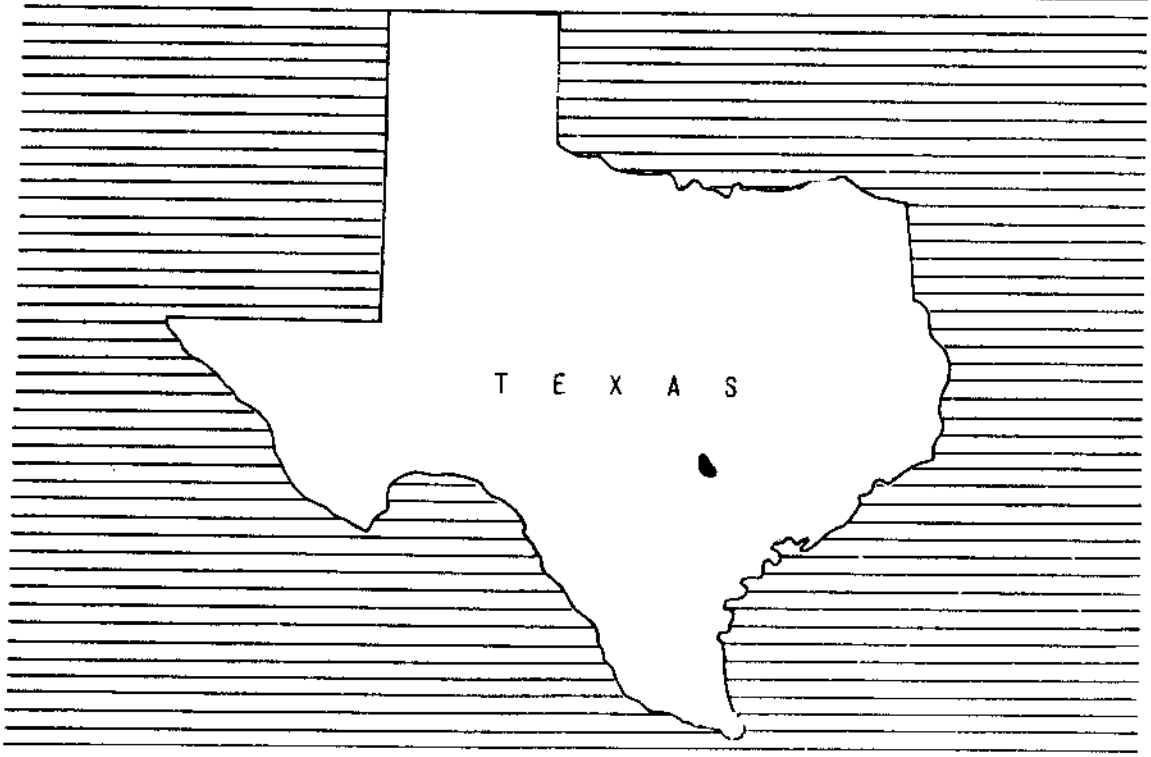
WORK PLAN

FOR WATERSHED PROTECTION AND FLOOD PREVENTION

COMAL RIVER WATERSHED

Comal and Guadalupe Counties, Texas



August 1968

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WATERSHED WORK PLAN AGREEMENT

between the

Comal-Hays-Guadalupe Soil and Water Conservation District
Local Organization

Comal County Commissioners Court
Local Organization

City of New Braunfels
Local Organization

Edwards Underground Water District
Local Organization

State of Texas
(hereinafter referred to as the Sponsoring Local Organization)

and the

Soil Conservation Service
United States Department of Agriculture
(hereinafter referred to as the Service)

Whereas, application has heretofore been made to the Secretary of Agriculture by the Sponsoring Local Organization for assistance in preparing a plan for works of improvement for the Comal River Watershed, State of Texas under the authority of the Watershed Protection and Flood Prevention Act (Public Law 566, 83d Congress; 68 Stat. 666), as amended; and

Whereas the responsibility for administration of the Watershed Protection and Flood Prevention Act, as amended, has been assigned by the Secretary of Agriculture to the Service; and

Whereas there has been developed through the cooperative efforts of the Sponsoring Local Organization and the Service a mutually satisfactory plan for works of improvement for the Comal River Watershed, State of Texas, hereinafter referred to as the watershed work plan, which plan is annexed to and made a part of this agreement;

Now, therefore, in view of the foregoing considerations, the Sponsoring Local Organization and the Secretary of Agriculture, through the Service, hereby agree on the watershed work plan, and further agree that the works of improvement as set forth in said plan can be installed in about 5 years.

It is mutually agreed that in installing and operating and maintaining the works of improvement substantially in accordance with the terms, conditions, and stipulations provided for in the watershed work plan:

1. The Sponsoring Local Organization will acquire without cost to the Federal Government such land rights as will be needed in connection with the works of improvement. (Estimated cost $204,300 .)

2. The Sponsoring Local Organization will acquire or provide assurance that landowners or water users have acquired such water rights pursuant to State law as may be needed in the installation and operation of the works of improvement.

3. The percentages of construction costs of structural measures to be paid by the Sponsoring Local Organization and by the Service are as follows:

Works of Improvement	Sponsoring Local Organization (percent)	Service (percent)	Estimated Construction Cost (dollars)
3 Floodwater Retarding Structures	-	100	850,238

4. The percentages of the engineering costs to be borne by the Sponsoring Local Organization and the Service are as follows:

Works of Improvement	Sponsoring Local Organization (percent)	Service (percent)	Estimated Engineering Costs (dollars)
2 Floodwater Retarding Structures	-	100	43,722

5. The Sponsoring Local Organization and the Service will each bear their costs for project administration, estimated at $1,500 and $126,099, respectively.

6. The Sponsoring Local Organization will obtain agreements from owners of not less than 50% of the land above each reservoir and floodwater retarding structure that they will carry out conservation farm or ranch plans on their land.

7. The Sponsoring Local Organization will provide assistance to landowners and operators to assure the installation of the land treatment measures shown in the watershed work plan.

8. The Sponsoring Local Organization will encourage landowners and operators to operate and maintain the land trestment measures for the protection and improvement of the watershed.

9. The Sponsoring Local Organization will be responsible for the operation and maintenance of the structural works of improvement by actually performing the work or arranging for such work in accordance with agreements to be entered into prior to issuing invitations to bid for construction work.

10. The costs shown in this agreement represent preliminary estimates. In finally determining the costs to be borne by the psrties hereto, the actual costs incurred in the installation of works of improvement will be used.

11. This agreement 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 Service in carrying out the watershed work plan is contingent on the appropriation of funds for this purpose.

    A separate agreement will be entered into between the Service and the Sponsoring Local Organization before either party initiates work involving funds of the other party. Such agreement will set forth in detail the financial and working arrangements and other conditions that are applicable to the specific works of improvement.

12. The watershed work plan may be amended or revised, and this agreement may be modified or terminated, only by mutual agreement of the parties hereto.

13. No member of or delegate to Congress, or resident commissioner, shall be admitted to any share or part of this agreement, or to any benefit that may arise therefrom; but this provision shall not be construed to extend to this agreement if made with a corporation for its general benefit.

14. The program conducted will be in compliance with all requirements respecting nondiscrimination as contained in the Civil Rights Act of 1964 and the regulations of the Secretary of Agriculture (7 C.F.R. 15.1-15.12), which provide that no person in the United States shall, on the ground of race, color, or national origin, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any activity receiving Federal financial assistance.

Comal-Hays-Guadalupe Soil and Water Conservation District
Local Organization

By Herman Blank
Herman Blank

Title Chairman of Board of Supervisors

Date December 18, 1968

The signing of this agreement was authorized by a resolution of the governing body of the Comal-Hays-Guadalupe Soil and Water Conservation District
Local Organization

adopted at a meeting held on December 17, 1968

Paul Beutnagel
(Secretary, Local Organization)
Paul Beutnagel

Date December 18, 1968

Comal County Commissioners Court
Local Organization

By Alvin B. Welsch
Alvin B. Welsch

Title County Judge, Comal County

Date December 18, 1968

The signing of this agreement was authorized by a resolution of the governing body of the Comal County Commissioners Court
Local Organization

adopted at a meeting held on December 16, 1968

Irene S. Nuhn,
County Clerk and Ex-Officio Clerk of the
Commissioners' Court of Comal County, Texas.
(Secretary, Local Organization)
Irene S. Nuhn

Date December 18, 1968

City of New Braunfels
Local Organization

By Harvey Westerholm
Harvey Westerholm

Title City Manager

Date December 18, 1968

The signing of this agreement was authorized by a resolution of the governing body of the City of New Braunfels
Local Organization

adopted at a meeting held on December 16, 1968

Patsy Weyel
(Secretary, Local Organization)
Patsy Weyel

Date December 18, 1968

Edwards Underground Water District
Local Organization

By Paul W. Jahn
Paul W. Jahn

Title Chairman

Date 1/14/69

The signing of this agreement was authorized by a resolution of the governing body of the Edwards Underground Water District
Local Organization

adopted at a meeting held on 1/14/69

Wm. H. Spice Jr.
(Secretary, Local Organization)
Wm. H. Spice, Jr.

Date 1/14/69

Soil Conservation Service
United States Department of Agriculture

By _____

Date _____

WATERSHED WORK PLAN

FOR

WATERSHED PROTECTION AND FLOOD PREVENTION

COMAL RIVER WATERSHED

Comal and Guadalupe Counties, Texas

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

Prepared By:

Comal-Hays-Guadalupe Soil and Water Conservation District
(Sponsor)

Comal County Commissioners Court
(Sponsor)

City of New Braunfels
(Sponsor)

Edwards Underground Water District
(Sponsor)

With Assistance By:

U. S. Department of Agriculture
Soil Conservation Service
August 1968

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WATERSHED WORK PLAN

COMAL RIVER WATERSHED

Comal and Guadalupe Counties, Texas

ADDENDUM

Since the preparation of this watershed work plan, the Federal interest rate for benefit and cost evaluations has been increased from 3.25 percent to 4.625 percent.

As a reault, annual equivalent costs for the installation of these structural meaaures will increase from $41,533 to $57,322. The total average annual cost of structural measures (amortized total installation cost, plus operation and maintenance costs) will be increased to $57,972. Average annual benefits, excluding secondary benefits, accruing to structural measures will change to $99,338, resulting in a benefit-cost ratio of 1.7 to 1.0.

Total average annual project benefits, including secondary benefits, will change to $108,087, resulting in a benefit-cost ratio of 1.9 to 1.0.

WATERSHED WORK PLAN

COMAL RIVER WATERSHED

August 1968

SUMMARY OF PLAN

The work plan for watershed protection and flood prevention for Comal River watershed has been prepared by the Comal-Hays-Guadalupe Soil and Water Conservation District; Comal County Commissioners Court; the city of New Braunfels, Texas; and the Edwards Underground Water District as the sponsoring local organizations. Technical assistance has been provided by the Soil Conservation Service, United States Department of Agriculture. The Bureau of Sport Fisheries and Wildlife of the United States Department of the Interior, in cooperation with the Texas Parks and Wildlife Department, made a reconnaissance study of the fish and wildlife resources of the watershed.

Comal River watershed comprises an area of 130 square miles in Comal and Guadalupe counties. It is estimated that 9.1 percent of the watershed is cropland, 5.5 percent is pasture, 76.9 percent is rangeland, 0.6 percent is wildlife-recreation land, and 7.9 percent is in miscellaneous uses such as the city of New Braunfels, public roads, railroads, farmsteads, and stream channels. There is no Federal land in the watershed.

The principal problem within the watershed is one of frequent and extensive flooding on portions of the 2,826 acres of flood plain which results in damages to crops, grasses, soils, agricultural properties, residential and commercial properties, roads, and bridges. The total floodwater, erosion, and indirect damages are estimated to be $105,142 annually.

The work plan proposes installing, in a five-year period, needed land treatment measures and three floodwater retarding structures. Two floodwater retarding structures presently are located in the watershed. They have been installed by Comal County under a previous agreement between the Comal County Commissioners Court and the Soil Conservation Service. Land treatment measures included are those which contribute directly to watershed protection and reduction of floodwater and scour damages.

The total project installation cost is estimated to be $1,426,535, including $200,676 for installation of planned land treatment and $1,225,859 for the structural measures. The cost for land treatment includes $8,300 from Public Law 566 funds to accelerate application of needed measures. The share of total project installation cost from sources other than Public Law 566 funds is estimated to be $398,176, and the Public Law 566 share is estimated to be $1,028,359. The Public Law 566 cost share for structural measures is estimated to be $1,020,059, and the local share is estimated to be $205,800.

Average annual damages will be reduced from $105,142 to $11,175 by the proposed project, including structural measures installed by Comal County. Average annual benefits accruing to structural measures in the watershed

will be $123,923, which includes $88,745 damage reduction benefits, $25,200 incidental ground water recharge benefits, and $9,978 secondary benefits. The ratio of the average annual benefits accruing to structural measures included in this plan ($112,585) to the average annual cost of these measures ($42,183) is 2.7 to 1.0. Additional average annual benefits of $11,338 will accrue to the two floodwater retarding structures installed by Comal County.

Land treatment measures will be operated and maintained by owners and operators of the land upon which the measures will be applied under agreements with the Comal-Hays-Guadalupe Soil and Water Conservation District. Operation and maintenance of structural measures will be carried out by the Comal County Commissioners Court. The cost of operation and maintenance is estimated to be $650 annually.

DESCRIPTION OF WATERSHED

Physical Data

Comal River watershed lies in south central Texas on the eastern edge of the Hill Country. It comprises an area of 130 square miles (83,200 acres), of which 125 square miles are in Comal County and 5 square miles are in Guadalupe County. The city of New Braunfels is located on the eastern edge of the watershed. San Antonio is 33 miles southwest and Austin is 48 miles northeast of New Braunfels.

Comal River originates at Comal Springs, within the city limits of New Braunfels, and flows through the city for a distance of about 3 miles before entering the Guadalupe River. The average flow of Comal Springs is 295 cubic feet per second. Principal tributaries of Comal River are Dry Comal and Blieders Creeks.

Two main prongs of Dry Comal Creek head in central Comal County near Smithsons Valley. Both prongs flow very sinuously toward the south and join in the southern portion of the watershed. Immediately downstream from this confluence, Dry Comal Creek turns abruptly toward the northeast and flows 12.5 miles to its confluence with the Comal River in New Braunfels.

Blieders Creek heads about eight miles northwest of New Braunfels, flows toward the southeast, and joins the Comal River in the Comal Springs area.

Physiographically, the watershed lies within the Balcones fault zone, a system of northeastward trending faults with upthrown sides generally on the northwest (figure 3). The Balcones escarpment, a very prominent topographic feature, separates the two major land resource areas of the watershed. The Edwards Plateau Land Resource Area includes the Balcones escarpment and covers the northwestern 80 percent of the watershed. The Texas Blackland Prairie Land Resource Area occupies the remaining 20 percent of the watershed and lies to the southeast of the Balcones escarpment.

The Edwards Plateau is moderately to steeply sloping, and the escarpment area is deeply disected with draws and canyons. The Texas Blackland Prairie portion is undulating to gently rolling. Elevations range from about 1,435 feet above mean sea level along the northern watershed divide to about 600 feet at the confluence of the Comal and Guadalupe Rivers.

Cretaceous strata underlie the watershed. The Glen Rose limestone and shale, Comanche Peak limestone, Edwards limestone, Georgetown limestone, Grayson shale, and Buda limestone, all of which belong to the Lower Cretaceous system, are exposed in the Edwards Plateau. The hard, fractured, and porous Edwards limestone is dominant. The Blackland Prairie portion of the watershed is underlain by Upper Cretaceous strata, including the Anacacho marly limestone and the Taylor marl and clay.

Soils of the Edwards Plateau are fine textured, very shallow to deep, and slowly to moderately permeable. There are large areas of exposed rock. The dominant soil series are Tarrant, Brackett, Crawford, and Denton.

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Blackland Prairie soils are primarily of the Austin, Heiden, Houston Black, Krum, Trinity, Stephen, Eddy, and Lewisville series. These are fine textured, mostly deep soils. A few are shallow. Most of the clay soils are very slowly permeable. They take up water rapidly when dry and cracked, but very slowly when wet. The permeability of Austin, Stephen, and Eddy soils is moderately slow to moderate.

The following tabulation shows the use of watershed land.

Land Use	Acres	Percent
Cropland	7,545	9.1
Pasture	4,600	5.5
Rangeland	63,967	76.9
Wildlife-Recreation Land	500	0.6
Miscellaneous 1/	6,588	7.9
Total	83,200	100.0

1/ Includes roads, highways, railroad rights-of-way, urban areas, farmsteads, stream channels, etc.

Hydrologic cover conditions range from poor to good on rangeland, but the majority is fair to good. Range sites within the watershed include Redland, Rocky Upland, Adobe, Deep Upland, Rolling Blackland, Chalky Ridge, and Bottomland. When these sites are in excellent condition, the dominant grasses are little bluestem, Indiangrass, plains lovegrass, Canada wildrye, big bluestem, sideoats grama, Texas wintergrass, and buffalograss. In climax condition tree canopy ranged from ten to fifteen percent on the upland and was moderately heavy on the bottomland. Some deterioration has taken place on much of the rangeland because of overgrazing. Texas grama, hairy tridens, tall dropseed, red grama, threeawns, silver bluestem, annual weeds, mequite, Texas oak, Ashe juniper, agrito, and liveoak have increased on land that was originally dominantly covered with little bluestem.

The climate is sub-humid. Summers are warm to hot. Winters are fairly mild but subject to rapid and wide changes in temperature with the passage of cold fronts. Temperatures range from a mean maximum of 96 degrees Fahrenheit in July to a mean mimimum of 40 degrees in January. The normal growing season, extending from March 6 to November 26, is 265. Average annual precipitation is about 32 inches. Rainfall is fairly well distributed, but winter is generally the drier period. The heaviest rainfall usually occurs in spring and fall.

Water for livestock and rural domestic use is supplied mostly by wells and surface ponds. The municipal water supply for New Braunfels is obtained from wells in the Edwards ground water reservoir. This reservoir extends along the Balcones fault zone in parts of Kinney, Uvalde, Medina, Bexar, Comal, and Hays Counties. In the New Braunfels area, the ground water reservoir is recharged primarily by ground water underflow from the southwest and secondarily by seepage from streams such as Dry Comal and Blieders

Adobe Range Site on Steep Brackett Soils in Edwards Plateau -

This is typical of the Glen Rose formation outcrop (figure 3).

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Creeks. In this area, the two principal outlets are Comal and San Marcos Springs.

In the vicinity of faults in the Balcones system, the harder rocks are generally highly fractured. Cavernous conditions exist in the more pure limestones, especially the Edwards. The larger caverns tend to be developed along and parallel to fault lines. Small floods originating upstream from the Balcones escarpment lose much of their volumes to the Edwards ground water reservoir as they cross the faulted area. High intensity rains, however, produce flood flows which greatly exceed the infiltration capacity of the limestones exposed in stream channels.

Economic Data

The agricultural economy depends on production of sheep, goats, and cattle, and a limited amount of cropping. Other elements of the economy include a textile mill, hosiery mill, regional power plant, flour mill, feed mill, lime plant, and crushed rock plant. Considerable business activities result from the extensive water based recreation facilities that exist because of Comal Springs.

The economy of the watershed is also influenced by the city of San Antonio, located 33 miles southwest of New Braunfels. A number of persons living in the watershed commute to work in San Antonio.

There are approximately 266 farms and ranches wholly or partially within the watershed, averaging 288 acres in size. About 57 percent of the farms are smaller than 260 acres. The number of small farms is expected to increase as people from centers such as San Antonio purchase tracts in or near the watershed for use as weekend retreats. About 65 percent of the farms and ranches in Comal County, which is representative of the watershed, gross less than $2,500 annually from agricultural sales. Approximately 50 percent of the farm and ranch operators worked off-the-farm for 100 days or more in 1964.

It is estimated that less than 10 percent of the agricultural land in the benefited area is devoted to farms and ranches using 1-1/2 man-years or more of hired labor.

Industrial production in the watershed area outside of New Braunfels includes a rock crushing plant and a lime plant. These establishments, together with businesses and industries in New Braunfels, provide the principal employment for residents of the watershed. The city of San Antonio, with is several military installations, offers additional employment opportunities for residents within the watershed area.

The average value of land and buildings per farm is estimated at about $71,280 (based on 1964 agricultural census data). The estimated current market price of land is $150 to $500 per acre. The range in land prices depends primarily on location and accessibility. Agricultural land is largely owner-operated with only about 9 percent being leased or rented.

The city of New Braunfels, located in the lower portion of the watershed, has an estimated population of 17,200. It is the county seat of Comal County and the trade center for the surrounding farm and ranch area, providing marketing and supply services which are important in the local community. It is one of the leading recreational areas in Texas.

The watershed is traversed by a number of paved Federal, State, and Farm-to-Market roads. There are also numerous county roads and city streets which provide access to all parts of the watershed. However, all-weather crossings of Blieders Creek, Comal River, and Dry Comal Creek are limited to the more important streets and highways. There are a number of low-water crossings which are frequently impassable. The Missouri-Pacific and the Missouri, Kansas, and Texas railroads have loading facilities in New Braunfels.

Land Treatment Data

Ranchers and farmers of the Comal River watershed are applying basic soil and water conservation measures on their land in cooperation with the Comal-Hays-Guadalupe Soil and Water Conservation District. The Soil Conservation Service work unit at New Braunfels is assisting the district in the preparation and application of basic soil and water conservation plans.

There are 266 operating units wholly or partially in the watershed, of which 151 (49,186 acres) are under district agreement. Sixty percent of the agricultural land is under basic plan. Current revision is needed on 25 conservation plans.

Soil surveys have been completed on approximately 6,000 acres. Nearly all rangeland has been range mapped. Approximately 55 percent of needed land treatment practices on rangeland, 25 percent on pasture and hayland, and 55 percent on cropland have been applied. An estimated 75 percent of the land is adequately protected from erosion. Land treatment applied to date has been very effective in keeping erosion at a low rate. No serious eroison problems resulting from improper land use exist within the watershed.

The level of accomplishment for needed practices is expected to reach 80 to 85 percent in five years as a result of the planned accelerated land treatment program.

Fish and Wildlife Resource Data

Fish and wildlife habitat and population are described by the Bureau of Sport Fisheries and Wildlife as follows:

> "Fish habitat in the watershed is confined to the Comal River and farm ponds. Blieders Creek and Dry Comal Creek are intermittent and support few fish.

The principal species of fish in the watershed are largemouth bass, bluegill, and channel catfish. Sport fishing is heavy in the project streams for largemouth bass and bluegill during the spring and summer months. Moderate amounts of fishing occur in these streams the year round for channel catfish. There is some fishing in the farm ponds by landowners and their friends.

In the future, the amount of sport fishing is expected to increase because of human population increases.

There is no commercial fishing in the project streams and farm ponds and none is expected to develop in the future.

Wildlife species in the watershed include white-tailed deer, wild turkey, mourning dove, bobwhite, fox squirrel, cottontail, raccoon, ringtailed cat, and gray fox. There are no significant waterfowl populations.

Deer occur abundantly over the entire watershed and a moderate amount of hunting is done for them. Turkeys are present in moderate to light numbers in many portions of the watershed and they are hunted lightly by deer hunters. Bobwhites and mourning doves are distributed over the watershed in moderate numbers and are also hunted lightly. Cottontails are not abundant and receive an insignificant amount of hunting. Squirrels occur in considerable numbers along timbered streams and in pecan groves, but they are not hunted much. Most of the hunting in the watershed is on a lease basis.

There is no significant amount of trapping for fur animals in the watershed. Sport hunting for raccoons and foxes is insignificant in the project area."

WATERSHED PROBLEMS

Floodwater Damage

An estimated 2,826 acres of the watershed, excluding stream channels, is flood plain. This is the area that would be inundated by a 100-year frequency flood.

Some progress has been made in attempting to control or prevent flooding on Dry Comal Creek. Local interests, working through the County Commissioners Court and the Comal-Hays-Guadalupe Soil and Water Conservation District, have constructed two floodwater retarding structures in the watershed at their own expense. Some attempts have been made to clean and enlarge the stream channel, but these efforts have had little effect on the reduction of flood damage. The adverse economic and physical effect of flooding has been felt throughout the entire watershed and will prompt local participation in the alleviation of the flood problem.

Flooding occurs frequently in the watershed and causes moderate to severe damages to agricultural lands and to urban developments in New Braunfels.

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Flooding on Dry Comal Creek, typical of that which occurs in the watershed, causing damage to agricultural lands.

(Reproduced with permission of New Braunfels Herald, New Braunfels, Texas.)

Floodwater in Comal Springs area overflowing into Landa Park swimming pool. Sediment and debris must be removed from the pool following flooding of this type.

4-27074 9-66

(Reproduced with permission of Seidel Studio, New Braunfels, Texas.)

Flood damage to resort cabin caused by flood of September 10-11, 1952. Note that cabin was washed from its foundation.

(Reproduced with permission of Seidel Studio, New Braunfels, Texas.)

Flood damage to mobile homes caused by flood of September 10-11, 1952. Note wrecker caught by rising water while attempting to tow mobile home to higher ground.

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Floodwaters of Dry Comal Creek, near the confluence with Comal River, submerged Landa Street bridge September 11, 1952.

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Small overflows occur at least annually in New Braunfels and cause minor damage to yards, streets, and crossings. Larger floods that cause damages in excess of $140,000 to urban developments occur on the average of every 9 to 10 years.

The most disastrous flood in recent years occurred during the night of September 10-11, 1952. The magnitude of the storm varied from an unofficial 18 inches of rainfall in the upper reaches of the watershed to an official 8.83 inches recorded at New Braunfels. The average rainfall on the Blieders Creek drainage area had a recurrence interval of about 33 years, while the average rainfall on Dry Comal Creek drainage area had a recurrence interval of about 7 years. The resulting flood inundated approximately 2,070 acres of flood plain in the watershed, of which 220 acres are located inside the urban area of New Braunfels. One life was lost. Several persons were rescued from roof tops by Air Force helicopters. Under the present level of development, the direct monetary floodwater damage from such a flood is estimated to be $476,200, of which $464,000 would be to urban properties.

Other recent damaging floods occurred in 1957, 1953, 1936, 1935, and 1932.

A flood resulting from a 100-year frequency storm event would cause direct floodwater damages in excess of $966,000, of which approximately $947,000 would be to urban properties in New Braunfels.

For the floods expected to occur during the evaluation period, which includes floods up to the 100-year frequency, the total direct floodwater damage is estimated to average $88,698 annually at ajusted normalized prices (table 5). Of this amount, $4,984 is crop and pasture damage, $6,125 is other agricultural damage, $2,383 is nonagricultural damages to roads, bridges, and railroad property, and $75,206 is damage to urban and other nonagricultural development.

Indirect damages such as interruption of travel, losses sustained by businesses, temporary dislocation of persons from homes and work, and similar losses are unusually heavy in this watershed. The total average annual value of such damages is esimated to be $16,395.

Sediment Damage

Damages caused by sediment are very minor. Good to fair hydrologic cover and low inherent erosion rates of watershed soils are primarily responsible for a lack of significant sediment deposition on flood plain lands.

Much of the fine fraction of sediment is transported out of the watershed. Stream bedload consists of coarse gravel with cobbles and boulders. Isolated overbank deposits, covering a very minor portion of the flood plain, are found near the streams and consist primarily of silty, sandy clay. The average thickness of deposits is less than one foot, and the land affected is almost entirely rangeland. In monetary terms, the value of this damage is insignificant.

Following major flooding, sediment and debris must be removed from the swimming pool at Landa Park, streets, and commercial and private properties. This type of damage is included under floodwater damage.

Erosion Damage

Because of the low inherent erodability of Edwards Plateau soils and the predominant land use being rangeland with fair to good hydrologic cover, erosion rates are low. The average annual rate of gross erosion is estimated to be 1.67 tons per acre in the Edwards Plateau and 8.63 tons per acre in the Blackland Prairie. Sheet erosion accounts for 97 percent, gully and streambank erosion 1 percent, and flood plain scour 2 percent of total erosion. The present erosion rate is expected to be reduced by about 20 percent through installation of land treatment measures included in this work plan.

Land damaged by flood plain scour represents less than five percent of the agricultural portion of the flood plain. Damaged areas range from 10 to 100 feet in width and from one to three feet in depth. It is estimated that flood plain scour causes a loss of productive capacity on 89 acres, distributed as follows: 38 acres, 10 percent; 33 acres, 20 percent; 17 acres, 30 percent; and 1 acre, 40 percent. Annual recovery from flood plain scour is approximately in balance with new damage. The average annual value of this damage is estimated to be $49 at adjusted normalized price levels (table 5).

Problems Relating to Water Management

Water for livestock and rural domestic use is obtained from wells and surface ponds. Water for recreation, municipal, and industrial purposes in the New Braunfels area is discharged from the Edwards ground water reservoir through wells and springs. The aquifer is easily recharged by by surface runoff, and ground water levels have fluctuated widely. According to the U. S. Geological Survey, the lowest level of record was in 1956 and early 1957, reflecting the drought of 1947 to 1957 and associated increased withdrawals. In 1968, water storage in the reservoir was near maximum capacity. However, as indicated in Report 34, Texas Water Development Board, the U.S.G.S. has estimated that recharge was less than discharge during the period 1934-1964.

Future water demands will increase with population growth. It is estimated that by 1990 the populations of New Braunfels and Comal County will be 24,300 and 30,200, respectively.

The existence of tourist attractions located along the Comal River is dependent entirely on the flow of Comal Springs.

Without controlled use of water in the Edwards ground water reservoir and additional measures to increase surface and/or ground water storage, critical water shortages could arise in the future.

Watering places used by wildlife include the Comal and Guadalupe Rivers, wells, and farm ponds. Dry Comal and Blieders Creeks are not reliable

sources of water because of the porous nature of bedrock and the depth to the water table. Also, locations are sparsely scattered where soils and bedrock are suitable for water storage in farm ponds. During extreme droughts, the only reliable watering places for wildlife are the rivers and wells.

Water quality management problems will increase with expansion of quarrying operations in the watershed. Without proper control, powdered limestone and waste material would be subject to transportation downstream by storm runoff. Runoff and waste from future quarry developments should be carefully controlled for prevention of water pollution.

Surface drainage of agricultural land is not a problem and irrigation is of little significance.

PROJECTS OF OTHER AGENCIES

Comal County has constructed two floodwater retarding structures above the city of New Braunfels (figure 5). These structures were installed under agreement between the Comal County Commissioners Court and the Soil Conservation Service, as part of the overall plan for watershed protection and flood prevention for the Comal River watershed.

The entire construction cost was borne by the County. Detailed plans and specifications, inspection services, and assistance in foundation investigations were furnished by the Soil Conservation Service. These structures control a combined drainage area of 14.35 square miles and have a total sediment storage and floodwater detention capacity of 3,998 acre-feet.

The Corps of Engineers has prepared a plan to provide flood protection to the city of New Braunfels from floodwaters originating on Blieders Creek. The plan is presented in their "Review of Reports on Guadalupe and San Antonio Rivers, Texas Covering Blieders Creek Watershed", dated June 1958. Local sponsors did not choose to participate in the project. Advanced planning for construction was suspended in 1964.

The Comal River watershed is within the area served by the Guadalupe-Blanco River Authority which is charged by State law with water conservation powers. The Authority is jointly engaged with the Corps of Engineers in a flood control and water conservation project, Canyon Dam and Reservoir, on the Guadalupe River. It is located 17 miles upstream from New Braunfels and was completed in June 1964. Canyon Dam offers flood protection to that portion of New Braunfels subject to flooding by the Guadalupe River and reduces the backwater effect on Comal River caused by simultaneous peak flood flows on the Comal and Guadalupe Rivers.

The Edwards Underground Water District has authority in the watershed for protecting, conserving, and recharging the Edwards underground reservoir.

PROJECT FORMULATION

Residents in the Comal River watershed are vitally interested in seeking ways to reduce damaging floods on agricultural lands in the watershed and

in the portion of New Braunfels effected by storm runoff from Comal River and its tributaries.

Local interest in this project can be best illustrated by the fact that the people of Comal County, working through the County Commissioners Court and the Comal-Hays-Guadalupe Soil and Water Conservation District, have paid the total cost of constructing two floodwater retarding structures in the watershed.

Recognizing the need for further protection, representatives of the Comal County Commissioners Court, the city of New Braunfels, Comal-Hays-Guadalupe Soil and Water Conservation District, and the Soil Conservation Service made studies and held meetings to identify existing flood problems and reach agreement on water and land resource development needs. Watershed protection, flood prevention, and recreation were the primary objectives expressed by the sponsors.

The following specific objectives were agreed to:

1. Establish land treatment measures which would contribute directly to watershed protection and flood prevention and make the watershed an outstanding example of soil and water conservation. At least 75 percent of the land above structures would be adequately protected from erosion before construction would begin on any structural measure.

2. Attain a reduction of 60 to 70 percent in average annual damages in the agricultural reaches in the watershed.

3. Attain a reduction of 90 to 95 percent in average annual damages in New Braunfels with consideration given to the 100-year frequency storm.

4. Study the feasibility of including recreation in one of the structures.

Alternate systems of floodwater retarding structures were investigated in order to select the least costly system needed to provide the agreed upon level of protection. Topographic, geologic, and hydrologic conditions had considerable influence upon the size, number, design, and cost of structures included in the plan.

Because of high seepage losses in the Edwards Plateau, consideration of a structure to include recreation was confined to sites available in the Blackland Prairie Land Resource Area. There was only one site with a drainage area large enough to yield sufficient runoff to warrant a study of recreation feasibility. This site has a drainage area of 2.99 square miles and is located about one half mile south of Solms. After full consideration of the topographic features of the site, storage of water for recreational purposes was found to be infeasible. Nearly flat topography at the site results in a poor depth-surface area relationship. This site was not included in the work plan as a floodwater retarding structure because

of an excessive installation cost in comparison to the protection it would afford. The high cost was a result of a large embankment volume, inundation of a large area of valuable cropland, and poor choices of dam and emergency spillway layout.

The Rock site, located two miles northeast of Comal, was investigated as a possible floodwater retarding structure site, but was not included in the work plan. Construction of a floodwater retarding structure at this site would involve a high construction cost attributed to a large volume of rock excavation in the emergency spillway and long hauls required to obtain suitable embankment materials. For its drainage area (5.79 square miles), this site would provide little protection at a high cost per square mile of control.

Two other sites, located upstream from Site 2, were also considered as locations of floodwater retarding structures. The drainage areas of these two sites can be stored at a lower cost in Site 2, and the need for providing protection to the intervening flood plain is negligible.

WORKS OF IMPROVEMENT TO BE INSTALLED

Land Treatment Measures

Farmers and ranchers of the watershed are applying and maintaining basic soil and water conservation plans on their land with assistance from the Comal-Hays-Guadalupe Soil and Water Conservation District. These plans, which are essential to a sound program for watershed protection and flood prevention, are based on the use of each acre within its capabilities and its treatment in accordance with its needs. Needed land treatment measures have been applied to date at an estimated expenditure of $324,428 by landowners and operators (table 1A).

Increased application and maintenance of land treatment measures is particularly important for protection of the 74.58 square miles which comprise the drainage areas of constructed and planned structural measures. This treatment will reduce the capacities required for sediment accumulation and will retard runoff into the structures.

There are 55.4 square miles downstream from floodwater retarding structures that will continue to contribute sediment and runoff to flood plain areas. Land treatment on these lands will further reduce floodwater and sediment damages.

The acreage in each major land use, on which land treatment measures will be established during the five-year project installation period, is included in table 1. These measures will be established and maintained by landowners and operators in cooperation with the Comal-Hays-Guadalupe Soil and Water Conservation District.

It is expected that approximately 1,000 acres of steeply sloping cropland will be converted to pasture during the project installation period.

Deferred grazing on rangeland improves stand of Indiangrass. Results include reduced rates of runoff, reduced erosion, increased grazing capacity, and improved wildlife habitat.

Excellent stand of KR bluestem following range seeding.

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Cultivated land will be treated with a combination of measures in keeping with a conservation cropping system for soil conditioning and protection from erosion. Conservation cropping systems in this watershed include cover and green manure crops, crop residue use, and contour farming. Terraces will be installed to control erosion and retard runoff from the more rolling areas.

A good base cover of desirable forage plants will be attained by pasture and hayland planting and pasture and hayland management.

Proper grazing use and range seeding will be practiced to improve the quality of vegetation and to maintain adequate cover for soil protection. Rangeland with infestations of woody plants will be either bulldozed, root plowed, chained, or sprayed to control brush. Destruction of cover caused by over-use around present watering places will be reduced by establishing additional farm ponds.

Damage to land caused by rapid runoff from steeper areas will be reduced by construction of diversions.

Protection of existing wildlife habitat and additional food, cover, and water for wildlife will be provided through the practices of wildlife habiatat development, wildlife habitat preservation, and wildlife watering facilities.

Adequate soil surveys are necessary for development of soil and water conservation plans. Public Law 566 funds in the amount of $4,100 will be provided for accelerated completion of a soil survey of the watershed.

In addition to funds for soil surveying, $4,200 will be available from Public Law 566 funds for accelerated technical assistance in planning and applying land treatment. Public Law 566 funds are in addition to funds presently available for technical assistance.

Local people will continue to install and maintain measures needed in the watershed following the project installation period.

The application of land treatment planned for the installation period will reduce average annual erosion by about 20 percent and increase infiltration of rainfall as a result of improved ground cover in cultivated areas and increased grass density and vigor on pasture and rangeland.

Structural Measures

A system of 3 floodwater retarding structures will be constructed in the Comal River watershed. Figure 4 shows a section of a typical floodwater retarding structure. The locations of structural measures to be installed are shown on the Project Map (figure 5). These structures will provide flood protection to agricultural land in the flood plain in the Comal River watershed and to urban property in the city of New Braunfels.

All planned floodwater retarding structures will be located primarily on the outcrop of the Edwards and Georgetown limestones. These formations consist mainly of hard, massive to medium bedded limestone and dolomite.

The principal spillways will be on non-yielding foundations and will have monolithic rectangular, reinforced concrete inlets. Structures Nos. 2 and

3 will have prestressed, concrete lined, steel cylinder pipe outlets, and structure No. 1 will have a monolithic rectangular, reinforced concrete outlet.

The principal spillway capacities and floodwater detention storage in all planned structures provide a one percent chance of emergency spillway use.

Investigations of the geologic strata, faults, joints, and cavities within each floodwater retarding structure reservoir revealed that increased ground water recharge could be expected as a result of impoundment of water. As a result of studies made on existing floodwater retarding structures within and adjacent to this watershed, reservoir seepage losses were computed for each of the planned floodwater retarding structures.

These seepage losses were considered in determining the size of the principal spillway for each structure.

Emergency spillway excavation will yield large volumes of rock. This will make zoning of the embankments necessary. The central sections will consist primarily of weathered shale, and the outer sections will be limestone obtained from emergency spillway excavation. This outer shell of limestone elimates the need for vegetating the embankments and will reduce maintenance costs.

All structures are designed with sufficient capacities to provide 100-year project life. Because of the expected seepage losses in the pools of floodwater retarding structures, no portion of the sediment capacity is expected to store water. All planned structure pools are considered as dry.

The three planned floodwater retarding structures, in conjunction with the two existing floodwater retarding structures, will detain an average of 4.50 inches of runoff from 74.58 square miles of drainage area. The five structures will control runoff from 57 percent of the total watershed.

EXPLANATION OF INSTALLATION COSTS

The total project installation cost is estimated to be $1,426,535, including $200,676 for land treatment measures and $1,225,859 for structural measures. The share from sources other than Public Law 566 funds is estimated to be $398,176, and the Public Law 566 share is estimated to be $1,028,359 (table 1).

Included in the local share of project installation costs are $171,921 for landowners and operators expenses in applying land treatment measures (including anticipated reimbursement from Agricultural Conservation Program Service funds); $20,455 for technical assistance in planning and application of land treatment under the going Public Law 46 program; $204,300 for land, easements, and rights-of-way expenses; and $1,500 for administration of contracts.

Included in the Public Law 566 share of project installation costs are $8,300 for accelerated technical assistance, $850,238 for construction, $43,722 for engineering services of structural measures, and $126,099 for

project administration. The $8,300 for technical assistance includes $4,100 for completion of standard soil surveys and $4,200 for stepped up planning and applicstion of land treatment for watershed protection.

The cost of applying land treatment practices is based on present prices being paid by landowners and operators to establish the measures and was estimated by sponsoring local organizations.

The costs of land, easements, and rights-of-way were determined by appraisal in cooperation with representatives of the sponsoring local organizations. These costs consisting of land easements ($167,200), relocation or modification of utilities ($900), raising or relocating county road ($3,000), improving low water crossings ($32,000), and legal services ($1,200) are estimated to be $204,300.

Relocation and modification of existing improvements involve a power line and county road at Site No. 3 and twelve private, county, or city low water road crossings that will require modification in order to provide safe passage of release discharges from principal spillways of both planned and existing floodwater retarding structures.

Construction costs include the engineer's estimates and contingencies for constructing floodwater retarding structures. The engineer's estimates were based on unit costs of structural measures in similar areas modified by special conditions inherent to each individual site location. Included are such items as foundation conditions, special placement of embankment materials, rock excavation, borrow of embankment material outside the site area, and site preparation. Ten percent of the estimate was added as a contingency to provide funds for unpredictable construction costs.

Engineering Services Costs and Project Administration Costs were based on an analysis of previous work in similar areas. Engineering Costs consist of, but are not limited to, detail surveys, geologic investigations, laboratory reports, designs, and cartographic services. Public Law 566 Project Administration Costs consist of construction inspection and supervision, contract administration assistance, maintenance of State Office records and accounts, and Washington Office and E&WP Unit costs. The local costs for Project Administration include costs for contract administration, overhead and organizational administrative costs, and whatever construction inspection the sponsors desire to make at their own expense.

The following is the estimated schedule of obligations for the five-year installation period.

Schedule of Obligations

Fiscal Year	Measures	Public Law 566 Funds (dollars)	Other Funds (dollars)	Total (dollars)
First	Land Treatment	1,494	34,628	36,122
Second	Land Treatment	1,577	36,551	38,128
	Structure No. 3	148,523	49,900	198,423
Third	Land Treatment	1,660	38,475	40,135
	Structure No. 2	399,261	94,150	493,411
Fourth	Land Treatment	1,743	40,399	42,142
	Structure No. 1	472,275	61,750	534,025
Fifth	Land Treatment	1,826	42,323	44,149
	Total	1,028,359	398,176	1,426,535

This schedule may be changed from year to year to conform with appropriations, actual accomplishments, and any significant mutually desirable change.

EFFECTS OF WORKS OF IMPROVEMENT

After installation of the combined program of land treatment and structural measures described above, in conjunction with the two existing floodwater retarding structures, average annual flooding will be reduced from 2,769 acres to 1,117 acres, a reduction of 60 percent.

This project will benefit directly the owners and operators of approximately 50 farms and ranches in the agricultural land of the flood plain and the owners and occupants of about 100 residential and business units in New Braunfels.

Reduction in area inundated varies with respect to location within the watershed. The general locations of the areas to be benefited as a result of reduced flooding caused by the combined program of land treatment and structural measures are presented in the following tabulations:

Average Annual Area Inundated

Evaluation Reach	Location	Without Project (acres)	With Project (acres)	Reduction (percent)
1	Blieders Creek	95	20	79
2	Urban Area-City of New Braunfels	45	10	78
3	Dry Comal Creek	2,629	1,087	59
	Total	2,769	1,117	60

Evaluation Reach (Figure 5)	Area Inundated: Average Recurrence Interval: 2-Year: Without Project (acres)	2-Year: With Project (acres)	5-Year: Without Project (acres)	5-Year: With Project (acres)	25-Year: Without Project (acres)	25-Year: With Project (acres)	100-Year: Without Project (acres)	100-Year: With Project (acres)
1	79	8	110	40	178	65	247	78
2	14	0	82	14	202	59	340	101
3	1,053	494	1,535	748	1,949	1,277	2,239	1,493
Total	1,146	502	1,727	802	2,329	1,401	2,826	1,672

Figure 4 shows the urban area of New Braunfels that will be inundated by a 100-year frequency flood without and with project conditions. The proposed project will provide protection from the 100-year event to all urban properties except several homes located in the Guada Coma addition and several other isolated homes and tourist facilities. The number of homes that will be flooded from a 100-year frequency event will be reduced from 75 to 10. Flooding will be eliminated or very minor in all but 5 of the 43 business establishments, consisting primarily of tourist facilities, that would be flooded without the project. The average depth in the areas subject to continued flooding from the 100-year frequency flood is 3.5 feet. These properties are located at an extremely low elevation in relation to Comal River and Dry Comal Creek. With the proposed project installed, damages to these properties will still be experienced from floods exceeding those of an expected 8 to 10 year frequency.

Additional structural works of improvement were considered but were of minor significance in providing increased protection to these properties. It is not economically feasible to provide the 100-year level of flood protection for the Guada Coma area of New Braunfels.

The sponsors are aware of the limits of protection provided by the project. The New Braunfels City Council will notify property owners in the Guada Coma area of the flood hazards that still will remain after project installation, and will discourage further construction of improvements within the area still subject to damage.

Application of the planned land treatment program is expected to reduce annual gross erosion from 265,000 tons to 195,000 tons, a reduction of 26 percent. Annual flood plain scour damage on 89 acres is expected to be reduced about 56 percent. Five percent will be attributable to land treatment measures and 51 percent to structural measures.

Incidental water management benefits will result from installation of the three floodwater retarding structures. It is estimated that ground water recharge will be increased by an average of 2,100 acre-feet annually during the evaluation period. The additional recharge will take place naturally as seepage from detention and sediment pools of the structures. Under present conditions, uncontrolled flood discharges exceed the intake capacity of the limestone.

The effects of the works of improvement on fish and wildlife habitat are described by the Bureau of Sport Fisheries and Wildlife as follows:

> "With the project, land treatment measures such as conservation cropping systems, crop residue use, and pasture planting would be beneficial for some upland game. The stirring of soils would stimulate weed growth which would be beneficial to seedeating wildlife. Brush control and land clearing for floodwater retarding structures would remove some habitat for wildlife. Flood protection below the floodwater retarding structures would improve the habitat for ground-nesting species."

Analysis of information collected indicated that no significant changes would be made in the use of agricultural land within the flood plain, either in the form of restoration of former productivity or in more intensive use. Conditions other than frequency of flooding are responsible for the rather low intensity of agricultural use on much of the flood plain.

No bottomland will be involved in the pool areas of planned structures. A total of 265 acres of upland in sediment pools, dams, and emergency spillways will be retired from agricultural production. Only 13 acres of this is presently in cultivation.

Secondary benefits, including increased business activity and improved economic conditions in the surrounding communities, will result from the installation of the complete project for flood prevention. The operation and maintenance of the project measures will provide some employment opportunities for local residents. In addition, there are intangible benefits such as the increased sense of security, better living conditions, and improved wildlife habitat.

PROJECT BENEFITS

The estimated average annual monetary floodwater, erosion, and indirect damages (table 5) within the watershed will be reduced from $105,142 to $11,175 by the proposed project, including structural measures installed by Comal County. This is a reduction of 89 percent, 94 percent of which will result from installation of the structural measures.

Benefits to landowners and operators from the planned land treatment measures were not evaluated in monetary terms since experience has shown that conservation practices produce benefits in excess of their costs.

Reductions in monetary flood damages vary with respect to locations within the watershed. The following tabulations show the general locations of damage reduction benefits attributed to the combined program of land treatment and structural measures included in this plan and the structural measures already installed by Comal County.

Average Annual Damage

Evaluation: Reach	Location	Without Project (dollars)	With Project (dollars)	Reduction (percent)
1	Blieders Creek - Above New Braunfels	230	23	90
2	Urban Area - City of New Braunfels	90,247	5,527	94
3	Dry Comal Creek - Above New Braunfels	14,665	5,625	62
	Total	105,142	11,175	89

Direct Monetary Floodwater Damage

Evaluation: Reach (Figure 1)	Average Recurrence Interval: 2-Year Without Project (dollars)	2-Year With Project (dollars)	10-Year Without Project (dollars)	10-Year With Project (dollars)	25-Year Without Project (dollars)	25-Year With Project (dollars)	100-Year Without Project (dollars)	100-Year With Project (dollars)
1	174	3	345	75	421	95	585	150
2	1,900	0	140,100	5,400	306,500	24,275	946,894	76,250
3	6,845	3,063	13,140	6,360	15,884	8,101	18,967	10,937
Total	8,919	3,066	153,585	11,835	322,805	32,471	966,446	87,337

The monetary value of the incidental ground water recharge is estimated to be $25,200.

It is estimated that the project will produce local secondary benefits, which excludes indirect benefits in any form, averaging $9,092 annually. Secondary benefits from a national viewpoint were not considered pertinent to the economic evaluation.

Comal and Guadalupe Counties have not been designated as areas eligible for assistance under the Economic Development Act. Consequently, no redevelopment benefits were considered.

COMPARISON OF BENEFITS AND COSTS

The total average annual cost of structural measures (amortized total installation and project administration cost, plus operation and maintenance) is $42,183. These measures are expected to produce average annual benefits, excluding secondary benefits, of $103,493, resulting in a benefit-cost ratio of 2.5:1.0.

The ratio of total average annual project benefits, including secondary benefits, accruing to structural measures ($112,585) to the average annual cost of structural measures ($42,183) is 2.7:1.0 (table 6).

PROJECT INSTALLATION

Landowners and operators will establish planned land treatment (table 1) in cooperation with the Comal-Hays-Guadalupe Soil and Water Conservation District during a five-year period. Technical assistance in planning and application of land treatment is provided under the going program of the district. A soil survey is in progress and has been completed on 6,000 acres.

Approximately 50 percent of the agricultural land is adequately treated with practices properly maintained. The goal is to increase the level of land adequately treated to 80 percent or greater during the installation period.

In reaching this goal, it is expected that accomplishments of additional adequate treatment will progress as shown in the following tabulation:

Land Use	Fiscal Year					Total
	1st	2nd	3rd	4th	5th	
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Cropland	500	500	500	500	500	2,500
Pasture	700	700	760	800	800	3,760
Rangeland	4,700	4,700	4,880	4,880	4,874	24,034
Wildlife and Recreation	60	60	60	60	60	300
Total	5,960	5,960	6,200	6,240	6,234	30,594

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The governing body of the Comal-Hays-Guadalupe Soil and Water Conservation District will assume agressive leadership in getting an accelerated land treatment program underway. Landowners and operators will be encouraged to apply and maintain soil and water conservation measures on their farms and ranches. District owned equipment will be made available to landowners in accordance with existing agreements for equipment usage in the district. The Soil Conservation Service will provide technical assistance in accelerating completion of the soil survey and the planning and application of soil, plant, and water conservation measures.

Special emphasis will first be placed on getting a higher degree of land treatment in the drainage areas of floodwater retarding structures. Then the emphasis will be on land outside drainage areas of structures.

The Extension Service will assist with the educational phase of the program by providing information to landowners and operators in the watershed.

The Comal County Commissioners Court and the city of New Braunfels have the right of eminent domain under applicable State law and have the financial resources to fulfill their responsibilities.

The Comal County Commissioners Court will have the following responsibilities pertaining to the three planned floodwater retarding structures.

1. Obtain the necessary land, easements, rights-of-way, and permits;

2. Provide for the relocation or modification of utility lines, roads, and privately owned improvements necessary for installation of structural measures;

3. Provide for the necessary improvement of low water crossings on public and private roads to make them passable during prolonged release flows from structures or obtain permission to inundate such roads where equal alternate routes are designated for use during periods of inundation;

4. Provide the necessary legal, administrative, and clerical personnel, facilities, supplies, and equipment to advertise, award, and administer contracts;

5. Determine legal adequacy of easements and permits for construction of the structural measures; and

6. Be the contracting agency to let and service contracts.

Technical assistance will be provided by the Soil Conservation Service in preparation of plans and specifications, construction inspection, preparation of contract payment estimates, final inspection, execution of certificate of completion, and related tasks necessary to install planned structural measures.

The three floodwater retarding structures will be constructed during the second, third, and fourth years of a five-year project installation period in the general sequence as follows:

Second Year - Floodwater Retarding Structure No. 3
Third Year - Floodwater Retarding Structure No. 2
Fourth Year - Floodwater Retarding Structure No. 1

The Comal County Commissioners Court will obtain necessary land, easements, rights-of-way, and permits. In order for construction to proceed according to schedule, all land, easements, rights-of-way, and permits for floodwater retarding structures are to be completely secured during the time periods as shown in the following tabulation. The time period will begin when the work plan is approved for operations.

Time Period	Floodwater Retarding Structures
First six months	No. 3
Third six months	No. 2
Fifth six months	No. 1

FINANCING PROJECT INSTALLATION

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

The cost of applying land treatment measures will be borne by landowners and operators. Public Law 566 funds will be used for technical assistance in accelerating the planning and application of soil and water conservation measures.

In 1958, residents of Comal County approved a $250,000 bond issue for flood control work. An ad valorem tax, at the rate of $0.15 per $100 valuation, is presently being collected. The Commissioners Court of Comal County has analyzed its financial needs in consideration of the scheduled works of improvement and is willing and able to carry out its responsibilities.

It is anticipated that approximately 50 percent of the easements for structural measures will be donated. Out-of-pocket costs for land, easements, rights-of-way, legal expenses, and contracts is estimated to be $122,000.

The sponsoring local organizations do not plan to use the loan provisions of the Act.

Structural measures will be constructed in a three-year period within the five-year project installation period pursuant to the following conditions:

1. Requirements for land treatment in drainage areas of floodwater retarding structures have been satisfied.

2. All lands, easements, rights-of-way, and permits have been obtained for all structural measures, or a written statement is furnished by the Comal County Commissioners Court that its right of eminent domain will be used, if needed, to secure any remaining land, easements, or rights-of-way within the agreed upon schedule by six months periods and that sufficient funds are available for this purpose.

3. Provisions have been made for improving low water crossings or bridges and/or culverts on public roads, or court orders, or necessary permits obtained granting permission to temporarily inundate the crossings, providing equal alternate routes are available for use by all people concerned, during periods when these crossings are impassable due to prolonged flow from principal spillways of floodwater retarding structures. If equal alternate routes are not available, provisions will be made, at no cost to the Federal Government, to make the crossings passable during prolonged periods of release flows from structures.

4. Utilities, such as power lines, telephone lines, and pipelines, have been relocated or permission has been obtained to inundate the properties involved.

5. The contracting agency is prepared to discharge its responsibilities.

6. Project agreements have been executed.

7. Operation and maintenance agreements have been executed.

8. Public Law 566 funds are available.

Various features of cooperation between the cooperating parties have been covered in appropriate memorandums of understanding and working agreements.

The soil and water conservation loan program sponsored by the Farmers Home Administration is available to eligible farmers in the area.

Educational meetings will be held in cooperation with other agencies to outline available services and eligibility requirements. Present FHA clients will be encouraged to cooperate in the program.

The County Agricultural Stabilization and Conservation committees will cooperate with the governing body of the soil and water conservation district by continuing to provide financial assistance for selected conservation practices.

PROVISIONS FOR OPERATION AND MAINTENANCE

Land Treatment Measures

Land treatment measures will be maintained by landowners and operators of farms on which measures are applied under agreement with the Comal-Hays-Guadalupe Soil and Water Conservation District. Representatives of the district will make periodic inspections of land treatment measures to determine maintenance needs and encourage landowners and operators to perform maintenance. They will make district-owned equipment available for this purpose in accordance with existing working arrangements.

Structural Measures

The Comal County Commissioners Court will be responsible for maintenance of the three floodwater retarding structures. The estimated annual operation and maintenance cost is $650 for the three structural measures.

Specific operation and maintenance agreements will be executed prior to the issuance of invitation to bid on construction of any of the structural works of improvement.

Structural measures will be inspected at least annually and after each heavy rain by representatives of Comal County Commissioners Court and Comal-Hays-Guadalupe Soil and Water Conservation District. A Soil Conservation Service representative will participate in these inspections for a period of at least three years following construction. The Soil Conservation Service will participate in annual inspections as often as it elects to do so after the third year. Items of inspection will include, but will not be limited to, conditions of principal spillways and their appurtenances, emergency spillways, earth fills, and vegetative growth in the reservoirs. The items of inspection are those most likely to require maintenance.

Maintenance of structural measures will be performed promptly as the need arises. Possible items of maintenance include (1) removal of any obstructions which may adversely affect functioning of the principal and emergency spillways, (2) repair of areas of embankments or emergency spillways damaged by erosion to conform to the original design, (3) removal of undesirable vegetation or debris from reservoirs and embankments, and (4) repair to areas of seepage through embankments and foundations or adjacent to principal spillways which threaten the stability of the structures.

The Soil Conservation Service will assist in operation and maintenance only to the extent of furnishing technical guidance.

Provisions will be made for unrestricted access of representatives of sponsoring local organizations and the Federal Government to inspect all structural measures and their appurtenances at any time and for sponsoring local organizations to operate and maintain them.

The Comal County Commissioners Court will maintain a record of all maintenance inspections made and maintenance performed and have it available for inspection by Soil Conservation Service personnel.

The necessary maintenance work will be accomplished either by contract, force account, or equipment owned by sponsoring local organizations.

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TABLE 1 - ESTIMATED PROJECT INSTALLATION COST

Comal River Watershed, Texas

Installation Cost Item	Unit	Number Non-Federal Land	Estimated Cost (Dollars) 1/ Public Law 566 Funds Non-Federal Land	Other Non-Federal Land	Total
LAND TREATMENT					
Soil Conservstion Service					
Cropland	Acre	2,500	-	22,450	22,450
Pasture	Acre	3,760	-	64,600	64,600
Rangeland	Acre	24,034	-	81,571	81,571
Wildlife-Recreation Land	Acre	300	-	3,300	3,300
Technical Assistance			8,300	20,455	28,755
TOTAL LAND TREATMENT			8,300	192,376	200,676
STRUCTURAL MEASURES					
Construction					
Soil Conservation Service					
Floodwater Retarding Structures	No.	3	850,238	-	850,238
Subtotal - Construction			850,238	-	850,238
Engineering Services					
Soil Conservation Service			43,722	-	43,722
Subtotal - Engineering Services			43,722	-	43,722
Project Administration					
Soil Conservation Service					
Construction Inspection			53,434	-	53,434
Other			72,665	1,500	74,165
Subtotal - Adminiatration			126,099	1,500	127,599
Other Costs					
Land Rights			-	204,300	204,300
Subtotal - Other			-	204,300	204,300
TOTAL STRUCTURAL MEASURES			1,020,059	205,800	1,225,859
TOTAL PROJECT			1,028,359	398,176	1,426,535

1/ Price Base: 1967

August 1968

TABLE 1A - STATUS OF WATERSHED WORKS OF IMPROVEMENT
(at time of work plan preparation)

Comal River Watershed, Texas

Measures	Unit	Number Applied To Date	Total Cost (Dollars) 1/
LAND TREATMENT			
Conservation Cropping System	acre	2,800	11,200
Crop Residue Use	acre	4,200	6,300
Grassed Waterway or Outlet	acre	55	6,875
Contour Farming	acre	1,300	1,950
Terrace	foot	295,000	20,650
Pasture and Hayland Management	acre	1,000	5,000
Pasture and Hayland Planting	acre	1,170	29,250
Diversion	foot	32,200	5,796
Farm Pond	no.	54	32,400
Proper Grazing Use	acre	32,668	49,002
Range Seeding	acre	680	5,440
Brush and Weed Control	acre	10,000	150,000
Wildlife Habitat Development	acre	50	500
Wildlife Habitat Preservation	acre	65	65
TOTAL LAND TREATMENT			324,428
STRUCTURAL MEASURES			
Floodwater Retarding Structures	no.	2	258,800
TOTAL STRUCTURAL MEASURES			258,800
TOTAL			583,228

1/ Price Base: 1967 for land treatment and actual costs for structural measures.

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TABLE 2 - ESTIMATED STRUCTURAL COST DISTRIBUTION

Comal River Watershed, Texas

(Dollars) 1/

Item	Installation Cost P. L. 566 Funds			Installation Cost Other Funds		Total Installation Cost
	Construction	Engineering	Total P. L. 566	Land Rights	Total Other	
Floodwater Retarding Structures						
No. 1	395,164	19,758	414,922	61,250	61,250	476,172
No. 2	334,071	16,704	350,775	93,650	93,650	444,425
No. 3	121,003	7,260	128,263	49,400	49,400	177,663
Subtotal	850,238	43,722	893,960	204,300	204,300	1,098,260
Project Administration			126,099 2/		1,500 3/	127,599
GRAND TOTAL	850,238	43,722	1,020,059	204,300	205,800	1,225,859

1/ Price Base: 1967

2/ Includes $53,434 for construction inspection.

3/ Contract administration.

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TABLE 3 - STRUCTURE DATA - FLOODWATER RETARDING STRUCTURES

Comal River Watershed, Texas

Item	Unit	Structure Number 1	2	3	Total
Class of Structure		C	C	C	xxx
Drainage Area	Sq.Mi.	18.52	30.15	11.56	60.23
Curve No. (1-day)(AMC II)		76	77	77	xxx
T_c	Hrs.	2.00	3.52	1.10	xxx
Elevation Top of Dam	Ft.	919.7	865.2	783.6	xxx
Elevation Crest Emergency Spillway	Ft.	904.5	848.8	773.2	xxx
Elevation Crest Principal Spillway	Ft.	863.9	807.0	743.2	xxx
Elevation Crest Lowest Ungated Outlet	Ft.	863.9	807.0	743.2	xxx
Maximum Height of Dam	Ft.	70	71	58	xxx
Volume of Fill	Cu.Yd.	518,900	598,400	189,150	1,306,450
Total Capacity	Ac.Ft.	3,793	7,878	3,422	15,093
Sediment Pool(Lowest Ungated Outlet) 1/	Ac.Ft.	79	177	111	367
Sediment Aerated 1st 50 years	Ac.Ft.	79	177	111	367
Sediment Aerated 2nd 50 years	Ac.Ft.	79	177	111	367
Sediment in Detention Pool - Aerated	Ac.Ft.	20	48	25	93
Retarding Pool	Ac.Ft.	3,615	7,476	3,175	14,266
Surface Area					
Sediment Pool(Lowest Ungated Outlet)	Acres	18	32	19	69
Sediment Pool Principal Spillway Crest	Acres	18	32	19	69
Retarding Pool	Acres	218	465	255	938
Principal Spillway					
Rainfall Volume (areal)(1-day)	In.	9.53	9.60	9.93	xxx
Rainfall Volume (areal)(10-day)	In.	15.79	15.70	15.97	xxx
Runoff Volume (10-day)	In.	7.82	7.60	8.08	xxx
Capacity (Maximum)	cfs	1,050 2/	224 2/	83 2/	xxx
Frequency Operation - Emergency Spillway	% chance	1	1	1	xxx
Size of Conduit	In.	66x66	36	24	xxx
Emergency Spillway					
Rainfall Volume (ESH)(areal)	In.	12.91	12.31	13.39	xxx
Runoff Volume (ESH)	In.	9.77	9.33	10.36	xxx
Type		Rock	Rock	Rock	xxx
Bottom Widrh	Ft.	400	325	600	xxx
Velocity of Flow (V_e)	Ft./Sec.	7.6	7.8	4.9	xxx
Slope of Exit Channel	Ft./Ft.	.0534	.0310	.0400	xxx
Maximum Water Surface Elevation	Ft.	911.2	855.3	777.1	xxx
Freeboard					
Rainfall Volume (FH)(areal)	In.	29.92	28.55	31.05	xxx
Runoff Volume (FH)	In.	26.43	25.25	27.73	xxx
Maximum Water Surface Elevation	Ft.	919.7	865.2	783.6	xxx
Capacity Equivalents					
Sediment Volume	In.	0.18	0.25	0.40	xxx
Retarding Volume	In.	3.67	4.65	5.15	xxx

1/ Volume included in aerated sediment 1st 50 years.

2/ In addition to principal spillway capacity, seepage losses were considered in determining minimum detention storage.

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TABLE 4 - ANNUAL COST

Comal River Watershed, Texas

(Dollars) 1/

Evaluation Unit	Amortization of Installation Cost 2/	Operation and Maintenance Cost	Total
Floodwater Retarding Structures Numbers 1, 2, and 3	37,209	650	37,859
Project Administration			4,324
GRAND TOTAL	37,209	650	42,183

1/ Price Base: Installation - 1967, O&M - Adjusted normalized prices, April 1966.

2/ 100-years at 3.25 percent interest.

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TABLE 5 - ESTIMATED AVERAGE ANNUAL FLOOD DAMAGE REDUCTION BENEFITS

Comal River Watershed, Texas

(Dollars) 1/

Item	Estimated Average Annual Damage: Without Project	Estimated Average Annual Damage: With Project	Damage Reduction Benefits
Floodwater			
Crop and Pasture	4,984	2,085	2,899
Other Agricultural	6,125	2,026	4,099
Nonagricultural			
Road and Bridge	2,383	1,002	1,381
Urban	75,206	4,606	70,599
Subtotal	88,698	9,719	78,978
Erosion			
Flood Plain Scour	49	22	27
Indirect	16,395	1,434	14,961
TOTAL	105,142	11,175	93,966 2/

1/ Price Base: Adjusted normalized prices, April 1966.

2/ Includes damage reductions attributed to floodwater retarding structures installed by Comal County.

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TABLE 6 - COMPARISON OF BENEFITS AND COSTS FOR STRUCTURAL MEASURES

Comal River Watershed, Texas
(Dollars)

Evaluation Unit	AVERAGE ANNUAL BENEFITS 1/				Average Annual Cost 2/	Benefit Cost Ratio
	Flood Prevention					
	Damage Reduction	Incidental Ground Water Recharge	Secondary	Total		
Floodwater Retarding Structures Nos. 1, 2, and 3	78,293	25,200	9,092	112,585	37,859	3.0:1.0
Project Administration					4,324	
GRAND TOTAL	78,293 3/	25,200	9,092	112,585	42,183	2.7:1.0

1/ Price Base: Adjusted normalized prices, April 1966.

2/ From Table 4.

3/ In addition, it is estimated that land treatment measures will provide flood damage reduction benefits of $5,221 annually.

4/ Additional benefits in the amount of $11,338 ($10,452 from damage reduction and $886 from secondary sources) are allocated to floodwater retarding structures already installed.

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INVESTIGATIONS AND ANALYSES

Land Use and Treatment

The status of land treatment for the watershed was developed by the Comal-Hays-Guadalupe Soil and Water Conservation District assisted by personnel from the Soil Conservation Service at New Braunfels, Texas. Conservation needs data were compiled from existing conservation plans within the watershed and expanded to represent conservation needs of the entire watershed. The quantity of each land treatment practice, or combination of practices, necessary for essential conservation treatment was estimated for each land use by capability class. Acres, by land use, to be treated during the project installation period were estimated (table 1). Hydraulic, hydrologic, sedimentation, and economic investigations provided data as to the effects of land treatment measures in terms of reduction of flood damage. Although measurable benefits would result from application of planned land treatment measures, it was apparent that other flood prevention measures would be required to attain the degree of watershed protection and flood damage reduction desired by local people.

Hydrologic soil and cover conditions were determined by detailed mapping of an 18 percent sample of the watershed.

Present hydrologic cover conditions for rangeland and pasture were determined on the basis of the percentage of desirable vegetative ground cover and litter. On cropland, present hydrologic cover conditions were determined after consultation with local Soil Conservation Service personnel concerning crops grown and rotations followed.

Future hydrologic cover conditions were estimated on the basis of the expected percentage of needed land treatment to be applied during the installation period and the probable effectiveness of the application.

Hydrology

Basic meteorologic and hydrologic data were tabulated from U. S. Weather Bureau Climatological Bulletins for the rainfall gage at New Braunfels, Texas, and from U. S. Geological Survey surface water records. These data were analyzed to determine seasonal distribution of precipitation, rainfall-runoff relationships, and monthly runoff volumes.

The present average condition II hydrologic soil-cover complex curve number (rainfall-runoff relationship) for the watershed was determined to be 79. With project conditions, with the land treatment and structures installed, the average condition II curve number will be 78.

Cross section rating curves and stage-area inundated curves were developed from field surveys of valley cross sections, by water surface profiles, and by using the computer service at the South Regional Technical Service Center.

Present and project condition runoff discharge relationships were determined by flood routing the 2, 5, 25, and 100 year, 24-hour duration, storm runoff.

Present and project condition peak dischsrges were determined from these routings.

Project formulation, hydrology, was accomplished by use of Technical Release 20 procedures.

Determinations were made of the agricultural area that would be inundated by storms of the frequency series for the following conditions: without project, with land treatment measures for watershed protection installed, and with land treatment and structural measures installed.

Calculations of urban damages within the city of New Braunfels were made in the following manner:

a. Percent chance storms versus discharge (cfs) were plotted for present and project conditions.

b. Percent chance storms versus depth of flooding were plotted at representative sections for present and project conditions.

Maximum release rates for principal spillways of the three floodwater retarding structures were designed to empty the detention pool volume in 10 days after inflow ceases, with consideration given to seepage losses from the pools into the Edwards limestone. All structures were designed to store the 100-year frequency storm runoff.

The appropriate emergency spillway and freeboard design storms were selected in accordance with criteria contained in NEH, Section 4-Hydrology, Part I - Watershed Planning, Chapter 21.

Engineering

Studies were made in both the agricultural and urban areas to locate and define flood damaged properties. These damaged areas were separated into evaluation reaches, making it possible to plan a system of structural measures which would reduce the damages to an acceptable level.

Because of the poor water holding potential of soils and bedrock in the Edwards Plateau, only sites located in the Blackland Prairie were given consideration as possible multiple-purpose structures.

Six floodwater retarding structures were investigated. These investigations provided valuable information for comparison of alternate combinations of control, benefits, and construction costs.

The following describes several alternate combinations of structural works of improvement that were analyzed.

East Prong of Dry Comal Creek

Two possible floodwater retarding structure sites were investigated. One site location was approximately 1-1/4 miles upstream from Farm-to-Market Road 1863 and was in

series with Site No. 2. Because of extensive rock excavation and the lack of on site borrow material suitable for use in the central section of the embankment, the site was not considered feasible for construction. Site No. 2 could be constructed to control the entire drainage area above it at less cost than that for the two sites in series.

Unnamed Tributary to Dry Comal Creek (Rock Site)

A detailed investigation was made on an unnamed tributary approximately 2 miles west of Dittlinger and one-half mile upstream from the Missouri Pacific Railroad. This site had a drainage area of 5.79 square miles. Because of extensive rock excavation in the emergency spillway, poor reservoir storage characteristics, and long hauls required to obtain suitable embankment material this structure proved to be too costly for the degree of protection it would afford. The sponsors decided not to include this structure in the work plan.

Solms Site

This was the only site investigated that had reliable water storage characteristics and could be considered as a multiple-purpose site with recreation as one of the purposes. Poor storage characteristics, limiting topographic features, intensive cropland within the pool area, and high installation cost made this site questionable. Also, the degree of protection the structure would afford when compared with the total project, was of minor significance. The sponsors decided not to include this structure in the work plan.

Three floodwater retarding structures were selected for inclusion in the final work plan. Their locations are shown on Figure 5.

All floodwater retarding structures were classified as "c" because of their proximity to the city of New Braunfels.

All structures were designed to provide capacities for both the expected 100-year sediment accumulation and the runoff from the one percent chance storm.

Minor grouting of voids in limestone foundations and sloping of rock bluffs may be required to insure stability of embankments.

All structures were designed in accordance with Washington Engineering Memorandum-27(Rev.) and Texas Engineering-Hydrology Memoranda TX-1 and TX-2. All planned structures meet or exceed the minimum design criteria of the Washington and Texas Memoranda.

All State laws have been complied with in the design of these structures.

Geology

Soils and Foundations

Preliminary geologic investigations were made at each of the floodwater retarding structure sites to obtain information on the nature and extent of embankment and foundation materials, types of materials in emergency spillway excavation, emergency spillway stability, and other problems that might be encountered during construction. These investigations included surface observations of valley slopes, alluvium, channel banks, and exposed geologic formations; hand auger borings; core drill borings; and hand portable seismograph tests. Geologic maps and reports pertaining to the watershed vicinity were studied.

Findings of these investigations were used in making cost estimates of structures and to assure that sites selected are feasible for construction.

All planned floodwater retarding structures will be located primarily on the outcrop of the Edwards and Georgetown limestones within the Balcones fault zone on the deeply disected eastern edge of the Edwards Plateau.

The Edwards and Georgetown formations consist mainly of hard, massive to medium bedded limestone and dolomite containing many solutional cavities.

Alluvial deposits are very minor, both in depth and areal extent. They occur as narrow strips along streams and consist of beds and lenses of silty clay, gravel, cobbles, and boulders.

Abutments are generally characterized by thin soils underlain by the Edwards and Georgetown limestones. Limestone is exposed on considerable portions of abutments. Much of the left abutment of Site 2, however, consists of clay soil underlain by weathered calcareous shale of the Grayson formation. This condition is the result of a small graben which has brought the Grayson shale downward into lateral contact with the Georgetown and Edwards limestones. Sloping of limestones along the faults will be needed on this abutment.

Embankment materials are scare. In order to obtain sufficient volumes within economical haul distances, weathered shales from the Grayson formation must be utilized. Outcrops of the shale occupy topographic highs with protective caps of Buda limestone. These borrow sources are separate from dam and pool areas.

Zoning of embankments will be necessary. Central sections will consist primarily of weathered shale, and outer sections will be limestone from emergency spillway excavation. Some selective placement of the shale may be required because of high gypsum content.

Preliminary estimates of rock excavation in emergency spillways are 93,000 cubic yards at Site 1; 76,700 cubic ysrds at Site 2; and 30,500 cubic yards at Site 3.

Detailed investigations, including exploration with core drilling equipment, will be made at all sites prior to final design. Laboratory tests will be made to determine suitability and methods of handling foundation and embankment materials.

Ground Water

An investigation was made to determine the effect the project would have on ground water resources of the area.

Pertinent information was gathered from recent United States Geological Survey publications concerning ground water in the vicinity of Comal River watershed. Field studies included mapping of surface geologic strata.

The watershed lies within the Balcones fault zone. The Edwards and associated limestones, the principal ground water reservoir of the area, underlie most of the watershed (figure 3). The reservoir extends along the Balcones fault zone in parts of Kinney, Uvalde, Medina, Bexar, Comal, and Hays Counties.

Numerous joints, fractures, and solutional channels in the limestones permit rapid infiltration into the ground water reservoir. Since the limestones are not homogeneous, the transmissibility varies. The size of openings ranges from caverns, through which the water moves freely, to minute solutional cavities and cracks where large head losses occur.

In the Comal River watershed, the greater volume of ground water in the reservoir evidently moves toward the northeast along inter-connected solutional cavities, which have formed along fractures associated with and parallel to faults. Principal natural discharge points are Comal and San Marcos Springs. Toward the southeast, water in the Edwards and associated limestones is highly mineralized, suggesting very little sub-surface movement in that direction.

During periods of low rainfall, annual well discharge exceeds annual spring flow. Although the aquifer is easily recharged by surface runoff and pronounced fluctuations in water levels occur, average storage in the reservoir is declining. During the period 1934-1964, the estimated average annual recharge has been less than average annual discharge.

Investigations of geologic strata, faults, joints, and cavities at floodwater retarding structure sites revealed that increased ground water recharge could be expected as a result of water impoundment and sustained release flows.

U. S. Geological Survey studies, as reported in "Ground-Water Resources of the San Antonio Area, Texas", Texas Board of Water Engineers, Bulletin 5608, Volume I, July 1956, provided a basis for estimating the effect of the project on ground water recharge. This bulletin indicates that of the average annual runoff which would occur in the Comal River watershed if there were no large losses, approximately 80 percent enters the ground water reservoir. Based on computed runoff and streamflow measurements in the area, it is estimated that an average of 24,800 acre-feet are presently being recharged annually.

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The recharge potential of floodwater retarding structures on the Edwards limestone has been demonstrated by four existing structures in the immediate vicinity of planned structures. These are structures Nos. 4 and 5 on Comal River watershed and structures Nos. 1 and 2 on York Creek watershed. During work plan development the recharge characteristics of these structures were studied. The pools become empty quickly, even after heavy inflow.

No measures are included in the work plan for ground water recharge. However, the installation of floodwater retarding structures is expected to have the incidental effect of increasing ground water recharge by an average of at least 2,100 acre-feet annually.

Sedimentation

Sedimentation investigations were made in accordance with procedures as outlined in "Guide to Sedimentation Investigations", South Regional Technical Service Area, U. S. Department of Agriculture, Soil Conservation Service, March 1965.

Determinations of 100-year sediment storage requirements for the floodwater retarding structures were made according to the following procedure:

Detailed studies were made within sample areas selected to represent each of three groups of geologic formations exposed in structure site drainage areas. The formations were grouped according to similarities in sediment producing characteristics. The groups are (1) Buda and Grayson formations; (2) Georgetown, Edwards, and Comanche Peak formations; and (3) Glen Rose formation (figure 3). Average annual sheet erosion rates, for both present and future conditions, were computed for each land use within each group of formations. The soil loss equation by Musgrave was used. Estimates of average annual sheet erosion within drainage areas of structure sites were based on the appropriate erosion rates applied to the area of each corresponding land use by geologic outcrop.

Computations of gully and streambank erosion were based on estimated lateral bank erosion rates, bank heights, and channel lengths affected by erosion.

Sediment delivery ratios and trap efficiency adjustments were applied to computed average annual total erosion to arrive at estimates of sediment volumes to be deposited in reservoirs.

Because of the expected high seepage losses in pools of floodwater retarding structures, all sediment was computed as aerated. Therefore, no allowance was made for differences in density between soil in place and sediment.

Allocation of sediment to the pools of floodwater retarding structures was based on sediment texture and reservoir topography. The allocation was 90 percent in sediment and sediment reserve pools and 10 percent in detention pools.

Investigations were made to determine the nature and extent of physical damage to flood plain lands. The cross-section method was used in accordance with prescribed procedures.

The eatimated reduction of scour damage due to installation of the project was based on reduction of depth and area inundated by floodwater.

Economics

Basic methods used in the economic investigations and analyses are outlined in the "Economics Guide for Watershed Protection and Flood Prevention", U. S. Department of Agriculture, Soil Conservation Service, March 1964.

Because of the diversity of damageable values and flood plain characteristics, the flood plain was divided into three evaluation reaches (figure 5). Of these, one was in the urban area of New Braunfels.

Determination of Nonagricultural Damages

Because the major floodwater damages in this watershed are to nonagricultural property, the snythetic frequency method of analysis waa used. Information was collected in the field on damages experienced from the flood of September 1952 and from several other minor floods. At the same time an evaluation was made of the damages that would occur from a flood which could be expected on an average of once in 100 years. Under without project conditions, a flood of this magnitude would result in high water elevations in New Braunfels of approximately 10.5 feet higher than the high water elevations recorded in 1952 along Dry Comal Creek and from 1.8 feet to 4.4 feet higher than experienced in 1952 along Blieders Creek. High water marks from the experienced floods were used to determine peak stages which in turn were related to stages calculated for the synthetic series. Stage damage curves were developed to cover the range of damage producing floods. Average annual damages under the present state of development were calculated for each evaluation reach.

The field investigations indicated that the value of urban residences and business property in the flood plain had increased approximately 3 percent per year for the past 10 years. Some areas remain where flooding is relatively infrequent that will be developed even in the absence of a project. Field studies indicate that some new development is constantly taking place and that damageable values are continuing to increase due to a general improvement in the standard of living of residents in the area and the gradual economic growth of the business community.

It is considered that this type of development, plus the normal improvements to developments already in existence, would cause the existing urban values to double during the first 50-years of the project life and to remain at this level for the remainder of the 100-year project life. Therefore, damage to the existing development was increased by 48.60 percent to reflect the gradual accrual of these values discounted to present worth.

Because a high percent of the damage by the larger floods is to businesses, including the loss of use of recreational facilities, indirect damages associated with urban flooding will bear a higher than normal relationship to the direct damage. Expenses associated with dislocation of residents and rehabilitation of businesses will be extremely high. For this reason, it is estimated that indirect damages to urban property would be about one-fifth of the direct damage.

Estimates of damages to roads, bridges, and railroads in the flood plain were obtained from county commissioners, state highway officials, railroad officials, and supplemented by information from local residents.

Determination of Agricultural Damages

Agricultural damage calculations were based on information obtained in interviews with owners and operators of approximately 40 percent of the acreage of the flood plain. Schedules covered flooding and flood damage; past, present, and intended future use; and yield data. Verification of information gained by interviews in the field was obtained from local agricultural technicians.

The synthetic frequency method of analysis of damages was used, and the occurrence of more than one flood in a growing season was considered in determining crop and pasture damage. The computed damages were discounted for the recurrence with allowance for partial recovery of crops between floods.

Other agricultural damages to fences and farm roads, livestock losses, and the cost of removing debris from fields were estimated from information collected in the field and correlated with area and depth of flooding.

Monetary damages to the flood plain from scour were based on the value of production losses. Scour damage reductions were related to the area of flooding, and influenced by the increased scouring effect from deeper flows.

Indirect damages involve such items as additional travel time for farmers in transporting products and farm equipment, cost of extra feed for livestock, loss of benefits from grazing, and other related items. It was estimated that indirect damage to agricultural property would approximate 10 percent of the direct damage.

Incidental Benefits from Ground Water Recharge

Ground water recharge will occur incidental to the installation of floodwater retarding structures Nos. 1, 2, and 3. Flood prevention was the only purpose considered in the location and design of these structures. No additional costs are involved in obtaining recharge as it takes place naturally as seepage. When the structures are installed, it is estimated that 2,100 acre-feet will be recharged annually.

Investigations were made in an attempt to determine the areas of recovery and probable use of the additional water made available by recharge. These

investigations indicated that because of the vastness of the Edwards aquifer and its hydraulic gradient, generally to the northeast, areas of recovery and purposes of use could not be predicted with a high degree of certainty. Undoubtedly most of the recharge will be recovered from that portion of the Edwards underground reservoir between the Comal springs at New Braunfels and the springs at San Marcos.

Water recovered from this area is used largely for agriculture, recreation at Comal and San Marcos springs, municipal and industrial use, and abatement of stream flow pollution. Based on studies made by the U. S. Army Corps of Engineers and the Edwards Underground Water District, the value of an acre foot of water to increase the pumping potential of the underground aquifer varies from about $15 to $38. In view of uncertainties regarding the efficiency of recovery, the value of ground water recharge was appraised at $12 per acre foot. Total annual benefits from this source were estimated to average $25,200.

Negative Project Benefits

Areas that will be used for project construction and areas to be inundated by pools of reservoirs were excluded from damage calculations. Net income from production to be lost in these areas after installation of the project was compared with the appraised value of the land amortized over the period of project life. No production in sediment pools was considered, and the land covered by detention pools was assumed to be grassland under project conditions. The annual value of the loss of net income from these areas was less than the amortized value of the land; therefore, the easement value was used in economic justification.

Secondary Benefits

The value of local secondary benefits stemming from the project were estimated to be equal to 10 percent of direct primary benefits, including those from reduction of damages and incidental recharge benefits. This excludes all indirect benefits from the computation of secondary benefits.

Allocation of Benefits

Damage reduction benefits and secondary benefits stemming from the project were allocated to structural measures included in this plan and to those constructed by Comal County on the basis of drainage area controlled by structural measures in relation to the areas to be benefited.

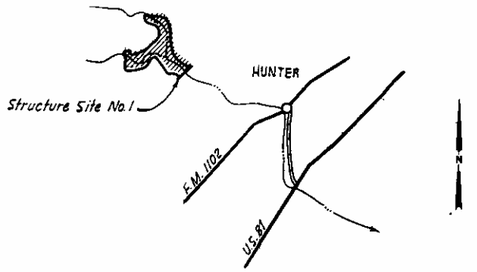
Benefits allocated to floodwater retarding structures constructed by Comal County are estimated to average $11,338 annually.

Fish and Wildlife

The Bureau of Sport Fisheries and Wildlife, in cooperation with the Texas Parks and Wildlife Department, has completed a reconnaissance study of Comal River watershed. This report was valuable in work plan development pertaining to fish and wildlife. In addition to data presented in other

parts of the work plan, the following recommendations are reproduced from the Bureau of Sport Fisheries and Wildlife reconnaissance survey report:

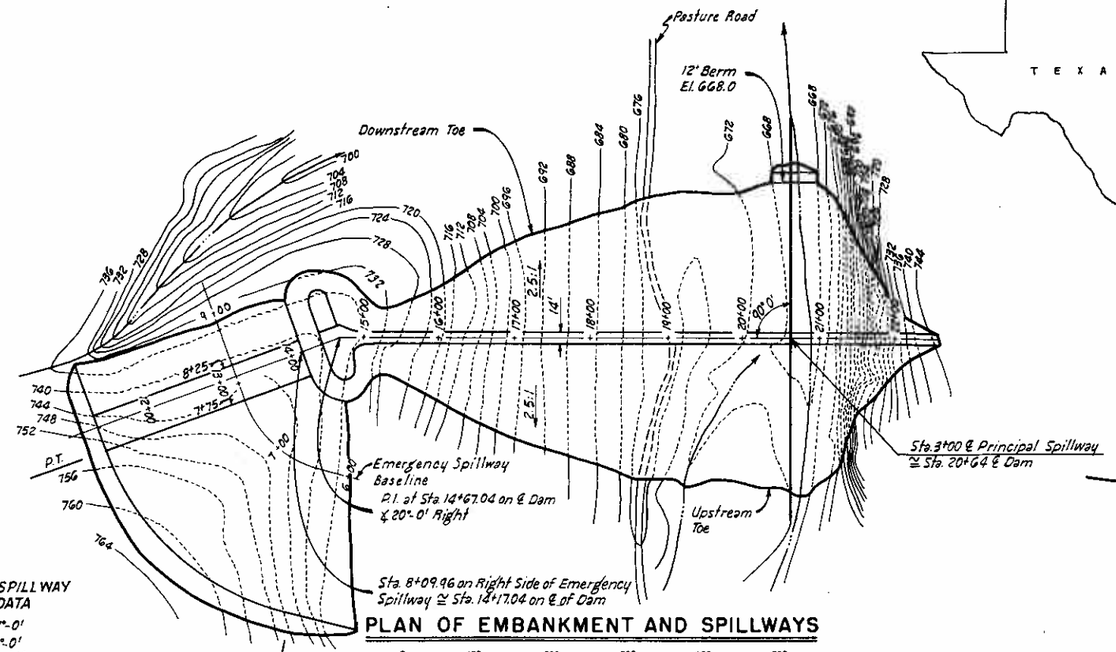
> "Consistent with project objectives as much brush and timber as possible should be retained in the watershed for wildlife. Losses of brush and timber resulting from project construction and inundation should be compensated for by planting trees and shrubs at suitable locations such as idle lands, eroded areas, streambanks, gullies, around reservoirs, and along fencerows.
>
> It is recommended that:
>
> 1. Clearing of timber and brush in the watershed be kept to a minimum during and following project construction.
>
> 2. Losses of brush and timber be compensated for by planting trees and shrubs suitable for wildlife at appropriate locations such as idle lands, eroded areas, stream banks, gullies, and along fencerows.
>
> The above recommendations are in conformance with U.S.D.A. Soil Conservation Service Biology Memorandum-7 (Rev. 1), National Standards for Biology Practices. If adopted as a part of the plan of development, losses of wildlife habitat would be mitigated and additionally, fish and wildlife benefits would accrue to the project.
>
> A detailed study of the watershed by the Bureau of Sport Fisheries and Wildlife is not considered necessary at this time. Should the sponsors desire, our Bureau, in cooperation with the Texas Parks and Wildlife Department, would be happy to be of further assistance."



Structure Site No.1 located approximately 1½ miles northwest of Hunter, Comal County, Texas.

VICINITY MAP

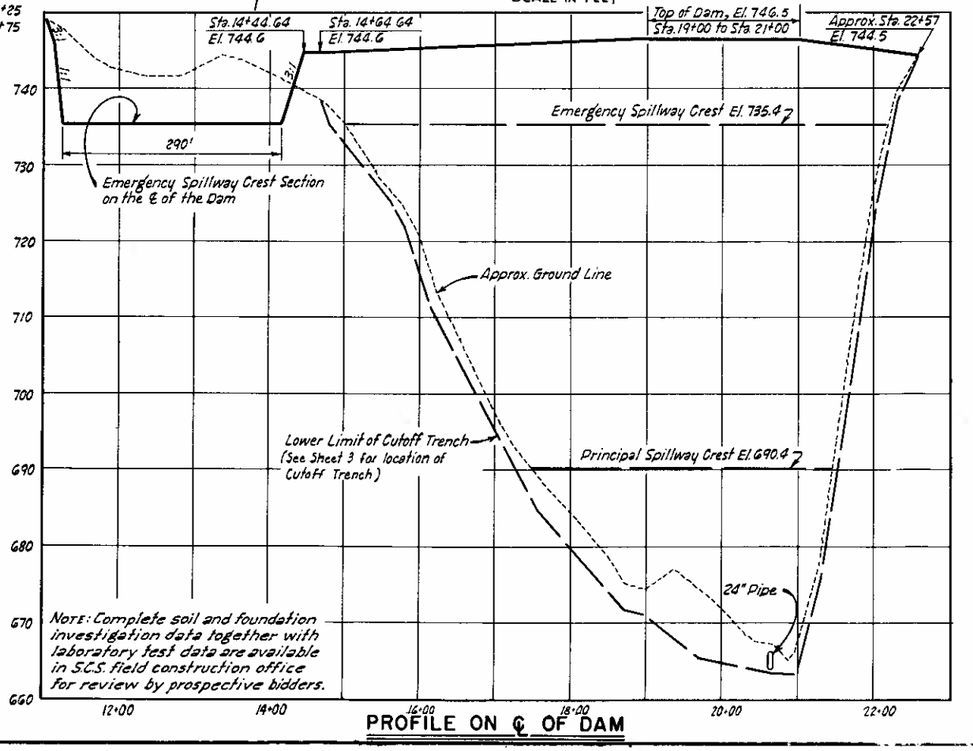
0 1 2 3 4
SCALE IN MILES



EMERGENCY SPILLWAY CURVE DATA
Δ = 57°-0'
D = 38°-0'
R = 150.78'
L = 150'
P.C. = Sta. 6+25
P.T. = Sta. 7+75

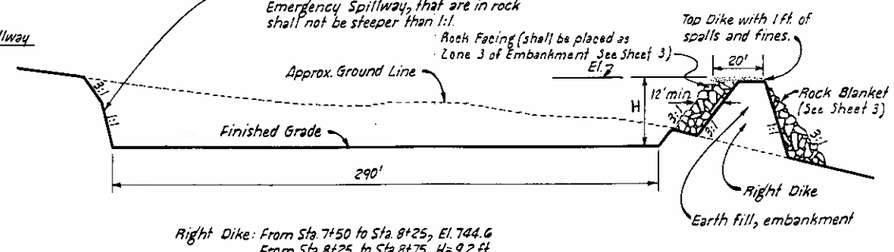
PLAN OF EMBANKMENT AND SPILLWAYS

0 100 200 300 400 500
SCALE IN FEET



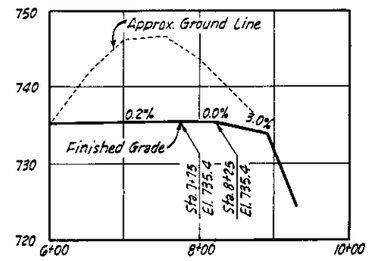
NOTE: Complete soil and foundation investigation data together with laboratory test data are available in S.C.S. field construction office for review by prospective bidders.

PROFILE ON ℄ OF DAM



Right Dike: From Sta. 7+50 to Sta. 8+25, El. 744.6
From Sta. 8+25 to Sta. 8+75, H = 9.2 ft.
Note: Materials used in forming dike shall be placed and paid as "Earthfill, Embankment". (See Sheet 3 for placement of rock materials)

TYPICAL SECTION – EMERGENCY SPILLWAY

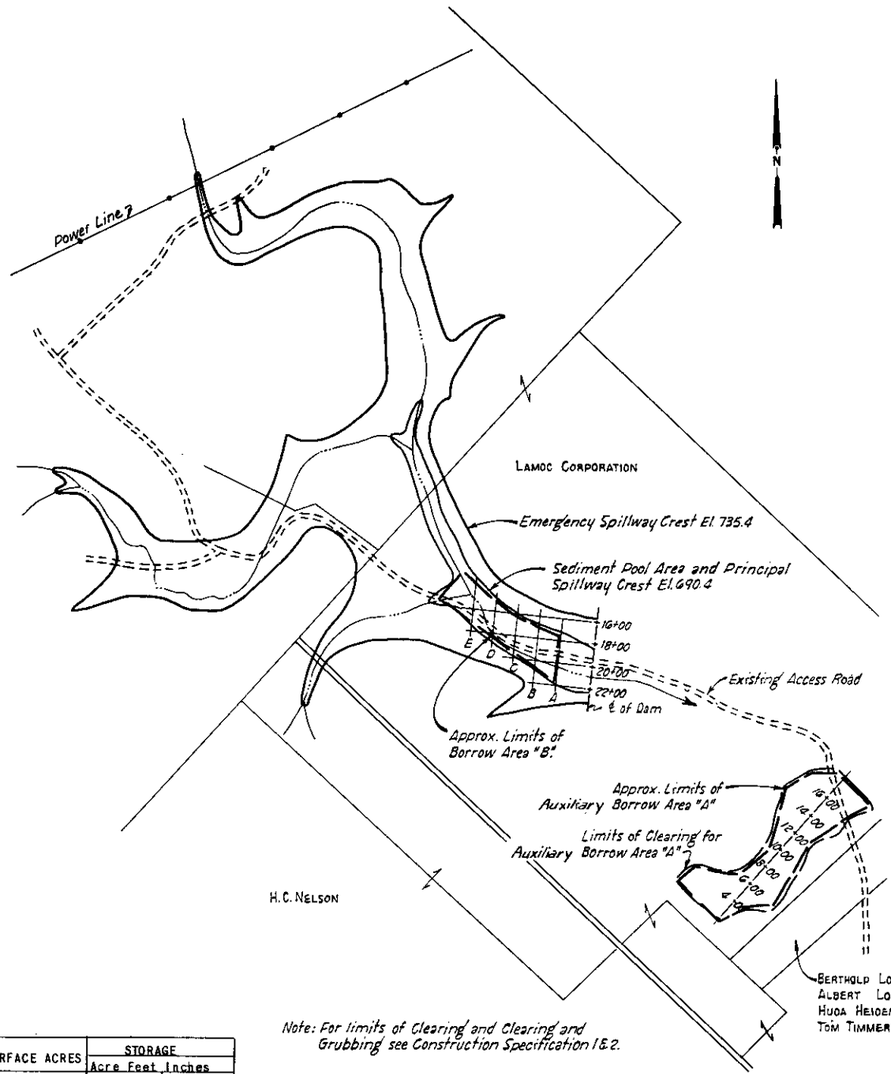


PROFILE ON BASELINE OF EMERGENCY SPILLWAY

Figure 1
TYPICAL
FLOODWATER RETARDING STRUCTURE
EMBANKMENT PLAN AND PROFILE

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

	Date	
Designed M.D.K.	2-66	Approved by: ACTING STATE CONSERVATION ENGINEER, TEMPLE, TEXAS
Drawn M.D.K.	2-66	
Traced R.C.G.	2-66	
Checked M.D.K. E.G.W.T.	5-66	Sheet No. 2 of 12 — Drawing No. 4-E-21,155



Note: For limits of Clearing and Clearing and Grubbing see Construction Specification 1 & 2.

GENERAL PLAN OF RESERVOIR

0 660 1320 1980 2640

SCALE IN FEET

ELEVATION	SURFACE ACRES	STORAGE	
		Acre Feet	Inches
688	16	94	0.14
690.4	18.5	135	0.20
692	20	166	0.24
696	26	258	0.37
700	32	374	0.54
704	39	516	0.75
708	49	692	1.00
712	59	908	1.32
716	70	1166	1.69
720	82	1470	2.13
724	95	1824	2.64
728	110	2234	3.24
732	128	2710	3.93
735.4	147.5	3178	4.61
736	151	3268	4.74
740	171	3912	5.67

Top of Dam (effective) Elev.	741.5
Emergency Spillway Crest Elev.	735.4
Principal Spillway Crest Elev.	690.4
Sediment Pool Elev.	690.4
Drainage Area, Acres	8,272
Sediment Storage, Ac. Ft.	138
Floodwater Storage, Ac. Ft.	3,040
Max. Emergency Spillway Cap., cfs	20,115

MATERIAL PLACEMENT DATA

Embankment Zone No. /1	Source of Fill Materials: Material Location /2	Average Depth, feet: From	To	Type or Unified Classification	Field Control Test: ASTM Test Number	Method	Placement and Compaction Requirements: Max. Allowable Particle Size	Max. Uncompacted Layer Thickness	Specified Compaction Class	Min. Dry Density, Percent of Field Test Max. Dry Density	Moisture Limits, Relative to Field Test Optimum: From	To	Laboratory Test Data: ASTM Test Number	Method	Curve No.	Max. Dry Density, p.c.f.	Optimum Moisture, %
1	Borrow A-1	0	2	MH	O-1557	A	6"	9"	A	90	Opt.	+4%	O-1557	A	1	101.0	20.5
1	Borrow A-1	2	4	CH	O-1557	D	6"	9"	A	90	-1%	+5%	O-1557	C	1-X	114.0	14.0
1	Borrow A-1	5	10	CH	O-1557	A	6"	9"	A	90	Opt.	+5%	O-1557	A	4	109.0	17.0
1	Borrow A-1	10	14	CL	O-1557	D	6"	9"	A	90	-1%	+4%	O-1557	C	2-X	119.0	14.0
1	Borrow A-3	0	9	CH	O-1557	D	6"	9"	A	90	-1%	+4%	O-1557	C	4-X	110.0	18.0
1	Borrow A-3	9	18	CL	O-1557	A	6"	9"	A	90	-1%	+4%	O-1557	A	8	116.5	14.5
2	Borrow A-1	3	6	GC	O-1557	A	6"	9"	A	90	-2%	+3%	O-1557	A	3	113.5	14.5
2	Borrow A-1	11	16	GC	O-1557	D	6"	9"	A	90	-1%	+4%	O-1557	C	3-X	127.0	10.5
2	Borrow A-3	0	11	GC	O-1557	D	6"	9"	A	90	-1%	+4%	O-1557	C	5-X	126.0	10.0
3	/3			Limestone Rock	-	-	24"	24"	/4								
4	/3			Limestone Rock	-	-	24"	24"	/5								

/1 The zone boundaries shown in the typical section are approximate. Adjustments will be made by the Engineer to permit the use, within the neat lines of the embankment, of all suitable materials from the required excavations.

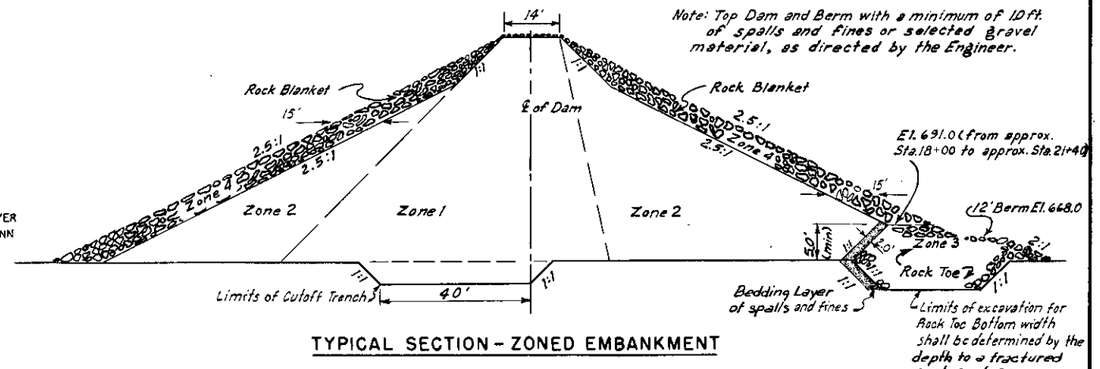
/2 Materials from the required excavations that are not tabulated in the table above and that are suitable and acceptable for earth fill shall have the same placement and control requirements as that specified for like materials covered under Materials Placement Data.

/3 Rock materials for construction of Zones 3 and 4 rock facing for the emergency spillway dike, and the rock lining of the plunge basin shown on Sheet 5 shall be obtained from the required rock excavation in the emergency spillway and foundation excavation and from the over-sized rock material from the borrow and other required excavations. The Contractor shall be required to excavate approximately 26,000 cu. yds. from Borrow Area "B" to fulfill the requirements for rock materials shown in the typical section.

/4 No specified compaction or moisture control will be required. The rock placed in Zone 3 and in the rock lining for the plunge basin shall be dumped and spread into place in approximately horizontal layers not more than 2 ft. in thickness and shall be placed in such a manner as to produce a reasonably homogeneous, stable fill that contains no segregated pockets of large or small fragments or large unfilled spaces caused by bridging of the larger fragments.

Where a bedding layer beneath the rock is specified, the bedding materials shall be spread uniformly on the prepared subgrade surfaces to the depths indicated. Compaction of the bedding layers will not be required, but the surfaces of such layers shall be finished free from mounds, dips, or windrows.

/5 No specified compaction or moisture control will be required. The rock placed in Zone 4 shall be dumped and spread into place in approximately horizontal layers not more than 2 feet in thickness. The rock shall be placed and manipulated so that the completed fill shall be graded with the smaller rock fragments placed toward the inner portion of the fill and the larger rock fragments placed on the outer slopes and shall be placed in such a manner as to produce a stable fill that contains no large unfilled spaces caused by bridging of the larger fraction. Inclusion of spalls, gravel, and other fine materials in an amount not in excess of that required to fill the voids in the coarser material will be permissible. Placement and manipulation of the rock material may be accomplished by initially depositing the rock material in a sequence of workable piles or layers near the outer edge of the concurrent lifts of Zone 2, in order to provide suitable room for a raking or combing operation to move the rock material into Zone 4 and accomplish the specified placement.



TYPICAL SECTION - ZONED EMBANKMENT

NOTE: The ℄ of the cutoff trench shall coincide with that of the embankment from Sta. 14+64 to Sta. 16+00 and from Sta. 22+00 to Sta. 22+57. From Sta. 16+50 to Sta. 21+50, the ℄ of the cutoff trench shall be located 20 ft. upstream from the ℄ of the embankment. Transition sections between Sta. 16+00 and Sta. 16+50 and between Sta. 21+50 and Sta. 22+00 shall be as staked by the Engineer.

ZONED EMBANKMENT DATA

Figure 1A

TYPICAL

FLOODWATER RETARDING STRUCTURE

GENERAL PLAN OF RESERVOIR & SECTION-ZONED EMBANKMENT

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

	Date	
Designed M.D.K.	2-66	Approved by HEAD ENGINEERING & WATERSHED PLANNING UNIT, FORT WORTH, TEXAS
Drawn M.D.K.	2-66	STATE CONSERVATION ENGINEER S.C.S.
Traced R.C.G.	2-66	TEMPLE, TEXAS
Checked M.D.K. EGWT	3-66	Sheet No. 3 of 12 — Drawing No. 4-E-21,155

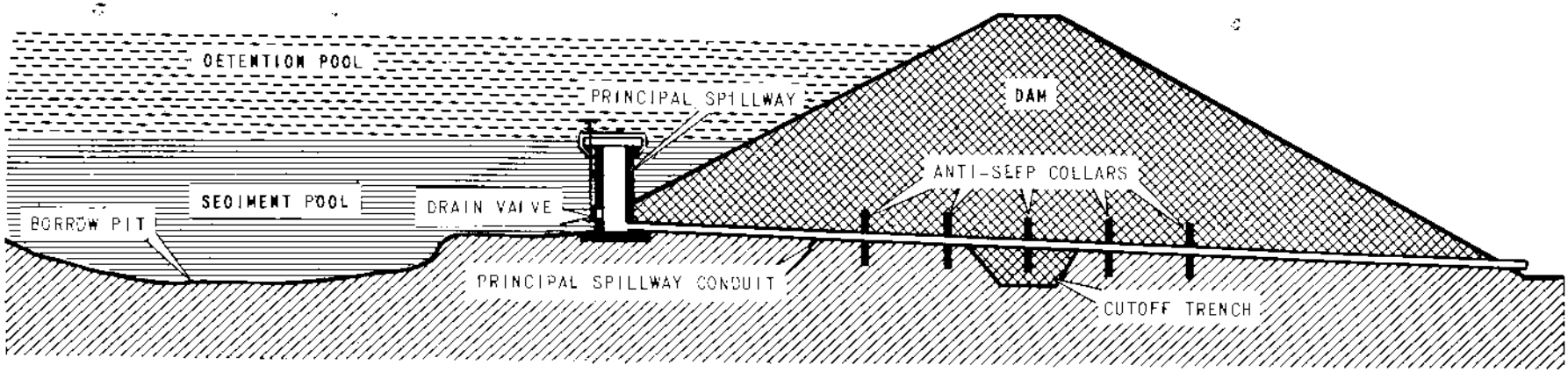
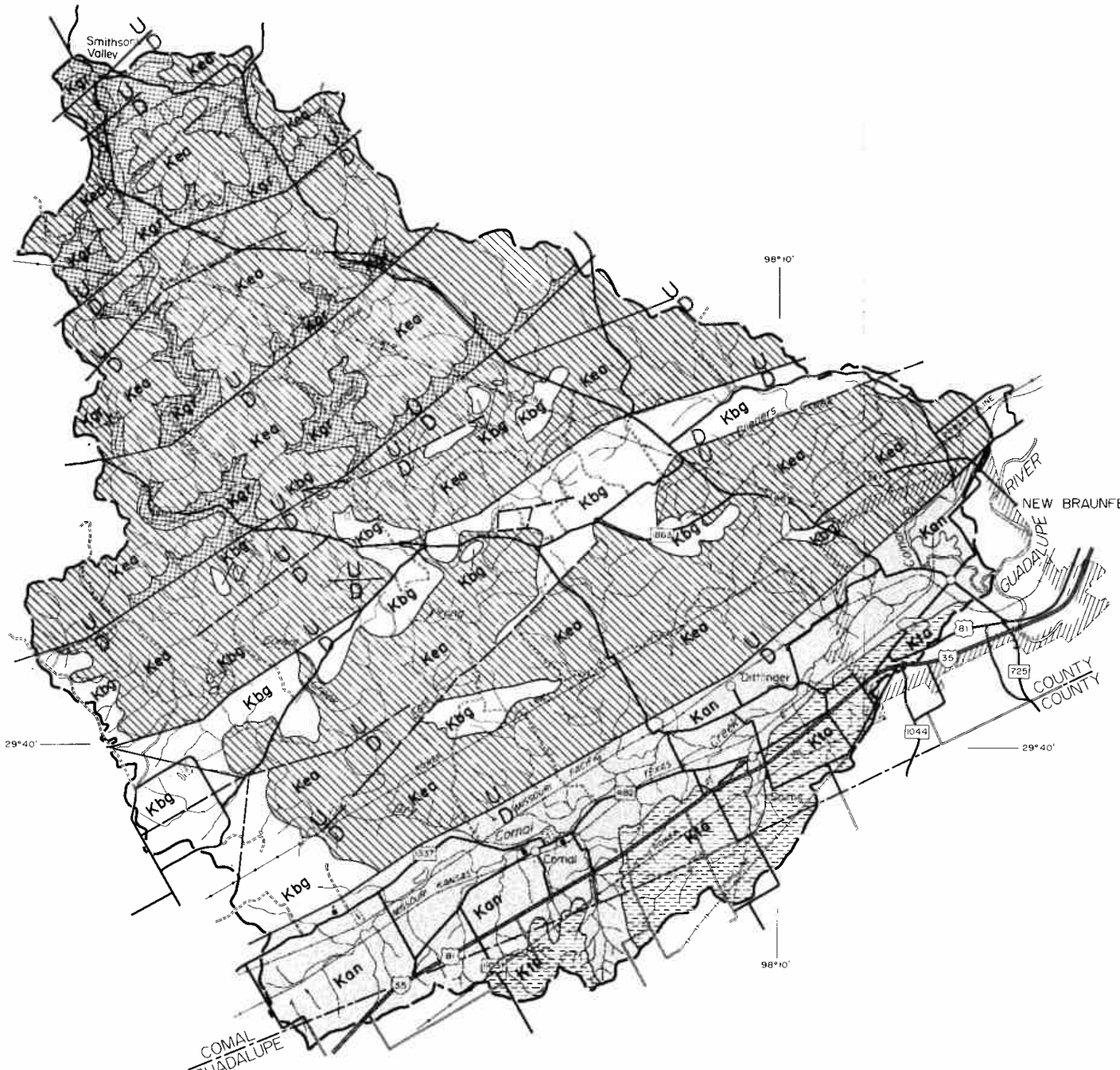


Figure 2

SECTION OF A TYPICAL FLOODWATER RETARDING STRUCTURE

U. S. DEPARTMENT OF AGRICULTURE, SOIL CONSERTATION SERVICE

9-68 4-L-10,071-B



LEGEND

- County Line
- City Limits
- Towns
- Railroad
- Unimproved Road
- Secondary Road
- Paved Road
- 81 U.S. Highway
- 35 Interstate Highway
- 46 State Highway
- 725 Farm to Market Road
- 337 Loop or Spur
- Power Line
- Pipeline
- Drainage
- Watershed Boundary

GEOLOGIC EXPLANATION

Cretaceous System (Gulf Series)

- Kta — Taylor shale, marl and limestone (undifferentiated)
- Kan — Anacacho marly chalk

Cretaceous System (Comanche Series)

- Kbg — Buda limestone and Grayson shale
- Kea — Edwards, Georgetown and Comanche Peak limestones (Edwards and associated limestones)
- Kgr — Glen Rose limestone and shale
- U/D — Fault (dashed where inferred) U—Upthrown side D—Downthrown side

Figure 3

GEOLOGIC MAP

COMAL RIVER WATERSHED

COMAL AND GUADALUPE COUNTIES, TEXAS

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
TEMPLE, TEXAS

0 1 2 3 4 5
APPROXIMATE SCALE - MILES

BASE COMPILED FROM LATEST USGS QUADRANGLES AND GENERAL HIGHWAY MAPS.

1-68 4-R-25738
Rev. 1-68 4-R-23194

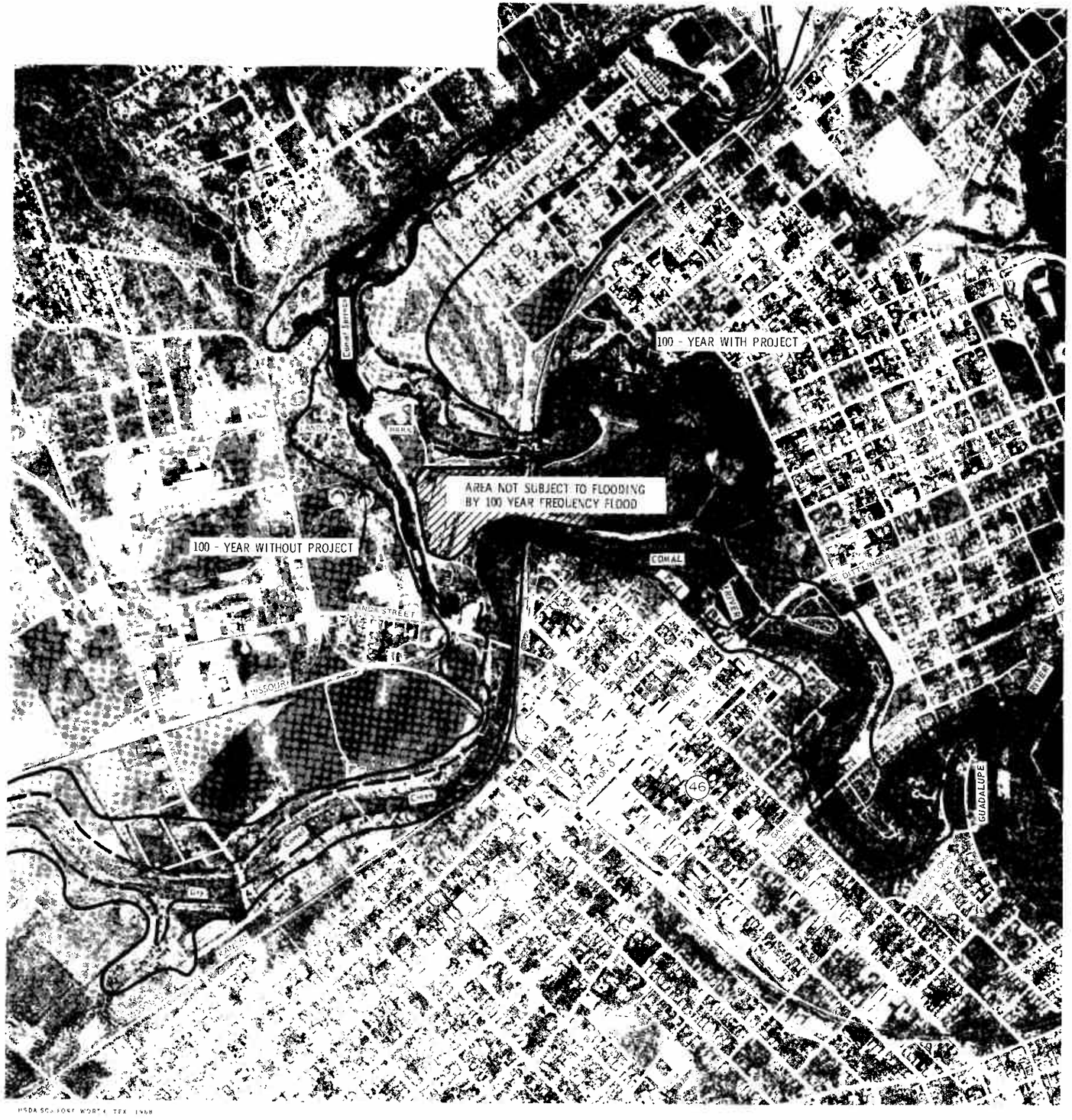


Figure 4

URBAN FLOOD PLAIN

NEW BRAUNFELS, TEXAS
COMAL RIVER WATERSHED
COMAL AND GUADALUPE COUNTIES, TEXAS

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

TEMPLE, TEXAS

7-67 Rev. 8-68 4-R-25568

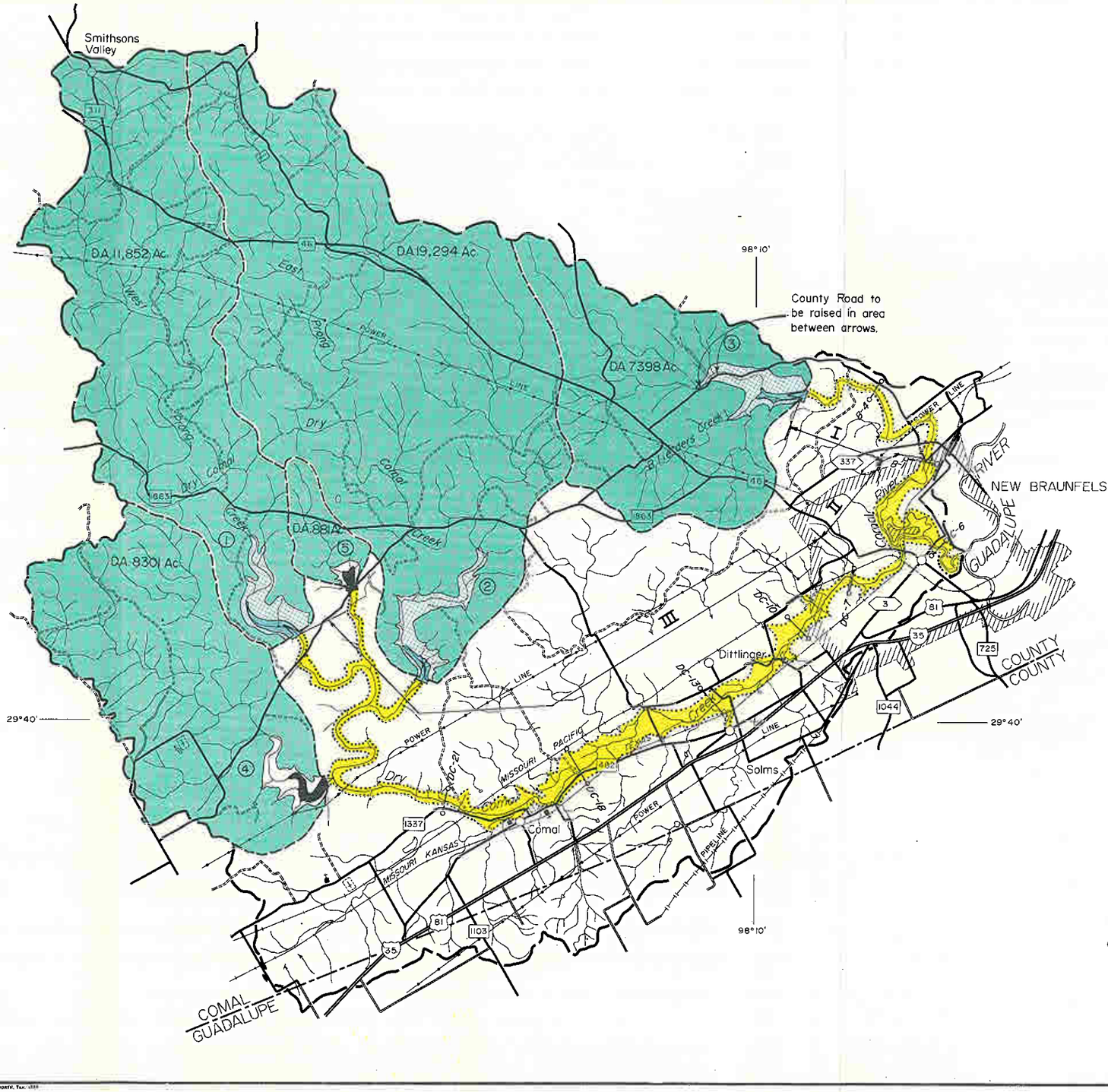


FIGURE 5

PROJECT MAP

COMAL RIVER WATERSHED

COMAL AND GUADALUPE COUNTIES, TEXAS

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
TEMPLE, TEXAS

BASE COMPILED FROM LATEST USGS QUADRANGLES AND GENERAL HIGHWAY MAPS.
Approx. Area 83,200 Acres

Rev. 8-68 I-68 4-R-25737
Rev. 1-68 4-R-23194