Land Formation

Field Development

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Field development refers to configuring the field shape and surface slope and installation of water control structures to optimize water management, crop production, conserve resources and improve operation efficiency. Most important to rice is accurate and easy management of water application, depth and drainage so that crop growth is improved and weeds controlled. Also important is conservation of water by using it more efficiently, minimizing the likelihood of accidental drainage and possibly by lower depth. Another goal is more efficient use of land, tillage and harvest equipment by minimizing the number of levees, straightening them and making them smaller.

History. Much of the Central Valley is naturally fairly level, ranging from two to five feet fall per mile (Willson, 1979), so not much leveling was done in the early days of the rice industry, with most efforts going to clearing native vegetation and building irrigation water structures such as canals, drains, weir boxes and levees. The prevailing belief at the time was to leave the soil surface between the levees alone because rice grew poorly in cut areas and rank in fill areas. But, by the mid-1920's, growers learned that leveling paid, although the first heavy earth movers and landplanes were not available until 1935 (Rice Journal, 1948). Leveling became widespread after WWII, with a sharp increase in the 1960's. A key concern was whether to maintain the natural contours, which was cheaper, or to make the slope uniform so straight levees could be used, but at higher cost (Figure 1). Wick, 1970, estimated an equipment efficiency gain of 12-15%, 10% higher yield, faster initial flooding, more critical depth management, gain in productive land, and increased land value by leveling for parallel levees. The leveling system most commonly used depended on installing a matrix of grade stakes, based on a detailed survey map, which guided the equipment drivers. Accuracy was dependent on the skill of the operator to match cuts and fills with specifications. In the early 1970's, laser guided equipment (Figure 2) revolutionized land leveling by increasing accuracy, automating some equipment operations and eliminating the need to set a complex matrix of grade stakes. With the adoption of the laser and its

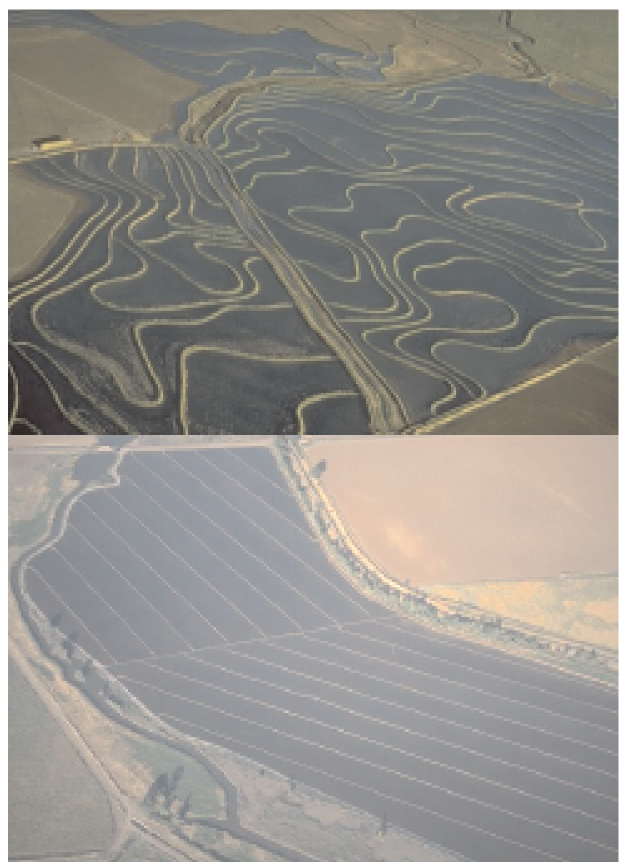

Figure 1. Typical contour levees required in unleveled land, above. Land leveled to uniform slope with parallel levees, below.

Figure 2. Typical scraper for leveling equipped with laser receiver that guides position of cutting blade. Signal is received from laser beam on stand in backround.

exceptional accuracy, growers changed their view of how flat fields could be.

Slopes decreased to zero in some cases, allowing wider levee spacing and bigger basins. In addition, in those areas where rice is the only crop, fields were specifically developed for rice, using permanent levees and very flat slopes. This is very good for rice but precludes rotation crops, given the absence of adequate slope and poor internal drainage of the soil. Today, a high percentage of rice fields are laser leveled and have parallel levees. Those which do not are usually in rowcrop areas or may be taken out of farming for other uses.

Site Selection. Because rice fields require the ability to pond water, soils with low infiltration rate are necessary to prevent excessive water use. Desirable rice soils are those with high clay content (35 to 60%) in the topsoil or subsoil, or which have a cemented layer or hardpan in the subsoil. The most productive rice soils have deeper topsoils although good rice yields may come from shallower soils if crop nutrition needs are adequately met. Fields developed along the edges of the Valley and near streams often have more variable soil across short distances, which should be factored into the development plan. Fields formed from naturally flat topography benefit from less disturbance of topsoils compared to fields developed on steeper land where less fertile subsoils are exposed during leveling. It is especially difficult to farm rice when a calcareous or sodic subsoil is brought to the surface. Such soils often have soil chemistry problems which are difficult to correct.

Leveling. Land leveling allows maintenance of a uniform water depth within the basin (the area between the levees, also called a paddy) and greatly facilitates subsequent management practices for stand establishment, weed control, and field drainage for harvest. When a new field is developed or an old one is improved, an engineering plan is usually developed that includes all the features of the new field such as placement of levees and whether they are straight or contour. It also includes position of roads, landings, irrigation intakes, canals, drains and other necessary structures. Often, several leveling options may be prepared and the producer decides which best fits his situation.

How a field is leveled depends on crops grown, irrigation method, field configuration, soil type, and cost. About two thirds of rice fields in the Sacramento Valley are set up to grow rice only, while the others grow row and field crops in a rice rotation. Fields growing rice only often have little or no slope while those in a crop rotation usually have slopes of 0.05 to 0.1%.

Fields may have a uniform slope across the whole field or the slope will vary because the natural contour of the land varies and it is more economic to work with the natural contours. It is not necessary to have the same slope everywhere in the field.

Soil type will affect how a field is leveled, primarily as it relates to whether or not a soil can economically support crops other than rice. Inclusions of well-drained soil in a rice field should be avoided if possible in the planning stage.

Cost is frequently the primary determinant of how a field is leveled. Very steep ground is most economically leveled into a series of 'benches,' each separated by a levee. This avoids the need to cut down large hills and fill in deep valleys and it leaves more topsoil in place. The area between the levees in benched fields is essentially a small field with its own uniform slope.

Soil Fertility. Leveled fields frequently have infertile and fertile spots related to the cuts and fills. Since most nutrients in the soil are concentrated in the plow layer, and subsoils are usually alkaline and may have infertile cemented hardpans, the effects of leveling on crop nutrition should be a primary consideration during the planning stage. The leveling plan should consider the depth to infertile subsoil and try to avoid it. The National Resources Conservation Service has irrigation land leveling specifications in which they may require special practices for their funded projects: "In cut areas, when highly permeable or otherwise unsuitable subsoil conditions are encountered, the cuts shall be overexcavated and the topsoil replaced. In the fill areas, if specified, the topsoil will be stripped, the fills partly made and the topsoil replaced." (NRCS, #464, 2000). While more expensive, this method will help reduce the damage from deep cuts and help maintain uniformity of soil fertility.

Levees. Levees can be either permanently installed or taken down annually and reinstalled each spring. Permanent levees predominate in rice-only areas while annually-installed temporary levees are common in mixed cropping areas or where a rotation crop may be grown occasionally. Construction of permanent levees should be integrated with the leveling plan because they are larger and require more soil. Temporary levees are built by pulling a large disk ridger or levee squeeze across the prepared field, gathering soil from a width of 11 to 13'. When the levees are knocked down and the field worked, the soil returns to it original position. In some rice only fields, the individual basins are large (>25 ac) and the levees around them wide enough for roads, which gives complete access for management. The benefits of permanent levees include freedom from annual installation, road access, no borrow-pits, and roll-overs. Roll-overs are flattened areas at the ends of levees for equipment to cross over from basin to basin. The disadvantages of permanent levees are that perennial weeds grow which may contaminate the crop and rodents establish and cause leaks. Some annual repair work is necessary to keep weeds and rodents under control, using herbicides, rodent baits, traps, and discs to repairs holes.

Temporary levees take extra work to build them may require a fresh survey each year, although most growers mark the ends and don't need a new survey every year. Fields in a rotation usually need a fresh levee survey when coming back into rice. Temporary levees are freer of perennial weeds and rodents, so leaks are less of a problem. The big advantage is that fields, especially those which have many basins, are more efficiently prepared when levees are not present. Boxes are usually reinstalled each year, although some growers leave the boxes in even though they remove the levee. Temporary levees are usually built on the prepared field, first marking their location, then pulling the levee. A large rice ridger can work in unplowed soil, but takes several passes to gather sufficient soil for the levee. A squeeze or crowder requires that the ground be loosened first by plowing and drying, then a single pass will create the levee. Both types leave a borrow pit which represents unproductive land.

All three levee types, temporary, permanent and road pad, use approximately the same amount of land. Growers have experimented with plastic levees supported with stakes and twine, and with paper covered birms. The objective was to increase productive land, although neither were adopted because of cost, complexity and efficacy. A typical level field usually as 3-5% of the land in levees. An unleveled field with contour levees may have as much as10% of the land in levees.

The orientation of levees relative to wind direction can be an important consideration during the planning stages, particularly if the basins are very long. Strong winds blowing across the surface of long basins will 'pile' the water on the downwind side, which may cause erosion damage to field sides and levees, and sometimes breaches in levees. In addition, the deeper water may impact rice growth and possibly uproot plants. Levees that are crosswise to the wind help reduce the damaging effects. Larger basins are more susceptible to the effects of wind but are more efficient in many respects, so some compromises are necessary.

Grade. Grade refers to the slope of the land surface. This really means very small elevation changes across the field, called either the 'slope' or 'fall'. Because rice needs fairly shallow and uniform water depth large variations in elevation cannot be tolerated. Slope is usually expressed in tenths of a foot per hundred feet of distance or in percent. For example a slope of 0.1′/100′ is the same as 0.1%. A 0.1% fall is equivalent to one foot every thousand feet. One foot is too great a fall for high yield rice production so levees are necessary to break up the field and make sure that water depth will vary no more than 3-4", and preferably no more than 2.5". Many fields are leveled to much less than 0.1%, often 0.02 to 0.05%, allowing for wide levee spacing and greater efficiency. Many fields that are used only for rice have no slope at all and are completely flat. Others have compound grades so that levees are set at an angle to the edges of the field. Many fields have more than one grade, so that levee spacing is not uniform across the field. This is usually related to the cost of leveling which may make it impractical to establish a uniform grade.

Two goals of leveling and setting levees is to space them far enough apart to minimize their number, but close enough together so that the fall between, which affects water depth, does not exceed what the crop can tolerate. Two examples in the shaded box deal with these primary goals.

The point of the first example is that you choose your levee spacing consistent with the slope of the land and needs of the crop. Usually, when the leveling plan is developed based on criteria discussed above, you can determine levee spacing on the map. If the field falls two directions, the calculation is the same although the levees will not be perpendicular to the side of the field. In practice, levee positions can be done with a laser transit simply by finding those spots in the field that represent the desired fall.

1. A field has a uniform slope of 0.1'/100' and the grower wishes to maintain a water level that varies no more than 2.5" between levees. What is the levee spacing he needs to achieve this, assuming zero slope parallel to the levees?

Convert tenths to inches: 0.1 x 12" = 1.2"

Determine levee spacing
(2.5"/(1.2"/100') = 208'

The contour interval would be 208'

2. A field has levees spaced 250' apart and a uniform slope of .1%. What is the difference in elevation between each levee, assuming zero slope parallel to the levees?

Find the fall in 250': 250' x .1 = .25'

Convert to inches: .25' x 12" = 3"

The fall between levees is 3"

The second example is really the corollary of the first. This may be useful if you know the slope and levee spacing, but the water on the low side is too deep and you want to move the levees.

Irrigation Systems. Water delivery and distribution must be considered in the development of the field. While the levees are the primary means of controlling and containing water, other structures are necessary to regulate and distribute it. The method of water management is also integrated within the field development plan. Several irrigation system design options are discussed in the section on Irrigation Water Management.

Irrigation boxes. Weir boxes in each levee are the primary means of regulating water flow and depth. Several materials have been used to build weir boxes, including wood, steel, cement, plastic and fiberglass. See Figure 3, which is typical of a wooden rice box. Redwood is cheap and easily repaired and is useful in fields where levees and boxes are

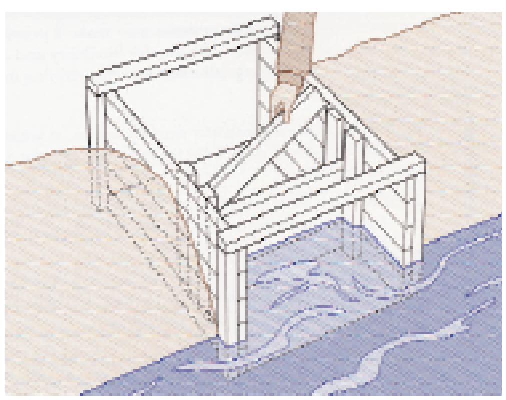

Figure 3. Typical wooden rice box.
From: Hill, et.al. 1991.

removed annually. Fields with permanent levees often use more durable materials such as corrugated plastic pipe connected to steel drop boxes. All have common properties including a flume or pipe to move water from one side of a levee to the other, and removable 'flash boards' which hold water back to a given depth and let the excess flow over the top. Water level in the basin above the box is regulated by adding or removing boards. Weir boxes are usually placed near the ends of levees, often in both ends, and sometimes opposite ends in adjacent levees to promote water circulation. The size and number of rice boxes is dependent on the required capacity to move water from one basin to another. Rice boxes, as in Figure 3, are typically 18" high, 48" long and 24-48" wide. The pipe diameter in permanent rice weirs is usually 12-18".

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