Table 3-4. *(Continued)*

Category		Continuous Flood	Furrow	Corrugations
Metric Units				
Land grading volumes	m^3/ha	100 - 400	200 - 1200	100 - 400
Land grading costs	$/ha	$100 - $370	$190 - $1,110	$100 - $370
Laser finish	$/ha	N/A	$150 - $150	N/A
Border/berm construction	$/ha	$70 - $70	N/A	N/A
Supply system				
Earth ditch	$/ha	$170 - $640	$170 - $640	$170 - $640
Concrete ditch	$/ha	$370 - $1,040	$540 - $2,150	$540 - $2,150
Pipeline	$/ha	$540 - $1,110	$540 - $2,150	$540 - $2,150
Add for gated pipe	$/ha	N/A	$120 - $490	$120 - $490
English Units				
Land grading volumes	yd^3/ac	50 - 200	100 - 600	50 - 200
Land grading costs	$/ac	$40 - $150	$75 - $450	$40 - $150
Laser finish	$/ac	N/A	$60 - $60	N/A
Border/berm construction	$/ac	$30 - $30	N/A	N/A
Supply system				
Earth ditch	$/ac	$70 - $260	$70 - 260	$70 - $260
Concrete ditch	$/ac	$150 - $420	$220 - $870	$220 - $870
Pipeline	$/ac	$220 - $450	$220 - $870	$220 - $870
Add for gated pipe	$/ac	N/A	$50 - $200	$50 - $200

Energy Cost

Energy costs are highly dependent upon the source of energy supply, the source of water, the method of water conveyance between fields, and the topography. It is not unusual for 60 ha fields using aluminum gated pipe to require booster pumps delivering 210 kPa (30 psi). Likewise, it is common to have ditch systems with no pumps involved. Effective tailwater return systems typically require pumps.

Labor Cost

Labor cost for operation of surface irrigation systems is highly variable, depending on system design, field size, supply stream size and degree of automation and whether day time only operation is practical. Table 3-5 can be used as an estimator for labor requirements for the various surface irrigation methods under average conditions, with the understanding that local conditions

Table 3-5. Labor Requirements for Surface Irrigation.

	Labor Required per Irrigation	
Method	Man-hrs/ha	Man-hrs/ac
Basin		
large scale	0.25	0.10
small scale	1.25	0.50
Border Strip		
standard	0.65	0.25
guided or contour	1.25	0.50
contour ditch	6.20	2.50
Continuous flood or ponding		
large scale	0.25	0.10
small scale	1.25	0.50
Furrow		
traditional sloping	4.95	2.00
traditional w/siphon tubes	1.25	0.50
traditional w/gated pipe	0.25	0.10
mechanized	0.10	0.05
contour	2.45	1.00
Corrugation		
earth ditch	6.20	2.50
siphon tube	1.85	0.75
gated pipe	0.50	0.20
mechanized	0.10	0.05

may cause the actual labor requirement to vary. A large flexible water supply requires very little labor as one man can handle irrigation of 200-400 ha if a large tailwater return flow system is also provided. Typically, the labor costs will be highest in the first year or two while the system stabilizes and will then reduce somewhat with time.

Operation and Maintenance Cost

Operation and maintenance cost (other than irrigation labor) for surface irrigation systems consists mainly of periodic re-leveling, reinstallation of secondary ditches, borders, berms, gated pipe, or furrows and maintenance of the water delivery system. Typically, releveling of precision leveled fields for basin, border strip and furrow irrigation occurs every two to three years for annual crops, at a cost of about $150 per ha ($60 per ac).

Maintenance of field structures (secondary ditches, borders, berms and furrow) may occur multiple times per year for crops that are cultivated between irrigations. For semi-permanent and permanent crops, they would occur primarily when the crop was reestablished or maintenance was required due to deteriorating conditions.

Maintenance of field ditches, pipe, outlet structures and control structures is required periodically to preserve the integrity and capacity of the system. The costs will depend upon the type and quality of the ditches and structures being maintained. Generally, earth ditches and control structures in them will require the greatest maintenance and pipe systems will require the least.

As a general guide to maintenance cost, the values presented in Table 3-6 may be used. Local experience should be used to refine these values when available.

Table 3-6. Typical Operation and Maintenance Costs for Surface Irrigation Methods.

Item	Basin	Border	Contour Ditch
	$/ha/yr		
periodic releveling	49 - 74	49 - 74	
field structure maintenance (borders, furrows, etc.)	10 - 12	10 - 12	
earth ditch maintenance	25 - 37	25 - 37	25 - 37
concrete ditch maintenance	12 - 17	12 - 17	
pipeline maintenance	5 - 7	5 - 7	
	$/ac/yr		
periodic releveling	20 - 30	20 - 30	
field structure maintenance (borders, furrows, etc.)	4 - 5	4 - 5	
earth ditch maintenance	10 - 15	10 - 15	10 - 15
concrete ditch maintenance	5 - 7	5 - 7	
pipeline maintenance	2 - 3	2 - 3	

Item	Continuous Flow	Furrow	Corrugation
	$/ha/yr		
periodic releveling		49 - 74	49 - 74
field structure maintenance (borders, furrows, etc.)	10 - 12	10 - 12	10 - 12
earth ditch maintenance	25 - 37	25 - 37	25 - 37
concrete ditch maintenance	12 - 17	12 - 17	12 - 17
pipeline maintenance	5 - 7	5 - 7	5 - 7
	$/ac/yr		
periodic releveling		20 - 30	20 - 30
field structure maintenance (borders, furrows, etc.)	4 - 5	4 - 5	4 - 5
earth ditch maintenance	10 - 15	10 - 15	10 - 15
concrete ditch maintenance	5 - 7	5 - 7	5 - 7
pipeline maintenance	2 - 3	2 - 3	2 - 3

CHAPTER 4
DRIP/MICRO IRRIGATION

DESCRIPTION

Drip/micro irrigation (also previously referred to as "trickle" irrigation) refers to a variety of irrigation methods in which water is delivered directly to small areas adjacent to individual plants through emitters or applicators placed along a water delivery line. In an orchard or vineyard there will typically be one or more emission devices per tree. A schematic of a typical drip/micro system for orchards or vineyards is shown in Figure 4-1. Figure 4-2 shows a microsprayer system in an almond orchard.

For row crops (e.g., broccoli, lettuce, peppers, cotton) and field crops (alfalfa, grains) the emission devices are spaced closely enough so that the capillary action of the soil provides water to each plant root zone. It is unusual to use drip on broadcast field crops because of the difficulties in wetting all of the plants and the low prices of such crops. A schematic of one subsurface row crop drip irrigation system design is shown in Figure 4-3. Everything is buried except the block valves and the flushouts and air vents. Block valves are shown in Figure 4-4.

In the irrigation industry the preferred terminology to describe these systems varies by individual and geography. However, "drip" irrigation generally refers to systems which use low flow rate emitters from which water drips onto the soil. "Micro" irrigation often refers to systems with emission devices that throw water horizontally and vertically with a spray or sprinkler pattern. Some people in industry distinguish between "microsprayers" that have no moving parts, and "microsprinklers" that have rotating parts. Drip/micro irrigation systems are almost always "solid set", meaning that equipment such as hoses and emission devices remain in one place during the growing season. Systems may be permanently installed (typical for trees and vines and for some row/field crops) or may be portable and moved to a different field after an irrigation season is completed. Other systems are hybrid, with a buried mainline distribution system and removable or disposable laterals and/or manifolds/submains.

Drip/micro irrigation systems require very clean water to avoid plugging of the emission devices. Filtration components represent a major portion of the cost and maintenance of drip/micro irrigation. In addition, chemigation is generally required to avoid plugging due to bacterial growth and/or chemical precipitation in the laterals and emission devices. Flow rates for individual emission devices are typically very small, although some microspray systems have such large nozzle diameters that they might also be classified as small flow rate permanent, solid set sprinklers. Typical ranges of emitter flow rates are provided in Table 4-1.

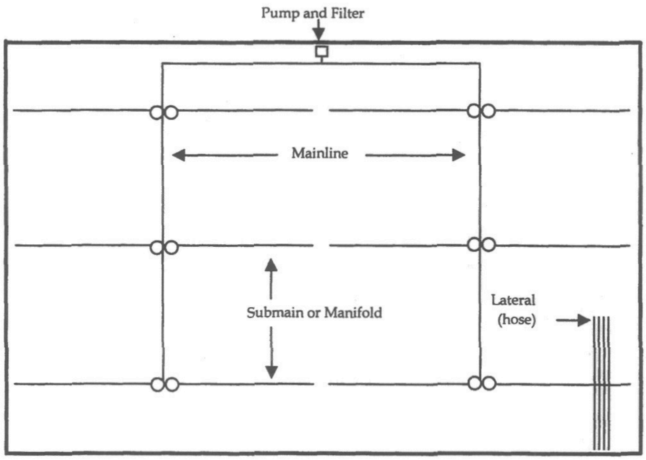

Figure 4-1. Schematic of Typical Drip/Micro Irrigation System on Trees or Vines.

Figure 4-2. Microspray System on a Newly Planted Almond Orchard. Bakersfield, Calif.

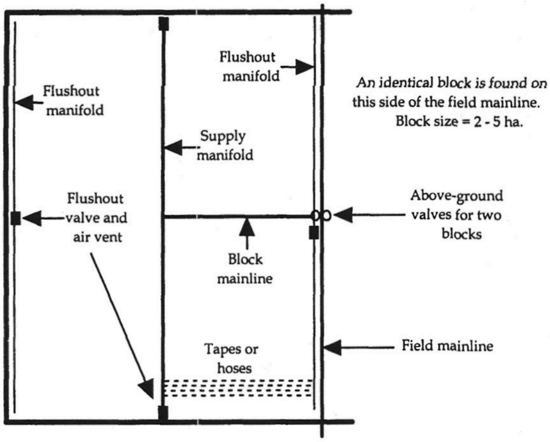

Figure 4-3. Schematic of a Subsurface Row Crop Drip Design Typical of the Central Coast of California.

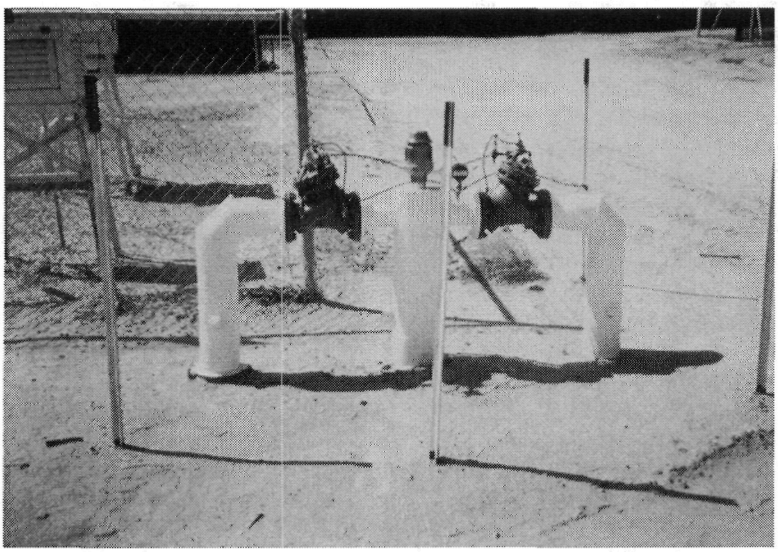

Figure 4-4. Block Valves for a Permanent Subsurface Row Crop Drip Design.

Table 4-1. Flow Rates of Typical Emission Devices in Drip/Micro.

Emitter Type	Typical Range of Flow Rates (LPH)
Row crop drip tape	0.5 - 1.2
Row crop drip hose with discrete emitters	1.2 - 3.6
Vineyard/orchard drip emitters (above ground)	2.5 - 11.0
Vineyard/orchard drip emitters (below ground)	1.3 - 3.0
Vineyard/orchard microsprayers/microsprinklers	22.0 - 75.0

Because drip/micro irrigation systems are "solid set", many of them are easily automated. They are ideal systems for irrigation managers who are interested in fine tuning the applications of water and fertilizer (fertigation) through the irrigation system. Irrigation water is generally applied through emission devices daily or several times per week. Some managers pulse the systems on hourly intervals, although that practice is not standard. Some of these irrigation systems are designed to irrigate a whole field at once. However, the trend toward higher emitter flow rates (such as microsprayers) or more closely spaced emitters (such as on row crops) usually requires that the full pump flow rate be rotated between two to eight blocks within a single field.

TYPES OF DRIP/MICRO IRRIGATION

There are many variations of drip/micro irrigation systems. Some of the differences are due to agronomic or horticultural requirements. For example, frost protection is very important for citrus and avocados in some regions, and micro sprinkler/sprayer designs offer better climate control than do emitters. Drip emitters may be preferred in almond orchards because they enable one to irrigate alternate tree rows without wetting the soil around adjacent rows, as would happen with microsprinkler/sprayer designs. This alternate row irrigation is important with almonds because alternate rows may be planted with different varieties that require stress at different dates prior to harvest. An orchard crop with an extensive, shallow root system such as avocado will typically perform better under microsprinkler/sprayer than under drip. Conversely, closely spaced (hedgerow spacing) trees are better suited to drip emitters, because there are so many emitters in such a design, the wetted soil volume is high, and microsprayer/sprinkler designs suffer from problem of tree and trunk interference of the sprayer patterns. Citrus growers in some regions prune the trees so that the leaves never touch the ground; microsprayers in these situations can wet a large area. If the citrus is pruned so that the leaves touch the ground, microsprayers in effect become high flow rate drip emitters because the water hits the leaves and cannot spread out. Drip emitters typically wet less soil area per emitter on sandy soils than on loam or clay soils, given the same water quality. Therefore, it is more expensive to use drip on sandy soils than on heavier texture soils because more emitters (and sometimes an extra hose per tree row) are needed on sandy soils to obtain sufficient soil wetted area (often desired to be in the 60% range). Microsprayer/sprinkler systems would cost the same on either soil type, because the wetted area is so large that the capillary spread of water beyond the spray pattern is not very important.

Orchard/Vineyard Drip (Above Ground)

These systems typically have one hose per plant row on closely spaced rows (row spacing less than 4 meters), and may have two or more hoses per row on wider spaced rows. Emitters are often spaced in arid regions so that at least 60% of the potential root zone volume is wet, which provides an adequate moisture reservoir for periods of high evapotranspiration, and as insurance against several days of breakdowns. Less wetted area is common in areas with supplemental rainfall.

The emitters used in orchards and vineyards are generally manufactured separately from the hose, and they may be installed on the hose either at the factory or in the field, depending upon the emitter configuration and design. Most hose is manufactured from polyethylene, with common diameters of 16 - 30 mm. Hose lengths (from the hose inlet) vary from about 100 to 200 meters. In the case of orchards, a single hose is generally installed down the tree row, on the soil surface, right next to the tree trunks with only a small percentage of extra length (1.5 - 2.5%) to accommodate hose expansion and contraction due to temperature changes. Recent designs rarely use spaghetti tubes to move water from the emitters to distant locations, although this was common in earlier designs. The use of spaghetti tubes has been discontinued because it was found that after time, the spaghetti tubes were typically wind-blown or kicked together. If a single line of emitters will not provide sufficient soil wetted area, it is common to install two hoses, one on each side of the tree row but out of the way of tractor traffic.

On vineyards a single hose per row is almost universal because the rows are tightly spaced. Usually one or two emitters per vine are used. Depending upon the region and harvesting/tillage equipment, the hose may be placed on the soil surface next to the vine trunks, or be suspended in the air at a height of approximately 0.3 meters (see Figure 4-5). Suspension requires the existence of a trellis system with wires onto which both the vine branches and the hose are attached. Suspension provides the ability to till under the vines without damaging the hose and emitters. There has recently been some interest in using 2 hoses per vine row, with each hose supplying one emitter per vine. By alternating the irrigation between the hoses (for example, one hose for 2 weeks and the other hose for another 2 weeks), the growers are able to alternately stress different sections of the root system. Some growers feel that this alternate stressing can reduce transpiration and increase grape quality without sacrificing grape tonnage.

Figure 4-5. Suspended Hose and Emitter on a Vineyard.

Orchard and vineyard drip systems were well established on large acreages in many areas of the world by the early 1980's. The equipment has continued to improve, with excellent choices now available of well designed emitters and hoses. Most emitters are now of one of two designs, tortuous path or pressure compensating. Tortuous path designs are popular because they provide relatively large passageways and reduced plugging problems compared to vortex or laminar flow emitter designs. Tortuous path designs also provides a reasonable degree of pressure compensation (flow rate changes are approximately proportional to the square root of pressure changes). Because they have no moving parts, emitters with tortuous designs tend to be relatively inexpensive, well made, and durable.

The second most popular emitter design incorporates some type of pressure compensation provided by a moving part that progressively restricts the passageway size as the pressure increases. There are many brands and models of such pressure compensating emitters available, but only some are robust and have the desired characteristics when new and for many years later. Some have excellent self-flushing characteristics. To minimize problems with these types of emitters, purchasers should specify a very low manufacturing coefficient of variation (manufacturing CV typically less than 0.05), and a guarantee that the pressure/discharge relationship follows a pre-defined curve. A well-written and backed warranty should also be obtained regarding those same factors (CV,