7 -13 SOIL HARDNESS TESTER

SOIL HARDNESS TESTER

Yamanaka Standard Type

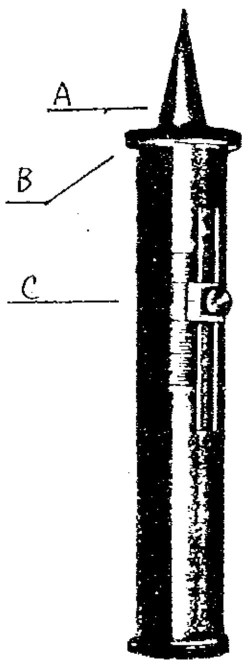
The Soil Hardness Tester was devised by Dr. Kinjiro Yamanaka of the Pacific Consultants, K.K. (former technical official of the National Institute of Agricultural Sciences, Japan) more than a decade ago. It was devised to be used for the field study of the soil profile of farm land. It is indispensable for the soil survey which has been carried out all through Japan. It accurately records the characteristics of each profile of the soil and the accumulated data supply important factors to; determine the genetic soil classifications, evaluate the soil productivity, and for the over-all development and improvement of the agricultural land.

As the farming in Japan is mechanized more and more in recent years, this highly scientific and technical and yet very simple device is valued and utilized in much wider field. It defines the critical limit of weak bearing capacity for the operation of farm tractors on the paddy fields.

It is realized the fact that the tester detects the hardness, stability, and other physical peculiarities of soil, it might as well be instrumental for the construction of civil engineering projects, like; road construction, bankings of dam and railroads and such.

In the engineering aspects, the tester serves to elucidate the field conditions directly or indirectly of:

Water Permeability; Soil Aeration; Compressive Strength; Shearing Strength; Cohesive strength; etc.



* Specifications

Hardness index range:	0 - 40 mm
Graduation:	1 mm
Bearing capacity range:	0 to infinite kg/cm^2
Maximum load:	8 kg (to 40 mm)
Cone size:	18ϕ x 40 mm
Dimensions:	4ϕ x 20 cm (5ϕ x 23 cm with case)
Weight:	400 g (650 g with case)
Case:	hard plastic cylinder

TESTING METHOD

Push the cone (Part "A") straight into the soil horizontally or vertically which surface is acraped flat. The guard (Part "B") inevitably come forward to come in contact with the soil surface as the spring inside the body shrinks and the cone sinks into it. The special indicating device works at the same time the cone sinks to indicate the hardness and bearing capacity of the soil. The indicator remains at the same spot even the SHT is pulled out of the soil. It can be easily pushed back to sero by finger after reading. The hardness of soil is figured out by calculating a. depth (strain of soil) and b. shrinkage of spring (enargy used for the cone penetration). The relation between a. and b. shall always be as follows:

$$a. + b. = 40 \text{ mm}$$

The hardness of the soil can be simply indexed by the m.m. scale engraved on the cylinder which indicates the shrinkage of the spring. Bearing capacity of soil increases rapidly as the soil hardness index increases. The percentage of which is as shown in Chart I.

This simple method avail the measurement of soil hardness in wide range from loose sand to quite hard clay shale. In other words, any materials which surface can be scraped or cut flat shall be measured. It is often used to test the quality of fruits and rootcrops, like; apples, potatoes, carrots, radishes, etc.

As for this tester, only the quite sharp end of the cone is pushed into the soil, the strain or compression caused by the force is too little to speak of and, therefore, the result of test is always stable.

To measure the bearing capacity of the soil foundation of 1 cm^2, the pressure due to the reactional force of soil must be calculated. On the opposite side of the hardness scale on the cylinder, bearing capacity scale is engraved. The method of calculation is shown hereunder.

Actual test reveals that the limit of soil hardness index necessary to operate the farming tractor and other heavy machineries on the paddy fields is 10 - 11 mm. Therefore, the soil with hardness of 15 mm will well support the operation of most any heavy machineries and equipment. The B-horizon of Kanto loam which is known to have high bearing capacity for construction is 20 - 23 mm in hardness. What is generally known as the hard pan layer is 28 - 29 mm or harder.

The strength of the spring inside the tester is 8 kg/40 mm and it is designed to be able to operate with one hand. In the event it is desired to be used vertically or greater force is available, it can be revised in larger scale with exactly the same proportion.

TESTING OPERATION

1. Cut the soil to be tested flat and smooth and gently push the part "A" straight into the soil until the part "B" comes in completed contact with the soil profile.

2. Then, gently pull the device out of the soil.

3. As the spring shrinks, the "C" part reacts smoothly and safely to indicate the scale on the cylinder. The scale on the left of indicator shows the hardness index of soil. The scale on the right shows the bearing capacity. One scale (kg/cm^2) shows the resistance value of 1 cm^2 bearing plane. It shall be calculated in the following manner:

   P = Bearing Capacity

   X = Shrinkage of Spring or Hardness Index

$$P = \frac{100\,X}{0.7952\,(40 - X)^2}$$

PRECAUTIONS FOR HANDLING

Most of the errors of the testing are caused by the irregular friction of the piston or of the indicator. Therefore, it has to be kept clean at all time. As the SHT is being pushed into the soil, the scale face shall be turned downward or sideward so that it would not be soiled by dirt. Each time the test is finished push the indicator gently back to zero mark and clean the dirt and others on the cylinder before getting down to the next test. In the event the dirt gets inside, it has to be taken apart for cleaning which is done as follows:

1. Screw off the part "B".
2. Screw off the screw nail at the end of the indicator slider to remove the cone.
3. Screw off the knob and the knob rest which serves as the indicator can be removed. As the indicator is removed, the body of part "C" falls inside the cylinder. Special care must be taken to unscrew the indicator knob as there is a very small spring under it.

And wipe them all with soft cloth. It is advisable not to use any oil or grease. It is is used, wipe it all off. The knob screw must be tightened at all times in use.

CHART I

SPRING SHRINKAGE VERSUS BEARING CAPACITY

Kg/cm²	mm		kg/cm²	mm
0	0		7.0	20.75
0.1	1.25		8.0	21.75
0.2	2.25		9.0	22.50
0.3	3.25		10.0	23.25
0.4	4.25		20.0	27.0
0.5	4.95		30.0	29.0
0.6	5.75		40.0	30.25
0.7	6.25		50.0	31.25
0.8	6.95		60.0	31.75
0.9	7.50		70.0	32.25
1.0	8.01		80.0	32.75
2.0	12.25		90.0	33.25
3.0	15.0		100.0	33.50
4.0	17.0		200.0	35.25
5.0	18.5		500.0	37.10
6.0	19.75		∞	40.00

8. DESIGNED WATER MANAGEMENT IN D/F

8-1 DESIGNED

WATER MANAGEMENT IN D/F

DESIGNED Water Management in D/F

A. Design

I. Scale of Designed Facilities.

1) Irrigation facilities.

Name of facility	Unit	capacity or scale	
Pond		$50.000m^3$	
Irrigation pump	2	$0.32m^3$/min/unit	bore 65m/mØ, Total head 4.0m
Underground water pump	1	$0.24m^3$/min/unit	bore 65m/mØ, Total head 10.0 m
Irrigation ditch		$0.0106\ m^3$/sec	cross section 0.5^m x 0.3^m concrete-lining S=1/20,000
Check plank			

2) Drainage facilities

Name of facilities	Unit	scale or capacity	
Bi-purpose pump	2	$6.29m^3$/min/unit	bore 250m/mØ, Total head 4.4 wl
Drainage canal		$0.412m^3$/sec	Trapizoid-type earth canal S=1/5000

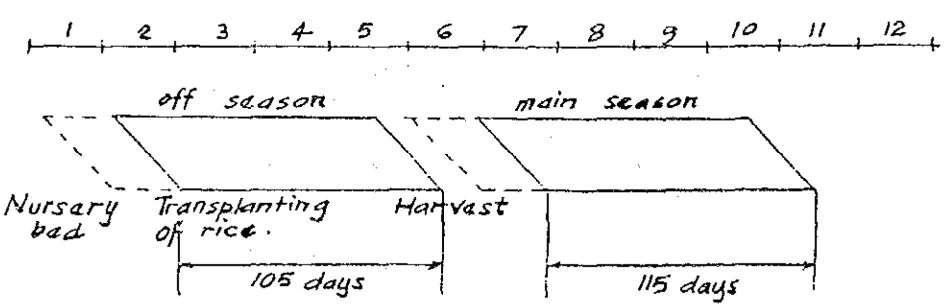
II. Decision of scale or capacity of each facility

Farm Total Area A = 4.6 ha

Catchment Area C = 11 ha

1) Water source ----- Pond and underground water

2) Cropping plan



3) Water distribution plan

Water is distributed to the fields with water flowing down naturally or pumped up water through the irrigation ditch made of concrete lining canal.

Distributing loss of 10% is considered when making the plan of water balance.

4) Design irrigation requirement

i) Irrigation requirement during presaturation period: Q

$$q = Eu + (Es + P) + H + S \quad \text{-------} \quad (1)$$

Where q : number of consumption in field at unit period in mm

Eu : Evaporation loss from unsaturated area in mm

Es : Evaporation loss from saturated area in mm

P : Percolation loss from saturated area in mm

H : Depth of water layer maintained in the field at the end of presaturation in mm

S : Water requirement in field in mm (Ref Irrigation in Malaysia III)

Supposing $Es + P = L$

$H + S = F$

$$Q = \frac{(Eu + L)}{2} \times T + F \quad \text{-----} \quad (2)$$

Where T = Presaturation period (days)

Q = Total irrigation requirement during presaturation: (m^3)

As this disign P, Es, Eu, H and S is considered as follows

P = 1 mm

Es = 5 mm

Eu = 4 mm

H = 75 mm

S = 75 mm

Therefore

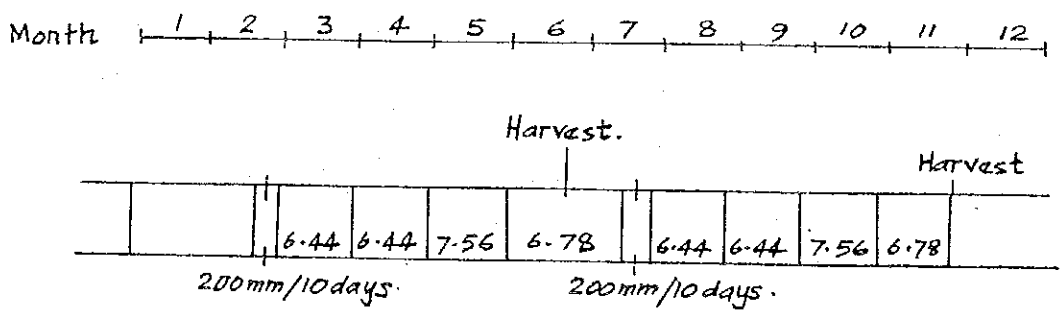
$$Q = \frac{(4 + 6)}{2} \times 10 + 150 = 200 \text{ (mm)}$$

ii) Normal irrigation period.

$$q = (Es+P) \times \frac{1}{1-loss} \qquad \text{--------} \qquad (2)$$

	Consumptive Use (mm/day)	Percolation (mm/day)	Total	Irri. Requirement (mm/day)
1st month	4.8	1.0	5.8	6.4
2nd month	4.8	1.0	5.8	6.4
3rd month	5.8	1.0	6.8	7.6
4th month	5.1	1.0	6.1	6.8

where q : figure of consumption in field at unit period in mm loss in considered as 10%



5) Design Basic Year

i) Return period ------ 10 year

ii) Design basic year------ 1971 to 1972

6) Calculation of water balance

i) Evaporation from the pond (E)

$E = 0.7\ Ep$

Where Ep : the figure of pan measured at Pasir Mas Pump Station per day in mm.

ii) Effective Rainfall (Re)

It is estimated that all rainfall exceeding 5 mm/day is utilized effectively,

iii) Calculation of Water Balance

See Table and Fig. 1

7) Design discharge for irrigation pump

$$Q = qp \times 10^{-3} \times A \times 10^{4} \times \frac{1}{24 \times 60}$$

Where Q : Rated discharge (intake)(m^3/min.)

qp : Irri. water requirement for presaturation 20 mm/day

A : Area of paddy field 4.6 ha.

$$Q = 20 \times 10^{-3} \times 4.6 \times 10^{4} \times \frac{1}{24 \times 60} = 0.639\ m^3/min.$$

8) Irrigation ditch

$$q = \bar{V} \times A$$

$$V = \frac{1}{n} \times R^{2/3}\ I^{\frac{1}{2}}$$ ---- manning's formula.

Where Q : Conveyance water volume

0.639^3/min. = 0.0107 m^3/sec.

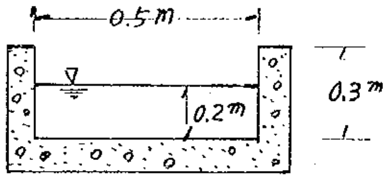
A : cross sectional area in flow

n : coefficient of roughness concrete flume --- 0.015

I : gradient of canal 1/20,000

R : A/P P : Perimeter

Design ditches cross section $0.5^m \times 0.3^m$ rectangular type supposing H = 0.2



H	A	P	R	$R^{2/3}$	$I^{\frac{1}{2}}$	$\frac{I}{n}$	$\bar{V}$	Q(m^3/s)
0.2	0.1	0.9	0.1/0.9	0.231	0.00707	66.67	0.109	0.0109 > 0.0107

9) Groundwater pump

1) Design quantity of water intaken

As groundwater is a supplementary water source, it is used only to supply irrigation water in the normal irrigation season. In case it is necessary to depend on groundwater for irrigation water required for puddling, groundwater is pumped up and stored in the irrigation pond in advance, and the water is distributed thereafter. Therefore, the design discharge is to be the irrigation requirement of the normal irrigation season.

$$Q = q \times 10^{-3} \times A \times 10^{4} \times \frac{1}{24 \times 60}$$

Where Q : Design quantity of water intaken (m^3/min.)

q : Irrigation requirement --- 7.6 mm./day

2) Drainage Plan

1) Drainage method

The method of drainage in the area is to collect drainage water in the lowest portion in the area through earth canals to be constructed on the outer circumference of the farm lots in three directions, and to drain water to the outside of the area or into the irrigation pond. Drainage to the outside of the area will be done naturally as much as possible. Pumping drainage is carried than the inside.

For the calculation of the volume of pumping drainage, it is assumed that the flooding of the fields in the area is within three days, and the allowable flooding depth is not considered since the Training Centre conducts the experimental raising of crops also.

i) Natural drainage

Non-irrigation season

When the outside water level is lower than the inside water level, the natural drainage is possible. Flooding of the fields in non-irrigation season is not allowed. Therefore, the highest water level is set at R.L. 2.40.

ii) Pumping drainage

a) Irrigation season

In the irrigation season, rainwater inside of the embankment and drainage water of the fields are stored temporarily in the drainage ditches inside of the embankment, and then pumped up and conveyed to the pond.

b) Non-irrigation season

When the outside water level is higher than the inside water level exceeds the allowable stage of R.L. 2.40, pumping drainage is necessary.

2) Design Basic Year

i)	Return period	5-year
ii)	Design basic year	1976 to 1977

3) Basic Rainfall

i)	72-hour rainfall	535.0 mm
ii)	24-hour "	351.0 mm

4) Volume of pumping drainage

When planning the volume of pumping drainage, it is assumed that the amount of 72-hour basic rainfall is drained in three days. In other words, it is considered that flooding for a period of three days is unavoidable.

$$Q = \frac{1}{3 \times 24 \times 60 \times 60} \times t_3 \times 10^{-3} \times A \times 10^4$$

Where Q = Design drainage (m^3/sec)

t_3= 72-hour basic rainfall 535.5 (mm/3 days)

A = Drainage area 10.15 (ha)

$$Q = \frac{1}{259,200} \times 535 \times 10^{-3} \times 10.15 \times 10^4 = 0.2095\ (m^3/sec)$$

$$= 12.57\ (m^3/min)$$

5) Drainage capacity of drainage ditch

For the capacity of drainage canals, it is planned to drain 24-hour basic rainfall in one day because there are more cases in which the natural drainage is possible.

$$Q = \frac{1}{24 \times 60 \times 60} \times t_1 \times 10^{-3} \times A \times 10^4$$

Where Q = Design drainage capacity (m^3/sec)

t_1= 24-hour basic rainfall 351 (mm/day)

A = Drainage area 10.15 (ha)

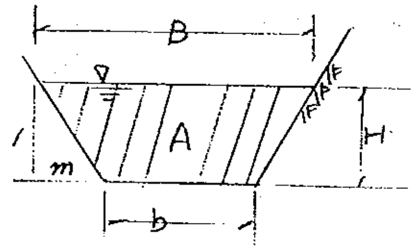
$$Q = \frac{1}{24 \times 60 \times 60} \times 351 \times 10^{-3} \times 10.15 \times 10^4 = 0.412(m^3/sec$$

6) Drainage ditch

As underground drainage is planned for a part of the field, it is planned to maintain a depth of about 1.5 m at the end of the drainage canal. And, as the capacity of the drainage pump is designed for draining 3-day rainfall in three days, the depth of flooding of the field can be reduced by increasing the quantity of water stored temporarily in the drainage ditches within the area. Upon consideration of these point, the cross section of the drainage ditch is planned as follows:

Bottom width	1.0 m
Side slope	1:1.5
Longitudinal gradient	1/5,000

Water depth for design drainage discharge $Q = 0.412\ m^3/sec$ is obtained as follows



B	P	R	A
$b + 2mH$	$b + 2\sqrt{Hm^2}H$	$\frac{(b+mH)H}{b+2\sqrt{1+Hm^2}H}$	$(b + mH)H$

$V = \frac{1}{n} \cdot R^{2/3} I^{\frac{1}{2}}$

$Q = A.V$

Substituting b = 1.0 m = 1.5 n = 0.035 I = 1/5000
Supposing H = 0.80

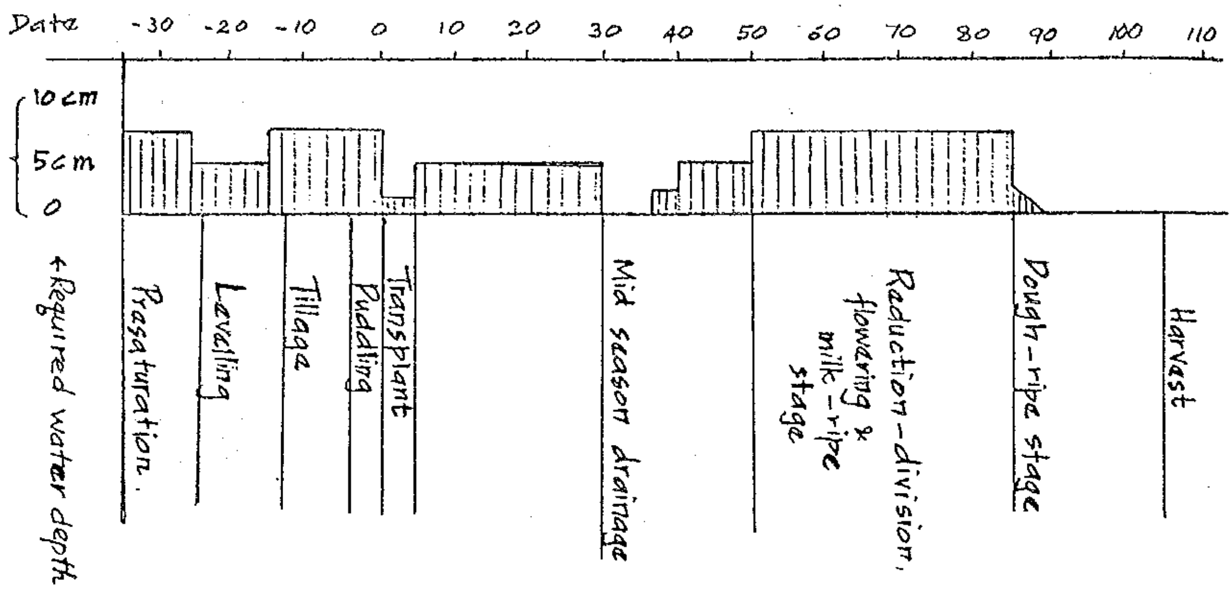
H	$\frac{1}{n}$	A	R	$R^{2/3}$	$I^{\frac{1}{2}}$	V	Q
0.80	28.571	1.76	0.453	0.590	0.0141	0.237	0.418>0.412

Therefore H = 0.8 m is O.K

B. Practice

I. Irrigation

1) Cropping schedule and water management at field.



2) an increased quantity of water consumption due to water management

Making variation of water layer in field come to an additional water consumption in irrigation.

From above mentioned data of cropping schedule, we can calculate an amount of additional water consumption and a ratio of it to design water requirement, approximately as follows.

i) Designed water requirement

Presaturation period	20 mm/day x 10 days = 200 mm
Normal period	61 mm/day x 100 days= 610 mm
	Total = 810 mm..(A)

ii) Additional water consumption

Date	increased water-depth
-15 to 0	25 mm
5 to 30	20
35 to 40	25
40 to 50	25
50 to 85	25
Total =	120 mm .... (B)

Therefore the ratio B/C = 0.15

II. Drainage

1. Bi-purpose pump

1) There are two purposes about this bi-purpose pump, one is for the purpose of drainage and other is for water storage to pond.

i) Drainage

To discharge flood water from field to outside area

ii) Water storage

To supply excessive water in field to pond

To supply flood water at outside area to pond.

2) Operation system

The operation of bi-purpose pump will be made as following flow chart (see Fig. 2). In this flow chart, R1, R2, R3, R4 and G1, G2, G3, G4, G5 and V1, V2 are mentioned as flow and shown in Fig-3, Fig-4.

R1 ... water level at upstreams edge of drainage canal.

R2 ... water level at downstreams edge of drainage canal.

R3 ... water level at drainage in outside.

R4 ... water level at pond

G1, G2, G3, G4, G5 ... Gate

V1, V2 ... control valve.

Fig. 2

FLOW CHART

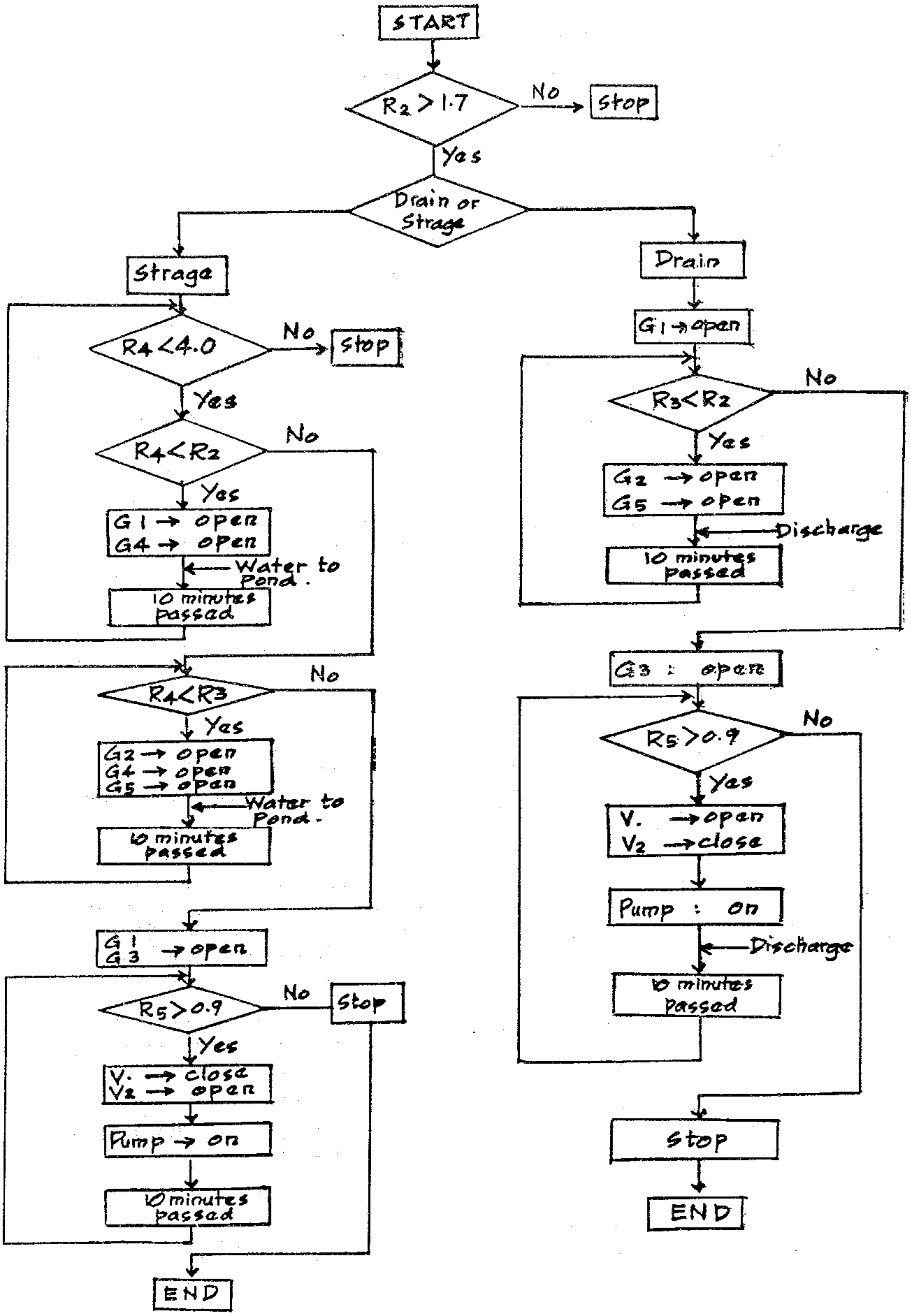
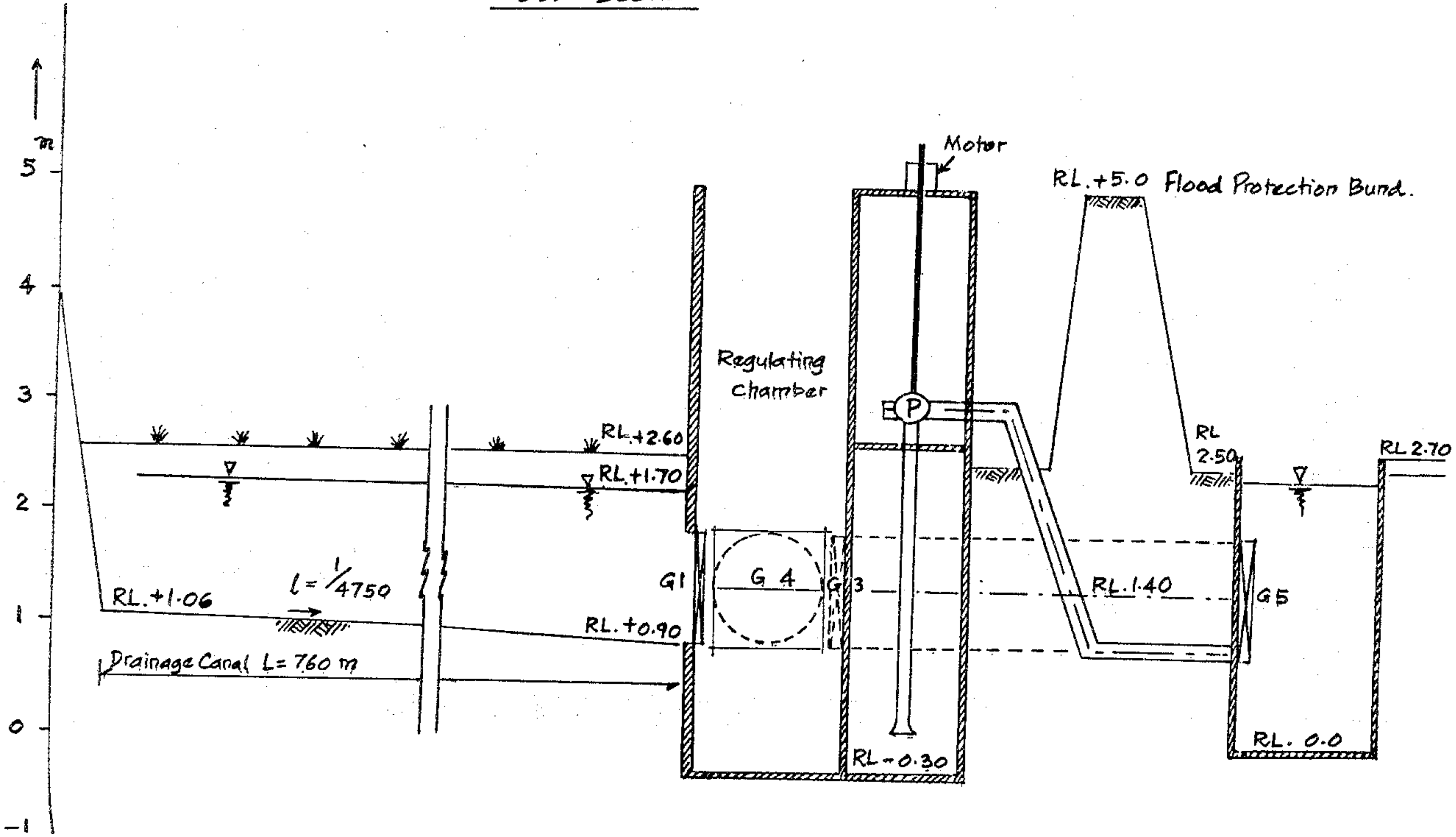


Fig. 3 : Bi-purpose Pump Station.

Cross - section



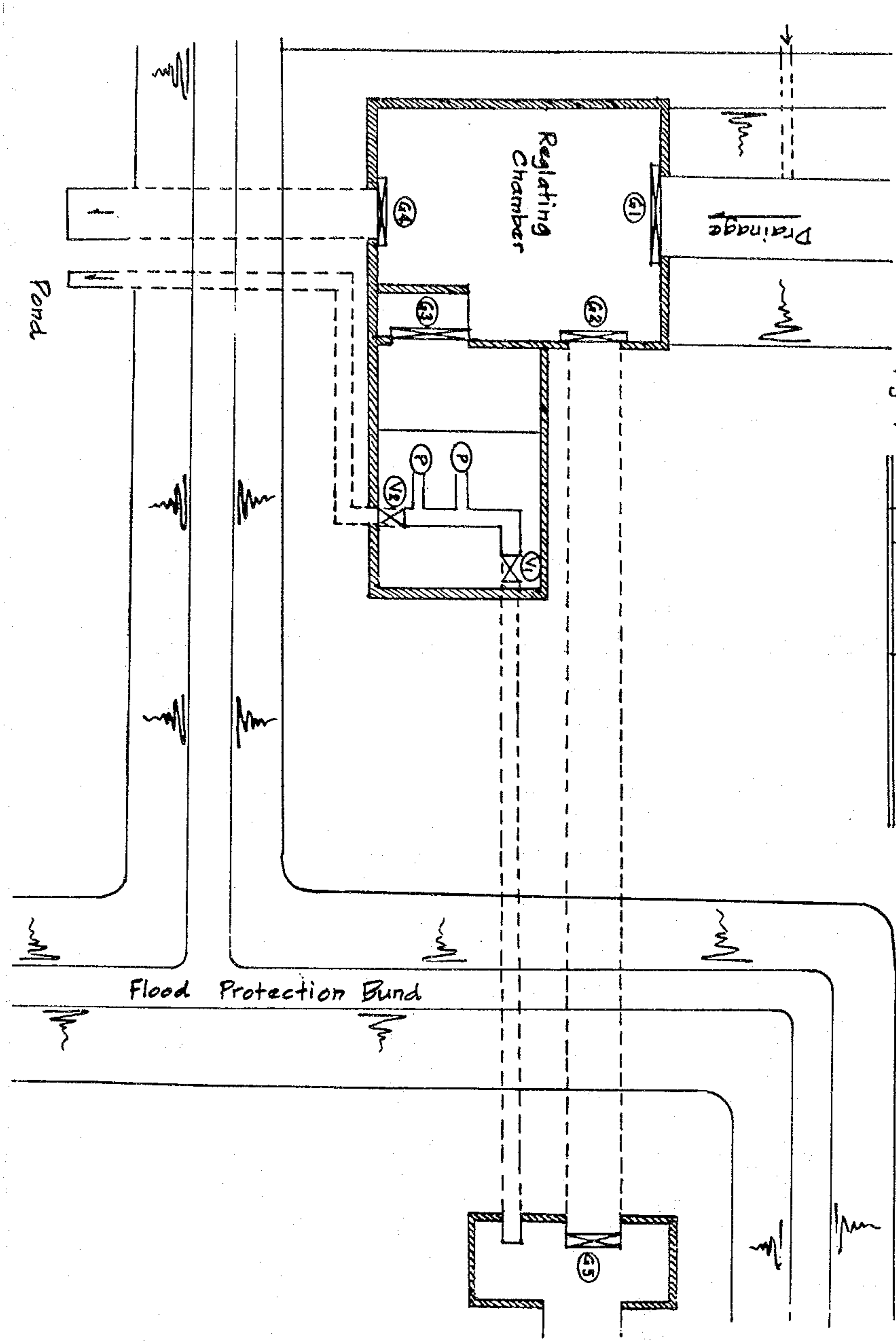


Fig. 4 Bi-purpose Pump Station Plan.

8 - 2. IRRIGATION AND DRAINAGE IN DEMONSTRATION FARM

(1) Irrigation and Drainage facilities.

1) Around the training center.

1. Total area:-

about 11 ha

2. Flood protection bund:-

a.	length	;	1,060 m
b.	top level	;	RL 5.00 m
c.	H.W.L	;	RL 4.73 m
d.	top width	;	2.0 m
e.	side slope	;	1 : 1.5
f.	banking height	;	1.95 - 2.59 m
g.	embankment volume	;	13,600 m^3

2) Demonstration Farm

1. Farm area:-

a. total area ; 4.6 ha

b. existing condition

- sub-irrigation
- underground drainage
- soil dressing
- measurement facilities (rectangle/triangle weir)

2. Irrigation facilities:-

a. irrigation pond

.	effective storage	;	50,000 m^3
.	dead storage	;	2,500 m^3
.	H.W.L	;	RL 4.30 m
.	L.W.L	;	RL 1.10 m
.	top level	;	RL 5.00 m
.	berm level	;	RL 2.50 m
.	bottom level	;	RL 0.90 m

- top width ; 2.0 m
- berm width ; 2.0 m
- side slope;
  outside ; 1:1.5
  inside ; 1:2.0
- pond area ; 1.82 ha
- catchment area ; 1.90 ha
- embankment volume; 8,800 m^3
- excavation volume; 23,600 m^3

b. bi-purpose pump (irrigation/drainage)

- type of pump ; vertical shaft mixed flow pump
- rated discharge ; 6.29 m^3/min/unit
- number of unit ; 2 units
- total head ; 4.4 m
- diameter ; 250 m/m
- rated output ; 5.5 kw, 8 p, 50 HZ, 750 rpm

c. irrigation pump (top water from pond)

- type of pump ; single section volume pump
- rated discharge ; 0.32 m^3/min/unit
- number of unit ; 2 units
- total head ; 4.0 m
- diameter ; 65 m/m
- rated output ; 0.75 kw, 4 p, 50 HZ, 1,500 rpm

d. ground water pump (supplementary irrigation supply)

- type of pump ; bore hole pump
- rated discharge ; 0.241 m^3/min/unit
- number of unit ; 1 unit
- total head ; 10.50 m
- diameter ; 65 m
- rated output ; 1.5 kw, 2 p, 50 HZ, 3,000 rpm

e. irrigaiton canal

- length ; 360 m
- max. discharge ; 0.0106 m^3/sec
- type of canal ; in-site concreting canal
  water depth 20 cm
- gradient ; 1/20,000

f. field drain

- bottom width ; 1.0 m
- side slope ; 1 : 1.5
- gradient ; 1/5,000
- designed depth ; 0.80 m

(2) Irrigation plan.

1) Irrigation water source

1st. plan – Pengkalan Datu River
- not suitable due to high salinity content.

final plan – through various kind of study
- make a pond for mainly use
- ground water for supplementary supply

2) Cropping Plan

Off-season 105 days (from Feb. to middle of May)

Main-season 115 days (from end of Jun to middle of Oct.)

10 days : for presaturation before puddling and for puddling

200 m/m : for water requirement

3) Irrigation method

1. Water storage method:-

a. natural inflow

flood level > pond level

ordinary year can store up to RL 3.00 m

b. pumping storage

mainly used in the rainy season, in order to keep the water up to H.W.L (RL 4.30 m)

2. Irrigation method:-

a. natural irrigation

pond water level > paddy elevation

possible up to RL 2.8 m

b. pumping irrigation

pond water level < RL 2.8 m

c. ground water irrigation

when the pond water level shows remarkably low.

(3) Drainage plan

Flooding day - within 3 days
allowable flooding depth is not considered.

1) Natural drainage:-

outside water level < inside water level
limit is RL 2.4 m (paddy E.L)

2) Pumping drainage:-

a. irrigation season

save the water inside the drain and pumping up to the pond.

b. non-irrigation season

outside water level > inside level RL 2.4 m

3) Basic rainfall:-

probability	1/5
expected rainfall per day	351 m/m/day
data period	1970 - 1977

- max. 24 hour
- 48 hour
- 72 hour

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