Computer Programming for the Distribution of Irrigation Water at Farm Level

by

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Irrigation engineers often have the experiences of knowing that an expensive irrigation project and costly water have been wastefully used for lack of proper management. Many of irrigation studies were chiefly aimed at getting more efficient and economy use of water. In some countries, the management of irrigation water may be very simple, while in others it may be a very complicated matter. Factors involved in the efficient and economy use of irrigation water are many and each have its characteristic influences. Following is an example for a very complicated management plan of water used at farm level. It may be for references to other areas having comparable problems.

The example area is in the service area of the largest irrigation system in Taiwan. The Chia-Nan Irrigation District. There are about 70,000 hectares of farm land served by a reservoir. Annual rainfall in this area is about 2,000 mm. in which about 80% is concentrated in the months from June to September and 20% in the months form October to May. Agricultural practices are very intensive and crops aregrown throughout the year. Other characteristic features of this area are as follows:

1, Water resources in this area can only supply roughly 1/3 of the service area to grow one crop of rice from mid June to October. And then is followed by one year of dry land crops. After that, a crop of sugar cane is followed which takes 18 months to grow and complete a three year crop rotation cycle.

, Major part of the reservoir service area is laid out in such a manner that a crop rotation unit about 150 hectars composed of three irrigation units. Each of the irrigation unit is to plant crops in alternate year according to the three year crop rotation cycle. It is called the three year corp rotation pattern in Taiwan.

3, Farm land in Taiwan are small and irregular Though the land reform program have consolidated some farming areas into standard farm size but still each field is only fraction of a hectare. There are numerous farm ditches to distribute water to the fields. It is assumed that same depth of irrigation water is given to all kinds of dry land crops, except that sugar cane is given a larger quantity. A turnout gate is installed for each irrigation unit. Ditch capacity is controlled at the turnout. The depth of water given to each field is regulated by length of time irrigating.

4, Because of the numerous irrigation unit and diversify cropping, irrigation schedule must be worked out for the whole season ahead of time. Durig the dry

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season, limited irrigation is given to the dry land crops only in a prearranged period of time. Therefore, the amount of water scheduled to deliver to the farm may not be the amount actually required by the crops at time of irrigating. Irrigation may be postponed in case of rain, but the overall operation schedule can not be altered for momentarily adjustments.

5, In the three year crop rotation areas, rice is not grown in dry season. Therefore, the problem concerned is largely for dry land crops grown in dry season. During the schedule irrigation period, each farmer is notified the exact time he should be ready on his field to receive his share of water. Any slight change will affect all the others. Therefore, the irrigation schedule must be straightly observed.

It is obvious that the present day irrigation operation have been carefully considered to make the utmost used of the reservoir and the irrigation system. Irrigation water is controlled at turnout of each irrigation unit. But there are a total of 1,917 of these irrigation unit in the reservoir service area. In each irrigation period, total time allowed for the whole area is limited. In order to deliver a certain amount of water to each irrigation unit at the proper time is already a very complicated task for its computation. In each of the irrigation unit, there are hundreds pieces of farm land grown to different kind of crops. It is impossible to compute the actual requirement of water for each farm since the irrignation schedule worked out for the whole season ahead of time is difficult to readjust for later changes. But the farmers may change their cropping plan or some may not wanted to be irrigated. For example, an Autumn crop of sweet potato planted in early September, irrigation in the late fall is very much needed. But the same potato if newly planted, or planted in late Spring and close to harvesting time, the farmer generally do not want irrigation scheduled for the late fall. Such changes were not known at the time of perparing the irrigation schdule, the result is a wasteful used of water and a low overall irrigation efficiency. It is hope that with the help of the computer, this difficulty may be overcame.

Dry land crop irrigation in Taiwan cannot be operated on a "served on demand" basis largely due to the limitation of water and the numerous small plots served by open ditch system. In present operation, the scheduled irrigation period for the whole unit is proportionally divided according to the area of each field. In such a manner, little consideration can be given to each field for factors affecting water used as the kind of crops, the efficiency for different method of application, and the differences in seepage lose of water in the field ditch system etc., dispite that such basic imformations are usually available.

Irrigation studies in Taiwan in the recent years have provided considerable amount of such useful basic data observed in the field. It may help to point out the actual water requirement for each field with adjustments made for various influencing factors. Compiling the result of experiments in the past years, for the Chia-Nan crop rotation area of medium texture soil, and assumming the length of field 120 metters, the average depth and expected efficiency of irrigation for different crops may be taken as in following table:

Table 1 Recommended irrigation depth and efficiency for crops grown in Chia-Nan area in meidum texture soil

Crop	Depth of irrigation (mm)	Irrigation eff.* (%)	Method of irrigatjon
Sweet potato	60	75	Furrow
Corn	60	70	Currogation
Sugar cane	75	75	Furrow
Vegetables	50	70	Furrow
Barley	60	70	Border
Peanut	60	60	Berder
Cotten	60	70	Furrow

* Correction should be made for other field length

In Taiwan, dry land corops were grown in rotation with rice. The field have little slope. Field ditch below the turnout gate of the irrigation unit is not lined. Water released from the turnout into the ditch system and irrigating from the far end progressing upstream. This is the rule made out for the operational management in the field. Irrigation schdule prepared ahead of time assumed that irrigation is given to every farm and the amount of irrigation water released from the turnout during the schedule period is not change. It was found from experiments that seepage lose in the farm ditch system was affected largely by the length of time after turnout released and the distance from the turnout to the irrigating field. Water released from turnout and travel in a dry ditch to the far end. The time lag is also considered and included in the irrigation period. Since ditch water is checked to a fixed elevation before turn into the field, slight change in the ditch capacity due to some farmer may not wanted to irrigate affect very little the depth of ditch water and the seepage lose during the irrigating period. It was found that the seepage lose of the ditch system during irrigation may be expressed by:

$$S = aL^{b}\ T^{c} \quad \cdots\cdots (1)$$

S, seepage lose in ditch (%)

L, length of ditch from turnout to field (m)

T, accumulated time of irrigating from the begining of period

To determine the time lag required for the stream to reach a field after water released into a dry ditch, for a given discharge, it may be expressed by:

$$t = \alpha L^{B} \quad \cdots\cdots (2)$$

t, time required for stream to reach the field after released into dry ditch

L, length of ditch which the stream traveled

In equation (1) & (2), a, b, c, & α, β were determined by experiment. In equation (2), slight change of ditch flow as due to some farmer change their cropping plan may slightly affect 't', but the effect is minor in the whole irrigation period.

In equation (1) & (2), factors really affecting a, b, c, & α,β is the difference of soil and the condition of ditch. Studies of this problem is still underway. For the present time, it is determined by experiment for a particular area.

The irrigation efficiency in table (1) is for field of 120 metter in length. For other field length, correction of irrigation efficiency may be made as follows:

$$E_1 = \frac{\bar{L}}{L_1} \cdot \bar{E} \qquad \bar{L} = \frac{\Sigma LA}{\Sigma A} \qquad \therefore\ E_1 = \frac{\Sigma (L_1 A)\bar{E}}{\Sigma (A) L_1} \quad \cdots\cdots (3)$$

E_1, irrigation efficiency of a field (%)

$\bar{E}$, average efficiency for a certain crop, as taken in table (1) (%)

$\bar{L}$, average field length for certain crop (m)

L, length of fields for certain crop (m)

L_1, length of field (m)

A, Area of fields for certain crop (ha.)

With the irrigation efficiency correction being made, time required for the irrigating of each field may be determined as follows:

$$t_1 = T^E - T^O = \frac{2A_1 d_1}{E_1 Q\,[2 - aL_1^b\,(T_e^c + T_o^c)]} \quad \cdots\cdots (4)$$

t_1, time required to irrigate a field

T_e, accumulated time when starting irrigation

T_o, accumulated time when completing irrigation

Q, amount of water released at turnout

A_1, area of field (ha)

d_1, depth of irrigation (mm)

L_1, length of ditch from turnout to field (m)

E_1, irrigation efficiency for the field (%)

Equation (4) is derived from:

$$t_1 = \frac{A_1\, d_1}{q_1\, E_1}$$

$$q_1 = 1/2\ (q_o + q_e)$$

$$q_o = Q\ (1 - aL_1^b\ T_o^c)$$

$$q_e = Q\ (1 - aL_1^b\ T_o^c)$$

$$\therefore\ q_1 = \frac{Q}{2}\ (2 - aL_1^b\ (T_e^c + T_o^c)]$$

$$t_1 = \frac{2A_1 d_1}{E_1 Q\,[2 - aL_1^b\ (T_e^c + T_o^c)]}$$

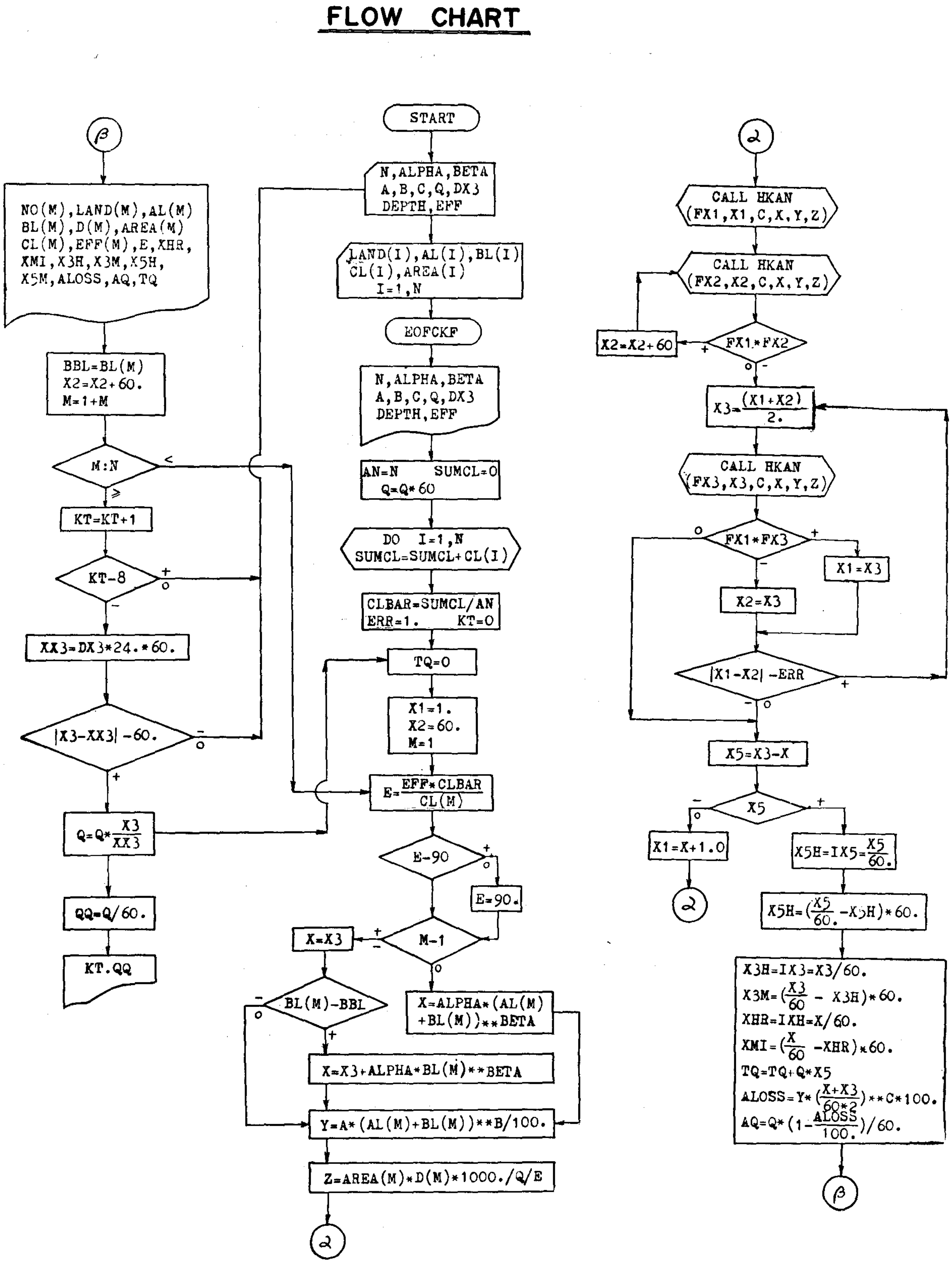
q_1, amount of water into the field

q_o, amount of water into the field when starting irrigation

q_e, amount of water into the field when completing irrigation

With the relation established for the influencing factors in irrigation operation of the Chia-Nan crop rotation areas, a flow chart may be written as follows:

Fig 1. Flow Chart for Irrigation Operation of a rotation unit



With the given flow chart, an example is taken for the computation of one of the irrigation unit in the Chia-Nan area. The area is the Liew-Jew irrigation unit. A representing area of diversity dry land cropping in medium texture soil. This unit is 37.31 hectares with 143 fields. The scheduled irrigation period is from December 6th to 16th, a total of 10 days. Checking is made before irrigation found that some of the field do not want to be irrigated. It is indicated in the shaded area of the ownership map. Field experiment found that for equation (1) & (2)

$$S = aL^b\ T^c \begin{cases} a = 4.6239 \\ b = 0.3700 \\ c = -0.3792 \end{cases}$$

$$t = \alpha L^B \begin{cases} \alpha = 0.102 \\ \beta = 1.10 \end{cases}$$

From the land ownership map (Fig.2) which is available for any irrigation unit, following imformations may be obtained.

1, Each field showing the order of irrigating may be numbered and listed

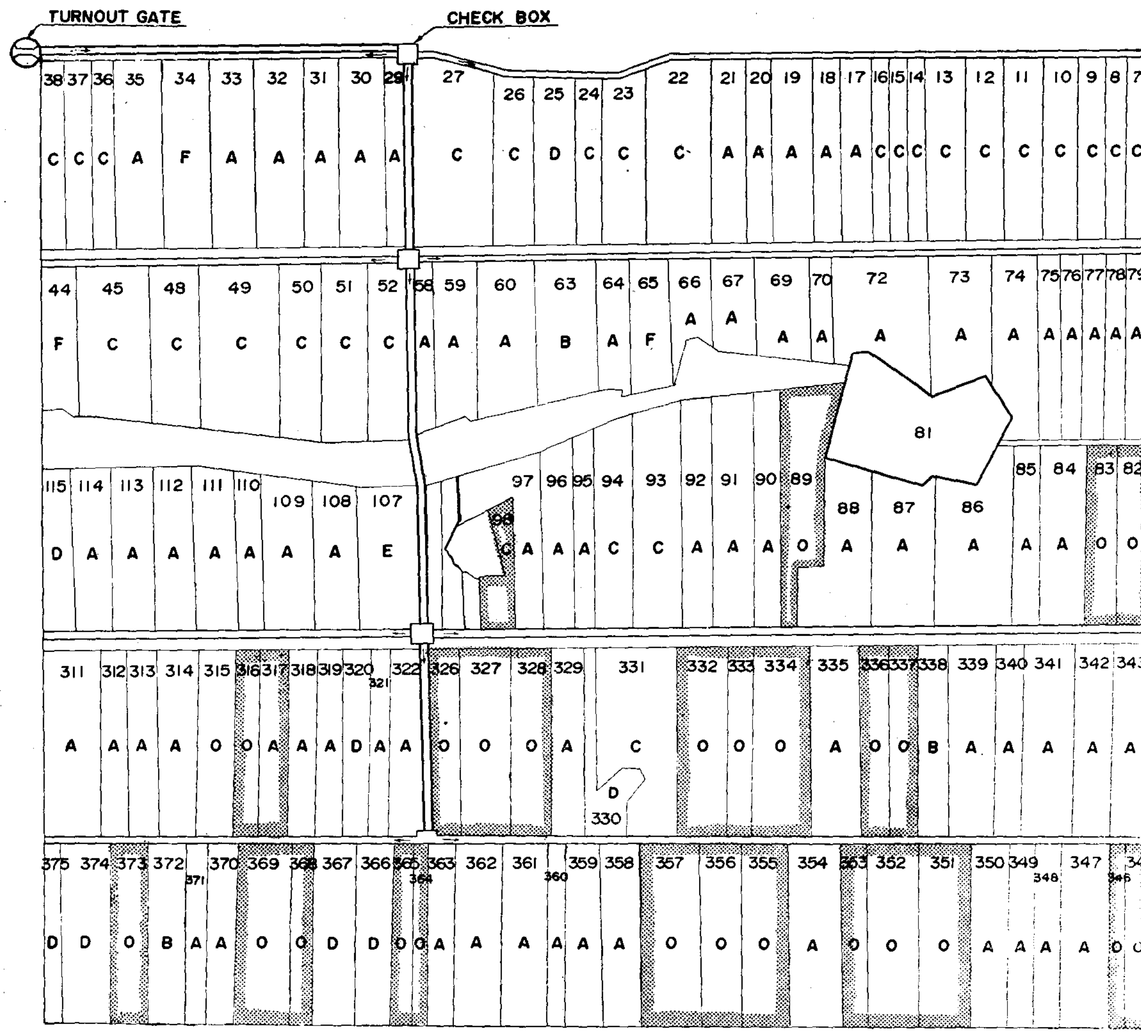
2, The area and length of fields and distance from turnout is known, the correction for irrigation efficiency can be made

3, Crop grown in each field and the need of irrigation may be checked and recorded

The original irrigation plan for the Liew-Jew unit for the 10 day period with an estimated turnout release of 0.0433 C. M. S.. The total of water used in the whole period will be 37,411 M^3. Average seepage lose is assumed 30%. But with the help of the computer, all available imformations and the major influencing factors being considered, for the 10 day period, turnout release only require 0.0293 C. M. S, and the total amount of water required is only 24,012 M^3. And in addition to the economy use of water each field also having its require efficiency. The computation is given in table2

From the example given, it is obvious that with the help of computer, irrigation determination can readily adjusted to the actual requirements in the field. Which not only resulting in an economy and efficient use of irrigation water, but also solved one of the so far untangible problem in our irrigation practices. For the 1917 irrigation unit in the whole Chia-Nan district, it will take time for the change ovsr. Howevr, to prepare the irrigation operation schedule has been the most complicated task for the irrigation district every year, this example may show the effective way for its solution.

Fig. 2 Land ownership map of Liew-Jew irrigation unit



CROPS	CODE NO.	CROP AREA (HA)	IRRIGATED AREA (HA)	RATIO OF IRR TO CROP AREA (%)
SWEET POTATO	A	18.02	12.57	69.76
CORN	B	0.89	0.64	71.91
SUGER CANE	C	7.65	5.55	72.55
VEGETABLE	D	2.58	0.90	34.88
BARLEY	E	0.34	-	-
PEANUT	F	0.73	0.36	49.32
COTTON	G	-	-	-
VACANT	O	7.10	5.15	72.54
TOTAL AREA		37.31	25.17	67.46

Table 2 Computer determination of irrigation requirements at farm level

Q=0.0290 C.M.S.

Irrigating Order	Field Number	Length of Ditch (m) Main	Length of Ditch (m) Lateral	Irrigation Depth (mm)	Field Area (ha)	Field Length (m)	Irrigation Efficiency (%) Eff. for Crop	Irrigation Efficiency (%) Eff. Corrected	Irrigation Time: Irrigation Starting hr.	Irrigation Starting min.	Irrigation Ended hr.	Irrigation Ended min.	Interval hr.	Interval min.	Seepage Lose (%)	Discharge into Field (C.M.S)	Accumulate Amount Water Used (m³)
1	345	718	436	60	.220	120.0	70	68	3	58.2	6	47.3	2	49.0	33.184	.019	294.536
2	343	718	424	60	.310	120.0	75	73	6	47.3	10	12.5	3	25.2	27.793	.021	652.081
3	346	718	424	60	.120	120.0	70	68	10	12.5	11	33.8	1	21.3	25.303	.022	793.665
4	342	718	402	60	.280	120.0	75	73	11	33.8	14	26.9	2	53.2	23.482	.022	1095.384
5	317	718	394	60	.380	120.0	75	73	14	26.9	18	17.3	3	50.4	21.464	.023	1496.754
7	341	718	368	60	.310	120.0	75	73	18	17.3	21	19.9	3	2.6	19.792	.023	1814.883
9	340	718	352	60	.220	120.0	75	73	21	19.9	23	27.8	2	7.9	18.788	.024	2037.782
10	350	718	336	60	.090	120.0	75	73	23	27.8	24	20.0	0	52.2	18.230	.024	2128.679
12	351	718	304	60	.380	120.0	70	68	24	20.0	28	14.3	3	54.4	17.384	.024	2537.012
14	337	718	290	60	.200	120.0	70	68	28	14.3	30	15.7	2	1.3	16.609	.024	2748.418
16	352	718	270	60	.390	120.0	70	68	30	15.7	34	11.7	3	56.0	15.891	.024	3159.618
18	335	718	240	60	.100	120.0	75	73	34	11.7	35	6.9	0	55.2	15.284	.025	3255.862
20	334	718	206	60	.440	120.0	70	68	35	6.9	39	29.7	4	22.7	14.665	.025	3713.652
21	355	718	198	60	.340	120.0	70	68	39	29.7	42	51.1	3	21.5	14.081	.025	4064.676
22	333	718	190	60	.170	120.0	70	68	42	51.1	44	31.3	1	40.2	13.724	.025	4239.185
23	356	718	174	60	.310	120.0	70	68	44	31.3	47	33.0	3	1.6	13.366	.025	4555.679
24	332	718	156	60	.410	120.0	70	68	47	33.0	51	33.0	4	.0	12.901	.025	4973.838
25	357	718	134	60	.470	120.0	70	68	51	33.0	56	5.3	4	32.4	12.385	.025	5448.405
26	331	718	126	60	.500	120.0	75	73	56	5.3	60	34.8	4	29.5	11.971	.026	5917.914
27	358	718	112	60	.270	120.0	75	73	60	34.8	62	59.4	2	24.6	11.640	.026	6169.874
29	359	718	90	60	.270	120.0	75	73	62	59.4	65	24.1	2	24.7	11.359	.026	6421.999
32	328	718	54	60	.300	120.0	70	68	65	24.1	68	14.9	2	50.8	11.000	.026	6719.630
33	361	718	48	60	.130	120.0	75	73	68	14.9	69	23.8	1	8.8	10.847	.026	6839.572
34	327	718	24	60	.210	120.0	70	68	69	23.8	71	23.8	1	60.0	10.628	.026	7048.648
35	362	718	18	60	.370	120.0	75	73	71	23.8	74	39.5	3	15.8	10.450	.026	7389.734
36	326	718	0	60	.120	120.0	70	68	74	39.5	75	46.6	1	7.1	10.239	.026	7506.618
37	363	718	0	60	.230	120.0	75	73	75	46.6	77	47.5	2	.9	10.160	.026	7717.205
39	311	718	194	60	.440	120.0	75	73	78	21.0	82	15.9	3	54.9	10.912	.026	8126.468
40	374	718	190	60	.420	120.0	70	68	82	15.9	86	15.0	3	59.1	10.698	.026	8542.990
41	312	718	178	60	.210	120.0	75	73	86	15.0	88	5.5	1	50.5	10.509	.026	8735.598
42	373	718	166	60	.280	120.0	70	68	88	5.5	90	44.5	2	39.0	10.357	.026	9012.687
43	313	718	160	60	.200	120.0	75	73	90	44.5	92	30.4	1	45.9	10.235	.026	9197.121
44	372	718	144	60	.290	120.0	70	68	92	30.4	95	14.1	2	43.7	10.073	.026	9482.416
45	314	718	138	60	.280	120.0	75	73	95	14.1	97	41.7	2	27.5	9.944	.026	9739.462
50	317	718	82	60	.320	120.0	75	73	97	41.7	100	29.0	2	47.3	9.600	.026	10030.944
51	369	718	80	60	.370	120.0	70	68	100	29.0	103	56.8	3	27.8	9.479	.026	10392.995
52	368	718	66	60	.160	120.0	70	68	103	56.8	105	26.5	1	29.8	9.331	.026	10549.387
59	365	718	8	60	.170	120.0	70	68	105	26.5	107	1.0	1	34.5	9.020	.026	10714.017
60	322	718	0	60	.230	120.0	75	73	107	1.0	109	1.0	1	60.0	8.926	.026	10923.096
61	364	718	0	60	.090	120.0	70	68	109	1.0	109	50.5	0	49.5	8.882	.026	11009.385
64	84	590	381	60	.300	116.0	75	75	111	.9	113	33.6	2	32.7	9.835	.026	11275.373
65	85	590	369	60	.200	116.0	75	75	113	33.6	115	15.6	1	42.0	9.721	.026	11453.174
66	86	590	318	60	.490	116.0	75	75	115	15.6	119	23.3	4	7.7	9.436	.026	11884.727
67	87	590	280	60	.390	100.0	75	87	119	23.3	122	13.3	2	50.0	9.186	.026	12180.934
72	92	590	161	60	.230	154.0	75	57	122	13.3	124	47.2	2	33.9	8.626	.027	12449.048
73	93	590	130	75	.510	142.0	75	61	124	47.2	131	18.5	6	31.2	8.377	.027	13130.719
74	94	590	106	75	.340	134.0	75	65	131	18.5	135	23.8	4	5.4	8.147	.027	13558.215
75	95	590	93	60	.110	126.0	75	69	135	23.8	136	22.9	0	59.1	8.032	.027	13661.105
76	96	590	74	60	.280	120.0	75	73	136	22.9	138	47.8	2	24.9	7.912	.027	13913.567
79	115	590	210	50	.210	115.0	70	71	139	24.3	140	57.7	1	33.3	8.416	.027	14076.159
80	114	590	187	60	.270	115.0	75	76	140	57.7	143	11.8	2	14.1	8.284	.027	14309.837
81	113	590	161	60	.280	115.0	75	76	143	11.8	145	30.1	2	18.4	8.131	.027	14550.893
82	112	590	138	60	.290	115.0	75	76	145	30.1	147	53.4	2	23.3	7.989	.027	14800.559
83	111	590	114	60	.270	115.0	75	76	147	53.4	150	6.8	2	13.4	7.844	.027	15033.006
89	78	350	432	60	.170	120.0	75	73	151	27.7	152	54.8	1	27.2	8.090	.027	15184.866
90	77	350	418	60	.170	120.0	75	73	152	54.8	154	22.5	1	27.7	8.007	.027	15337.669
93	74	350	362	60	.310	120.0	75	73	154	22.5	157	2.0	2	39.5	7.746	.027	15615.575
94	73	350	323	60	.320	84.0	75	90	157	2.0	159	14.7	2	12.7	7.542	.027	15846.792
97	69	350	217	60	.240	84.0	75	90	159	14.7	160	53.0	1	38.3	7.046	.027	16018.082
98	67	350	190	60	.100	62.0	75	90	160	53.0	161	34.0	0	40.9	6.901	.027	16089.423
101	64	350	116	60	.200	84.0	75	90	161	34.0	162	56.2	1	22.2	6.519	.027	16232.660
102	63	350	78	60	.350	86.0	70	90	162	56.2	165	18.7	2	22.5	6.290	.027	16481.009
103	60	350	40	60	.350	94.0	75	90	165	18.7	167	40.6	2	21.9	6.044	.027	16728.217
104	59	350	14	60	.240	98.0	75	89	167	40.6	169	19.6	1	39.0	5.865	.027	16900.736
105	58	350	0	60	.190	103.0	75	85	169	19.6	170	40.9	1	21.3	5.761	.027	17042.319
108	48	350	128	75	.340	100.0	75	87	171	2.1	174	1.4	2	59.3	6.430	.027	17354.656
109	49	350	80	75	.530	103.0	75	85	174	1.1	178	48.8	4	47.4	6.131	.027	17855.441
113	7	350	444	75	.150	120.0	75	73	180	12.1	181	48.7	1	36.6	7.618	.027	18023.694
115	9	350	414	75	.170	120.0	75	73	181	48.7	183	38.3	1	49.6	7.483	.027	18214.700
116	10	350	392	75	.250	120.0	75	73	183	38.3	186	17.8	2	39.5	7.368	.027	18492.606
118	12	350	346	75	.290	120.0	75	73	186	17.8	189	23.0	3	5.2	7.154	.027	18815.346
119	13	350	321	75	.290	120.0	75	73	189	23.9	192	28.5	3	5.4	7.014	.027	19138.388
120	14	350	310	75	.130	120.0	75	73	192	28.5	193	51.6	1	23.2	6.941	.027	19283.264
121	15	350	298	75	.130	120.0	75	73	193	51.6	195	14.8	1	23.1	6.875	.027	19428.138
122	16	350	284	75	.110	120.0	75	73	195	14.8	196	24.7	1	9.9	6.803	.027	19549.964
123	17	350	268	60	.220	120.0	75	73	196	24.7	198	17.1	1	52.4	6.719	.027	19745.873
124	18	350	250	60	.200	120.0	75	73	198	17.1	199	59.2	1	42.0	6.623	.027	19923.673
125	19	350	228	60	.280	120.0	75	73	199	59.2	202	21.7	2	22.5	6.507	.027	20172.023
126	20	350	210	60	.090	120.0	75	73	202	21.7	203	7.5	0	45.8	6.413	.027	20251.772
127	21	350	190	60	.260	120.0	75	73	203	7.5	205	18.7	2	11.2	6.310	.027	20480.416
128	22	350	128	75	.480	115.0	75	76	205	18.7	210	9.4	4	50.7	5.992	.027	20986.951
129	23	350	120	75	.310	103.0	75	85	210	9.4	212	57.4	2	48.0	5.914	.027	21279.676
130	24	350	104	75	.130	108.0	75	81	212	57.4	214	11.2	1	13.8	5.818	.027	21408.247
131	25	350	80	50	.270	105.0	75	83	214	11.2	215	49.5	1	38.3	5.688	.027	21579.462
132	26	350	56	75	.270	105.0	75	83	215	49.5	218	17.2	2	27.7	5.548	.027	21836.847
133	27	350	0	75	.620	110.0	75	79	218	17.2	224	13.0	5	55.8	5.214	.028	22456.725
138	34	350	120	60	.360	120.0	60	58	224	32.8	228	19.5	3	46.8	5.764	.027	22851.883
139	33	350	90	60	.300	120.0	75	73	228	19.5	230	50.6	2	31.1	5.595	.027	23115.110
140	32	350	63	60	.360	120.0	75	73	230	50.6	233	51.4	3	.8	5.441	.027	23430.061
141	31	350	42	60	.240	120.0	75	73	233	51.4	235	51.3	1	59.9	5.315	.027	23639.003
142	30	350	14	60	.310	120.0	75	73	235	51.3	238	25.9	2	34.6	5.152	.028	23908.350
143	29	350	0	60	.120	120.0	75	73	238	25.9	239	25.7	0	59.8	5.064	.028	24012.467

Summery and conclusion:

In irrigation practices, economy and efficient use of water is usually highly emphsized. Modern irrigation science point out what can be done and how it may be accomplished. Generally, the leading topics in this field of studies is the consumptive use of crops, the irrigation efficiency and the irrigation lose during application etc.. There are numerous related reference materials published all over the world. But very often there are problems in the field which is more complicated and difficult to interprete by laboratory researches. Irrigation system in Taiwan is predominately open ditch system. The farm plot is very small and the field ditch is unlined. Irrigation water is not served on demend but according to a prearranged schedule. Water is controlled at the turnout gate of the irrigation unit, and release into the dry ditch during the irrigation period. Therefore, the seepage lose is kept on changing throughout the entire irrigating period but the entire irrigating period but the release from turnout remain unchange. Conventional formula for seegage lose is very difficult to apply. But the problem is quite real.

The field such as pointed out in this example is to receive an exact amount of water in each small parcel of land and to maintain a required application efficiency. And at the same time to fulfill other requirements such as to complete the irrigation in a given period of time and to consider a few farmers who do not want to irrigate. In order to meet all these requirements, assumptions may be summarized as follows:

1, The field laid out in such a menner that the same order of irrigation should be followed in each application. It is a rule in present day operation in the Chia-Nan crop rotation area.
2. Release of water is controlled at turnout and is assumed unchange. However, there may be slight change due to farmer changing their cropping plan, it is assumed such change affect very little in the use of equation (1) & (2), andthe auer all irrigation schedule.
3, Dry land crop is grown in rotation with rice, the field have little slope and its effect on equation (1) & (2) is not considered. For dry season irrigation, water is released from turnout into dry ditch, a. b, c, and α, β in equation (1) & (2) is determined by field experiment for a particular area.
4. In the derivation of equation (4), the change of q_o to q_e during the application of water into a field is assumed lineal.

In an area having the most intensive agricultural practices with a water shortage, and the farm is very small and served by unlined ditch system, in order to irrigate each field to a require efficiency, is no doubt a very complicated problem of management. The example may be interesting for refernce to other areas of comparable consideration.