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Preliminary Evaluation of SOILS AND IRRIGATION PRACTICES IN THE IMPERIAL VALLEY

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This Technical Information Record (TIR) was prepared to document pertinent information developed during the basic data acquisition phase of the Desert Areas Water Action Plan and for planning studies on agricultural water conservation. The findings in this TIR have not been fully reconciled with all the technical aspects of the total investigation, which will be fully reviewed when all phases of the investigation have been completed. Hence, this TIR is only for internal office use and should be considered as preliminary and subject to revision.

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I. INTRODUCTION

A. Objective

The objective of this study is to classify the soils in the Imperial Valley and to assess the effectiveness of the practices used. The information will serve as basic reference data to be used in water management studies. In particular, they will serve as back-up data for an element of the Coachella-Imperial Valleys Agricultural Water Use Study.

Analysis of the information was conducted in view of providing a working background for later studies.

B. Scope

The study was limited to surveying existing information that is readily available.

A review was made of literature available through the files of the Department of Water Resources (DWR) and the extensive collections housed in the Water Resources Center Archives of the University of California, Los Angeles. Persons contacted locally in the Imperial Valley were chosen on the basis of their expertise in a specific field. Many of the references cited are the result of scientific research conducted by these individuals.

Research on salinity management and improvement of irrigation techniques is still under way by various agencies (i.e., University of California Extension, Soil Conservation Service, and others).

Only data pertaining to the Imperial Valley were reviewed. Review of data on similar problems in other areas was limited in light of time constraints.

C. Background

The Imperial Valley (Plate 1) is one of the world's most productive and intensively farmed areas. Agriculture is dependent upon imported Colorado River water, supplied by the Imperial Irrigation District (IID). Approximately 1 168 800 hectares (475,000 acres) of land is farmed each year, with about 25 percent being double cropped. Over 2 837 000 cubic dekametres (2,300,000 acre-feet) of water is delivered annually to farms in the Imperial Valley.

Colorado River water contains an average of 3.36 tonnes of salt per cubic dekametre (1.5 tons of salt per acre-foot), which, when combined with the saline soils, creates a salinity problem. Because of the relatively high level of soluble salts in the irrigation water and soils, salt-tolerant or moderately salt-tolerant crops are grown.

Salinity problems have been solved by using soil, irrigation, and cropping practices that have minimized the detrimental effects of salt on crop production. However, these problems still exist and require careful management to maintain the productivity of Imperial Valley agriculture.

The following analysis will provide the resource planner with a background on soils and irrigation practices in the Imperial Valley.

II. SUMMARY

Aside from overcoming pedologic characteristics, cultivation and irrigation practices have led to the minimization of problems brought on by salinity. The inherent salinity of the soils in the basin, coupled with moderately saline incoming irrigation water, presented problems that initially caused noticeable declines in the agricultural productivity. Leaching practices, various methods of tilling (leveling and sod busting), irrigation management, the installation of tile drainage, and overall better management have led to observable improvements in the agricultural productivity in the Valley.

Soils in the Imperial Valley may be classified according to the type of agriculture being practiced on them. Because of the character of the general soil classes, which are delineated in Plate 2, only specified crops can be successfully grown on them. A closer investigation reveals that these soil groups repeatedly occur in small clusters throughout the basin. Good cultivation and irrigation practices tend to overcome the problems brought on by the pedologic structure and to permit the growth of certain crops.

Soil information will be updated with the soon-to-be published report by the Soil Conservation Service (SCS) entitled "Soil Survey of Imperial County". Field contact with the SCS would undoubtedly bring to light many more facts dealing with the soil-crop suitability. The data discussed in the following text are in most part taken from works produced by researchers in the Imperial Valley.

III. SOILS

A. Geologic Background

Soils in the Imperial Valley are highly stratified. Recent lacustrine and alluvial deposits, largely from mixed sedimentary rock parent material originating primarily from the Colorado River and small streams in the surrounding mountains. The area was formerly inundated by ancient Lake Coahuilla. Changing climatic conditions and variations in annual floods have, over the years, caused a widespread variation in soils.

Soil strata of any one type do not extend over large areas, but generally occur as lens or pockets. This highly variable sedimentary deposits have been estimated to be over 1 520 metres (5,000 feet) in depth. In general, there are no sand or gravel water-bearing strata. Practically no boulders or cobbles are found in the soil. The occasional perched ground water tables in the basin are the result of seepage from extensive irrigation canals. The ground water table is very diffused and highly saline.

Finer textured soils are found in the central portion of the valley while those nearer the surrounding mountains tend to be coarser textured. Slopes throughout the valley floor range from 0.1 to 0.2 percent. Elevations range from about 70 metres (230 feet) below sea level adjacent to the Salton Sea to almost 61 metres (200 feet) above sea level around the West Mesa.

B. Classification

B1. Previous Investigations

The highly complex, stratified soils found in the Imperial Valley have been studied extensively over the past 70 years. In regard to understanding soils and irrigation practices, there are two previous investigations of practical research which are useful.

The Drainage Investigation in Imperial Valley, California, 1941-51 (A 10-year Summary)[(2)*] examined soil stratification and its effect on the movement of water through the soil profile. The study's primary purpose was to solve the problem of an ever-increasing high water table resulting from conveyance losses and irrigation seepage. The study combined research efforts from the Soil Conservation Service and IID. Data and methodology developed from the study provided the first thorough understanding of drainage problems in the Imperial Valley. With the results, technicians could determine:

1. Which lands were feasible and economical to drain.
2. The size and location of tile lines so as to provide maximum drainage.
3. Optimum depth and spacing of tile lines.
4. Leaching required to maintain salt balance in the soil.
5. Cropping system required for reclamation.

Several of the findings and methodologies have been updated as a result of recent research; however, the study was the first of its kind in the Imperial Valley and laid the groundwork for managing the drainage problem. Many of the farming practices developed as a result of the investigation are still in use today.

The Report for General Soil Map, Imperial Valley[(16)] was conducted by the Soil Conservation Service as a part of the National Cooperative Soil Survey. Soil strata classification within the irrigated area was provided by IID. The study area covered all Imperial County, excluding the Chocolate Mountains Gunnery Range.

The report mapped 26 soil associations within Imperial County (not all of these are within the cropped area). Detailed descriptions of the soils are included in the report; however, the soils series names as used were tentative until they were correlated into the National Soil Classification

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* Numbers in parentheses refer to references listed in Appendix A. Persons and organizations contacted are listed in Appendix B.

System, which is discussed in the following section, IIIB2. Any change in names will not affect the descriptions of the soils.

A useful soil interpretation is presented in this report. The national system of Land Capability Classification has been applied to the soils mapped by this study. The classification grouped the soils into eight classes based on their ability to produce common crops and pasture plants. This grouping provides information on which crops are suitable and any cultural limitations for each class or grouping. Combining this classification system with data from the SCS El Centro, the land capability of the Imperial Valley can be determined. As shown in Table 1, 73 percent of the soils in Imperial Valley have severe limitations that reduce the choice of plants and require special cultivation practices. Only 25 percent of the soils are rated as requiring moderate cultivation practices with some restrictions as to crop selection. It can be seen from this table that most of the soils in the Imperial Valley are problem soils and require special cultivation practices to be productive.

B2. Soil Conservation Service, 1975 Study

The following has been excerpted from a draft copy of a portion of the soil survey of Imperial Valley, which will be published some time in 1981.(33)

The SCS soil survey reclassified those soils within the IID service area. The reclassification is based on the National Soil Classification System and replaces the nomenclature used in the 1967(16) report.

Ten soil units, or soil associations, were classified. These associations, along with their general characteristics, are presented in Table 2. Note that the Lacustrine Basin forms 66 percent of the area. Almost all of the farmed area is located on the ancient Lake Coahuilla lake bed.

TABLE 1
LAND CAPABILITY CLASSIFICATIONS

Class	Of area surveyed*	Limitations
I	2%	Few limitations that restrict their use
II	25%	Some limitations that restrict the choice of plants or require moderate cultivation practices.
III	67%	Severe limitations that reduce the choice of plants or require special cultivation practices or both.
IV	4%	Very severe limitations that restrict the choice of plants, require very careful management, or both.
VII**	2%	Soils and landforms have limitations that preclude their use for commercial plant production and restrict their use to recreation, wildlife, water supply, or aesthetic purposes.

(from: Report for General Soil Map[16])

*From Doug Welch, SCS, El Centro
**There are no Class V through VI soils in the Imperial Soil Survey Area

TABLE 2
SOIL ASSOCIATION CHARACTERISTICS

Associations	Characteristics
Lacustrine Basin	
1. Imperial 2. Imperial-Holtville-Glenbar 3. Meloland-Vint-Indio 4. Niland-Imperial 5. Glenbar-Imperial 6. Fluvaquents	The soils are found primarily in the Lake Coahuilla bed. They are nearly level and range in elevation from 70 metres (230 feet) below sea level to 61 metres (200 feet) above sea level on the West Mesa. Moderately well drained, but some adjacent to the Salton Sea are poorly drained. A perched water table is present due to seepage from canals and extensive irrigation. The surface layers range from gravelly sand to silty clay. Its primary use is for agriculture.
East and West Mesas	
7. Rositas 8. Rositas-Superstition 9. Antho-Superstition-Rositas 10. Holtville-Antho	These soils are found predominantly on the mesas and range in elevation from 9 metres to 107 metres above sea level. Most are well drained and vary in slope from level to moderately steep. Surface layer ranges from sand to silty clay. Desert Recreation is main use. Wildlife habitat is the primary land cover.

(from: Draft of General Soils Map[33])

Each of these soil associations has a distinct pattern of soils, relief, and drainage features. An association typically consists of one or more soils that are predominant and some soils of minor extent. The association is named for the major soils. Soils may be found in other associations, but in a different pattern in the profile. A broad perspective of the soil associations within the cropped area is shown in Plate 2.

B3. Soil Associations Within the Cropped Area

The soils found within the cropped area are listed in Table 3. An overlay of the 1978 land use as mapped by the Department of Water Resources (DWR) was used to determine the area of each soil under cultivation. Note that the Imperial-Holtville-Glenbar Association forms the largest cropped area. Fluvaquents along the shoreline are being inundated by the rising Salton Sea.

A brief description of the soil associations within the cropped area follows:

Soils in the Imperial Valley can be divided into two broad areal groupings, those in the Lacustrine Basin and those in the East and West Mesas.

Lacustrine Basin soils were at one time the lake bed of Lake Coahuilla. The main use of these soils is for irrigated cropland, in addition to urban development. Almost all the agriculture is located on these soils.

Most farmland is found within the Imperial, Holtville, and Glenbar soils. Other soils which are farmed to a lesser extent are the Meloland, Indio, and Vint. These soils, in addition to being calcareous (pH of 8.0), are inherently low in organic matter and nitrogen. Nitrogen fertilizer is needed for maximum production of nonleguminous crops. Legumes and winter vegetables need phosphorus as a soil amendment. Other nutrients are available in the soil or irrigation water.

TABLE 3
SOIL ASSOCIATIONS WITHIN THE FARMED AREA

Soil association	Acres *	%
1. Imperial	61,600	13
2. Imperial-Holtville-Glenbar	322,300	68
3. Meloland-Vint-Indio	75,800	16
4. Niland-Imperial	9,500	2
5. Glenbar-Imperial	0	0
6. Fluvaquents	100	**
7. Rositas	4,700	1
Farmed area	474,000	100

(Based on planimeter measurements of Draft of General Soil Map, 1975[33], overlaid onto DWR 1978 land use mosaic at a scale of approximately 1:125,000.)
*One acre = .4064 hectare
**Less than .01%. These soils are along the shoreline and are slowly being inundated by the Salton Sea.

Soils in the Valley have little structure except for alternating horizontal layers in the profiles. The predominant clay type to be found is montmorillonite (expanding lattice clays). The soils generally have low hydraulic conductivity. In many of the soil profiles the clay layers inhibit movement of water down through the profile.

East and West Mesa soils are found on the mesas and fans surrounding the old lake bed. The major use of this area is for desert recreation and wildlife habitat. A very small acrage of irrigated cropland is located directly adjacent to the Lacustrine Basin. (Refer to Tables 2 and 3 and Plate 2 for the following discussion.)

Lacustrine Basin. The Lacustrine Basin associations were formerly inundated by old Lake Coahuilla. The soils are found from about 70 metres (230 feet) below sea level, adjacent to the Salton Sea, to around 61 metres (200 feet) above sea level in areas of the West Mesa.

The surface layers range from gravelly sand to silty clay. The soils are very deep and have virtually no slope, with most being nearly level. They are moderately to well drained. Some soils adjacent to the Salton Sea are poorly drained, as a result of agricultural activity and proximity to the Salton Sea. A perched water table is present in most associations throughout the Lacustrine Basin, due to seepage from canals and extensive irrigation.

Six soil associations are located within the Lacustrine Basin. Almost the entire farmed area, about 99 percent, is situated in this basin. The six associations are:

1. Imperial Association

The Imperial Association covers approximately 25 000 hectares (61,600 acres), or 13 percent of the farmed area. About 85 percent of the association consists of Imperial soils. The remaining 15 percent is made up of minor soils which are the well-drained Glenbar, Holtville, Meloland, and Indio soils.

These alluvial soils have very deep profiles and contain a high volume of calcium carbonate precipitates. Natural drainage has been altered by seepage from canals and the extensive irrigation. Slopes are less than 2 percent, while elevations range from 70 metres (230 feet) below to 9 metres (30 feet) above sea level.

Agricultural use is mainly for field crops. The main management concern is to maintain a favorable salt balance while maintaining the water table below the root zone. Proper installation of tile drains is required, in addition to good irrigation management.

2. Imperial-Holtville-Glenbar Association

This association covers approximately 131 400 hectares (323,300 acres), or 68 percent of the farmed area. The soils are nearly level, moderately well-drained silty clays, silty clay loams, and clay loams. Formed from alluvial deposits, these soils have deep profiles that are inherently calcareous. Elevations range from 70 metres (230 feet) below to 9 metres (30 feet) above sea level. Three major soils make up this association, they are:

o Imperial soils which are moderately well drained. The profile consists of a surface layer of either a silty clay loam or silty clay, which is underlain also by a silty clay.

o Holtville soils are well drained with a profile that consists of silty clay loam or silty clay to a depth of 0.61 metres (2 feet), underlain by stratified clay loams and silty clay loams.

o Glenbar soils are also well drained. They have a surface layer of clay loam or silty clay loam underlain by a stratified clay loam and silty clay loam.

Minor soils which occur in this association are the well-drained

Meloland, Indio, Vint, and Rositas soils.

Field and truck crops are grown successfully on these soils. The main management concern is to maintain a favorable salt balance while keeping the water table below the root zone. Good irrigation management is required in addition to the use of tile drains.

3. Meloland-Vint-Indio Association

This association covers approximately 30 700 hectares (75,800 acres), which represent 16 percent of the farmed area.

Soils within this group have an inherently enriched calcareous profile. Source material for these soils were alluvial and aeolian deposits. Most of the farmed area of this association is found within the old lake bed; however, a small portion is located on low fans in the West Mesa. Elevations range from about 61 metres (200 feet) below to about 6 metres (20 feet) above sea level. Slopes are generally less than 2 percent. Three major soils make up this association; they are:

o Meloland soils have a surface layer of very fine sandy loam or fine sand that is underlain by stratified loamy fine sand and silty loam to a depth of approximately 0.61 metres (2 feet), below which is a silty clay.

o Vint soils have a surface layer of very fine sand or very fine sandy loam underlain by a stratified layer of fine sand.

o Indio soils have a surface layer of a very fine sandy loam underlain by stratified layers of silty loam and fine sand.

Minor soils within the association are the Rositas, Holtville, Antho, and Glenbar series.

Field and truck crops are the main crops grown in these soils. Citrus is grown to a limited extent on the West and East Mesas.

The main management concern is maintaining a favorable salt balance while keeping the water table below the root zone.

4. Niland-Imperial Association

This association covers approximately 3 800 hectares (9,500 acres), which comprise 2 percent of the farmed area.

The soils are very deep and calcareous and were formed in alluvial or aeolian deposits. These soils are mostly found around the edge of the old lake bed and are nearly level, with slopes less than 2 percent. Elevations range from about 61 metres (200 feet) below to 61 metres (200 feet) above sea level.

Two soils predominate, with small areas consisting of minor soils. The soils are:

- Niland soils have a stratified surface layer of gravelly sand or fine sand underlain with silty clay at a depth of approximately 0.67 metres (2 feet).
- Imperial soils have a surface layer of silty clay or silty clay loam underlain by a silty clay.

Minor soils in this association comprise about a fifth of the surveyed area. These soils are: Meloland, Glenbar, and Holtville and would also include the Rositas and Carsitos (which are not farmed).

Extensive irrigation has altered the water table in these soils. A perched water table can be found in the root zone of most crops. Field and vegetable crops are commonly grown.

The major management concern is to maintain the water table below the root zone and to keep a favorable salt balance.

5. Glenbar-Imperial Association

This association is within the Lacustrine Basin; however, no crops are grown. Most areas are barren or support only salt-tolerant ephemerals. Although this association is not farmed, it is mentioned to maintain continuity within the associations listed in Table 3 and various other references.

6. Fluvaquents

This association presently covers approximately 40 hectares (100 acres), or less than .01 percent of the farmed area. Areas of this association are along the shoreline of the Salton Sea.

These soils are very deep and strongly saline, and they were formed in the alluvium of the ancient lake bed. They are nearly level and poorly drained. Textures range from silty clay to fine sand and the profile is stratified.

The water table is within 1 metre (3 feet) of the surface. Areas used for farming lack drainage to the Salton Sea and are protected from flooding by dikes.

East and West Mesas. The soils in this grouping are on the mesas surrounding the old Lake Coahuilla Basin. Four soil associations are in this group; however, only one, the Rositas Association, is used for agriculture.

1. Rositas Association

The Rositas Association covers about 1 900 hectares (4,700 acres) of cropped land, or less than 1 percent of the farmed area in the Imperial Valley. The soils are used mostly for field and vegetable crops and, to some extent, for citrus. Only a small portion of the association is actually cultivated.

Formed from alluvial and aeolian deposits, the profile is comprised of a surface layer of fine-grained sands intermixed with silty-loam particles and underlain predominately by fine-grained sands. It is excessively drained and very calcareous.

The remaining three associations serve as wildlife habitat and are not suitable for agriculture. They are:

2. Rositas-Superstition

3. Antho-Superstition-Rositas

4. Holtville-Antho.

IV. IRRIGATION PRACTICES

A. Overview

Agriculture in the Imperial Valley is dependent on imported Colorado River water for its irrigation needs. Average annual precipitation is 6.9 centimetres (2.7 inches) and does not always occur at beneficial times during the growing season. IID is the sole water purveyor in the Valley. It operates a gravity-flow irrigation and drainage system.

Imperial Valley soils are predominately fine textured and inherently saline and require subsurface drainage or tile-lined drains to prevent salt buildup in the root zone.

A typical analysis of Colorado River water as it enters the IID system at Imperial Dam is shown in Table 4. It can be seen that the total soluble salts are appreciable, while the relative amounts of calcium and magnesium are favorable. Irrigation combines Colorado River water with saline Imperial Valley soils, which in most cases have drainage problems. To maintain a favorable salt balance in the root zone, leaching and proper drainage are required. A favorable salt balance is achieved when the salt content of drainage water is equal to, or greater than, the salt content of the irrigation water (24).

In summary, use of Colorado River water requires soil management practices that control salinity. These management practices depend on the type of soils to which the water is applied. Soils in the Imperial Valley require salinity control practices because of their unique chemical and physical properties. Thus to prevent salt accumulation in the root zone, proper irrigation and drainage management are mandatory (24).

TABLE 4
COLORADO RIVER WATER CHEMICAL COMPOSITION
August 1976 through May 1977

Element	milligram per liter
Dissolved calcium, CA	89
Dissolved magnesium, MG	37
Dissolved sodium, NA	135
Dissolved sulfate, SO_4	350
Hardness, CA, MG	375
Non-carbonate hardness	235
Total dissolved solids	840
Dissolved solids (tons per acre-foot)	1.15

B. Irrigation Techniques

Cropping practice in the Imperial Valley is based on cultivation of many salt-tolerant crops and irrigation practices that lessen the effect of saline water and soils.

The IID system is a gravity operation which lends itself to border and furrow irrigation systems. Irrigation in the Imperial Valley does not use pumped water except for sprinkler systems, which are becoming common for use in seed germination. Economics prevents a widespread use of pumped water to irrigate for an entire growing season.

Major crops and their associated irrigation methods are illustrated in Table 5. Note that border and furrow systems are the two major methods of irrigation. Border systems predominate in use, while furrow systems are used on about a third of the acreage. Comparison of application efficiencies by Dickey (1) has shown that well-managed border and furrow systems can achieve an application efficiency of 80 percent, while a well-managed sprinkler system may only reach 75 percent. Use of sprinklers is hampered by several problems which are discussed in Section IV B2.

B1. Suitable Practices

Because of the relatively high level of soluble salts in the irrigation water and soils, many salt-tolerant crops and irrigation practices that control salinity are used. Sufficient water must be supplied to meet the crop water requirements as well as to leach salts out of the root zone.

Successful farm management must take into account the type of crop and proper management practices needed to grow a particular crop in a certain soil. Consideration must be given the high TDS found in the irrigation water and any permeability problem of a given soil profile.

TABLE 5
CROPS AND IRRIGATION METHODS

Crop	1979 Acreage*	Irrigation system	Total area by irrigation system
Alfalfa	185,000	Border	
Barley	5,000	Border	Border
Cotton	95,000	Furrow	320,000 acres,
Sorghum	4,000	Furrow	or: 68%
Sorghum	5,000	Border	
Sudan grass	25,000	Border	Furrow
Wheat	100,000	Border	154,000 acres,
Cantaloupes	10,000	Furrow	or: 32%
Carrots	5,000	Furrow	
Lettuce	40,000	Furrow	
Total farmed area	474,000		

(from Hagemann[6])
*One acre = .4064 hectare

TABLE 6
SOIL-CROP COMPATIBILITY

Soil association	Crops	Management problems
1. Imperial	Field	Maintaining a favorable salt balance and keeping the water table below the root zone. Requires good irrigation management and proper use of tile drains
2. Imperial-Holtville-Glenbar	Field, vegetable	
3. Meloland-Vint-Indio	Field, vegetable, citrus (limited)	
4. Niland-Imperial	Field, vegetable	Most lands are left idle due to marginal economic returns
6. Fluvaquents	Wetland wildlife habitats	Along shoreline lack drainage outlets, are subject to flooding and drainage water must be pumped out
5. Glenbar-Imperial	These soils are not suitable for agriculture	
7. Rositas		
8. Rositas-Superstition		
9. Antho-Superstition-Rositas		
10. Holtville-Antho		

(from Draft of General Soil Map[33])

A generalization of soil-crop compatibility is presented in Table 6. If the saline soils inImperial Valley are managed properly, drainage is adequate, and excess salts are removed by leaching, the soils can approach the classification of normal soils. Management problems will still exist with soil profiles and the inherent high quantity of dissolved salts in the irrigation water. The main management concern of maintaining a favorable salt balance in the root zone still remains. This requires good irrigation management and proper design, installation, and use of the drains.

Drainage performance has been investigated by Hermsmeier (9). This study found that present drain design provides adequate salinity control for salt-sensitive crops, but only in light-textured soils. For most salt-tolerant field crops, present drainage design controls salinity in all but the very fine-textured soils. Drains can account for up to 75 percent of salts removed from the fields. Actual drainage design can vary widely, depending on the soil profile and texture.

Salt-tolerant crops can withstand moderately high levels of alkalinity in the soil and still produce a marketable yield. Crop suitability, based on salt tolerance and the associated electroconductivity (EC) range, is detailed in Table 7. Salt tolerance, or suitability, is based on the limiting factor of a 50 percent reduction in yield (24). The determining factor on what crop can be grown in any particular soil is the residue EC value in the root zone after irrigation is completed and proper drain design has leached out excess salts.

Field investigations (9) have determined residual root zone EC values for various soil textures and actual cropping practices. Cultivation requirements based on existing practices are outlined in Table 8. Note that salt-sensitive crops can be grown in coarse-textured well-drained soils with properly designed drains. This is not always the case in Imperial Valley. The

TABLE 7
SALT TOLERANCE OF CROPS

Salt tolerance	EC range **	Crop suitability @ Yield 50% Optimum
Low	0-4 mmhos/cm*	Grapefruit, oranges, lemons, radishes, celery green beans, clover
Medium	4-8 mmhos/cm	Tomatoes, cabbage, lettuce, carrots, onions, cucumbers, Sudan grass, alfalfa, sorghum, flax, castor beans, cantaloupe
Good	8-16 mmhos/cm	Beets, date palms, asparagus, kale, spinach, cotton, barley, Bermuda grass

(from Molof)

*millimhos per centimetre.
**EC within the root zone.

TABLE 8
CULTIVATION REQUIREMENTS
(In relation to soil texture and residual root zone EC)

Cultivation requirements	*EC in mmhos/cm. @ the root zone	Soil Texture
Salt-sensitive crops grow best in well drained soils. Present design for drain suitable with this combination.	3-6	Coarse
Field crops are best suited. Additional drainage required to grow salt-sensitive crops. Drain spacing is sometimes reduced to 50% of design spacing. Yields decrease above 6 mmhos/cm.	6-8	Medium to moderate
Salt-tolerant crops do best. Field crop yields decrease substantially above 8 mmhos/cm. Sprinkler irrigation is necessary for germination. These soils require much closer drain spacing and additional gravel in drain envelope	8-12	Very fine

(After Hermsmeier[9])
*Residual root zone EC resulting from existing irrigation practices.

most common soil varieties found are those which are medium- and very fine-textured. Salt-tolerant crops are best suited for the soils found in Imperial Valley. Even then, additional control of salt within the root zone is needed. When the residual EC exceed 8.0 millimhos per centimetre (mmhos/cm), crop yields are reduced significantly, and germination is difficult.

Sprinkler irrigation is now commonly used for preirrigation and for germination. Sprinkling reduces surface accumulations of salt which retard and make germination difficult in most soils. The application rate must be controlled so that any clay in the soil profile does not swell, close up pore spaces, and become impermeable. Sprinkling is not used on mature crops because of several problems which are presented in Section B2. After they emerge and undergo additional irrigations, crops are irrigated by conventional methods such as furrow and border flooding.

Border and furrow irrigation methods are used for crops grown in the Imperial Valley. Both methods require uniform application of water to ensure even water distribution and to prevent salt accumulation on high spots. Leveling of land is common throughout the area. Fields are leveled frequently to maintain good grade control and ensure uniform water application. Grading is done to achieve a slope of 0.30 to 0.61 metres per 305 metres (1 to 2 feet per thousand feet). Some soil types require a steeper slope. Dead leveling has been attempted; however, problems exist with its use. These are discussed in Section B2.

Gravity flow irrigation is the type of irrigation best suited for Imperial Valley conditions. Border irrigation is used for close-growing crops such as alfalfa, small grains, and sorghum. Furrow irrigation is used for row crops.

Furrow irrigation crops are cultivated using various planting and bed shaping techniques that reduce the effects of high soil salinity. As furrows are irrigated, salts are carried to the tops of the furrow by the irrigation water and by capillary action in the bed itself. Various furrow designs are employed to combat this buildup of salt around the seed bed. Double row beds and sloping sides are used in situations when the topsoil salinity exceeds 8.0 mmhos/cm. Alternate row irrigation with single row beds is used where soil salinity is still a problem, even though the salinity may be less than 8.0 mmhos/cm.

As water is removed by evapotranspiration, salt is left behind with each new irrigation. Imperial Valley crops are irrigated more frequently than usual to reduce the effects of salinity on crop growth.

Several other problems unique to the area also necessitate frequent light irrigations. Swelling of montmorillonite clays in the soils when exposed to moisture closes off pores in the soil, thus effectively sealing off and preventing any downward movement of irrigation water. High summer temperatures sometimes cause scalding of the root zone and subsequent plant damage when water stands on a saturated soil on a hot day (21).

The border irrigation method has a problem similar to that with the furrow method. Control of excess salinity on the surface and within the root zone is of utmost importance. Sprinkler irrigation is used initially for seed germination of these crops, with border flood irrigation being used exclusively thereafter. The seed bed is essentially a flat basin enclosed by small berms and it acts as a cache basin for the irrigation water. Proper leveling of the field is necessary with this variety of irrigation. Irrigation water must be kept moving so as to prevent ponding and eventual salt buildup. "Dead level" irrigation has been tried, but has not been successful.

B2. Unsuitable Practices

Sprinkling is commonly used for preirrigation and germination; however, the practice of sprinkling mature crops is not suitable because of the high level of dissolved salts in the water and economics of pumping.

Studies have indicated that even salt-tolerant crops are sensitive to salt damage (26). After a sprinkler irrigation, water which will eventually be evaporated and residue salt remains on the plant leaf. With repeated sprinkling, salts begin to accumulate on the leaf surface. Damage that will occur to the crop depends on the volume of salt that accumulates on its leaves. Plant leaves seem to be more susceptible to salt damage than root systems. Salt concentrations of 600 to 1 000 milligrams per liter (parts per million) can injure field and vegetable crop leaves, while the same crop can tolerate 700 to 1 000 milligrams per liter (parts per million) in the root zone.

Researchers have compared the economics of side-roll sprinklers with that of border irrigation for alfalfa (5). The study compared cost versus yield of the two systems. Results showed that there was a yield advantage of 2 tonnes per hectare (1 ton per acre) and a savings of 0.5 cubic-dekametres per hectare (1 acre-foot per acre) of water; however this was offset by higher pumping and equipment costs.

Border irrigation was found to cost less and require less energy. Sprinkling did not yield a higher profit for the farmer. The net profit for border irrigation was $23.23 per hectare ($57.16 per acre) and $1.40 per hectare ($3.46 per acre) for sprinkling.

"Dead level" irrigation is a gravity method whereby water is supplied to a level soil surface within a catchment basin and not drained out. The water either evaporates or percolates downward (37). The water first moves into the basin, then becomes static while it percolates into the soil. This method of irrigation is best suited for soils that have low to moderate infiltration capacities. Advantages of this system are that surface runoff is reduced and deep percolation minimized. Limitations of this method are that an over application of water would saturate the soil profile much quicker and any excess water would eventually be lost through deep percolation and evaporation. Also, with variable soil infiltration rates, an uneven distribution of water will occur in the profile. Problems with this method in the Imperial Valley occur during hot weather. Scalding of the root can occur when irrigation water is allowed to stand over the root zone. Soils in the Valley are not suitable (in most farmed areas) to be irrigated by ponding, and many of the crops grown in the Valley are sensitive to inundation.

Drip and trickle irrigation methods are best suited for use with permanent crops. Most crops grown in Imperial Valley are seasonal and require tillage of the entire field between plantings. A few acres of citrus are being experimentally grown on the East Mesa with a drip system. The climate in the Valley is unsuitable for extensive farming of permanent orchard crops. Therefore, there are actually no commercial crops grown that are suitable for irrigation with drip methods.

C. Irrigation Efficiency

One method for determining irrigation efficiency is by using the following equation:

$$\frac{\text{Total water delivered to farms for irrigation less total drainage to Salton Sea (ET)}}{\text{Total water delivered to farms for irrigation (applied water)}} \times 100.$$

Using average values for the 1975-79 period, irrigation efficiency for IID is calculated as follows:

Total flow to the Salton Sea less water from Mexico = 1 324 000 dam^3 (1,073,000 acre-feet).

Total water delivered to farms for irrigation = 3 129 000 dam^3 (2,537,000 acre-feet).

$$\text{Irrigation efficiency} = \frac{3\ 129\ 000\ dam^3 - 1\ 324\ 000\ dam^3}{3\ 129\ 000\ dam^3} \times 100,$$

$$= 58 \text{ percent.}$$

Allowing 2 percent for storm runoff and seepage losses to drains, the irrigation efficiency for the District would then be 60 percent. This figure closely approximates that obtained by calculating irrigation efficiency from ET estimates provided by Kaddah and Rhoades.[1/]

Langley, using U. S. Bureau of Reclamation (USBR) ET estimates, concluded that irrigation efficiency ranged from 65 to 73 percent for the 1975-78 period.[2/] His calculations were based on estimated ET values rather than actual ET.

The difference in reported irrigation efficiencies can be traced to the ET values used in the computations. The lack of accurate field-tested ET values for all the crops grown in the District results in different estimates of irrigation efficiency.

1/ Kaddah, M. T. and Rhoades, J. D., "Salt Balance in Imperial Valley, California". Soil Science Society of America Journal. Vol. 40. 1976.

2/ "Affidavit of Maurice N. Langley..." in Civil Action No. 76-10957 in the U. S. District Court. (No date).

The on-going "Water Conservation Opportunities Study, Imperial Irrigation District" by the USBR should try to resolve the problem of questionable crop ET values, as well as measuring tailwater flows and identifying proper leaching requirements for Valley crops. Solutions to each of these problems would permit a more accurate determination of irrigation efficiency.

Appendix A

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Appendix B

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El Centro

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Meloland Field Station
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El Centro

Zimmerman, Bob
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Reno, Nevada

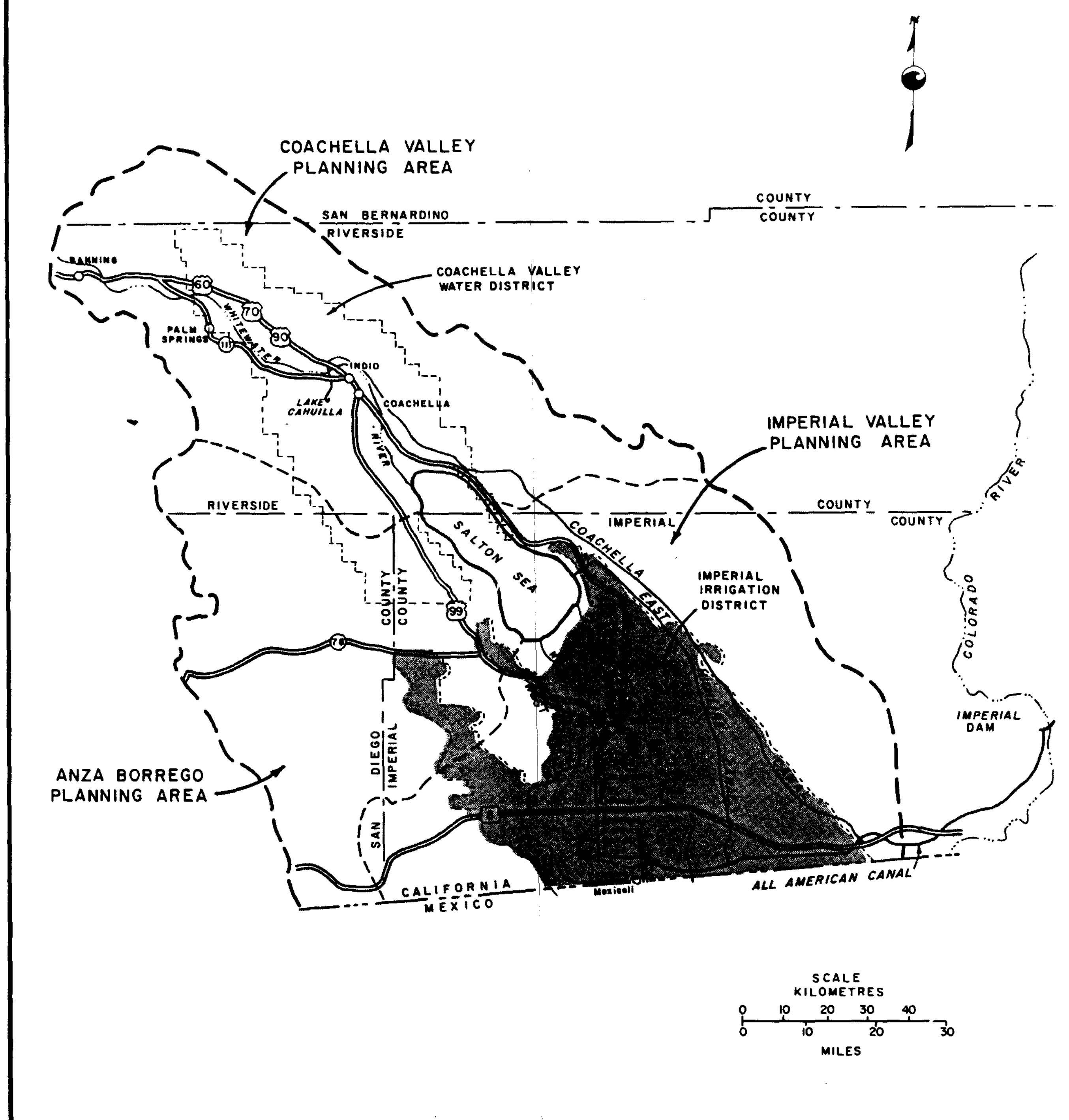
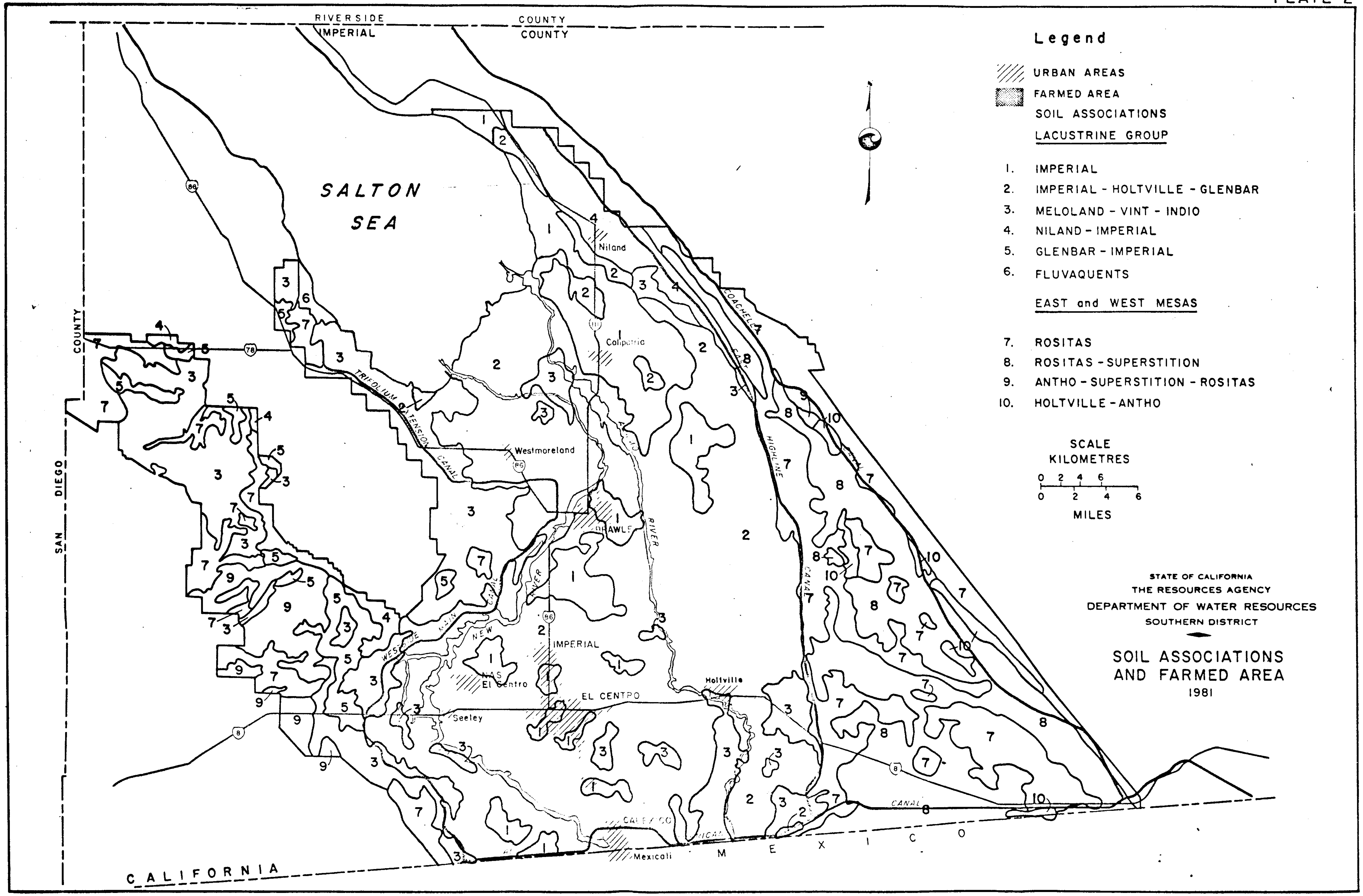


PLATE 1 – LOCATION OF THE IMPERIAL IRRIGATION DISTRICT IN RELATION TO THE COACHELLA AND IMPERIAL VALLEYS

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1981


Legend
URBAN AREAS
FARMED AREA
SOIL ASSOCIATIONS
LACUSTRINE GROUP
1. IMPERIAL
2. IMPERIAL - HOLTVILLE - GLENBAR
3. MELOLAND - VINT - INDIO
4. NILAND - IMPERIAL
5. GLENBAR - IMPERIAL
6. FLUVAQUENTS
EAST and WEST MESAS
7. ROSITAS
8. ROSITAS - SUPERSTITION
9. ANTHO - SUPERSTITION - ROSITAS
10. HOLTVILLE - ANTHO
SCALE
KILOMETRES
0 2 4 6
0 2 4 6
MILES
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SOIL ASSOCIATIONS
AND FARMED AREA
1981
RIVERSIDE COUNTY
IMPERIAL COUNTY
SAN DIEGO COUNTY
SALTON SEA
Niland
Calipatria
Westmoreland
BRAWLEY
IMPERIAL
NAS El Centro
EL CENTRO
Holtville
Seeley
CALEXICO
Mexicali
CALIFORNIA
MEXICO
COACHELLA CANAL
HIGHLINE CANAL
TRIFOLIUM EXTENSION CANAL
WESTSIDE MAIN CANAL
NEW RIVER
RIVER
CANAL