Forestry in cooperation with the U. S. Forest Service:

A. Tree Planting (2,000 acres) - Reforestation of appropriate open land is necessary to adjust land use with capability and to reduce runoff and erosion by developing a protective cover and an absorbent forest floor "sponge" of humus and litter.

B. Hydrologic Cultural Operations (4,000 acres) - These cultural operations are aimed at improving hydrologic conditions by manipulation of stand composition to create favorable conditions for the maximum production and protection of litter, humus and forest cover. They include weedings, thinnings, improvement, release and harvest cuttings.

C. Woodland Grazing Control (2,400 acres) - The fencing out of domestic livestock prevents impairment of hydrologic conditions in woodlands by reducing soil compaction, damage to tree roots, seedlings and other ground cover and the loss of litter and humus.

D. Skid Trail and Logging Road Erosion Control (1,000 acres)- This measure will reduce runoff, erosion and sedimentation by diverting water from the eroding skid trails and logging roads. Simple water bars (ditches with pole or earthen diversions) spaced at specified intervals are the usual means used to allow or divert water.

Contributing to the overall effect of treatment on the watershed will be the works of improvement carried on the state forest lands by the Virginia Division of Forestry. One thousand five hundred acres will be treated by various measures and combination of measures listed above during the installation period of the project.

Structural Measures

The structural measures will consist of 11 floodwater retarding dams and 14.91 miles of stream channel improvements. The dams will be constructed of compacted earth. The principal spillways will consist of a conduit of reinforced concrete and all will have two stage drop inlets. The sediment storage capacity for the dams will be the equivalent to the estimated sediment accumulation for a 100-year period and will total 2,457 acre-feet.

The total floodwater detention capacity will be 11,367 acre-feet which is the equivalent to an average of 2.94 inches of runoff from the total area above dams. The total area above all dams is 46,451 acres which comprises 26 percent of the entire watershed. The estimated installation cost of the dams is $975,339. The construction of the dams will not require the relocation of any existing facilities.

There will be 14.91 miles of stream channel improvement on the tributaries and main stem of the Willis River. This will consist of 14.27 miles of deepening and widening and 0.64 miles of brushing and snagging. The total installation cost for the channel improvement is estimated to be $148,937.

The combination of dams and channel improvements will provide the desired 3-year level of protection in the 15 reaches designated by the sponsors. In fact 11 of these reaches will receive 5-year protection. The 6 reaches which will not receive the 3-year level of protection are reach V and VI which are wholely or partly in a swamp area and reaches I through IV which are furtherest down stream on the main stem. It was mutually agreed early in the planning stage that 3-year protection in reaches I through IV was economically impractical because of land use, ownership and required construction cost.

EXPLANATION OF INSTALLATION COSTS

Land Treatment Costs

Details of the installation costs for land treatment measures are shown in Table 1. The total installation cost for the Soil Conservation Service land treatment measures is $621,060. Of this total P.L. 566 costs are $188,743 and the costs for other funds $432,317. The P.L. 566 funds represent the cost of technical assistance and materials for the roadside erosion control. The other funds represent the actual cost of installing the land treatment measures.

The total cost of installation of forest land treatment measures is $174,400. Total P.L. 566 costs are $26,200 all of which is for technical assistance. Total funds other than P.L. 566 are $148,200, which include $50,800 in State funds ($26,200 matching funds for technical assistance to private landowners, $22,600 for installation measures on State forest land and $2,000 for tree seedlings furnished private forest landowners) and $97,400 for installation cost to private forest landowners. It is expected that Agricultural Conservation Program (ACP), cost sharing will be available to qualified landowners for forest land treatment measures.

The costs described above are in addition to $597,936 which the landowners have expended to establish land treatment measures prior to the preparation of this plan.

Costs for the installation of land treatment measures are based on current costs of supervision, labor, equipment and materials needed for each measure. Estimated costs of technical assistance are based on actual expenditures and accomplishments. An analysis of cost against accomplishments was made for each measure to determine unit costs.

Structural Measures

The detail break-down for the installation costs of the structural measures are shown in Table 2. The P.L. 566 costs are broken down into three major components: construction costs, engineering costs, and other costs. The construction cost is made up of the engineer's estimate and is based upon unit cost of major construction items using unit prices taken from recent contracts for similar structures in nearby areas. An additional 12 percent of the engineer's estimate was added for a contingency factor to cover any unforeseen difficulties and expenses that might occur later. The engineering services are roughly 20 percent of the construction cost and include the estimated cost of final surveys, site investigations, design and supervision of construction. The other costs include administrative and miscellaneous costs and are nearly 8 percent of the construction costs. The estimates are computed on the basis of the experienced relationship to the estimated construction cost.

The remainder of the costs in Table 2 will be provided by the sponsors. They include the cost of administering the contracts and providing land, easements, and rights-of-way for the installation of the structural measures.

Rights-of-way cost estimates were obtained by an easement committee of the sponsors. The land values vary from $50 to $150 per acre for the pool area, borrow, structure and emergency spillway areas depending on location and present and anticipated use of the land. Construction of structural measures will not require the relocation of any existing facilities.

The cost estimates for administration of contracts were based on the most recent costs experienced by local organizations in similar watersheds.

Total installation costs of all structural measures are estimated to be $1,124,276. Of these costs $1,074,624 will be borne by P.L. 566 funds and the balance of $49,652 from other funds. Tables 1 and 2 summarize all installation costs.

Fund Schedule (By Fiscal Years)- The sponsors have agreed upon a five year installation period. The installation costs by years are as follows:

Year	P.L. 566 Funds Structural Measures	P.L. 566 Funds Land Treatment Measures	Other Funds Structural Measures	Other Funds Land Treatment Measures	Total
1st	144,214	42,989	31,714	116,104	335,021
2nd	284,754	42,989	385	116,104	444,232
3rd	204,310	42,989	11,123	116,103	374,525
4th	228,316	42,988	6,175	116,103	393,582
5th	213,030	42,988	255	116,103	372,376
Total	1,074,624	214,943	49,652	580,517	1,919,736

EFFECTS OF WORKS OF IMPROVEMENT

Reduction of Floodwater Damages

The installation of this project will permit the farmers to more fully and more efficiently use 7,528 acres of flood plain bottomlands. This will result in a higher farm productivity level and an increased overall cash return.

The primary objective of this project is to provide 3-year protection to 2,723 acres of flood plain bottomland generally above U. S. Route 60 and the Hatchers Creek tributary. The 3-year event in these areas inundates 1,627 acres without the project. After the project is installed, only 56 acres will be inundated by the 3-year storm. These 56 acres are located in reach VI and adjacent to swamp located in reach V.

The frequency of flooding will be reduced significantly over the entire watershed. With the project installed the acres flooded by the 100-year event will be reduced by 1,511 acres; the 10-year event by 2,092 acres; the 5-year event by 2,039 acres; the 3-year event by 2,142 acres; and the 2-year event by 2,435 acres. Six of the 21 reaches in the watershed will receive protection from the 10-year event. Of the 21 reaches in the watershed, 15 will receive complete protection from the 3-year event.

Reaches I, II, III and IV are located along the lower portion of the main stem of Willis River. Much of the flood plain in these reaches is either in or immediately adjacent to the Cumberland State Forest, with only scattered agricultural development. In addition, the flood plain in the upper portion of reach IV, which is beyond the boundary of the State Forest, is controlled by a private sportsmans club. Because of the ownership and land use, the sponsors felt that it would be economically infeasible to provide 3-year protection in these reaches.

The major portion of the flood plain in reach V is a swamp area. Technicians from the U. S. Fish and Wildlife Service investigated this swamp and found it to be a natural refuge for wildlife. On the strength of their findings and recommendations the sponsors agreed not to make channel improvements in this area.

Reduction of Sediment

The land treatment measures will reduce the rate of erosion on the uplands and thereby reduce the sediment contribution in the flood plain area. The trap efficiency of the dams will also reduce the sediment contribution. The combined effects of the land treatment, dams and channel improvements will reduce the area subject to sediment damage. Overall, sediment damages will be reduced 67 percent.

Reduction of Erosion

The damage resulting from erosion will be lessened by reducing the stages and velocities for any given storm. This will be reflected in reduced flood plain scour. Also the land treatment measures will reduce the erosion on the uplands. The project will reduce erosion damages by 43 percent.

When this project is installed some 120 landowners will receive direct identifiable benefits while many others in the area will enjoy the benefits of fewer traffic interruptions, less turbid stream flow, a more pleasant appearing countryside and overall increased economic vigor.

PROJECT BENEFITS

Monetary Benefits

The combined land treatment and structural measures will reduce average annual damages within the watershed 88.2 percent. The average annual value of this reduction is $35,023, of which $1,051 is attributed to land treatment measures and $33,972 to structural measures.

The floodwater damage reduction benefits to crops and pasture total $26,500 of which $23,591 is the result of restoration of former productivity level and is included under crop and pasture damage in Table 5.

Other agricultural benefits total $585 and result from the reduction of damages to fences, water gaps, fords and other fixed agricultural improvements. The benefits to roads and bridges are estimated to be $5,043. The benefits from reduced sediment and erosion damages total $1,398.

Indirect benefits amount to $1,497. These benefits result from the reduction of indirect damages stemming from interrupted services and feed deliveries, delayed marketing, increased expense of detouring traffic and other such losses which do not readily lend themselves to detail monetary evaluation.

The installation of the project will make it possible for the landowners to use the flood plain more intensively. The flood protection will make it practical for the farmers to use higher quality seed varieties, larger quantities of and higher analysis fertilizers. It will also give to the farmers more freedom in selecting the proper soil and slope conditions for the various crops. The annual benefit from this more intensive use is estimated to be $10,343.

Local secondary benefits stemming from the project are such items as increased use of transportation, processing and marketing goods and services that produce the primary project benefits. These benefits are considered to be 10 percent of the direct primary project benefits and total $4,392. Local secondary benefits induced by the project are considered to be 10 percent of the increased cost that primary producers will incur in connection with increased production and total $4,695 annually. The secondary benefits from a National viewpoint were not considered pertinent to the economic evaluation.

Benefits Not Measured in Monetary Terms

The reduced margin of profit on agricultural products and repeated flood damages have greatly reduced the agricultural income in the Willis River watershed, and in turn the economic welfare of the entire general area has suffered. In fact, both Buckingham and Cumberland Counties have an underemployment problem and Cumberland County has been so designated under the Area Redevelopment Act of 1961. Even though this project will stimulate agricultural and other related businesses creating a fuller employment and a growing economy, no redevelopment benefits are claimed in the plan.

COMPARISON OF BENEFITS AND COSTS

The average annual cost of the structural measures which includes the installation cost amortized over 100 years plus the annual maintenance is estimated to be $42,836. The average annual benefits from the planned structural measures not including local secondary benefits are estimated to be $44,315, giving a benefit cost ratio of 1.0 to 1.0. The inclusion of local secondary benefits increases the estimated average annual benefits $53,402 and the benefit cost ratio to 1.2 to 1.0.

PROJECT INSTALLATION

An installation period of 5 years has been established for the Willis River watershed. The sequence of installation is as follows:

YEAR	DAMS	CHANNEL IMPROVEMENTS
1st year	7 & 9	IIIA
2nd year	1A, 1B, & 2	VIII & IX
3rd year	3 & 4	VI & VII
4th year	6 & 6A	XI & XIII
5th year	5E & 5F	VA

While this order of construction is presently desired, it may be altered by the sponsors within other limits of the plan.

The structural measures are grouped into 5 construction units. The dams and channel improvements within each unit are interrelated measures producing benefits common to the group. The absence of any one structural measure in a unit will reduce the protection below the desired level. All five of the construction units are independent units.

The units are as follows:

CONSTRUCTION UNIT	DAMS	CHANNEL IMPROVEMENTS
1	1A,1B,2,3, & 4	VI, VII, VIII, & IX
2	5E & 5F	VA
3	6 & 6A	XI & XIII
4	7	IIIA
5	9	

All of the land, easements and rights-of-way must be assured for an entire construction unit before Federal financial assistance is made available for any part of that unit.

The Robert E. Lee Soil and Water Conservation District, the Buckingham County Board of Supervisors and the Cumberland County Board of Supervisors (the local sponsoring organizations) will be responsible for the successful application of the plan. The District will assume the responsibility for negotiating all contracts. The District will also be responsible for obtaining the land, easements and rights-of-way necessary for the installation of the works of improvement.

The Soil Conservation Service will furnish technical services for farm planning and application, and the portion of the construction cost of the structural measures allocated to flood prevention. The Service will also furnish design, layout and installation services for all structural measures.

The Robert E. Lee Soil and Water Conservation District with the assistance of Soil Conservation Service technicians will assist cooperating landowners and operators in the preparation and application of farm conservation plans. At least 50 percent of all

farm land above each of the dams will be under cooperative agreement with concerned districts when construction of the dams is initiated.

The Robert E. Lee Soil and Water Conservation District will be responsible for operation and maintenance of all works of improvement.

The Agricultural Stabilization and Conservation Service County Committees of the involved counties will assist in accelerating the completion of the planned land treatment measures through the Agricultural Conservation Program. This assistance will be in the form of approval of requests for ACP cost-sharing for land treatment practices to be carried out on farms within the watershed. Assistance will of necessity be limited by the amount of funds available under the ACP. The amount of assistance furnished will also be influenced by the needs and desires of the landowners.

The forest land treatment measures will be installed by the landowners with technical assistance furnished by the Virginia Division of Forestry, in cooperation with the U. S. Forest Service.

The Virginia Commission of Game and Inland Fisheries will furnish assistance and planting materials for the development and improvement of wildlife food and cover. The Commission will also furnish guidance in wildlife management.

The Virginia Department of Highways will install roadside erosion control measures (critical area planting) with the assistance of the Soil Conservation Service.

The Soil and Water Conservation District, the Soil Conservation Service, the Virginia Division of Forestry and the County ASCS Committees will annually develop plans for a joint effort to accelerate completion of the land treatment measures needed in the watershed. The County ASCS Committees will contribute to these plans by taking into consideration the needs for the watershed in approving ACP cost-sharing by setting up an annual reserve of funds for this purpose.

To stimulate interest in watershed activities the Agricultural Extension Service will assist the soil and water conservation district in developing and carrying out an information and education program.

Federal assistance for carrying out the works of improvement as described in this work plan will be provided under the authority of the Watershed Protection and Flood Prevention Act (Public Law 566, 83rd Congress, 68 Stat. 666) as amended.

FINANCING PROJECT INSTALLATION

The installation costs of the land treatment measures, other than roadside erosion control measures, will be the responsibility of the local landowners. Advantage will be taken of cost-sharing under the Agricultural Conservation Program and other available programs insofar as possible.

The installation costs of roadside erosion control measures will be the responsibility of the sponsors. However, through a secondary agreement with the sponsors, the Virginia Department of Highways will perform the installation. They will do the necessary grading, seeding and mulching (estimated cost $30,500).

There will be $188,743 available from P.L. 566 funds for technical assistance for land treatment measures on open land. An estimated $20,460 will be provided from P.L. 566 funds for materials for the roadside erosion control. The furnishing of these funds will be contingent upon satisfactory accomplishment of this work by the Highway Department. The cost of technical assistance for the forest land treatment measures is estimated to be $52,400. This cost will be shared equally by State and Federal Governments.

The Robert E. Lee Soil and Water Conservation District will assume the responsibility for negotiating all contracts at an estimated cost of $1,480. Fifty percent of the cash costs of the same will be borne by the Virginia Soil and Water Conservation Commission and the remainder by donations and funds presently on hand. The District will also have the responsibility of obtaining all easements necessary for completion of the project without cost to the Federal Government. The estimated value of the lands, easements, and rights-of-way necessary to complete this project is $48,172. This cost will be met by donations and funds presently on hand.

The total installation cost of all structural measures in this project will be $1,124,276 of which P.L. 566 will bear $1,074,624.

This work plan does not constitute a financial document to serve as a basis for the obligation of Federal funds, and financial and other assistance to be furnished by the Soil Conservation Service in carrying out the watershed work plan is contingent on the appropriations of funds for this purpose.

PROVISIONS FOR OPERATION AND MAINTENANCE

The Robert E. Lee Soil and Water Conservation District will assume the responsibility for operation and maintenance of structural works of improvement. The total annual cost for these measures is estimated to be $6,005. The maintenance responsibilities

of the District will be implemented by maintenance agreements with the landowners. In the event of default by the landowners, the Virginia Soil and Water Conservation Commission of the Commonwealth of Virginia will assist the District within the policy of the following resolution:

> "Be it resolved by the Virginia Soil and Water Conservation Commission that it is the policy of this State Agency to do everything within its legal power and financial ability to see that watershed projects developed under the authority of Public Law 566, as amended, and Public Law 534, as amended, are maintained by the local soil and water conservation districts. Under appropriate conditions the Commission will assist in the maintenance of said projects, should it be demonstrated that the local district is unable to maintain such works of improvement. It is understood that the powers, duties, and appropriations of the Virginia Soil and Water Conservation Commission are subject to being changed by the General Assembly of Virginia."
>
> Authority for this policy is contained in SOIL AND WATER CONSERVATION DISTRICTS LAW, Title 21, Chapter 1, Sec. 21-10. "Duties in General. In addition to the duties and powers hereinafter conferred upon the Virginia Soil and Water Conservation Commission, it shall have the following duties and powers: (Item 1) To offer as a gift or loan such financial and other assistance as may be appropriate to the Supervisors of Soil and Water Conservation Districts, organized as provided hereinafter, in the carrying out of any of their powers and programs."

The maintenance of the dams will consist mainly of fertilizing, liming and mowing the fills and spillways, seeding and mulching bare areas, painting the trash racks, and repairing gullies that might occur. Maintenance of the channel improvement will consist of controlling the vegetative growth in the channel and on the channel banks and removing any debris, bars or other obstructions which impair the functioning of the channel.

The structural measures will be inspected at least annually and after each major storm by representatives of the sponsors and the Soil Conservation Service to see that they are properly maintained. All maintenance agreements will be properly completed before the execution of project agreements.

of the [illegible]
the Commonwealth [illegible]
Virginia Soil and Water Conservation [illegible] Commonwealth
of Virginia [illegible] the [illegible]
following [illegible]

[illegible] particular [illegible] 570 [illegible] amendment [illegible] conservation districts [illegible] to make [illegible]

Authority [illegible] in SOIL CON[illegible] 21, Chap[illegible] In addi[illegible] conferred [illegible] Supervisors [illegible] Conservation [illegible]

The [illegible]

[illegible]

The roadside erosion control measures will be maintained by the Virginia Department of Highways through a memorandum of understanding between the Soil and Water Conservation Districts and the Virginia Department of Highways.

The forest land treatment measures will be operated and maintained by the landowners with technical assistance furnished by the Virginia Division of Forestry in cooperation with the U. S. Forest Service through the cooperative Forest Management Program.

All other land treatment measures will be maintained by the local landowners under cooperative soil and water conservation agreements with the Soil and Water Conservation District.

TABLE 1 - ESTIMATED PROJECT INSTALLATION COST

Willis River Watershed, Virginia

Installation Cost Item	Unit	No. to be Applied	Estimated Cost (Dollars) 1/ Non-Federal Land P.L. 566	Other	TOTAL
Land Treatment					
Soil Conservation Service					
Cropland	ac.	14,852		103,608	103,608
Grassland	ac.	20,397		256,730	256,730
Miscellaneous Land	ac.	2,644		11,259	11,259
Critical Area Planting	ac.	160	20,460	30,500	50,960
Technical Assistance					
Planning and Application			113,775	26,460	140,235
Soil Surveys			54,508	3,760	58,268
SCS Subtotal			188,743	432,317	621,060
Forest Service					
Forest Land	ac.	10,900		122,000	122,000
Technical Assistance			26,200	26,200	52,400
FS Subtotal			26,200	148,200	174,400
TOTAL LAND TREATMENT			214,943	580,517	795,460
STRUCTURAL MEASURES					
Soil Conservation Service					
Floodwater Retarding Struc.	no.	11	723,718		723,718
Stream Channel Improvement	mi.	14.91	115,296		115,296
SCS Subtotal			839,014		839,014
Subtotal Construction			839,014		839,014
Installation Services					
Soil Conservation Service					
Engineering Services			169,804		169,804
Other			65,806		65,806
SCS Subtotal			235,610		235,610
Subtotal - Installation Services			235,610		235,610

TABLE 1 - ESTIMATED PROJECT INSTALLATION COST Continued

Willis River Watershed, Virginia

Installation Cost Item	Unit	No. to be Applied	Estimated Cost (Dollars) 1/ Non-Federal P.L. 566	Land Other	TOTAL
Other Costs					
Land, Easements & R/W				48,172	48,172
Administration of Contracts				1,480	1,480
Subtotal - Other				49,652	49,652
TOTAL STRUCTURAL MEASURES			1,074,624	49,652	1,124,276
TOTAL PROJECT			1,289,567	630,169	1,919,736
SUMMARY					
Subtotal SCS			1,263,367	481,969	1,745,336
Subtotal FS			26,200	148,200	174,400
TOTAL PROJECT			1,289,567	630,169	1,919,736

1/ Price Base: Current

Date August 1964

TABLE 1A - STATUS OF WATERSHED WORKS OF IMPROVEMENT
(at time of Work Plan Preparation)

Willis River Watershed, Virginia

Measures	Unit	Applied to date	Total Cost (Dollars)1/
LAND TREATMENT			
Soil Conservation Service			
Conservation Cropping System	acres	9,000	90,000
Contour Farming	acres	2,200	26,400
Cover & Green Manure Crops	acres	600	6,000
Critical Area Planting	acres	6	1,200
Crop Residue Use	acres	300	300
Drainage Mains or Laterals	ft.	10,000	3,000
Farm Ponds	no.	100	25,000
Grasses & Legumes in Rotation	acres	4,000	40,000
Grassed Waterways	acres	85	17,000
Irrigation System, Sprinkler	no.	1	4,979
Irrigation Water Management	acres	40	200
Land Clearing	acres	1,000	50,000
Pasture and Hayland Planting	acres	4,500	270,000
Pasture, Proper Use	acres	1,150	1,150
Pipeline for Livestock Water	ft.	20,000	2,000
Spring Development	no.	5	500
Stripcropping, Contour	acres	300	3,189
Stripcropping, Field	acres	600	6,000
Tile Drains	ft.	2,500	1,125
Trough or Tank	no.	10	640
Wildlife Habitat Development	acres	50	3,750
Subtotal SCS			552,433
Forest Service			
Tree Planting	acres	3,000	38,356
Hydrologic Cultural Operations	acres	1,280	7,147
Subtotal FS			45,503
TOTAL	XXX	XXX	597,936

1/ Price Base: Current

Date August 1964

TABLE 2 - ESTIMATED STRUCTURAL COST DISTRIBUTION
Willis River Watershed, Virginia
(Dollars) 1/

Structure Site No.	Installation Cost - P.L. 566 Funds				Installation Cost-Other Funds			Total Installation Cost
		Installation Services						
	Construction	Engineering	Other	Total P.L.566	Adm. of Contracts	Easements & R/W	Total Other	
Dam 1A	57,773	12,478	4,718	74,969	100	6,410	6,510	81,479
Dam 1B	53,827	11,628	4,395	69,850	100	2,600	2,700	72,550
Dam 2	89,298	19,288	7,291	115,877	125	4,240	4,365	120,242
Dam 3	55,628	12,016	4,542	72,186	100	3,305	3,405	75,591
Dam 4	54,347	11,738	4,437	70,522	100	3,620	3,720	74,242
Dam 5E	85,038	18,669	6,941	110,648	125	2,985	3,110	113,758
Dam 5F	63,623	13,742	5,195	82,560	100	2,570	2,670	85,230
Dam 6	119,021	15,828	8,251	143,100	150	7,865	8,015	151,115
Dam 6A	38,492	8,314	3,143	49,949	100	2,260	2,360	52,309
Dam 7	72,139	15,582	5,890	93,611	100	8,385	8,485	102,096
Dam 9	34,532	7,460	2,820	44,812	100	1,815	1,915	46,727
Channel Imp. IIIA	4,477	896	318	5,691	20	75	95	5,786
Channel Imp. VA	15,595	3,120	1,107	19,822	30	300	330	20,152
Channel Imp. VI	23,690	4,738	1,682	30,110	50	398	448	30,558
Channel Imp. VII	24,780	4,956	1,756	31,492	50	340	390	31,882
Channel Imp. VIII	17,192	3,439	1,221	21,852	40	273	313	22,165
Channel Imp. IX	1,814	363	129	2,306	20	33	53	2,359
Channel Imp. XI	24,110	4,821	1,711	30,642	50	515	565	31,207
Channel Imp. XIII	3,638	728	259	4,625	20	183	203	4,828
GRAND TOTAL	839,014	169,804	65,806	1,074,624	1,480	48,172	49,652	1,124,276

1/ Price Base: Current

Date August 1964

TABLE 3 - STRUCTURE DATA

FLOODWATER RETARDING STRUCTURES

Willis River Watershed, Virginia

ITEM	UNIT	STRUCTURE NUMBER 1A	1B	2	3	4	5E	5F	6	6A	7	9	Total
Drainnge Area	sq.mi.	9.77	4.62	9.31	3.86	4.42	6.35	5.16	12.45	2.98	11.00	2.66	72.58
Storage Capneity													
Sed. in Sed. Pool	ae.ft.	169	96	238	91	82	94	61	190	76	104	44	1245
Sed. above Perm. Pool	ae.ft.	164	93	232	89	80	91	60	185	74	101	43	1212
Total Sediment	ae.ft.	333	189	470	180	162	185	121	375	150	205	87	2457
Floodwater	ne.ft.	1667	691	1440	515	590	812	688	2470	508	1584	382	11347
Total	ac.ft.	2000	880	1910	695	752	997	809	2845	658	1789	469	13804
Between high and low stages	ae.ft.	521	247	497	205	236	338	275	824	159	587	142	4031
Surfaee Area													
Sediment Pool	ac.	38	16	36	15	15	19	12	39	18	36	10	254.0
Floodwater Pool	ae.	156	65	124	60	57	69	63	199	63	170	46	1072
Volume of Fill	eu.yds.	28,001	25,436	82,954	34,890	40,929	92,577	54,548	101,366	26,642	26,859	20,606	524,808
Elevation Top of Dam	ft.	475.9	470.0	406.8	400.8	354.5	426.2	380.0	361.2	484.5	335.7	355.4	xxxx
Maximum Height of Dam	ft.	33.4	37.0	39.8	36.8	38.5	37.7	36.5	43.2	28.5	29.7	29.9	xxxx
Emergeney Spillway													
Crest Elevation	ft.	471.3	465.5	402.0	396.3	349.7	420.6	375.6	353.9	478.7	331.1	352.4	xxxx
Bottom Width	ft.	200	30	200	150	150	150	150	250	100	200	100	xxxx
Type		Veg.	Quartzite	Veg.	Veg.	Veg.	Veg.	Veg.	Veg.	Veg.	Veg.	Veg.	
Pereent Chance of Use		2	2	2	2	2	2	2	2	2	2	2	xxxx
Ave. Curve No. - Cond. II		67	67	65	67	65	65	63.5	67.5	67.5	65	65	
Emergeney spillway hydrograph													
Storm Rainfall (6-Hr.)	in.	7.4	5.95	7.40	7.40	7.40	7.40	7.40	9.70	10.80	7.30	6.54	xxxx
Storm Runoff	in.	3.64	2.50	3.41	3.64	3.41	3.41	3.25	5.64	6.60	3.33	2.75	xxxx
Velocity of Flow (V_c) 1/	ft/sec.	2.75	-	3.41	5.14	4.83	6.30	4.35	6.5	6.8	2.90	-	xxxx
Discharge Rate 1/	e.f.s.	130	-	250	630	530	1155	380	3280	1345	165	-	xxxx
Max. w.s. elev. 1/	ft.	471.8	463.6	402.7	397.9	351.4	422.8	376.7	355.7	481.6	331.5	351.7	xxxx
Freeboard Hydrograph													
Storm Rainfall (6-Hr.)	in.	11.90	8.95	11.90	11.90	12.26	11.90	11.90	15.80	17.60	11.80	10.30	xxxx
Storm Runoff	in.	7.53	4.93	7.23	7.53	7.53	7.23	7.00	11.20	12.86	7.14	5.82	xxxx
Velocity of Flow (V_c) 1/	ft/sec.	9.35	9.40	9.75	9.40	9.60	10.50	9.25	10.4	10.2	9.50	7.5	xxxx
Discharge Rate 1/	c.f.s.	5105	775	5800	3925	4175	5400	3750	13600	4085	5290	1320	xxxx
Max. w.s. elev. 1/	ft.	475.9	470.0	406.8	400.8	354.5	426.2	380.0	361.2	484.5	335.7	355.4	xxxx
Principal Spillwny													
Capaeity - low stage	c.f.s.	98	46	93	51	44	85	52	166	40	110	35	xxxx
Capaeity - High stage	c.f.s.	178	118	185	118	117	182	118	360	62	244	61	xxxx
Capneity Equivnlents													
Sediment volume	in.	.64	.77	.95	.87	.69	.55	.44	.56	.94	.35	.61	xxxx
Detention volume	in.	3.20	2.80	2.90	2.50	2.50	2.40	2.50	3.00 2/	3.20	2.70	2.70	xxxx
Spillwny storage	in.	1.59	1.29	1.30	1.42	1.35	1.28	1.15	2.74	2.73	1.48	1.03	xxxx
Class of Structure		a	a	a	a	a	a	a	b	b	a	a	xxxx

1/ Max. during passage of hydrograph.

2/ Storage based on drainage area 15.43 sq.mi.

Date August 1964

TABLE 3A - STRUCTURE DATA
CHANNELS
Willis River Watershed, Virginia

Channel Name		Station	D. A. (sq.mi.)	Req'd. Cap. (cfs)	Manning's "N" Value Present	Manning's "N" Value Design	Bottom Width (ft.)	Side Slopes	Hydraulic Gradient (ft/ft.)	Water Surface Elev. (m.s.l.)	Design Depth (ft.)	Velocity at Design Depth (fps) Chan. Seg.	Velocity at Design Depth (fps) O.B. Seg.	Flow Area at Design Depth (sq.ft.) Channel Seg.	Flow Area at Design Depth (sq.ft.) O.B. Seg.	Cap. at Design Depth (cfs)	Volume of Earth Excav. 1000 c.y.	Stability Check As-Constructed Conditions Flow (cfs)	Stability Check As-Constructed Conditions Vel. (fps)
Main Stem																			
		320+00	Upper limit of channel work							364.3									
		335+88	21.80	345	.068	.04	B&S		.00142	362.0		3.0		116.0		348		348	3.0
		349+41	21.90	349	.068	.04	13	1½:1	.00175	359.6	5	3.4		102.5		349	.65	349	3.4
	2/	357+12	22.00	354	.068	.04	14	1½:1	.00175	358.2	5	3.4		107.5		365	.64	365	3.4
		361+37	31.60	405	.068	.04	16	1½:1	.00175	357.5	5	3.5		117.5		411	.43	411	3.5
		370+57	32.00	438	.071	.04	18	1½:1	.00175	355.9	5	3.5		127.5		446	1.57	446	3.5
		387+35	33.60	480	.071	.04	19	1½:1	.00175	353.0	5	3.6		132.5		477	3.51	477	3.6
		410+36	34.20	515	.071	.04	17	1½:1	.00125	350.1	6	3.3		156.0		515	12.29	515	3.3
	1/ 2/	442+27	35.10	543	.071	.04	18	1½:1	.00175	346.1	6	3.3		162.0		535	11.33	535	3.3
		475+09	39.80	585	.064	.04	20	1½:1	.00125	342.0	6	3.4		174.0		591	7.65	591	3.4
	1/	510+69	40.80	625	.064	.04	21	1½:1	.00125	337.5	6	3.4		180.0		612	10.10	612	3.4
	1/	511+69	40.80	625	.064	.04	25	3/4:1	.00125	337.4	6	3.5		177.0		620	.43	620	3.5
	1/	553+44	41.00	635	.062	.04	22	1½:1	.00125	332.2	6	3.4		186.0		632	21.79	632	3.4
		746+38	Upper limit of channel work							298.0									
		776+98	50.20	755	.071	.04	21	1½:1	.00183	292.5	6	4.2		180.1		756	12.18	756	4.2
		807+56	50.70	762	.062	.04	34	1½:1	.00114	289.0	5.3	3.1	2.4	219.0	35.0	679	15.88	679	3.1
		847+00	51.20	Blend back into swamp													9.76		
Little Willis R.																			
		220+00	Upper limit of channel work							392.1									
		229+10	6.70	161	.062	.04	4	1½:1	.00450	388.0	4	4.1		40.0		164	.08	164	4.1
		244+20	6.85	167	.062	.04	6	1½:1	.00344	382.8	4	3.8		48.0		182	.35	182	3.8
		265+50	Upper limit of channel work							376.3									
		291+00	9.11	254	.069	.04	5.5	1½:1	.00300	368.6	5	3.9		65.0		254	1.41	254	3.9
		307+60	9.50	272	.069	.04	6	1½:1	.00300	363.6	5	4.0		67.5		270	1.16	270	4.0
		495+70	Upper limit of channel work							306.0									
		521+80	17.60	205	.065	.04	10	1½:1	.00095	303.5	5	2.4		87.5		210	2.37	210	2.4
		546+80	23.00	350	.100	.04	17	1½:1	.00195	298.6	5	3.6		97.5		351	7.13	351	3.6
		580+70	23.80	370	.065	.04	13	1½:1	.00195	292.0	5	3.6		102.5		369	10.02	369	3.6
		630+40	24.60	396	.068	.04	18	1½:1	.00131	285.5	5	3.1		127.5		395	12.21	395	3.1
		650+90	24.70	398	.068	.04	28	1½:1	.00063	284.2	5	2.3		177.5		408	4.21	408	2.3
Whispering Creek																			
		388+00	Upper limit of channel work							302.0									
		422+50	24.23	465	.074	.04	18	1½:1	.00190	295.5	5	3.7		127.5		472	7.54	472	3.7
		448+50	24.80	483	.100	.04	19	1½:1	.00190	290.5	5	3.7		132.5		490	12.47	490	3.7
	2/	458+50	24.80	483	.100	.04	22	1½:1	.00300	287.5	4	4.3		112.0		482	4.00	482	4.3
Hatcher Creek																			
		243+00	Upper limit of channel work							246.5									
		247+85	17.50	285	.069	.04	B&S		.00309	245.0		4.4		99.0		435		435	4.4
		261+15	17.85	310	.069	.04	B&S		.00188	242.5		3.6		110.0		396		396	3.6
	1/	275+65	18.10	330	.069	.04	9	1½:1	.00262	238.7	5	3.9		82.5		322	1.37	322	3.9
	1/	305+00	18.53	347	.065	.04	10	1½:1	.00262	231.0	5	4.0		87.5		350	4.19	350	4.0

1/ Hydraulic gradient is below bank full sufficiently to allow additional capacity so that there is no out of bank flow for the design storm.
2/ Next upstream cross section transposed to this point.
Note: All channel design is based on the 12-hour, 3-year frequency flow.

Date August 1964

TABLE 4 - ANNUAL COST

Willis River Watershed, Virginia

(Dollars) 1/

Evaluation Unit	Amortization of Installation Cost 2/	Operation and Maintenance Cost	Total
All Dams & Channel Improvement	36,831	6,005	42,836
TOTAL	36,831	6,005	42,836

1/ Price Base: Installation Cost - Current; Operation and Maintenance Cost - Long-term projected based on Agricultural Price and Cost Projections, September 1957.

2/ Installation cost was amortized for 100 years at 3-1/8 percent interest.

Date August 1964

TABLE 5 - ESTIMATED AVERAGE ANNUAL FLOOD DAMAGE REDUCTION BENEFITS

Willis River Watershed, Virginia

(Dollars) 1/

Item	Estimated Average Annual Damage: Without Project	With Project	Damage Reduction Benefit
Floodwater			
Crop and Pasture	28,107	1,607	26,500
Other Agricultural	905	320	585
Nonagricultural			
Roads and Bridges	6,291	1,248	5,043
Subtotal	35,303	3,175	32,128
Sediment			
Overbank deposition	1,615	540	1,075
Subtotal	1,615	540	1,075
Erosion			
Flood Plain Scour	756	433	323
Subtotal	756	433	323
Indirect	2,038	541	1,497
Total	39,712	4,689	35,023

1/ Price Base: Long-term projected based on Agricultural Price and Cost Projections, September 1957.

Date August 1964

TABLE 6 - COMPARISON OF BENEFITS AND COSTS FOR STRUCTURAL MEASURES

Willis River Watershed, Virginia

(Dollars) 1/

Evaluation Unit	AVERAGE ANNUAL BENEFITS				Avg. Annual Cost	Benefit Cost Ratio
	Flood Prevention					
	Damage Reduction	More Intensive Land Use	Local Secondary Benefits	Total		
All Dams and Channel Improvement	33,972	10,343	9,087	53,402	42,836	1.2 to 1.0
GRAND TOTAL	33,972 2/	10,343	9,087	53,402	42,836	1.2 to 1.0

1/ Price Base: Benefits long-term projected based on Agricultural Price and Cost Projections, September 1957. Cost estimates based on current prices.

2/ In addition, it is estimated that land treatment measures will provide flood damage reduction benefits of $1,051 annually.

Date August 1964

TABLE 7 - CONSTRUCTION UNITS

Willis River Watershed, Virginia

(Dollars) 1/

Measures in Construction Unit	Annual Benefit	Annual Cost
1. Dams 1A, 1B, 2, 3, & 4 and Channel Improvement VI, VII, VIII & IX	19,683	19,326
2. Dams 5E & 5F and Channel Impr. VA	8,586	8,032
3. Dams 6 & 6A and Channel Impr. XI and XIII	10,595	9,664
4. Dam 7 and Channel Improvement IIIA	4,539	4,084
5. Dam 9	2,228	1,731

1/ Price Base: Benefits long-term projected based on Agricultural Price and Cost Projections, September 1957. Cost estimates based on current prices.

Date August 1964

INVESTIGATIONS AND ANALYSES

General

The Willis River watershed is a typical Piedmont watershed with gentle gradients and slow flows. It basically consists of three major tributaries converging near the mid-portion with a number of side tributaries feeding in as it continues in a northernly direction to its confluence with the James River. The flood plain in the upper half of the watershed is devoted almost exclusively to agriculture; however, in the lower half of the watershed a swamp, a private recreation area and the Cumberland State Forest limits the agricultural use of the flood plain. The type and intensity of the project was the first determination made. The sponsors mutually agreed that a project which would provide protection from the three year frequency flood in the predominately agricultural areas would be the most practical.

With these desires in mind it was obvious that the land treatment program should be accelerated and that a system of floodwater retarding structures with possibly some stream channel improvement should be developed. A reconnaissance study was made to determine the most feasible location for structure sites to give protection to the greatest amount of flood plain with the most economical cost.

Land Treatment Measures

Additional land treatment measures were planned in accordance with the capabilities of the land to reduce erosion and sedimentation and improve hydrologic conditions. Field investigations were made of all public roads in the watershed, and on-site determination was made as to whether or not the areas were actively producing sediment. On each actively eroding area, a record was made of the length and width to determine the area to be treated. These determinations were made by Service personnel and representatives of the Virginia Department of Highways.

Alternatives Considered

During the investigation and planning stage some 19 different dam sites were considered. These dam sites were weighed one against the other to determine which combination would provide the most desirable project. Various amounts of channel work were also considered with the different combinations of dams. Evaluations indicated that a combination of 11 dams and 14.91 miles of stream channel improvement proved to be the most economically feasible while accomplishing the desired results.

Economic Investigations

Determinations of Annual Benefit from Reduction in Damages - The principal type of flood damages in the watershed is the flooding of agricultural land. Agricultural damage estimates were based on interviews with approximately 40 landowners. These interviews covered land use, crop distribution, average yields and experienced flood damages. Further information on flood plain land use was developed by field delineation of the present use on a flood plain strip map and measuring the area by land use. Information obtained from these interviews was analyzed and used with other data to develop future damage rates for crops by seasons and depth of flooding. The applicable rates of damage were applied to acreage inundated, as shown by the hydrologic data, to determine average annual damages by the frequency method.

The flood plain land use and estimates for normal yields of crops were based on information obtained from the interviews supplemented by information obtained from work unit personnel and other agricultural workers in the area. Because of the uniform use, a composite crop distribution was used for each reach. Damages to improvements, such as fences, roads and bridges, were obtained from analysis of interviews and correlated with the size of floods.

Indirect damages to crop and pasture and agricultural fixed improvements in the flood plain were determined to be at least 10 percent of the direct damage. The indirect damages to non-agricultural improvements appear to be about 20 percent of the direct damages.

During the field investigations, farmers were asked what changes had been made in the use of their flood plain lands as a result of past flooding. They were also asked what changes they would make if flooding were reduced. Analysis of these responses and projected future land use trends and land capability for the area provided the basis for estimating the benefits from restoration of their lands to former use.

Additional factors considered in this analysis were: size and location of the affected farms, land capability, existence of markets, managerial skill of operation and reduction in flood frequency.

Costs of producing crops, pasture, and other farm products were obtained locally and from experiment station data. All installation costs were based on 1963 prices. All costs of production and benefits were based on long-term projected prices as projected by ARS, September 1957.

Easement costs for the works of improvement were determined by the easement committee of the sponsoring local organizations based upon land sales and appraisals of similar land in the community.

The methods of economic evaluation conform to those set up in the Economic Guide.

Benefits from Restoration of Former Productivity and More Intensive Land Use - The benefits from restoration of former productivity were calculated by summarizing land use acreages, yields and net income and changes in cropping patterns. The loss from the original production was considered as crop and pasture damage and its restoration a benefit in Table 5. The change in cropping pattern involves land now in woods, idle and native pasture, which would normally be used as crop and improved pasture land with the hazard reduced. The restoration benefits on the reaches involved were reduced by the estimated associated costs of preparing these areas for crop and pasture uses. These benefits were further discounted for lag in accrual.

The benefits from more intensive use were based on those acres of the restored flood plain where it was indicated high intensity agriculture would be practiced. The present intensity of use, degree of flood protection, indicated managerial skill, soil capabilities, resources available and other factors were taken into consideration in determining those acres on which high intensity agricultural practices might be followed. The benefits from more intensive land use were derived from the difference in net income between the intensively use acre and the restored acre. These benefits are listed in Table 6 as more intensive land use benefits.

The restoration and more intensive land use benefits are based on the following land use changes:

	Without Project	Net Income	With Project	Net Income
Crop	Acres	Per Acre	Acres	Per Acre
Corn	149	50.18	470	55.43
Small Grain	55	13.03	140	14.54
Hay	338	17.33	608	18.65
Pasture (Improved)	309	23.45	836	23.50
Pasture (Native)	550	12.21	149	12.21
Woods, Idle & Miscellaneous	6,127	0	5,325	0
Total	7,528		7,528	

The installation of the works of improvement making possible these land use changes will not result in an increased acreage of surplus crops. The present trend in the watershed is toward an increase in the acreage devoted to corn. This increase is necessary for on farm feeding to balance the farm enterprises and will have little or no effect on the

commercial market. The implementing of this plan will divert a part of this increase from the steeper more erodible uplands to the more favorable bottom lands. Therefore, the plan will reduce the ill effects of the present trend in the area.

Benefits from the Reduction in Land Damages - The monetary appraisal of the physical damage from sediment and erosion damage on the flood plain was based on lost or deferred agricultural income. The benefits were based on the reduction in sediment, reduced area flooded, and reduced velocities of floodwaters on the areas flooded, following the procedure outlined in the Economics Guide.

Local Secondary Benefits - Local secondary benefits stemming from the project are considered to be 10 percent of the direct primary project benefits. These benefits include such items as increased use of transporting, processing and marketing of these goods and services that produce the primary project benefits. Local secondary benefits induced by the project are considered to be 10 percent of the increased costs that primary producers will incur in connection with increased production. These benefits include such items as the increased net return to suppliers of farm equipment and materials, increased net returns to local retailers and wholesalers and other such items.

Sedimentation Investigations

A field examination of the flood plain was conducted to determine the type and extent of sediment and related damages. Erosion rates were calculated by the use of the Musgrave formula and data from field investigation. Highways were investigated to determine where active bank erosion was occurring.

All procedures and formulas used are similar to those in the Work Plan Party Guide for the Northeast, Chapter IV.

Geologic Investigations

Geologic investigations consisted of a study of the available literature 1/ and aerial photographs of the region and a thorough surface examination of the conditions in the field. A preliminary examination of each damsite was conducted and depths of overburden were determined where possible with a hand auger and other hand tools.

1/ Geologic Map of Virginia, Division of Mineral Resources, 1963. Kyanite Belt of Central Virginia, Jonas, A., Bul. 38, VGS, 1932.

The structure sites are located in the Piedmont Physiographic Province. The bedrock consists of granite, granodiorite, diorite, diabase, gabbro, hornblende gneiss, pegmatite, schist, gneiss, phyllite, quartzite, kyanite-quartzite, sandstone, shale and conglomerate. The depths to bedrock under the foundations appear to be 10 feet or less. The rock surfaces are expected to be uneven due to the differential weathering characteristics of these types of rocks. The material to be encountered in the emergency spillways will range from GM to CH (according to the Unified Soil Classification System) with sandy silts and sandy clays predominating. Substantial amounts of highly weathered bedrock will be found which will minimize the rock excavation in the damsites.

Depths of ground water in most cases are approximately equivalent to the stream level. Flood plain borrow is available but, some drainage prior to construction may be necessary. A certain amount of seepage should be expected near the surface of hard bedrock. No geologic conditions were found which would adversely affect construction costs.

Stream Channel Improvement - A study of the soils and field observation of channel, streambank and flood plain conditions in the reaches involved in excavation indicated no restrictive rock ledges at expected depths of excavation. A study of the soils in the channel area indicated the suitability of side slopes shown in this plan.

Engineering Investigations and Analysis

The structure sites were originally located on USGS Quadrangle sheets. They were picked for watershed control, narrowness of the centerline cross section and storage possibilities. Each site was checked by a stereoscopic study of aerial photographs. The height of each dam was estimated by use of a storage curve computed from planimetered contours of USGS Quadrangle sheets. This information was used as a guide in the amount of survey coverage needed from the field. The final locations of dams were made in the field giving due regard to geologic conditions. Preliminary data was worked up on several sites that were either moved or dropped from consideration. The final dams left in were the ones that did the most good in the overall project and were economically justifiable, as determined by flood routings and cost estimates.

Elevations above mean sea level were carried to each damsite from USGS bench marks. Complete topographic surveys were made of the storage basins by the baseline cross section method and plotted to 4' contour intervals. A topo survey was also made of the area for the emergency spillway on each structure site. The ends of the valley cross section for the centerline of each

dam were marked with iron pins driven into the ground. These pins were tied to reference points, and a sketch of the layout was made in the engineering field books.

A system of valley and stream channel cross sections was run to conform to the hydraulic and economic needs. All of these were tied to elevations above mean sea level carried along the valley of each tributary by a level and compass traverse. The traverse was used also to measure the channel distance between surveyed cross sections. Considerable detail in the field survey of bridges and road fill was made in order to show the restriction to flow.

The dams were designed to conform to Soil Conservation Service criteria set forth in Engineering Memorandum No. 27, Technical Release No. 10, and the National Engineering Handbook.

The sediment storage for all dams is based on accumulation for a 100-year period.

All dams were designed with 50-year frequency floodwater storage. None of the sites was used to their maximum capabilities, as far as storage is concerned. For this reason multiple use storage could conceivably be added to any of these sites.

All dams were designed with two stage drop inlets. The orifice openings in the drop inlets were designed in various sizes depending on the drainage area controlled by each structure. The sizes were adjusted to hold the release rates as low as possible, with due consideration given to channel size and draw down time. Principal spillway conduit sizes were chosen to give release rates that would not cause undue channel excavation and at the same time would not require excessive flood storage to be retained behind the dams. Various sizes were considered before selecting the ones to be used. The emergency spillway widths were based on a geologic study of each site, a study of maximum allowable velocities, and a study of the capability of each spillway site as a borrow producing area.

Stage-storage curves were drawn up from the storage basin topographic maps and stage-discharge curves were drawn for the orifice, weir, pipe and emergency spillway of each dam. This data was used in the routings of the emergency spillway and freeboard storms mentioned under Hydraulic and Hydrologic Analysis.

Cost estimates for construction were made for all dams and were based on unit costs of recent jobs completed in Virginia.

The channel was designed to carry a 3-year 12-hour storm as determined by the hydrologist. Hydraulic tables were used to

design the channel. It was then checked for adequacy by running water surface profiles. The yardage of excavation was computed by the average end area method using the surveyed cross sections. Clearing was calculated by use of recent aerial photographs and field observation. Cost estimates were based on recent channel construction jobs in similar areas.

Tables 3 and 3A were made up for the work plan to show pertinent data for the dams and the channel works of improvement.

Hydraulic and Hydrologic Analyses

A synthetic storm series was set up for the Willis River watershed by use of rainfall data obtained from the U. S. Weather Bureau Technical Paper No. 40. The storms chosen for routing through the damage reaches were the 2-year, 10-year, and 100-year frequency storms of 12-hour duration.

The damage reaches for flood routing purposes were chosen by consultation with the planning party's economist. They were marked off on a base map of the watershed that was traced from USGS Quadrangle sheets and completed by use of county highway maps. Use of a flood plain map, that was drawn from consecutive contact prints of aerial photographs, was also made in determining the reaches of the valley for flood routing. The flood plain map was roughly outlined on the contact prints by use of a stereoscope. Corrections where necessary were later made in the flood plain width by use of surveyed cross sections of the valley. These cross sections were chosen in such a way as to not only represent the hydraulic characteristics of the valley and channel, but also to represent the width of the valley for the purpose of computing acres of flood plain inundated by various frequency storms.

The drainage area for each subarea of the watershed was planimetered from the USGS quadrangle sheets covering the watershed.

The runoff used in developing the subarea hydrographs for routing purposes was determined from the hydrologic curve numbers for antecedent moisture condition II. The curve numbers were developed from soil cover and land use information provided by the Work Unit Conservationist, Soil Scientist and in conjunction with Virginia State Forest Service personnel. The procedure used is described in chapters 3.8, 3.9 and 3.10 of Supplement A of the National Engineering Handbook, Section 4.

The hydrographs for each subarea were set up according to chapter 3.16 of Supplement A of the National Engineering Handbook, Section 4, and were routed through the watershed by the Wilson Graphical Method. Routings were made with the watershed in its present condition. Then the subarea hydrographs

were modified for land treatment and were routed with the structures assumed to be in place. After the channel design was made the routings were again run with the structures in place to determine the effect of the overall project on flood peaks.

Water surface profiles were run through the valley and channel system for the channel in present condition and then with the channel works of improvement assumed to have been completed. The variation of Leach's method, described in chapter 3.14 of Supplement A of the National Engineering Handbook, was used for water surface profiles. Stage-discharge curves were drawn from the water surface profiles for both present condition and with channel improvement completed.

From the above routings, a discharge-frequency curve was set up for each evaluation reach. This was used along with the stage-discharge curves for each reach to determine the depth of flooding for various frequency storms. A tabulation of cross section width, valley length and stage above stream banks was also made. From this a set of stage-area inundated curves was drawn. These curves were used in connection with the stage-discharge curves and the discharge-frequency curves to determine the acres of flood plain in each evaluation reach inundated by various frequency storms. This process helped to determine the effect of the floodwater retarding structures and the amount of channel work needed. Two dams on Randolph Creek, a tributary of the Willis River, were dropped from the project after routings were made with them in the project and without them in the project.

A channel design was first tried to give full protection from the 5-year 12-hour storm. This produced a design which was not economically feasible. The channel was finally designed to carry a storm of 12-hour duration that would have a frequency of occurrence of once in 3 years.

The emergency spillway crest elevations of the dams were set to give the flood storage as determined by Technical Release No. 10, prepared by the Soil Conservation Service. A 50-year, long duration rainfall from Technical Paper No. 40 of the U. S. Weather Bureau was used in each case for the storage computations. Dam No. 6, a dam in series with dam No. 6A, was designed to include the storage of runoff from the total area above it including that above dam No. 6A. This was done because the storage was readily available and it allowed the use of a smaller principal spillway conduit. This design not only gives better flood plain protection but also reduces the required channel excavation.

The emergency spillway and freeboard hydrographs were routed through each structure to determine the design high water and

the top-of-dam elevations. These hydrographs were developed according to the method set forth in chapter 3.21 of the National Engineering Handbook, Section 4. The rainfall used was based on the Soil Conservation Service criteria for class "a" structures in all but two dams. Class "b" criteria was used for the two dams in series. The routing procedure for the dams in series was done to conform to Engineering Memorandum No. 43 of the Soil Conservation Service. All routings were made by the graphical procedure (method No. 2) as described in chapter 5.8 of the National Engineering Handbook, Section 5.

37°30'

Drainage Area Controlled by Structure

Area Benefited

Reach

PROJECT MEASURES

Floodwater Relarding Structure

Channel Improvement for Flood Prevention

LOCATION MAP

BUCKINGHAM CO.

CUMBERLAND CO.

DA 6,250 Ac.

DA 2,960 Ac.

DA 5,960 Ac.

DA 4,060 Ac.

DA 7,040 Ac.

DA 2,470 Ac.

DA 1,910 Ac.

DA 3,300 Ac.

DA 2,830 Ac.

DA 1,700 Ac

DA 9,880 Ac.

Andersonville

Dillwyn

Gold Hill

Randolph Creek

Sports Lake

Trico Lake

Lakeside Village

Sheppards

Little Willis River

Whispering Creek

Hatcher Creek

Co Ira Pond

Bear Creek Lake

Whiteville

Cumberland

Raines Tavern

PROJECT MAP
WILLIS RIVER WATERSHED
Virginia

0 1 2 3 4 5 6 Miles

78° 15'

37° 30'