Flood-plain management along the upper Santa Ana River

Terrance Troy

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"FLOOD-PLAIN MANAGEMENT ALONG THE
UPPER SANTA ANA RIVER"

A Thesis
Presented to the
Faculty of
California State
College, San Bernardino

by
Terrance Troy
January 1984

Approved by:

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Committee Member
FLOOD-PLAIN MANAGEMENT ALONG THE
UPPER SANTA ANA RIVER

A Thesis
Presented to the
Faculty of
California State
College, San Bernardino

In Partial Fulfillment
Of the Requirements for the Degree
Master of Arts
With a Special Major
in
Urban Environmental Planning

by
Terrance Troy
January 1984
ABSTRACT

The objective of this investigation was to analyze the San Bernardino Flood-plain region with the use of physical and historical data in order to develop probable measures for flood control effectiveness. The data examined encompassed a review of seismicity, soil associations, climate network and drainage data, sequential aerial photos, population growth, as well as interviews with key members of the San Bernardino Municipal Water Department. Conclusions derived from the study of the data include:

1. Failure of San Bernardino County Flood Ordinance 2417, (Reg. Governing Flood-Control in San Bernardino Basin).
2. Cost-benefit ineffectiveness and infeasibility of the All-River Plan (Mentone Dam Proposal). Based on the preceding conclusions, the investigator recommends:

   A. Revision of Ordinance 2417 pertaining to updated standards of construction and realistic flood control heights.

   B. Continuation of government supervision and control of designated land essential to non-development of land by private industry.

   C. Cost effective measures, vs. proposed Mentone Dam, to include reinforcement and construction of levees, tributary channels and the main-stream Santa Ana River.
# TABLE OF CONTENTS

INTRODUCTION ................................................. 1
  Background ................................................. 1
  Statement of Problem ...................................... 15
  Purpose .................................................... 17
  Assumptions and Qualifications ............................ 17
  Significance of Study .................................... 20

LITERARY REVIEW ............................................... 23

SOIL AND WATERSHED ANALYSIS ............................... 31

HISTORICAL GROWTH ON THE FLOOD PLAIN .................. 50

HISTORICAL DATA AND PHYSICAL GEOGRAPHY ................. 62

SUMMARY ..................................................... 77

SOLUTION .................................................... 86

CONCLUSION ................................................ 92

NOTES ....................................................... 98

LITERATURE CITED .......................................... 101
LIST OF TABLES

1. Precipitation measurements, 1934-1960 ........................................... 41
2. Runoff Data .................................................................................. 43
3. Water Use. .................................................................................. 47
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Aerial Photos, 1-7</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Overview of Entire Area, Big Bear Lake to Ocean</td>
<td>9</td>
</tr>
<tr>
<td>3</td>
<td>San Bernardino County Ordinance No. 2417</td>
<td>13</td>
</tr>
<tr>
<td>4</td>
<td>The All-River-Plan</td>
<td>18</td>
</tr>
<tr>
<td>5</td>
<td>Mentone Dam Area</td>
<td>19</td>
</tr>
<tr>
<td>6</td>
<td>Rock Formation Map</td>
<td>33</td>
</tr>
<tr>
<td>7</td>
<td>Soil Analysis Map</td>
<td>36</td>
</tr>
<tr>
<td>8</td>
<td>Seismicity Map</td>
<td>39</td>
</tr>
<tr>
<td>9</td>
<td>Precipitation Stations</td>
<td>44</td>
</tr>
<tr>
<td>10</td>
<td>Map of Tributaries Discussed</td>
<td>45</td>
</tr>
<tr>
<td>11</td>
<td>Original Site of San Bernardino</td>
<td>54</td>
</tr>
<tr>
<td>12</td>
<td>Original Site of San Bernardino and Growth Pattern</td>
<td>55</td>
</tr>
<tr>
<td>13</td>
<td>Lytle Creek Protected Forest Area</td>
<td>60</td>
</tr>
<tr>
<td>14</td>
<td>Shifting Area of Flood-Plain, near San Bernardino</td>
<td>61</td>
</tr>
<tr>
<td>15</td>
<td>History of Flood Patterns</td>
<td>74</td>
</tr>
<tr>
<td>16</td>
<td>Prado Dam</td>
<td>78</td>
</tr>
</tbody>
</table>
INTRODUCTION

The very beauty of the mountain helped deceive most people. It was a mountain in praise of mountains, towering over lesser peaks, its near perfect cone glistening white in all seasons. For all its splendor, Mt. St. Helens, like so many other sites in nature, was a time bomb. Thousands through the years had given it their hearts—climbers, artists, photographers, lovers of beauty's ultimate expression. Some were among the sixty-one people drawn into its deadly embrace on that shining Sunday morning, May 18, 1980.

In California there is a river that, like Mt. St. Helens, has drawn into its deadly embrace by deception, many, many hundreds of people. It covers roughly one hundred and twenty miles and includes the Counties of San Bernardino, Riverside and Orange. The Santa Ana River begins in the mountains northeast of San Bernardino near Big Bear Lake. The river runs down the mountain, coming out of the canyon a few miles east of San Bernardino onto an alluvial flood-plain. The river then shifts southwest in and near various cities including Redlands, San Bernardino and Riverside, and on into Santa Ana Canyon towards Anaheim. The river ends at the Pacific Ocean, between Newport Beach and Huntington Beach. (Aerial Photographs 1-7, (Figure 1) and Figure 2, an overall view of above mentioned area.)
Figure one (No.1) Santa Ana River meeting the San Bernardino Basin at the toe of the San Bernardino Mountains.
Figure one (No.2) Area between the toe of mountains and Norton Air Force Base.
Figure one (No. 3) Santa Ana River flowing past Norton Air Force Base in the San Bernardino Basin.
Figure one (No. 4) Santa Ana River flowing under the San Bernardino Freeway Exchange.
Figure one (No. 5) Santa Ana flowing between the cities of Colton and Riverside California.
Figure one (No. 6) Santa Ana River flowing between Riverside and Norco California.
Figure one (No. 7) Santa Ana River flowing through cities of Garden Grove and Westminster near the mouth of the river.
On most days of each year, the channel is far from full; and the water fills only the bottom section. Several days each year the channel is one-quarter full, and about twice every several years is about one-half full. Individuals looking at the channel would never believe that throughout the Santa Ana River's one hundred and twenty years of recorded history, hundreds of lives as well as millions of dollars have been lost from flood waters that could not be contained within the river's channel.

The first record of such a flood was in January 1862. The storm and flood was unusual in two ways. First, it occurred during the very severe drought of 1856-1864. Secondly, the duration of flooding was extremely long, lasting for twenty days. In the San Bernardino Valley area, the prosperous colonies along the banks of the river were completely inundated, and vineyards, orchards, and grain fields were transformed into barren wastes. In January 1910, a major flood on the upper Santa Ana River isolated Colton and parts of San Bernardino. Seven people were killed when a Southern Pacific train plunged into the Santa Ana River while crossing a bridge.

During the 1930s Congress deemed it necessary to authorize a nationwide flood control program. Federal participation in flood control and management on a nationwide basis came with the first general Flood Control Act in 1936. In it, Congress asserted broadly that flood
control and management on navigable waters or on their tributaries is a federal responsibility and that improvements, including those to be made on watersheds, are in the interest of the general welfare. Two important concepts, both basic statements of federal policy, are contained in a section of the 1936 Act. The first concept is that flood control and management are proper federal functions and that the federal government should improve them or participate in their improvements if the benefits, to whomever they may accrue, are in excess of estimated costs. The second concept is that a flood program is justified if the lives and security of people are otherwise adversely affected. The Corps of Engineers was authorized by Congress in 1936 to take over this broad interpretation of flood management policy. Within a year, the Corps of Engineers indicated an intent to move gradually away from this broad interpretation of federal responsibility—that every man, woman, and child shall be protected against floods—if economic justification can be found for doing so. In 1937, Congress authorized that local interests, defined as state political subdivisions thereof, or other responsible local agencies (counties), should cooperate in all federal flood control projects and management to the extent of regulating zoning of building along rivers, and providing lands and easements for construction of reservoirs. Congress has now given the difficult task of flood management to local agencies, with
 occasional assistance from the Corps of Engineers.

The flood of March 1938, two years after the enactment of the General Flood Control Act, was perhaps the most intense flood in the San Bernardino Basin this century. The most intense rainfall and greatest flood damage along the river occurred in Orange County, when over $8,000,000.00 in damages occurred to residential, commercial and utility property. The total destruction of Riverside and San Bernardino Counties along the river was approximately $3,000,000.00. Orange County, realizing the potential flood threat in future storms, constructed with the assistance of the Corps of Engineers, the Prado Dam which was completed in 1941.

In the decades following the 1938 flood, industrial and residential expansion doubled in San Bernardino and Riverside Counties along the river. As a result, flood damage increased. As discussed previously, Congress accordingly first charged the Corps of Engineers with the responsibility for federal investigation of flood control and management. Management of such vast proportions was quickly eliminated, with local agencies given this power under the Flood Control Act of 1936; San Bernardino County initiated its own flood control policies under Ordinance No. 2417, (Figure 5).

The purpose of the ordinance is to protect the public health, safety and welfare and to minimize public and
A Portion of
ORDINANCE NO. 2417

AN ORDINANCE OF THE COUNTY OF SAN BERNARDINO
STATE OF CALIFORNIA, REGULATING FLOOD
HAZARD AREAS AND IMPLEMENTING THE
NATIONAL FLOOD INSURANCE PROGRAM, AND
DECLARING THE URGENCY THEREOF.

The Board of Supervisors of the County of San Bernardino
State of California does ordain as follows.

SECTION 1. This ordinance is adopted pursuant to the
requirements of the National Flood Insurance Program, 42
United States Code 4001 et. seq., as amended, including all
regulations adopted pursuant thereto. The purpose of the
ordinance is to protect the public health, safety and welfare and
minimize public and private costs caused by flooding by
regulating development within flood hazard areas.

SECTION 2. Definitions as used in this ordinance, the
following terms shall have the following meanings.

a. 100-year Flood/Base Flood. A flood that has a one
percent (1%) chance of being equalled or exceeded in any given
year.

b. Floodway. The channel of a river or other watercourse
and adjacent land areas necessary to discharge the waters from
the 100-year flood without increasing the water surface elevation
of that flood more than one (1) foot at any point as defined
by the H-1 Zone District shown on the Official Land Use maps
of San Bernardino County.

c. Flood Plain. The land areas that are subject to
flooding from the 100-year flood, but not including any actual
floodway as defined by the H-2 Zone District shown on the
Official Land Use maps of San Bernardino County.

d. Structure. All buildings and structures, including
mobilehomes, and solid walls and fences, the use of which
requires a more or less permanent location on the ground, or an
attachment to something having a permanent location on the
ground.

e. Substantial Improvements/Substantially Improved.
An improvement or repair of a structure, the costs of which
equals or exceeds fifty percent (50%) of the market value of the
structure either before the improvement is commenced or, if the
structure has been damaged before the damage occurred. The
term does not include any alterations necessary to comply with
state or local health, sanitary or safety code specifications or
regulations or any alterations of a structure listed on the
National Register of Historic Places or a State inventory of
Historic Places.

Figure 3. A Portion of San Bernardino County
ORDINANCE NO. 2417
private costs caused by flooding, by regulating development within flood hazard areas. This ordinance, along with the Flood Control Act of 1936, was truly never enforced in entirely in the decades following the 1938 flood. Therefore industrial and residential expansion was ever increasing along the flood-plain in San Bernardino County. The flatness of the flood-plain is a valuable topographic asset for many uses, particularly transportation and industrial growth. Flood-plain occupancy, however, is in direct competition with the river. Floods, meaning water stages above bank-full capacity, are characteristic of rivers. The mere existence of a flood-plain is prima facia evidence of floods.

As mentioned previously, Orange County had $8,000,000. in flood damages during the 1938 flood. Ignoring the past dangers of encroaching upon the flood plain, San Bernardino County continued to disregard flood management policies.

In January 1969, and February of the same year, there were two major storms. Rain began January 18th., and continued for nine days, with only short, or partial periods of clearing. The January storms produced the greatest rainfall and flood flows of record for most of San Bernardino County. On January 25th., San Bernardino County was declared a local disaster area by the Board of Supervisors and the Governor of California. On January 26th., the President declared San Bernardino and five other counties
national disaster areas. In San Bernardino County four persons died and $23,000,000.00 in damages occurred to residential, commercial, utility, railroad, highway and agricultural property. The February flood was even more dangerous, causing $32,000,000.00 in damages. Twelve lives were also lost in this severe rain storm. The flow of water from the 1969 floods could not be contained in the river channel; therefore, as seen in past storms, the water spread out over the flood-plain. The flood-plain is the place where nearly all the flood damage occurs during heavy storms, because buildings are built on an area which the river must at times cover with water. The question is, did we learn from the 1969 floods that the ordinances needed to be enforced to protect the public health, safety and welfare of the people. Nine years later the floods of 1978 answered our question, when heavy storms caused $9,000,000.00 worth of destruction to residential and industrial areas within the flood-plain. San Bernardino County was an excellent example of the consequences of man's utilization of the flood-plain as a site for his activities.

Statement of Problem

Flood damage can be reduced by decreasing the amount of damageable goods on the flood-plain. It is logical that some limit be placed on the type and degree of use of this protected area. This restriction may take
many forms, but essentially it may be thought of in terms of zoning ordinances. Flood-plain zoning is much the same as housing zones, except that it has a somewhat different objective or purpose. Flood-plain zoning has for its purpose the zoning of the flood-threatened areas along the stream. These areas would be restricted from building construction of any type, industrial or residential. In actuality though, flood-plain zoning is disregarded in its entirety. For example, Section 12, a restrictive ordinance in Los Angeles County, entitled "Land Subject to Flood Hazard," states that "areas which are subject to inundation, overflow by storm water, or any other dangerous condition, shall not be subdivided."¹ The regulations in existence in the Los Angeles area have had little or no effect on the development of land subject to flood hazard. The pressure for expansion of a rapidly growing city has been so great that ordinances and regulations either have been ignored or else only a minimum amount of flood control has been provided concurrently with development.

This problem is in existence in San Bernardino County today. The regulations and ordinances have had little or no effect on the development of land subject to flood hazard. The pressure for expansion within our own county has been so great that ordinances and regulations have been, and are totally ignored.
The Purpose

The purpose of this investigation is to analyze the San Bernardino flood-plain region with the use of physical and historical data in order to develop probable measures for flood control effectiveness.

Assumptions and Qualifications

Examining physical and historical data in the San Bernardino Basin region will interpret weaknesses within the Flood-Plain Management Program, which includes Ordinance No. 2417. Once the weaknesses are visible, the writer will suggest new regulations and safeguards for maximum flood-plain management. The writer has observed that the same method used to discover weaknesses within the present Flood-Plain management Program can also provide valuable information for future revisions in the area of flood control.

The examination continues with a proposal submitted by the Corps of Engineers entitled, "The All River Plan," (Figure 3). The Corps proposed to build the dam on a broad gravel-bed area where Mill Creek enters the Santa Ana River. The main objective of the Mentone Reservoir (Figure 4) is to collect floodwaters from Big Bear lake, the Upper Santa Ana River, Mill Creek and Plunge Creek. The cost of $1,000,000.00 will be partially paid by San Bernardino County taxes with assistance from the federal government. The Corps suggests that the All River Plan is most adequate,
LEGEND

- IMPROVEMENTS
- FLOOD PLAIN MANAGEMENT
- OPEN SPACE PRESERVATION
- WILDLIFE MITIGATION & PRESERVATION AREA

The Recommended All-River Plan

Figure 4.
meeting protection for residential and commercial development presently and in the future. The plan, which would be financially and environmentally disturbing to the County of San Bernardino, has been entirely advocated by government agencies, (Figure 3).

**Significance of Study**

Flood control has grown to be a big business; whether one lives near a river or in a house on the top of a hill, every person in the United States has a stake in this enterprise. When all the proposed and installed big dams and levee systems on the major rivers are considered together with land management and the small dams upstream, flood control and its related programs probably constitutes one of the largest activities of the federal government, other than national defense. It is difficult to achieve a proper sense of proportion with regard to the magnitude of the flood control work being undertaken in the United States. It has been stated that sixty-five percent of the projects investigated are recommended for construction. The total number of reports dealing with investigations is very large indeed. The list of projects reported annually for control and improvements of rivers and harbors is published in a volume containing four hundred and sixty-eight pages of fine print. This full-sized book is required merely to list the projects that have been investigated and proposed for construction.
Rarely does the Corps propose a zoning regulation to prohibit excessive development on hazardous areas of the flood-plain. In its reports it rarely proposes moving industrial or urban developments to other locations instead of providing a degree of flood protection, even though the former might be done at a lower cost. Therefore, Corps programs tend to increase development on the flood-plain. The Corps has been under attack by the public for acting in an irresponsible manner toward flood-plain management. The Mentone Proposal, which encompasses the All-River-Plan, demonstrates that the government is willing to buy our flood-plain occupancy in San Bernardino at a very high price.

Supporters of the Mentone Dam argue that the proposal would provide greater flood protection to the basin region and also create recreational facilities for future urban growth. The Corps of Engineers has also argued that because of the greater flood protection from the proposed Mentone Dam, the San Bernardino Basin could develop within the flood-plain region, which would result in increased tax revenues. The San Bernardino Valley Municipal Water Department (SBVMWD) argues that the flood-plain has already been saturated with urban encroachment and that tax revenues gained from urbanization are at a near maximum. The Municipal Water Department has charged that the Corps of Engineers has acted irresponsibly by not publicly discussing the fact that even if the Dam was built, flood plain occupancy would increase at the same
rate as if other flood control methods were implemented. The (SBVMWD) also argues that the Mentone proposal does not give greater protection for downstream urbanization. Secondly, total occupation of the flood plain region is impossible because during extreme flooding, flood gates would be released in order for the water to flow onto the flood-plain. Therefore, a maximum development width would continue to be maintained in order to hold released flood waters during high water peaks.

Flood damage is a consequence of man's utilization of the flood-plain as a site for his activities. By evaluating San Bernardino's flood-plain management policies with the data in the field of history and physical geography, we shall find that the policies are in direct competition with the Santa Ana river. Revising the ordinances and enforcing regulations along the flood-plain will prevent man's utilization of this site for his activities. This study is significant in that it will introduce to the public a better understanding of the associated problems in the field of flood management and control. By investigation of facts regarding flood control management, the public can become more aware of one of the most extreme controversies in the San Bernardino Basin in recent years. The regulations of zoning and building, if enforced would provide the public with immediate protection from flood damage at a much lower cost than the proposed ALL-River-Plan. Public interest and participation could save millions of dollars in tax money.
LITERATURE REVIEW


The purpose of this investigation by Sahm was to analyze zoning ordinances in relation to flood-plain management. The main focal point of the study is ordinances which prohibit development in areas subject to inundation. Los Angeles Municipal Ordinance No. 79310, § E3, and Los Angeles County Subdivision Regulations Ordinance No. 3114 (regulations in existence in the Los Angeles area) were found to have little or no effect on the development of land subject to flood hazard.

Historical data which included aerial photographs were significant in Sahm's investigation of land use change within the areas subject to flood hazard. There were significant findings which included that pressure for expansion of a rapidly growing city has been so great in Los Angeles that ordinances and regulations have been ignored. The examination of aerial photographs prior to, and after the enactment of zoning ordinances, showed there had been no significant change in the land use of flood hazard areas.


The purpose of this investigation was to study flood
zoning regulations in Milwaukee County, Wisconsin, with the use of physical and historical data. The investigation revealed that residential construction was taking place along water courses or streams, sometimes in areas of low elevation subject to flood.

The author discovered by the use of the data that many of the areas which were recently urbanized were subject to inundation. Milwaukee County ordinances, according to the study, were having no effect on the development of land subject to flood hazard. The County Board, realizing that development had been unregulated along water courses, erected flood control works at great cost and inconvenience to residents of Milwaukee County. Eventually, because of the costs, consideration was given by the County for removal of buildings and other permanent values from the areas subject to overflow, and to the conversion of such areas to use which involved less potential loss. This usually involved the purchase of the lands in question by a governmental body and their conversion into parks. The master plan by Milwaukee County envisioned the gradual incorporation of such lands into the parkway system.


White investigates man's utilization of the flood-plain as a site for his activities. With the use of physical and historical data, the author explains that flood-plain occupancy is in direct competition with the
river. Floods, meaning water stages above bank-full capacity, are characteristic of rivers. Moving existing factories or people out of the flood-plain is usually impractical and unjustified, but to prevent redevelopment it may be both practical and economical.

The author suggests that in the aftermath of a great flood, when damage has occurred to property and buildings, there should be some thought given to the relative merits of re-building on the old site compared to selecting a new site out of reach of floods. The study advocates strict enforcement and guidelines of developing upon a flood-plain region.


The purpose of this investigation was to analyze San Bernardino, Riverside and Orange Counties' flood hazard. The paper offers a unique, timely review of a problem stemming from powerful natural forces which possess the potential for very grave human consequences at any time. The author uses data from the fields of history and physical science to describe the potential of a flood which could devastate vast portions of the densely populated areas through which the Santa Ana River passes. In conclusion, the suggestion by the author is that an all-out program to prevent a future catastrophic flood be implemented. The control works authorized by the Corps of Engineers list several flood hazard projects and their objectives. Ahlborn relies on the Corps of Engineers report of the All-River Plan, Phase One
(general design memorandum) to conclude that the All-River Plan is the best way to mitigate the Santa Ana River Basin flood problem.


The general objectives of the Santa Ana River Investigation were to secure data and information from historical and physical research, to recommend solutions for growth increases in the basin water consumption, flood control and water rights. Data was gathered by Corps of Engineers, Div. of Water Resources, Orange Co. Flood Control Dist., San Bernardino Co. Flood Control Dist., and the Metropolitan Water Dist. of Southern California. Personal interviews were used to help derive information concerning the present development, native cover, floods, and proposed flood control.

As a result of the investigation and analysis of available data on water resources and water problems of the Santa Ana River Basin, the following was recommended:

1. Programs of hydrologic investigation being conducted by county, state and federal agencies be coordinated and expanded for the purpose of facilitating more definite evaluation of water problems under continuing growth and development of the Santa Ana River Basin, and for their elimination.
2. Construction of flood control works planned by counties or recommended by Corps of Engineers, United States Army, and authorized by the Congress, be continued as rapidly as possible, and probable benefits to be derived form considered flood control projects be re-examined periodically in order that construction may be initiated when the projects become economically justified.

3. Continuing support be given to the investigation financing, and construction of major multi-purpose water resource developments under the California Water Plan, particularly those relating to importation of water to the Southern California area under the Feather River and Delta Diversion Projects.


The aim of the investigation by the Corps of Engineers was to (1) verify the nature and severity, and, (2) examine associated problems which the Corps might help solve along with the flooding problem.

The topics discussed within each chapter were The All-River Plan, the National Economic Development Plan and The Environment Quality Plan. The task of evaluating the four plans was to examine them from many points of view to provide the information necessary to select one plan in the best over-all interest of the communities affected and served. The Corps of Engineers prepared this very compre-
hensive study with primary and secondary data gathered from catalogs, Engineer reports, newspapers historical records, and personal interviews. Findings of the study suggest that the All-River Plan is the best plan for flood control in the Santa Ana River. The All-River Plan was one of the four alternative flood control proposals by the U.S. Army Corps of Engineers. The plan called for building the Mentone Dam, major levee improvements, the phase construction of raising Prado Dam, and acquisition of land. This investigation is important because it recognized the need for extensive flood control measures to protect against the most severe flood likely to occur in the basin.


The objective of this investigation was to analyze zoning regulations and their practices in Charlottesville, Virginia. The study by Yokley involved a detailed account of the history and development of Charlottesville, Virginia and the area’s particular need for zoning ordinances for agriculture, housing and flood control. The author also analyzed the failure to Charlottesville's flood control ordinances by the use of historical and physical data. Primary and secondary materials utilized included professional files of Charlottesville's planning department, personal interviews, selected historical and physical data, library reference materials, and local newspapers.
Findings of the study suggested that zoning regulations for agriculture and housing were sufficient for a continued orderly growth. Flood control ordinances were criticized because of lack of proper enforcement, being established by government agency instead of local planners, and proper data research. Yokeley argued that the data used by the Corps of Engineers neglected to represent the region's particular historical and physical uniqueness. The investigation presented information which eventually assisted in major revisions of Charlottesville's flood control ordinances.


The objective of this investigation was to evaluate the necessity for local flood prevention. The author compares local flood prevention programs to those enacted by state and federal agencies for flood control works.

Findings of the study suggested that local flood prevention planning was much more effective than state and federal flood control planning programs. Local planning involved inputs from many fields and disciplines, including engineering data. Primary and secondary material utilized in the study included professional files of cities which had enacted their own flood control work programs, personal interviews, and library reference materials. In conclusion the author suggests that local planning agencies have total
responsibility over flood control programs in their region. The reason is that local flood control planning serves the entire community by the use of citizen participation in the establishment of goals and objectives. This investigation was important because it recognizes the need for local public input into projects which involve community cooperation. Flood control works are only as good as the public support which they receive. Without community recognition of the governing ordinances, flood control becomes totally ineffective.
SOIL AND WATERSHED ANALYSIS

The analysis of the San Bernardino Flood-Plain commences with an examination of the natural environment in the region. This analysis discusses soils, seismicity activity, climate and the network of drainage patterns of tributaries flowing to the Santa Ana River.

The tributaries which flow into the Santa Ana River are utilized extensively for varied purposes. The network of drainage routes is most vital, not only for relieving the land of water, but for the future survival of the Santa Ana River. Throughout the last several decades, these networks have been threatened by man's continuous desire to occupy the flood plain. Channelization of major tributaries and reservoir development along the mainstream Santa Ana River has enabled man to continue to develop the flood-plain region.

This analysis of the flood-plain will conclude with an examination of sequential aerial photographs and historical data relating to the urbanization of the valley region and the effects of this upon the land, the network of water drainage routes and the surrounding basin.

The upper San Bernardino Valley is 5 to 7 miles wide and is surrounded by the high and rugged San Bernardino
Mountains on the north and east side, and the relatively low Crafton Hills on the southeast, and also the Badlands on the south. Elevations range from approximately 1,300 feet to 11,502 feet on the San Gorgonio Mountains, 18 miles east, and to 3,600 feet on Zanza Peak in the Crafton Hills. The Santa Ana Wash is about 1 mile wide at Mentone and has a gradient of about 100 feet per mile.

The region is composed basically of crystalline rocks and alluvial sediments derived from them, see (Figure 6). The San Bernardino Mountains are made up of several varieties of igneous and metamorphic rock, primarily quartz, monzonite, diorite, and some schists and gneiss, all at least 65 million years old. The Crafton Hills are also composed of these schists and mylonites and other igneous and metamorphic rocks, over 570 million years old. Materials eroded from these higher areas have coalesced to form the San Bernardino Valley floor. The combined fans of the Santa Ana River and Mill Creek at the damsite are the largest and most distinct in the valley. The San Bernardino Valley contains several alluvial units of Pliocene to recent age. The oldest of these units is the consolidated Potato Sandstone located in the Mill Creek area. Progressively younger, the other units range through older alluvium and plain and bench deposits around the valley rim, to younger alluvium with river channel deposits across the valley floor.
Crystalline and metamorphic rocks of Jurassic or greater age.

Sedimentary rocks of Marine Origin largely of tertiary age.

Alluvium and associated deposits of Recent or Pleistocene age.

Figure 6  Geology of San Bernardino Basin Map portion (Jenkins, 1938).
"In general, the younger alluvium is underlain by older alluvial deposits."2

The specific region in which this study focuses on has two primary soil associations. Soil associations are landscapes in which soil patterns are proportionally distinctive. (Figure 7), a map showing associations is useful to people who want a breakdown of the soils within the San Bernardino Basin region. The information provided by the soil map is compiled in text by the United States Department of Agriculture & Soil Conservation, in cooperation with University of California Agricultural Experiment station. The text is entitled Soil Survey of San Bernardino County, Southwestern Part, California. "The soil associations in this survey were grouped into two general kinds of landscapes for broad interpretive purposes. The first of these broad groups is further subdivided on the basis of color or texture, or both."3 For example, one of the two primary soil associations within the Santa Ana River floodplain is Tujunga-Sobaba Association. This association makes up the largest percent of the survey in the area in which this paper focuses on. The association between Tujunga-Sobaba as one association is done for the simple reason that soil differences are so intricately mixed, or so small in size that they cannot be shown separately on the soil map. "Tujunga soils are a somewhat excessively drained surface layer of brown, slightly acid loamy sand, that is
The soils of this association are used mainly for irrigated crops. They formed in an alluvium derived from granite rock. "Elevation ranges from 900 to 2,200 feet. The average annual rainfall is 12 to 16 inches. The mean annual temperature ranges from 61° to 65°F, and the frost free season is 230 to 280 days."^6

The second major group is Hanford-Greenfield-San Emigdio Association, which makes up the rest of the percentage of the area in which this paper focuses on. The map survey, (Figure 7 ), gives a general understanding of the location of particular association. "Hanford soils have a surface layer of pale-brown, slightly acid sandy loam."^7 "Greenfield soils have a surface layer which is pale-brown, slightly acid sandy loam."^8 "San Emigdio soils have a surface layer of light brownish-gray, moderately alkaline fine sandy loam."^9 The association is formed in an alluvium derived mainly from granitic rock. "Slopes range from 0 to 9 percent; elevation ranges from 1,000 to 3,400 feet."^10 "The average annual rainfall is from 12 to 16 inches, the mean average temperature is from 61° to 65°F."^11

Both associations discussed are moderately sloping, well drained, very deep soils on alluvial valley floors. These associations are used mainly for irrigated crops,
Figure 7. Map Showing the Soil Analysis Divisions

- Hanford-Greenfield-San Emigdio Association
- Tujunga-Soboba Association
dryland crops, limited grazing and other related uses, because the associations are well drained. Moderately sloping, the basin is well organized for industries such as citrus and dryland crops. Citrus grows excellently in both associations discussed; in fact, if one would trace the citrus industry in the basin region they would find the existence of these soil associations. The soil associations were complimented by the growth of dry land farming and citrus industry in the San Bernardino Basin and the flood-plain region. The soil associations which make up part of the San Bernardino flood-plain have become much more stable due to the planting of this well drained, sloping region. The citrus industry, which covered nearly 43,524 acres during the 1940s, acted as protective cover for the flood-plain region. According to a U.S. Army Corps of Engineers report, "the demise of the dry land farming and the citrus industry within the flood-plain region has largely intensified runoff and erosion in the basin in the last several decades." The soil associations provided protection because the area was well drained; the citrus industry which flourished in these same soils provided an even greater stability during the floods. With the continued demise of the citrus industry and other agriculture, due to urban sprawl, the flood-plain has increasingly developed into the potentially dangerous environment of the 1980s.
A review of the seismicity of the basin region shows conclusively that the Santa Ana River is in a zone of high seismic hazard. The San Andreas Fault is a dividing line which separates two major plates of the earth's crust. The plate to the west is known as the Pacific Plate and the plate to the east of the San Andreas Fault is the North American Plate. These plates and others forming the land areas on the surface of the earth are in motion, slowly drifting past each other along the San Andreas, at a rate estimated between 1/2 and 2 inches per year. This drift causes regional shear and compressional strain build-up, which is relieved by occasional sudden movements along the fault or along major associated faults. There have been reports that the ground has been displaced a maximum of 20 feet horizontally and 5 feet vertically along the San Andreas Fault due to sudden movements.

The most recent trace of the Fault, which is located about 1/4 mile from Mentone on the South Branch of the San Andreas Fault, is the most likely site of future rupture. Horizontal ground displacement of up to 20 feet should be assumed, according to U.S. Geological Surveys (USGS). There are also several minor faults which dissect the valley floor in two general directions parallel with the San Andreas, and near normal to it, see (Figure 8). "The Santa Ana River is in a zone of high seismic hazard which has a continuous influence on the river's drainage pattern."
You can see traces of both Mill Creek and San Andreas Faults as they cross over Highway 30. The San Jacinto Fault passes through San Bernardino Plain and then assumes a northwesterly course parallel to the San Andreas. San Andreas Fault starts at Burro Flat and continues Northwest in an unbroken line.
The Santa Ana River Basin enjoys an equable climate that may be classed as semi-arid, characterized by warm dry summers and mild winters. Precipitation in the Santa Ana River Basin varies widely, both seasonally and geographically. Precipitation characteristically comes in the form of rain on valley lands. The greater part falls during the months of November through April. Shown in Table 1 are precipitation stations which are located in various parts of the basin. The precipitation stations covering all portions of the study area were selected and have been located. Every station is given a data location number so that seasonal precipitation averages in each location can be identified with the location number. Table 1, gives the selected station's yearly precipitation depth from the years 1934-1960. Examining the precipitation data from Table 2, serves to prove that the Basin varies widely, both seasonally and geographically, in rainfall depth. "Moving northeast from Station SB 127 to Station SB53 during the year 1959-60, we find that SB 127 had 15.69. The overall difference in data was caused by extreme ranges in the elevations of the two stations." The Santa Ana River principal stream of the Basin rises in the San Bernardino Mountains, flows southwesterly across the valley of the Upper Santa Ana Unit, through the narrow Santa Ana Canyon, and across the valley of the Lower Santa Ana Unit, entering the Pacific Ocean near
<table>
<thead>
<tr>
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<th>SBCFCD 1</th>
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<th>SBCFCD 72</th>
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<td>13.83C</td>
<td>27.31C</td>
<td>15.71</td>
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<td>27.56C</td>
<td>55.72C</td>
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<td>44.96C</td>
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<td>5.14</td>
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<td>59-60</td>
<td>11.79</td>
<td>23.77</td>
<td>12.65</td>
<td>15.69</td>
<td>10.51</td>
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<tr>
<td>26 YEAR AVERAGE</td>
<td>15.56</td>
<td>32.68</td>
<td>16.32</td>
<td>18.42</td>
<td>13.96</td>
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TABLE 1 Selected stations yearly precipitations depth from the years 1934-1960, Department of Water Resources, 1971.
Newport Beach. Tributaries originating in the San Bernardino and San Gabriel Mountains provide a unique drainage net for Basin regions. There are at least 6 large tributaries which contribute to the flow of the Santa Ana River. They are Plunge, Lytle and City Creeks from the north and Mill, San Timoteo, and Temescal Creeks from the South. All are partially diverted for either use of flowing into Prado Dam, irrigation, power generation or domestic use. The continuous year-around flow of these important tributaries has set them apart from many storm runoff drainage streams. Table 2 gives the runoff data for each of the 6 tributaries. (Figure 9), shows the exact vicinity and location of the tributaries which are discussed. (Figure 10), describes many smaller tributaries which outline the Santa Ana River Basin. Most of these tributaries flow only during the winter season.

The diverted water from these tributaries serves the community in several very important areas. The major portion of the flow in Mill Creek is diverted by the Southern California Edison Company to be used for power generation. After the water diverted from the creek passes through the powerhouses, it is divided—with one portion going to Crafton Water Company and another to the City of Redlands. During the winter months, the flow is diverted into spreading grounds above Mentone to replenish the ground waters of the valley. City Creek water is diverted for irrigation and domestic use by City Creek Water Company.
### Recorded Seasonal Run-Off Data (in Acre Feet)

<table>
<thead>
<tr>
<th>Season</th>
<th>Lytle Creek</th>
<th>City Creek</th>
<th>Plunge Creek</th>
<th>Mill Creek</th>
<th>San Timoteo Creek</th>
<th>Temescal Creek</th>
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<tr>
<td>1940-41</td>
<td>74,180</td>
<td>18,700</td>
<td>12,860</td>
<td>41,900</td>
<td>64,660</td>
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<tr>
<td>41-42</td>
<td>26,970</td>
<td>4,620</td>
<td>3,140</td>
<td>22,000</td>
<td>15,570</td>
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<td>65,260</td>
<td>15,270</td>
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<td>30,900</td>
<td>32,320</td>
<td>13,350</td>
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<td>43-44</td>
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<td>2,100</td>
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<td>45-46</td>
<td>30,770</td>
<td>5,330</td>
<td>4,500</td>
<td>21,700</td>
<td>11,130</td>
<td>800</td>
</tr>
<tr>
<td>46-47</td>
<td>33,230</td>
<td>5,880</td>
<td>4,140</td>
<td>18,000</td>
<td>6,660</td>
<td>30</td>
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<tr>
<td>Mean for 53 Year Period 1894-1947</td>
<td>34,200</td>
<td>9,000</td>
<td>6,600</td>
<td>30,100</td>
<td>28,900</td>
<td>6,800</td>
</tr>
<tr>
<td>Mean for 21 Year Period 1922-1943</td>
<td>30,500</td>
<td>8,100</td>
<td>5,600</td>
<td>26,300</td>
<td>29,500</td>
<td>5,200</td>
</tr>
</tbody>
</table>

**TABLE 2.** Run-off data for 6 major tributaries which flow year-around. Many of the tributaries recording Seasonal Run-off data are less than 10,000 Acre feet, (Department of Water Resources, 1959)
Figure 9. Location of Precipitation Stations
Figure 10. Entire tributary network system of Santa Ana River Basin (Department of Water Resources, 1959).
The East Highland Orange Company diverts water from the Plunge Creek to irrigate their citrus trees. Water is diverted from Lytle Creek by Meeks and Daley Water Company, which pumps water through the Daley Canal to the Chino-Riverside area. Only minor surface diversions occur to the Sam Timoteo Creek, and generally the use is for irrigation purposes. Temescal Creek deposits most of its water in the Prado Dam region, which is in turn used as a power source. Many of the other tributaries supply water as well to many public and private groups who use the diverted water in a number of ways, (See Table 3 ) "The water which flows into the Santa Ana River constitutes only about 25% of the actual precipitation which falls on the flood-plain region during a storm. The cyclic storage within ground water reservoirs is so large that the amount of water lost by runoff to the ocean is only a small part of the total supply."16 Because of the vast importance of the Santa Ana River's continuous flow downstream to public and private entities, construction of flood control improvements on the Santa Ana River and its tributaries has been very slow in maturing. Many years of litigation over water rights between state, county, and private industry have virtually disrupted improvements throughout the 75-mile length of the Santa Ana River and its tributary network. These improvements included levees, storm drains, concrete channels, wire mesh reinforced fencing, stone walls, extensive channel
**TABLE 3**

**WATER USES**

**Irrigated Agriculture**

<table>
<thead>
<tr>
<th>Category</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>Hay, seed or pasture</td>
</tr>
<tr>
<td>Pasture</td>
<td>Lawns, parks, cemeteries</td>
</tr>
<tr>
<td>Deciduous, walnuts</td>
<td></td>
</tr>
<tr>
<td>Citrus</td>
<td>Avocado and subtropical fruits</td>
</tr>
<tr>
<td>Truck Crops</td>
<td>Melons, hay, grain, etc.</td>
</tr>
<tr>
<td>Vineyards</td>
<td>All varieties of grapes</td>
</tr>
<tr>
<td>Native vegetation</td>
<td>Trees, plants</td>
</tr>
<tr>
<td>Riparian vegetation</td>
<td>Swamps and marshes</td>
</tr>
</tbody>
</table>

**Urban and Suburban**

<table>
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<tr>
<th>Category</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>Water for domestic use</td>
</tr>
<tr>
<td>Commercial</td>
<td>Hotels, churches, theatres</td>
</tr>
<tr>
<td>Industrial</td>
<td>Paper mills, steel plants, processing</td>
</tr>
<tr>
<td>Unclassified</td>
<td>Schools, dairies, livestock and poultry feed</td>
</tr>
</tbody>
</table>

**Basin Projects**

1. Lemon Basin
2. Atwood Basin
3. Badger Basin
4. Baseline Basins
5. Daley Canyon
6. Devil Canyon
7. Harrison Basin

8. Lynwood Basin
9. Macy Basin
10. Patton Basin
11. Sweetwater Basin
12. Wiggins Basin
13. Wilson Basin

Wiggins Dam
Twin Creek
Mill Creek
East Lugonia-Beryl Street Well
improvements (on some tributary streams), and 5 active dams, the largest of which is the Prado Dam. Prado Dam was constructed immediately following the flood of 1936, in which extensive damage resulted in Orange County. According to the State of California Water Resources, "runoff in surface streams constitutes about 25% of the natural water supply available to the valley floor area of the Santa Ana River Basin.\textsuperscript{17} "Surface runoff is important economically as a source of water for direct diversion and use, and as the largest natural contributor to ground water storage in the Basin.\textsuperscript{18} Most improvements along the river and tributaries, except Prado Dam, were fought with much resistance through litigation. Tributary improvements, for example storm drains, concrete channels, levees etc. impeded the flow of the natural drainage pattern of the Santa Ana River. Table 3 has already discussed, in detail, uses in which the water affects surrounding agriculture and urban lands. The importance of continuous natural flow and the effect which this flow has on outlying areas is clearly described in a report put out by the State of California water resources Agency. There is a legal obligation for outflow of water to areas downstream in the Santa Ana River Watershed. Urban and agricultural uses demand delivery of a certain quantity of water to meet their urban and agricultural demand. In the San Timoteo and Bunker Hill area, approximately 60% of the delivered
water is for urban demand, while 40% is for agricultural demand. A judgement in effect on October 1, 1970, stipulated that the San Bernardino Valley Municipal Water Department (SBVMWD), shall be responsible for the delivery of an average annual supply of water to the City of San Bernardino. The delivery and obligation to supply water regardless of source, must meet the quantitative demand. The Santa Ana and tributaries are the only source to fulfill the delivery obligation of water from the SBVMWD to the city of San Bernardino. There are hundreds of obligations by public and private organizations to supply water for one reason or another. Companies which must meet their legal obligations depend entirely on the natural flow of the tributaries and Santa Ana River. Whenever improvements are demanded by the Corps of Engineers, there is approximately 2-3 years of litigation between either the approval or disapproval of the project. The reason is that private companies using the waters in the tributaries believe any improvements might impede the water flow. Engineers and hydrologists who work for (SBVMWD) have accurate accounts of when improvements took place along the Bunker Hill tributaries. Their investigation found that water department storage reservoirs had 57% more silt. The increase of silt decreased the amount of water which could be stored within the reservoir's total capacity. The most unique observation, when analyzing proposed improvements by the Corps of Engineers, and litigation problems which result thereafter, is the vital necessity for the Basin's use of the Santa Ana River and its tributaries.
HISTORICAL GROWTH ON FLOOD-PLAIN

Historically, settlements within the Santa Ana River Basin have had their beginning along tributary and river fronts. Author H.F. Raup writes that, "The San Bernardino area was occupied by a loosely organized groups of Shoshonean stock during the early 1800s."19 "The Indians had several settlements; Kotainat lay east of the city in the wash of the Santa Ana River, north of Redlands; and Wachak was at the junction of the Santa Ana River and Lytle Creek."20 In general, these rancherias were located near the large tributaries of the river for agricultural and domestic uses. The total population in San Bernardino was estimated to be not more than 1500, among the tribal organizations. During the later 1800s, with heavy migration and influence from the Mormons, the San Bernardino area was transformed to resemble Salt Lake City. H.F. Raup writes that, "not only in street pattern, setting and site did the new town resemble the parent city, but even the street names suggested Mormon influence."21 The transformation also included irrigation ditches in San Bernardino streets. The water was used for domestic and garden plots. Crops requiring irrigation, such as grapes, were generally located nearer to the Santa Ana River."22 The modern
transformation increased the growth in the area and also enabled the population to exist at a further distance from the river's edge because of the irrigation ditches.

Eventually artesian wells were to assure a larger water supply for the irrigation of agricultural fields. Raup states that, "When larger amounts of water were brought in to San Bernardino, the land use changed from dry-farmed grains to irrigated sub-tropical crops, including some citrus fruit." By 1940, there were 51,728 acres of irrigated citrus and avocado groves in the San Bernardino Basin area. Raup also writes that in 1940, "The land use in the vicinity of San Bernardino is now almost exclusively agricultural."

The population of the San Bernardino Basin grew more or less steadily from the Mormon migration to the 1940s. After the war years, many people who migrated to the area because of newly built military bases, stayed because of the equable climate and pleasant living conditions. During the next several decades, there was extreme rapid growth within the basin region, with most of the population remaining within the original city area established by the Mormons. After 1940, the spread of urbanization away from the original city site began to bring a decline upon the San Bernardino agricultural industry. R.E. Caryl writes that, "the citrus industry, which comprised 90% of the agriculture industry in the Basin, began to decline as
early as the 1940s. With the increasing urbanization, disease, escalation of land values and taxes, he states that "The citrus industry went from a thriving 43,584 acres in 1940, to 27,739 acres in 1960, and predicted decline by 1980 to the figure of 11,025 acres." In analyzing land use changes in San Bernardino Basin sequential aerial photographs and historical data will give accurate account of the settlement and growth of the city of San Bernardino. Discussing H.F. Raup's description of the original settlement site for San Bernardino in the late 1800s will give an insight into the land use changes which over-developed the flood-plain region. These changes are shown in sketches based on tracings from historical data and aerial photos from the period 1887 through 1978. The original site had its beginning on the north side of the Santa Ana River, between Cajon, Warm, and Lytle Creeks, which afforded an abundant supply of water for irrigation. Mills and manufactories are shown in (Figure 11-12). The 1936 aerial photograph in comparison to Raup's 1887 description of the site, shows a southerly and northerly expansion of the city. New methods in irrigation, with combined technology, in communications and agriculture, expanded markets during the late 1800s and early 1900s, in an easterly direction. As previously discussed, the citrus industry, which comprised 90% of the agriculture industry in the Basin, was at its peak at the time the aerial photographs
The Cooley Ranch (Settled in 1857)  
just west of the San Bernardino-Riverside Freeway

San Bernardino County Court House-1874
Figure 11. Original Site of San Bernardino

PROPOSED ENLARGEMENT OF PRADO DAM AND RESERVOIR

Riverside County
Figure 12 is original site of the city of San Bernardino.
of 1936 were taken. "The most important commercial operations in the Basin during the late 1800s were the lumbering mills." When the spring season came to the Basin, the stock of lumber yards was seriously depleted and prices were high because of the demand. By late summer, the lumber yards within the city would be stacked high with lumber to meet the demands of the coming winter. These lumber yards and other commercial businesses in the center of the city, are non-existent in the aerial photographs of 1936. Transportation routes had developed in response to local needs. "Cajon Pass, Warner's Springs and Los Angeles Highways, marked principal routes, throughout the Basin. The entrance of the Santa Fe into the San Bernardino area had a tremendous effect upon, not only the transporting of materials, but the commercial district which began growing toward the train depot." Evidence of the land-changes in the Basin are described adequately in the statistics previously discussed on the decline of the citrus industry. In the 1940s there were approximately 43,584 acres of citrus. During the 1970s, it was estimated that the total acreage in the Basin for citrus was 21,232 acres. The spread of urbanization away from the original city site began escalations of land values and taxes, which devastated the annual profit from the citrus crops. During the decades from 1936 to 1978, there was a major increase in commercial services, which was a result of the population
growth in the Basin. Aerial photos from 1936 to 1978 show the commercial areas to have shifted further east toward recently acquired lands. The flood basin region has become so populated that cities and counties have had to force land-use restriction upon the population, in the form of moratoriums or zoning. Even restrictions on building and land-use have not deterred the growth of the Basin area. In the period of 100 years, the population increased in flood-plain regions from 150 settlers to approximately 200,000.

The influence of urbanization upon the physical land changes is most extreme when analyzing the Basin. The dramatic influence, which growth has had on altering the physical landscape, is most difficult to discern. The growth of urbanization which was analyzed in the previous discussion, changed the entire land surface of the Basin floor. Agricultural fields not only provided food for the surrounding areas, but also absorbed the running water during rains. The dry ground and fields served as a percolation base, absorbing partial amounts of the rain water. Because of urbanization, new transportation routes, parking lots, housing tracts and large stores have been constructed to accommodate urban growth. Because of this construction, the physical landscape throughout the entire Basin has been completely altered. Concrete and asphaltating, which has replaced the natural landscape, compounds the
actual flood-plain drainage area. With less seepage of water into the ground, there has been an increase in the areas exposed to flood hazards. Sketches drawn from aerial photographs in 1936 and 1972 reveal the only major landscape change is the decrease on agriculture and increase in urbanization. The only bright spot is that the Upper Santa Ana River between Mill Creek Levee and Mentone has not been disturbed by development. This area is owned and maintained by the United States Department of Forestry, which restricts all development for the protection of the natural environment, (Figure 13). Lytle Creek, which is a major tributary of the Santa Ana River, has also been preserved by the United States Department of Forestry. The area is virtually undeveloped, except for some scattered residential homes, which were built in the early 1900s, before major environmental restrictions were initiated. During the 1960s, the San Bernardino Flood Control Department learned through investigative studies by the State of California, Department of Water Resources, that, "development along the channel of the river had caused a possible shifting of drainage route several miles downstream." The development of Norton air Force Base in the vicinity of the flood-plain region, had a major impact upon the drainage net in the area. The State of California Department of Water Resources was notified by the San Bernardino County Flood Control Department, that, "downstream
flooding during minor rainfalls was caused by possible upstream development." The Department of Water Resources focused their study on an area located approximately two miles downstream, (this location is now the freeway interchange for Interstate 10 and Interstate 15). The study conclusively provided detailed information that revealed the drainage course was shifting to the north, toward the San Bernardino Mountains, (Figure 14). According to studies made by the State Department of Water Resources, which had been brought to the Basin as intermediary organization between federal government, (representing Norton Air Force Base), and the County Flood Control Department, (which maintains the Upper Santa Ana River), it was recommended by the California State Department of Water that the channel walls be cemented and concrete reinforced to prevent continued erosion and shifting of the river. The prevention methods are very successful. The area has remained very stable and is easily maintained by the County Flood Control Department.
Figure 14. Shifting of the river's channel caused by the development of Norton Air Force Base 2 miles upstream brought litigation between the federal government and San Bernardino County Flood Control Department. Eventually the channel shifting north was concreted and reinforced to prevent further eroding. Based on Department of Water Resources, 1959.
HISTORICAL DATA AND PHYSICAL GEOGRAPHY DATA

The large alluvial valley along the southern toe of the San Gabriel and San Bernardino Mountains, extending from Pomona on the west to Mentone on the east, has been designated the upper Santa Ana Valley, or San Bernardino Valley, and is recognized as a semi-arid region. It is an area where the vagaries of weather are such as to reflect flood conditions one year and drought the next, with continuous recurrence of prolonged droughts. In this one sentence is contained the substance of the flood problem and factors which tend to mislead us in evaluating the flood menace. A drought period may lull one into a state of false security where the flood assumes the position on an unusual or remote event. This is definitely not the case, as history teaches us, but rather, a flood and its effects is always poised above us and may occur tomorrow; if not it can be counted on to strike shortly thereafter, perhaps when least expected.

The entire problem was called to the attention of the people of San Bernardino County during the floods of March 1938, which destroyed many lives and caused millions of dollars of property loss. In October of 1938, six months after the March floods, the San Bernardino Flood Control
District created and enacted Ordinance 2417, which sought regulation and development in specific areas along the Santa Ana River flood-plain. It is the purpose of this analysis to focus on the failures of flood-plain Ordinance 2417 by the use of historical data. Most of man's endeavors rely on history, experience and observations as the basis for meeting the challenges of the future. The flood problem in the San Bernardino Valley fits well into this historical model. The study will demonstrate that Ordinance 2417 fails to regard historical observations and experience as a means of meeting the challenges of the future. It will also suggest revisions of Ordinance 2417 by the use of historical data and observations which would be more likely to assure a reliable flood-plain management program.

1. The analysis commences with a descriptive presentation of historical data of floods which have caused damage to particular areas along the Santa Ana River.

2. A discussion of what Ordinance 2417 was designed to do will follow the historical description.

3. Data comparison between historical observation and the stated purpose of the governing flood-plain ordinance, illustrating their discrepancies, will conclude the analysis for this section.

The earliest references to floods are found in the diaries of the Spanish Mission Fathers. These early records examined by Juan Collell Cabaleria, History of San
Bernardino Valley from the Padres to the Pioneers, indicate that there were floods in 1770-71, 1771-72, 1775-76 and 1779-80. This is the historical data period commencing about 1770 and termed the Mission Period, resulting from the arrival of the Spanish Missionaries in the vicinity in 1769, the time of institution of agricultural activities in San Bernardino County. Because of the importance of establishing reliable food supplies, these early missionaries also acted as agriculturists. They made many notes referring to rainfall, floods and droughts occurring in the area. Father Juan Crespi first observed the evidence of a great flood along the Santa Ana River. The flood runoff from the San Bernardino Mountains and other mountain ranges has periodically submerged, damaged, and washed away crops, homes, bridges, missions and other structures located by man, for his convenience, near flood channels that have been established by nature for the passage of flood waters from the mountains to the sea. The written accounts of the floods prove that for over two-hundred years the Santa Ana River has plagued settlements which have occupied land near its banks. Specific areas inundated by the floods along the river in San Bernardino during this period are not found in the mission records. Father Crespi's observations were general estimates in which the aftermath of destruction was observed.
As time passed into the season of 1861-62, the San Bernardino Valley was to experience, unexpectedly, the impact of a major event, a great flood. Many accounts of this famous wet season may be found, which outline specific areas in San Bernardino that were inundated near the Santa Ana River Basin, (Figure One-1). The first of many accounts discussing the flood of 1862 is found in George William Beattie and Helen Pruitte Beattie, "Heritage of the Valley," in which the author states that, "all of the flatland from the Santa Ana River to Pine's Hotel, (corner of present Third Street and Arrowhead), was under water, inundating the valley for miles up and down the river." The San Bernardino Sun Telegram reported in January 1862, that "It rained both day and night for three weeks. Great rivers flowed through the streets of pioneer towns. The Valley floor was one vast lake, stretching from the present courthouse to the north side of Redlands." Pauliena B. LaFuze, "Saga of the San Bernardinos," reports that, "The rain continued for many weeks. The Santa Ana, joined by Mill Creek, City Creek and Warm Creeks, cut through the town and foundered an army encampment to the southeast. Many thriving farms along the Santa Ana River in San Bernardino County were completely ruined; barren wastes of sand supplanted fields, orchards and vineyards." The Santa Ana River, according to G. Lewis Fletcher, "Agua Mansa and Flood of January 22, 1862, Santa Ana River," "Water rushed down a
narrow valley in which lay the settlement of Agua Mansa in 1862. Almost the entire community was uprooted and carried along bodily; the land was cut and washed, and the fertile fields were buried under deposits of coarse sand and gravel."

Between 1862 and 1938, the Santa Ana River would create only minor difficulties for those who encroached upon its banks. San Bernardino County thrived during the next eighty years after the flood of 1862. Never would anyone have believed that a storm of that magnitude had inundated settlements and communities. In the beginning of this paper, the writer described San Bernardino Valley as a semi-arid region. It is an area where the vagaries of weather reflect flood conditions one year and drought the next, with continuous recurrence of prolonged droughts. A drought period may lull one into a state of false security. Such was the state of the inhabitants of San Bernardino and nearby communities. With only minor floods in the Basin in 1884, 1891, 1910 and 1916, people had forgotten the destruction which occurred in the floods of 1862. During the winter of 1937-38, California was visited by two disastrous floods, one in December 1937, in the northern part of the state, and the other in March 1938, in the southern part of the state. The flood runoff from the storm of March 1938 was especially heavy in the larger streams in the mountains and in the main-streams crossing
the valley floor. The area centering at Colton, where Warm and Lytle Creeks join the Santa Ana River, was extensively overflowed and parts of the cities of San Bernardino and Riverside were also submerged, (Figure 11). During the floods of March 1938, houses both large and small, were destroyed; and highways, bridges, and many other public improvements were washed away or damaged. The San Bernardino Sun Telegram reported that,

The Santa Ana halted traffic across North Orange Street and Tippicanoe in Redlands and Loma Linda...mud as high as four feet washed up to the grounds of Loma Linda grammar School on North Anderson Street,.... In San Bernardino County, property was directly damaged to an estimated amount of $11,550,000.00 and indirectly to an estimated amount of $6,167,600.00. A total of over one hundred bridges collapsed; and major railroad routes, such as the Southern Pacific, lay under mud. The final report estimated fifty-seven lives had been lost during the twenty two days of continuous rain in March 1938."

A committee of approximately one hundred persons met in October 1938, and continued studies and hearings on the problem of flood control along the Santa Ana river's flood-plain. Out of these studies and hearings, a recommendation was made that the County adopt statutes and ordinances which would regulate development within the flood-plain and especially along the Santa Ana River's edge. Zoning has been the most widely advocated of all the various methods of regulating development in flood- plains. Zoning is a legal tool used by cities and counties to control and direct the use and the development of land and property within
their jurisdiction. This is done by dividing the area into districts and specifying the uses that can be made of the land in each district. Districts which are subject to flooding have special restrictive use-provision, so that flood damage can be minimized. These districts, labeled flood-plains, are regulated by cities and counties for the protection of the health and general welfare of the community, but the main purpose is to reduce flood damage.

San Bernardino County was assigned the task of regulating the use of land throughout the flood-plain in the County. The guidelines for development of the flood-plain lands are to be discovered in Ordinance 2417, which specifies the uses that can be made of the land. Ordinance 2417, which has been only slightly revised since its enactment in October 1938, has been the single most important legal tool used by the County to regulate the use of the flood-plain, (Figure 5). This ordinance sets several major restrictions which regulate development and growth on the flood-plain. The first restriction is encroachment lines, which prevent channel encroachment and may well be considered the first line of attack in any program of flood-plain regulation. The County maintains that their encroachment lines have sufficiently prevented development along the flood-plain area, near the river. Later in this analysis we shall discover that development continues to take place that is serious encroachment during moderate and major flood
flows; and the enforcement procedure for even such minimal channel lines is inadequate to serve the purpose of the ordinance. The second major restriction is building codes, which are effective in reducing flood losses along the flood-plain. The County has drafted standards which require builders to develop improvements to ensure protection from a flood within the area. An example of the County's building restrictions is found in Section 6, of Ordinance 2417. This section states, that, "non-residential structures will be floodproofed so that the structure is water tight, with walls below the base of flood level being substantially impermeable to the passage of water." 38 (Ord. 2417, §6).

The two major restrictions discussed, along with several minor restrictions, were presented to the people of San Bernardino County after the flood of 1938. After months of planning, engineering and mapping of the March 1938 Flood, the experts had secured what they believed were excellent flood-plain regulations. By assessing water heights, damage, and river course change, engineers and planners were in agreement that their data would assure San Bernardino County maximum flood protection.

By 1940, the population of San Bernardino, according to the San Bernardino Redevelopment Agency, 1980, was 43,646, but the years that followed were not comfortable ones. They were years of decline. The pressures of a population growth of almost one hundred percent, between 1940
and 1960 put heavy burdens on the city's physical and social structure, straining utilities, streets, schools, sewer systems, and housing to their capacity and beyond. Industries which comprised the central city area began to migrate from the core of the city to the fringes. Industries from outside the region were in need of new markets, cheaper labor, and land which could be purchased at a reasonable price. With new industry, jobs were abundant from 1942 to 1949. Over 6,000 jobs were created in industry alone. With new jobs created each day, the demand for housing during the years 1946-47 nearly doubled from the previous year of 1945. Because of the continued development of industrial, agricultural and residential housing within the county, pressure mounted to develop the flood-plain.

During the 1950s, encroachment of industries upon the flood-plain became a very common occurrence. It cannot be assumed that once a channel-encroachment law has been passed, the problem has been solved. San Bernardino County, like so many other counties, felt that by ignoring the provisions of encroachment, growth along the flood-plain would bring a financial gain. A study by the Massachusetts Legislative Research Council, in 1956, revealed that, "In Massachusetts, ordinances passed to prevent flood-plain encroachment have never been enforced or maintained by the regulating authorities."\(^{39}\) The Massachusetts Research Council also discovered that many counties had statutory provisions
preventing encroachment, but only one had enacted its laws. Apparently the counties in Massachusetts, as well as in San Bernardino County, felt that by administering the statutory provisions, development would be hindered because cheaper lands on the flood-plain could not be purchased by future industries. San Bernardino County, like so many other counties, was experiencing the difficulties of growth. Throughout the next several decades, the County remained at a steady pace of achieving a status of an area with an excellent economic growth rate. From the period of 1936 to 1965 the County had experienced on one minor flood, which occurred in November, 1965. The Santa Ana River only caused a total of $3,000,000.00 in damage to property which aligned the flood-plain. One third of this damage was caused to a sewage treatment plant which over two feet of silt washed into its generators by the rushing storm. It would be just four years later, in January of 1969, that extreme flooding with major property damage would occur. A drought period of approximately thirty years was enough to lull the County into a state of false security, which would prove to be very costly to property and lives along the river's edge. Flood waters on the Santa Ana River overflowed the channel bank, eroded agricultural lands, washed out dip crossings and damaged bridges. Several large ranches along the river sustained loss of land as a result of bank erosion and heavy silt deposits on fields and grazing lands. The floods
of January and February 1969 were the most damaging floods of record in San Bernardino County. Unprecedented property damages were sustained by the County. The storms and floods caused the deaths of at least eighteen persons. Flood damages in San Bernardino County from January and February floods totaled more than $54,000,000.00. The overflow of the Santa Ana River caused approximately $22,165,000 in damage to property aligning its channel.

According to documents by the San Bernardino Municipal Water Department, the 1969 floods were half the size of the 1938 flood. Yet, damages sustained by the January 1969 rains were twice that of the March 1938 floods. San Bernardino County had found that economic advantages could be derived from occupancy of the flood-plain; also that greater losses were sustained as a result of that occupancy. The development near and on the flood plain—in recent decades has compounded the effects of rain, making runoff difficult to control. Even with statutes which control encroachment upon the flood-plain, we find that very few are actually in use.

The accepted record flood by engineers, planners and other officials in the area of flood-plain control, is the flood of 1938. The March 1938 flood and the destruction which it brought, was observed, recorded and documented by public officials. These observations and records guide all flood-plain policy for San Bernardino County. The writer
advocates that Ordinance 2417, which governs San Bernardino's flood-plain policy, is totally non-representative of historical data presented earlier in this paper. By the use of observations and recording of destruction caused by the 1938 Flood, public officials totally disregarded documented historical data. Data documented by G. Lewis Fletcher in *Agua Mansa* and *The Flood of January 22, 1862, Santa Ana River*, tells us that, "A new maximum flood record must be reckoned with which is over three times the magnitude of the previously accepted record flood of 1938,"\(^{40}\) (Figure 15).

San Bernardino County Museum Association wrote in their Bicentennial Commemorative Edition, that, "In 1862 a devastating flood, by far the worst recorded in history rolled along the Santa Ana River."\(^{41}\) By not encompassing historical data into the analysis of regulating San Bernardino's flood-plain, public officials have opted to rely on their own experience and observations as the window of the future.

There have been a number of floods, including the flood of 1862 in which the magnitude of the rains have been much larger than in March of 1938. The writer finds that since historical data was disregarded, the present extensive encroachments along the flood-plain have compounded the need for a complete revision of policy which governs the county's flood-plain. If, in 1938, there was a loss of fourteen lives and $12,000,000.00 in direct
flood damages in San Bernardino County, the question now posed is what might be expected today, with a recurrence of an 1862 flood peak and a five-fold population and ten-fold valuation. To compound the effect, note must be made of the extensive encroachments (discussed previously) into floodways since 1938 and the tremendously increased areas exposed to flood hazards. With a new, maximum flood of record to contend with, and extensive encroachments into the floodways, it is readily apparent that a re-evaluation and revision of Ordinance 2417 is in order. Thus, the need to re-evaluate Ordinance 2417 is readily apparent with the use of historical data.

Comparing major maximum flood records of January 1862 and March 1938, with visual map interpretation of their respective high water marks, provides excellent insight into the need for a revision of Ordinance 2417. When examining the recorded high water marks, in (Figure 15) we notice immediately that the mark for the flood of 1862 is substantially beyond the mark of the 1938 flood. The majority of ordinances used this elevation, (or some number of feet above this elevation), and available data on the a aerial extent of the flood of record as criteria for flood limits. The flood of record is used to govern all regulations, and to control all development in areas which have been flooded in the past. The writer believes that historical data of the flood of 1862 invalidates the
high water mark used by public officials to regulate San Bernardino's flood-plain, and suggests that by use of historical data the major revisions be introduced into Ordinance 2417 in order to protect the public from future floods.

Before there can be revisions, public officials must accept historical data which introduces a new maximum flood height for San Bernardino County. Once accepted, the writer suggests that public officials reconsider many of the provisions that have failed in the present regulation. Within the next several pages, the writer intends to examine Ordinance 2417 and make suggestions and revisions which will protect the public from future floods.
SUMMARY

By investigating the geographical setting of the river, its drainage area, climatic conditions, historical growth pattern, and flood history, we realize the extreme importance of protective measures upon the San Bernardino flood-plain.

Concern over Santa Ana River flooding led to various proposals in the early part of this century. Initiated by San Bernardino County and supported by the federal government, Ordinance No. 2417 was put into effect. The purpose of the ordinance was to protect the public's health, safety, and welfare and minimize public and private costs caused by flooding, by regulating development within flood hazard areas. The ordinance was never enforced in its entirety. Therefore, industrial and residential expansion was ever-increasing along the flood plain in San Bernardino County.

During this same period, the Corps of Engineers was authorized to construct the Prado Dam (Figure 16). The Prado Dam was to protect Orange County from essentially any flooding which might result. Throughout the next several decades, beginning in the 1940s, San Bernardino County, with the assistance of federal government, has installed flood control improvements for the main stem of the Santa
Figure 16, part of
The Recommended All-River Plan
Ana River, which includes Santiago Creek, Oak Street Drain, and Mill Creek Levee (Figure 16). Also, repairs from what is known as river shifting, which is caused by upstream construction, has brought about approximately 132 million dollars in channel improvements since 1940.

The current study of the Santa Ana River Main Stem, including Santiago Creek and Oak Street Drain, has a fifteen year history. In 1976, Congress authorized advanced engineering and design studies for the project. District Corps designed in detail nine plans, which were evaluated. After several years of design study, the Los Angeles District selected of the nine proposals, alternative No. 6, the All-River-Plan, (Figure 16). The estimated cost of these improvements in September of 1975 was $741 million. The All-River-Plan included:

I. Raising Prado Dam and Reservoir.

II. Constructing a new dam, to be called Mentone, on the Santa Ana River near the communities of East Highland and Mentone.

III. Making channel improvements in the Coastal Plain Reach, below Santa Ana Canyon.

IV. Providing some structural protection along certain bends in the river.

The major alternative to the All-River-Plan was to enlarge Prado Reservoir substantially, thus avoiding the building of mentone Dam. All other improvements would remain the same. While the district estimated this alternative to be less expensive; it recommended the All-River-Plan because it was believed to be the most feasible over
all, and it was the plan most acceptable to government organizations, and residents in the river basin. In 1980 Congress authorized advanced studies, which were called Phase I, to proceed on the recommended plan. The District Corps Office re-evaluated each alternative in terms of the issues raised since 1975, project objectives, planning and design constraints, and economic environmental and social impacts. The one major change was the cost of the All-River-Plan, which escalated from 741 million in 1975, to a staggering 1.2 billion in October of 1981. The Phase I Study also verified the fact that continued residential and commercial development had greatly escalated within the flood-plain region in the last five years during the Phase I study. Despite the name "Phase I", the new study was the second stage in the flood control project. Complaints and outright opposition from property owners, environmental organizations, and city and county governments began to be voiced. The criticism was focused on the Mentone Dam, which was to collect floodwaters from the Big Bear lake, the Upper Santa Ana River, Mill Creek and Plunge Creek. The proposed Mentone Dam, under discussion for more than a decade, was finally confronted with more than negligible public opposition. The U.S. Corps of Engineers conducted several public hearings and affirmed their position that the All-River-Plan was the most feasible overall plan.
Before discussing the opposition which confronted the Corps of Engineers, it is essential to briefly analyze the proposed Mentone Dam. The cost to construct the Mentone Dam has reached an estimated $400 million. The main objective of the dam will be to collect runoff water from Mill Creek, Big Bear Lake, Plunge Creek, and the Upper Santa Ana river. The reservoir will detain runoff waters for 5-7 days until the level at Prado Reservoir can adjust to larger amounts of floodwater. The plan is to acquire outright 3,110 acres of land for the dam and reservoir and levee improvements. Construction of the dam calls for about 66 million cubic yards of material, most probably from the excavation of the Mentone Basin and from a borrow area within Prado Reservoir. About 200 families will have to relocate. The design calls for a dam, 3-4 miles long and 250 ft. high. It will have a gross storage capacity of 181,500 acre feet. The construction will be disruptive over an 8 year period, with the noise level and air pollution slightly increasing. Mentone Dam is the most essential part of the All-River-Plan.

During August of 1980 major opposition confronted the proposed Mentone Dam. The Corps of Engineers, realizing the major importance of the dam to the essential overall proposed flood-control program, confronted the opposition. The first major opposition appeared in
August of 1980, in the local newspaper, The Sun, 22, Aug., which was headlined, "Highland Area Residents Blast Mentone Dam." Complaints and outright opposition, from a vocal group of East Highlands property owners and an environmental organization were voiced at a U.S. Corps of Engineers hearing focused largely on the part that the Mentone Dam would play in the All-River Plan. Some citizens objected that delays in federal purchases of their properties could pose financial hardships for the, while others expressed worry that the dam would bring various disruptions to the community and, in being close to the San Andreas Fault, might be unsafe. The National Audubon Society representative was quoted as saying that, "This visual intrusion of a 250 foot high, 3 1/2 mile long structure will destroy the aesthetic beauty in this area forever."

There were also complaints expressed by the County Supervisors on the Carter Administration's proposal for a local cost share of 25 percent, that would amount to $250 million for the state and the three counties. In October of 1981, the East San Bernardino County Water District sent a letter to the Board of Engineers for rivers and Harbors. The letter stated,

The East San Bernardino County Water District continues to be concerned by the apparent lack of an adequate evaluation of the effects of the placement of the Mentone Dam on the hydrology of the San Bernardino Basin. The San Bernardino Basin is an extremely complex geohydrologic unit. It is characterized by faults, barriers, horizons of differing permeability and an active artisan aquifer.
In recent years, the ground water basin has experienced alternating cycles of overdraft and replenishment. As late as 1966 the Basin experienced an all time low in available ground water. While the Corps Phase I Report addresses what appears to be surface hydrology, there is a total lack of any comprehensive evaluation of the effect of the Mentone Dam on the ground basin itself.  

The letter went on to discuss significant questions which had never been reviewed by the Phase I Report. For example, compensation (monetary) to owners of lands and residents in the proposed Mentone Site. The East San Bernardino County Water District would become the most outspoken critic and opponent of the Mentone Dam Proposal.

Headlined in the Los Angeles Times, in February of 1982 was, "Dam Project Stirs Bureaucratic War." A bureaucratic war has developed between the local agencies that want to see the project stopped, and the Corps of Engineers, who sees the dam as essential insurance against the threat posed by the Santa Ana River in full flood.

A number of local cities and their agencies have joined in the opposition to the Mentone Dam Project, including San Bernardino and Redlands. A consultant for the San Bernardino Water District was quoted as saying that, "The cost alone will defeat the proposed dam."

Lewis Fletcher, General Manager of the San Bernardino Valley Municipal Water District believes the Dam could actually result in the suggested catastrophe which
it is designed to prevent. "If a large earthquake strikes the dam and causes it to fall during a period when the dam is full, a horrible inundation of the downstream area would occur." The Mentone Dam, which was once heralded as a possible solution to a potential flood threat in the Basin Regions had become engulfed in a political entanglement.

Because of political controversy of the proposed project, recommendations for continued studies for future flood control in the flood-plain region have been discussed. Ultimately, the true test of the Mentone Plan will come when Congress is asked to appropriate the more than one billion dollar cost. But in a period when the federal government is sharply reducing spending, the fight to fund the Mentone Dam promises to be most difficult. Every year the All-River-Plan is studied the price tag of its construction rises approximately $200 million. Therefore with the political opposition and outrageous construction prices, the demise of the Mentone Dam is inevitable, according to most critics.

Continued residential and commercial development within the Santa Ana River Basin has only increased the possibility of flood damage in the region. Mentone Dam, which is engulfed in political entanglements, has been rendered by many as unacceptable for the flood-plain protection in the Basin. The difficulty of rendering a project such as the Mentone Dam as unacceptable is the
potential threat of flooding in the Basin Region remains and increases with time. Therefore, it is necessary for an immediate viable and feasible solution to be implemented to assure protection of lives and property within the Basin Region.
SOLUTION AFTER DISCUSSION OF PRESENTLY PROPOSED METHOD

The first suggestion is for San Bernardino County to use basic historical data to prepare the revisions of Ordinance 2417. In the present Ordinance, the basic data used to delineate the flood area came, in most cases, from some organization other than the community preparing the ordinance. This, of necessity, was an engineering organization which interpreted the data consisting of topographic maps and data of the record flood in the San Bernardino area. The writer suggests that the community, rather than outside organizations, prepare the provisions for regulating flood-plain development.

A major factor for public officials to determine would be the establishment of minimum building code requirements. Ordinance 2417, (Figure 5), realizes that the purpose of building codes is to safeguard life, health, property and public welfare by regulating and controlling the design, construction, quality of materials, use and occupancy, and location and maintenance of all buildings and structures within the county flood-plain area. When revising building codes, the writer recommends that building codes regulating the flood-plain development contain provisions meant to safeguard a person's investment in a
structure. The present building codes are not recommended standards of construction or to contain provisions to safeguard a person's investment in a structure. Most established building codes need to be analyzed to establish, from the new maximum water height, whether they safeguard life, health and property. Due to new data, many changes will definitely require a re-organization of structures being developed within the flood-plain.

Time was not available to make a detailed study of the effectiveness of all subdivision regulations to reduce flood damages. However, it quickly became apparent from a limited survey and from other sources, that in a large percentage of cases, this method of regulation does not protect against medium or major floods. Evidence from the 1969 flood has given insight into the many failures of subdivision regulations along the flood-plain in San Bernardino County. Taking a closer look at Ordinance 2417, we find that, the subdivider may either be prohibited from subdividing that portion of the tract subject to flooding, or, he may subdivide it provided that certain protective measures are incorporated in his plan. The writer believes that by giving subdividers the option of subdividing a tract, the County is enhancing enchroachment within the flood-plain area. Ordinance 2417 fails to recognize that even with protective measures to subdivisions, flood conditions are aggravated by the presence of construction.
It is recommended that all development remain outside the maximum water height in the flood plain.

One of the more promising methods of regulation development in flood areas entails the procurement of the land by local municipalities. With planning and imagination much can be done by this method to develop flood areas into desirable parks, parkways, wildlife refuges, and other beneficial uses that would incur little damage from floods. Ordinance 2417 fails to advocate outright purchase of land subject to flooding. Instead, land along the flood-plain is completely restricted from public use or subdivided with restrictions. The writer strongly suggests that the County expand its river-front recreational facilities by buying several hundred yards of river frontage on each side.

In evaluating flood risk and flood damages, it is necessary to introduce the concept of flood frequency. People either do not think of the magnitude of a flood in terms of frequency or, if they do, they quite often have a misconception of its meaning. A flood that appreciably higher than any previous flood experienced, is apt to be considered "unusual" - something that cannot happen again. This in entirely erroneous. Engineers commonly indicate the frequency of a flood by giving its recurrence intervals. A flood having a one-hundred year recurrence interval is one which will be exceeded or equalled every one-hundred
years on the average. This does not necessarily mean that if a flood of this magnitude occurs one year, a flood as severe would not be experienced again before one-hundred years elapse. There may be several floods greater than the one-hundred year flood in the next one-hundred year period; or a period of two-hundred years may pass during which all floods are smaller than the one-hundred year flood. In Ordinance 2417, the recurrence interval has been determined to be one hundred years in San Bernardino County. The writer recommends that a new recurrence interval be established, which would represent a new maximum probable flood. This is used as a guideline to all flood-plain regulations in the community. Historical data of floods before 1938, prove that the one-hundred year recurrence interval is incorrect and the establishment of a new recurrence interval of one-hundred and fifty years is in order. The recurrence interval of one-hundred and fifty years would mean that a maximum probable flood, (flood of 1862), is equalled or exceeded every one-hundred and fifty years on the average. The establishment of a new recurrence interval would mean a revision of all flood protection measures which have used the one-hundred year maximum probable flood data. Some counties throughout California are advocating a recurrence interval of five-hundred years. This would mean that all data pertaining to floods in the last five-hundred years could be used to
influence regulations for the protection against the maximum probable flood. The writer strongly suggests that San Bernardino County use the five-hundred year recurrence interval to gain the maximum amount of data available on flood occurrence in the County. If administered properly, flood insurance could be used as an instrument for reducing flood losses. Recently, Ordinance 2417 has been under attack for insuring development in areas considered to be frequently flooded. One such area in San Bernardino County is the newly developed Riverview Industrial Park, developed at an estimated cost of $36,000.00 and insured for nearly twice that amount. The area has been inundated five times according to historical data, and at one such time the water was nearly five feet high. The writer suggests that in future revisions, insurance in Ordinance 2417 be used as a restriction, rather than an incentive for development on the flood-plain in San Bernardino County.

On a shining Sunday morning in May of 1980, sixty-one people were to be drawn into the deadly embrace of Mt. St. Helen. One eyewitness account told news reporters that the signs of destructive disturbance were very apparent, with billowing smoke, small earthquakes, and a general uneasiness. The eyewitness also said that even with forewarned knowledge of repeated disturbances, the party of four, which included two photographers and two climbers, continued their climb. The rest of the expedition was found
approximately nine hours after the eruption covered by seven feet of ash. It is particularly interesting that even with advance knowledge of a possible major disturbance, the climbers continued without any hesitation. The Santa Ana River Flood-Plain in similarity to Mt. St. Helens, has provided man with advance knowledge of a possible major disturbance. The recorded flood of 1862 provides San Bernardino County with unique information, which, if applied, can deter the public from the Santa Ana River's deadly embrace.
CONCLUSION

The most realistic ideal for flood-control protection is to discontinue San Bernardino's utilization of the flood-plain as a site for development. Flood-plain damage can be reduced by decreasing, not increasing the amount of damageable goods on the flood-plain. It is only logical then that some limit should be placed on the type and degree of use of this protected area. This restriction may take many forms, but essentially it may be thought of in terms of zoning ordinances. Flood-plain zoning would have a somewhat different objective and/or purpose than residential housing, commercial or other zoning in more highly populated areas. The object would be protection of property and people, rather than certain areas being reserved for only residence and other areas being allowed to be used being allowed to be used for business, multiple and mobile dwellings, agriculture, factories etc. Flood-plain zoning has for its purpose the zoning of the flood threatened areas along the stream. These areas would be restricted from building construction of any type, industrial or residential. For the most part, flood-plain zoning is a reality only in printed form. For example, Section 12, a restrictive
ordinance in Los Angeles County, states that, "Areas which are subject to inundation, overflow by storm water, or any other dangerous condition, shall not be subdivided." These regulations in existence in Los Angeles area have had almost no effect in the development of land subject to flood hazard. The need for expansion of a rapidly growing city, in combination with the politics involved, have required the regulations to be observed only in a minimal way, if at all.

The same problem exists today in San Bernardino County. Ordinance # 2417, San Bernardino County's law regulating development within flood hazard areas has been buried in the pressure and politics of expansion, and totally ignored.

The first step to reducing damage in the flood-plain is to enforce the established regulations. By enforcing the ordinances the amount of damageable goods will decrease on the flood-plain. Moving existing houses, factories, or people out of the flood-plain is usually impracticable or unjustified, but to prevent new development, may be both practical and economical. George White suggested in his article, "Human Adjustment to Floods." that, "While in the aftermath of a great flood, when damage has occurred to property and buildings, there should be some thought given to the relative merits of re-building on the old site, as against selecting a new site out of reach of floods."
The need for San Bernardino to enforce the guidelines for development of the flood plain is imperative for future safety of property and inhabitants in the Basin. A thorough flood-control program in the Basin Region would also have to entail federal restrictions. Much of the Upper Santa Ana River has been reserved by the Federal Government as National Forest. The region encompasses a large land area which traces the route of the river from the mouth, at Big Bear Lake, to the valley floor, near Mentone. The federal government, by protecting the forest region, has preserved the unimpeded flow to the Santa Ana River. Also the major tributary, Lytle Creek has been designated as National Forest land (Figure 13). Even though the primary actions of the federal government were to preserve wilderness from development, a secondary factor has surface in which the importance of not disturbing a major river or tributary at the mouth is most vital for downstream safety from flooding. A major suggestion by private and public engineers which specialize in flood-control, is that if development would not occur at the mouth of the major rivers and their tributaries, downstream flooding would be conceivably minor compared to most instances where development has occurred. San Bernardino Basin Flood Control Program would benefit tremendously by advocating a strict policy of excluding development near the mouth of all tributaries in the
region. The designated lands could be preserved, either by local zoning restrictions or federal acquisitions for public use.

Important measures for reinforcing levees and channel improvements will contribute to the downstream safety of property and lives. The All-River-Plan was proposed to strengthen many of the levees and tributaries which branched into the mainstream Santa Ana River. One such proposal by the Corps of Engineers involved recommendations for structural changes of the Mill Creek Levee, constructed several decades ago. (Figure 4). This recommendation would contribute to the control overflow from Mill Creek. The Corps of Engineers proposed to update the levee and use the full potential of the site to reconstruct modern facilities in place of the outdated levee. The approximate cost is estimated to be nearly $14 million for the entire construction of levee facilities. These facilities, according to most engineers will have an excellent benefit-cost-ratio. The benefit-cost-ratio determines whether the benefit of the proposed project compares to estimated costs. For example, the ratio 2.0 means that the benefits are two times the costs; and so on. The Corps of Engineers has estimated the Mill Creek Levee to have a benefit-cost-ratio of 10.0, which means that the benefits derived from the facility are ten times greater than the costs. Even opponents of the
Mentone Dam agree that the benefit-cost-ratio of a newly constructed levee in Mill Creek area is a sound and beneficial proposal for the basin communities.

Proposed improvements for the tributaries in the Basin include flood control plans for Warm Creek, Plunge Creek, and San Timoteo. The Corps of Engineers recommended in the All-River Plan that these tributaries receive channel improvements in the form of easements, concreting enlargements and flood-proofing. These main channels will have a capacity for the most severe flood likely to occur in the area. In the past ten years, San Bernardino County has improved many of the tributary channels significantly, but not enough to control severe flooding. A Corps of Engineers proposal recommended installing, along with other channel improvements, new drop structures and stabilizers, (stair-like features to slow the rush of water). Also recommendations for additional improvements include plans for channel rock-revetted side slopes where the tributaries enter the main-stream Santa Ana River. Several bridges have been recommended by the County Flood Control Department for upgrading, re-design and structural improvements. In several areas, bridges have been proposed to increase the channel's capacity of flow. The main stream Santa Ana River flows under several streets and allows only a minimum capacity for drainage during high water peak periods. The County Flood Control Department had suggested that bridges
be built to increase channel capacity in areas where water flows under surfaced streets. The estimated cost for flood control preparation in the main-stream and tributaries is approximately $16 million.

The most important measure for flood control is the realization of those who occupy the flood-plain that: by their utilization of this site, they are in direct competition with the inevitable periodic flooding of the river, (an act of God, which cannot completely be controlled). Floods are characteristic of rivers; flood damage is a consequence that is bound to happen during heavy extended periods of rain or melting snow. Those who occupy the flood-plain must be educated on the fact that they are competing with nature's forces, (the river), not other humans who may be totally outwitted. Some control of this situation is possible, but, with occupancy certain losses must be expected. They should expect losses if they insist on occupying this particular area. It should be the duty of those in charge to enforce non-occupancy laws, rather than promise help after the disaster has occurred, which encourages occupancy and a higher cost to all citizens, in the form of taxes to cover this National Disaster Aid.
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2 California Department of Water Resources, Meeting Water Demands in the Bunker Hill-San Timoteo Area, 9171, p. 22.


4 Ibid.

5 Ibid., p. 3.

6 Ibid.

7 Ibid.

8 Ibid.

9 Ibid.

10 Ibid.

11 Ibid., p. 2.


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