Government of Central Kalimantan

Government of Indonesia

Government of the Netherlands

Master Plan for the Rehabilitation and Revitalisation of the Ex-Mega Rice Project Area in Central Kalimantan

REDESIGN OF HYDRAULIC INFRASTRUCTURE IN THE DEVELOPMENT ZONE OF THE EX-MEGA RICE PROJECT AREA IN CENTRAL KALIMANTAN

Technical Guideline No. 6

OCTOBER 2008

Euroconsult Mott MacDonald and Deltares | Delft Hydraulics
in association with
DHV, Wageningen UR, Witteveen+Bos, PT MLD and PT INDEC

Master Plan for the Rehabilitation and Rehabilitation of the Ex-Mega Rice Project Area in Central Kalimantan

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Redesign of Hydraulic Infrastructure In the Development Zone of the Ex-Mega Rice Project Area in Central Kalimantan

Arnoud Haag[1] with a contribution from Marnix van der Vat[2]

1) Euroconsult Mott MacDonald

2) Deltares | Delft Hydraulics

Government of Indonesia

Royal Netherlands Embassy, Jakarta

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PT. MLD
PT. Indec

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ABBREVIATIONS

CKPP	Central Kalimantan Peatlands Project
DEM	Digital elevation model
DGPS	Differential global positioning system
EMRP	Ex Mega Rice Project, also called the 1 million ha project or ex-PLG (Proyek Lahan Gambut, peatland development project)
IISP	Irrigation Improvement Sector Project
IMU	Integrated Management Unit
Inpres	Instruksi Presiden (Presidential Instruction)
ISDP	Integrated Swamp Development Project
MSL	Mean sea level
MWL	Mean water-level
O&M	Operation and maintenance
PLG	Proyek Lahan Gambut (see also EMRP)
PU	Departemen Pekerjaan Umum (Department of Public Works)
TAM	Tata air mikro (on-farm water management system)

SUMMARY

In many transmigration schemes constructed over the past decennia in the development zone of the ex-PLG area there are still serious problems with water management and related issues, like flooding, acidity, and inadequate drainage. In some cases the hydraulic infrastructure had not been completed by the time the PLG project was stopped, in other areas the design of the infrastructure was based on principles which are now considered outdated. Many areas are at present only partly cultivated.

Within the framework of the Inpres 2/2007 and the subsequent Master Plan prepared for the ex-PLG area a high priority is given to rehabilitation of these schemes. Besides agricultural and socio-economic measures, a prerequisite for development is a review and where necessary a re-design of the hydraulic infrastructure. This note intends to give guidelines for such a re-design. The note is partly based on earlier guidelines for swamp development developed by the Ministry of Public Works.

Re-design of the hydraulic infrastructure should be embedded in the overall development of the region. Though initially often designed as separate hydraulic units, over the years new canals and many interconnections have been added so that hydraulic interventions should now be viewed at a broader, regional level within natural hydrologic boundaries, or Integrated Management Units as defined by the Master Plan study. Besides identifying short-term improvement measures, the re-design should also include a long-term view on development of the hydraulic infrastructure in the region.

At field level, improvement of the infrastructure should go hand-in-hand with agricultural revitalization. Small variations in topography or other field conditions are important and determine whether flood protection, tertiary gates, quaternary drains, on-farm water management systems etc. would be beneficial or not. The need for such improvement measures can only be identified through a participatory assessment of the present infrastructure. Much can also be learned from positive experience by ‘advanced’ farmers in the area or in other schemes with similar conditions. However, one should be careful in blindly transferring experience from other areas, and a programme of trials and demonstrations is recommended before implementing certain measures at a large scale. Such trials could well be combined with farmer field schools to include other cultivation practices besides water management.

Chapter 2 and 3 of the report give an overview of available data and surveys required for the redesign. Many data on rainfall, topography and hydrology have been collected by the Hydrology cluster of the Master Plan study and are in principle accessible from the project’s database. Chapter 4 gives recommendations on system improvements for different parts of the area. In general the improvements aim at increasing drainability through a denser canal system and shorter drainage paths to the main rivers. In developed lands adjacent to peat conservation areas (Adaptive Management Zone) measures are recommended to separate high water-levels in the conservation zone from (limited) drainage in the developed areas.

Chapter 5 outlines the possibilities of computer modeling to support the design of the hydraulic infrastructure. In the last chapters the possible effects of climate change are briefly mentioned, and monitoring activities are recommended to be able to evaluate the effect of the measures implemented and to support identification of possible future improvements needs.

1 INTRODUCTION

Purpose of this note

In the 1980’s and 1990’s parts of the EMRP area have been developed for transmigration settlements (for location see Figure 1.1):

- The Pangkoh areas in the south of Block C and D on both banks of the Kahayan river
- The Terusan scheme in the south central part of Block D
- The Palingkau, Lamunti and Dadahup areas in the south of Block A

However, for various reasons the hydraulic infrastructure of the settlements was not always completed or up to standard, contributing to many soil and water related problems and as a consequence to poor agricultural production in most of the areas Some transmigrants left the site, while others were forced to make a living by working outside the area.

On the basis of Keppres 2/2007 and the subsequent Master Plan prepared for the area (Euroconsult et al, 2008), agricultural revitalization of the settled areas has now a high priority. Re-fill is considered for abandoned areas, while there are also plans for new schemes in so far undeveloped areas. To avoid the mistakes of the past, the hydraulic infrastructure in these areas need to be thoroughly reviewed and where necessary redesigned on the basis of accurate topographical and hydrological data. The purpose of the present note is to serve as a guideline for (re)design of the hydraulic infrastructure in these areas by government agencies and consultant companies.

The note is partly based on ”Technical Guidelines on Swamp Land Development Volume II – Surveys, Investigations and Designs” prepared on behalf of PU by the IISP and ISDP projects in the late 1990s (ISDP, 2000). The present note includes a recommendation on preparation of regional hydraulic improvement plans and gives preliminary suggestions how the infrastructure in the above areas could be improved. The report emphasizes the need for trying out designed infrastructure works before applying these at a large scale.

Present condition of the infrastructure and main focus of re-design

In recent years the Government has started several improvement works of the hydraulic infrastructure in the areas, including flood protection in the Dadahup area, construction of more quaternary drains in Lamunti and Dadahup, and in places installation or rehabilitation of water control gates. Maintenance of the systems, severely neglected after the financial crisis and the termination of the PLG project in the late 1990s, has been actively resumed. Nevertheless, major problems related to the hydraulic infrastructure in the areas persist:

- Flooding in some parts
- Insufficient drainage and water control at field level because of too widely spaced canals (especially in the northern schemes) and the absence of functioning gates and on-farm water management systems
- In many places long, dead-ended canals which prevent water circulation and removal of polluted, acid water

- As a result of the above deteriorating soil and water quality, high acidity and many fields abandoned with no maintenance the infrastructure in those areas

In the southern schemes, the original designs included ponds or *kolams* at the tail of the dead-ended main canals. Their function was to increase the tidal in- and outflow, and so improve water quality. Many such systems were also built in South Kalimantan province, but they did not perform as was hoped, many of the ponds silted up or were overgrown with vegetation, and they have rightly not been rehabilitated. The focus of re-design here should be on improvement of water circulation and drainability by connecting dead-ended canals, possibly adding more outlets to the main river, and gradually introduce gates for better water control. Special attention is needed for the schemes in the Adapted Management Zone on the Kahayan west bank where drainage of the adjacent peat dome should be prevented. The possibilities for tidal irrigation in the most southern Pangko schemes and in the Terusan area should be enhanced by large, open canals.

The originally designed separate supply and drainage canals in the Lamunti and Dadahup areas have not functioned as was hoped for, partly because of misunderstandings regarding the hydrology and topography of the peatland areas traversed by the canals, and partly because the system was never completed. No gravity irrigation of the lands here is possible without a far more elaborate hydraulic infrastructure. The focus of re-design here should be on flood protection and improvement of drainability and on-farm water management by double connecting canals, reducing the large tertiary and maybe secondary drain spacing, and introducing water control gates and on-farm systems (TAM) where needed and desired by the water users. However, options for improving water supply from the upstream rivers, in particular the Barito River, should not be neglected entirely. They can, however, only be studied seriously if much better topographic and hydrometric information becomes available.

A main constraint to all (re-)design work is the lack of a topographic network in the area linked to a common reference level and/or Mean Sea Level. Practically no hydrometric monitoring takes place in the area other than during short periods by individual studies. Seasonal river-level fluctuations and maximum flood levels are largely unknown.

Re-design in regional context

Design of a particular system should be viewed not only in relation to river levels near the main drain outlet, but should consider the hydrological boundaries surrounding the entire area, i.e. the entire hydrological landscape unit, or Integrated Management Unit. If more than one scheme is present within such a unit, upgrading of their hydraulic systems should be viewed in a combined, integrated way. Even if originally designed as separate systems, most schemes are in fact no independent hydraulic units anymore, with their canals extended and connected to other schemes, small rivers, or *andils* of local people. The following Integrated Management Units have been identified by the Master Plan study in the development zone (see Figure 1.1):

V Jenamas area, between Barito and Mengkatib rivers (no transmigration settlements)
VI Dadahup area, between Barito/Murung and Mengkatib rivers
VII Lamunti area, between Mengkatib and Kapuas rivers
VIII Palingkau area, between Murung and Kapuas rivers
IX Block D, between Kapuas and Kahayan rivers

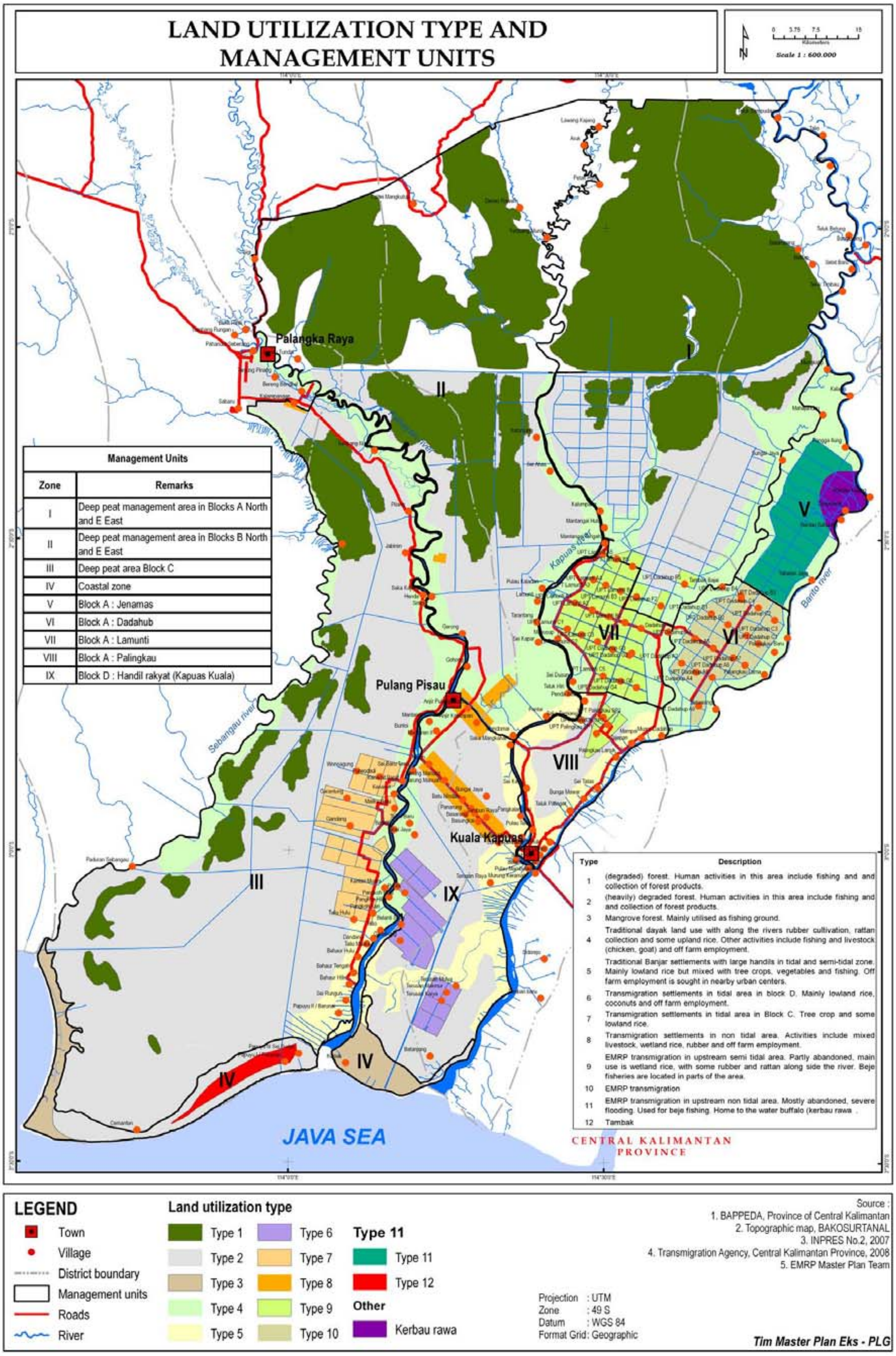
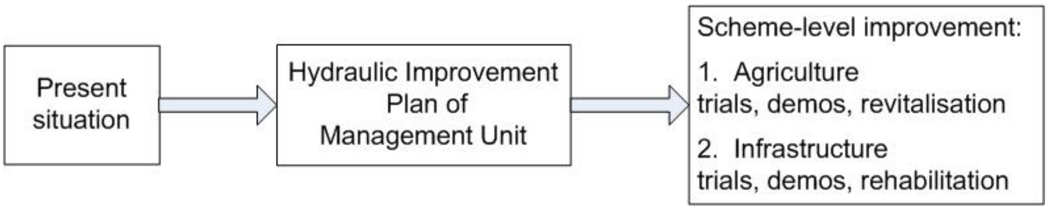


Figure 1.1- Integrated Management Units of the EMRP area

In addition, there are local and transmigration settlements along the fringes of Management Units I to III in the conservation zone, where adapted hydraulic management will be required.

By viewing the entire unit as a whole, more options become available for improving the system layout, for connecting canals to promote water circulation, for making use of more favourable boundary conditions further downstream along the river, etc. This calls for Regional Hydraulic Improvement Plans for each of the above management units. The plans should be based on accurate topographic and hydrometric surveys and hydraulic modeling of the unit-wide canal system. Various options for improvement of the system can then be analyzed. The plans should preferably be made by specialized consultants, separate from the more detailed (re-)designs of specific schemes.



Particular attention should be given to the local farmer-made canals or *andils* within the hydrological unit. Even though integrating these small canals in the overall hydraulic system is not always beneficial, or would not be desired by the people, improvement of the systems should be considered simultaneously with improvement of the transmigration areas, if only to avoid jealousy.

At several places private companies have started plantations and are developing their own hydraulic infrastructure. Strict supervision by the government is required to ensure that these systems do not infringe upon the government- or people built systems, and that they are in line with the overall hydraulic improvement plans of the area.

Redesign as part of agricultural revitalization

Improvement of the hydraulic infrastructure will only have a positive effect if it is part of a broader program of agricultural revitalization. Besides infrastructure improvement, equally important or maybe even more important are:

- land titling
- land consolidation and (re-)fill of abandoned areas (*lahan tidur*)
- agricultural extension and introduction of improved farming practices (mechanized land preparation, on-farm water management systems (*TAM*), improved varieties, synchronized planting, fertilizer etc.)
- credit and marketing facilities
- empowerment of farmers organizations
- a program of trials and demonstration (field schools) to test water management practices and to demonstrate best practices
- other essential services like water supply, access, education, health etc.

An integrated approach has proven to be successful elsewhere in the lowlands of Indonesia, but results obtained there cannot be directly applied to the areas at hand without further testing and adjusting to local conditions.

Redesign as part of a long-term process

Lowland areas are seemingly flat and homogenous. The fact is however, that small differences in topography or hydrology can have large consequences for soil development and the agricultural potential of the area. These variations can often not be mapped out even with detailed surveys. Moreover, over time field conditions are changing: after improved drainage peat soils subside, mineral soils ripen, farmers may shift to different crops, while lack of maintenance may lead to stagnant water conditions and acidification. The physical and biological processes taking place are often not well understood, but greatly influence the agricultural potential. In the long term, climate change will also effect the areas: a small raise in sea levels may increase flooding (which in the non-saline tidal zone may well be beneficial for wetland cultivation) and will reduce the drainability of large area.

In such a dynamic environment, development of the hydraulic infrastructure cannot be a once-and-for-all fix but should rather be a continuous process. See Figure 1.2. Conditions should be continuously monitored and regularly evaluated to see whether adjustments in infrastructure are needed. Trials should be carried out to assess the best water management practices in each area, because what works in one place may not necessarily work elsewhere. The effects of different water management options should be closely monitored, and best practices should be demonstrated to the farming community.

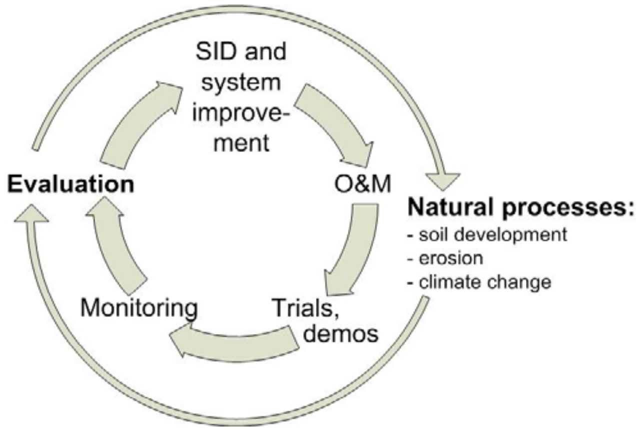


Figure 1.2 – System improvements: depending on local experience and environmental changes

Scope of work and TOR for re-design work

Besides the more or less standard technical aspects, the Terms of Reference (TOR) for the (re-) design studies should reflect all the above issues and should include requirements for:

- a review of successful experiences in the area and lessons to be learned from these regarding infrastructure development
- preparation of a Regional Hydraulic Improvement Plan at the level of the hydrological landscape unit
- a participative needs assessment involving relevant administrative agencies and representatives of local communities and farmers

- a distinction between short-term improvement possibilities and likely long-term requirements
- preparation of simplified drawings and plans for discussion with the water users
- local consultations during field surveys and before major steps in the design process
- formulation of a programme of trials, tests and demonstration and for monitoring these.

It should be recognized that design consultant companies do not always have the personnel trained in all the above activities, and part of these may better be carried out by the government agencies themselves or by a third party (other consultants, NGOs, universities). Proper planning of such activities is important to ensure smooth implementation and to avoid one party blaming the other for delays. Also, instead of relying too much on the consultant company, the government could already include certain layout options in the TOR for further investigation and design. Making sure that system improvements go hand-in-hand with other agricultural revitalization activities is clearly the task of the government agencies.

Steps in the redesign process

Figure 1.3 shows the steps in the re-design process, similar to the design of other rural infrastructure works but with the addition of three activities which need to be completed before the scope of the re-design work can be determined. The following chapters focus on the technical aspects of the re-design of the central Kalimantan schemes.

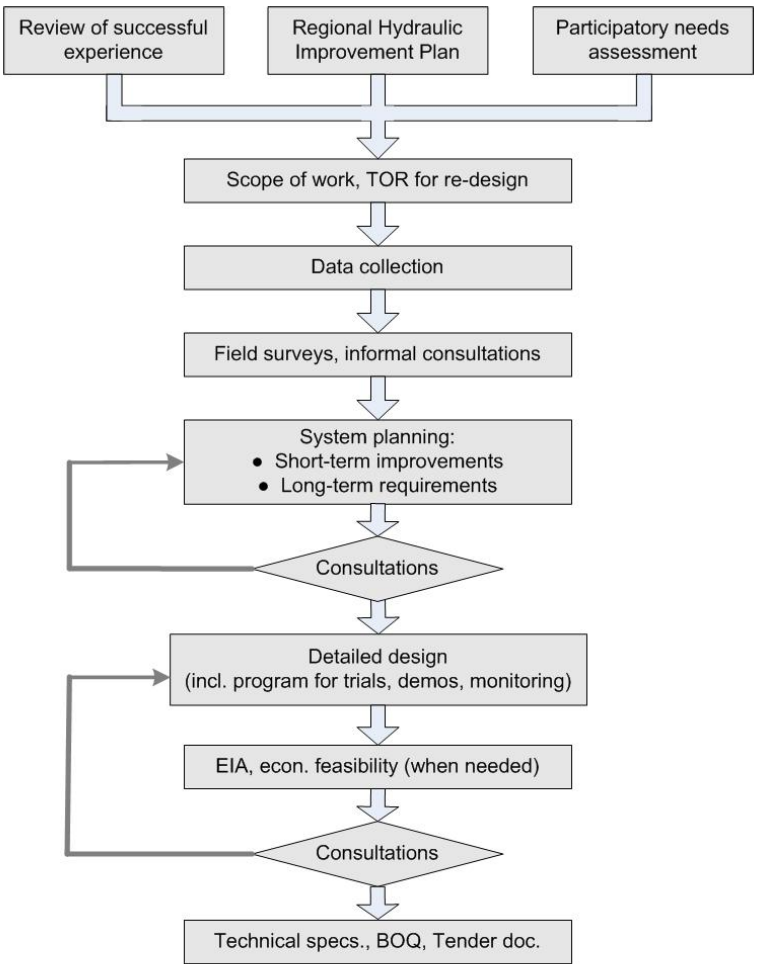


Figure 1.3 – The design process

2 AVAILABLE DATA

As part of the Master Plan study for the EMRP area a vast amount of climatologic, topographic and hydrological data have been collected and analyzed by Cluster 3 team members. This chapter is mainly based on these analyses. A more detailed account of the analyses is given in various technical reports prepared by the hydrologists of the team. The data are accessible through the project's on-line database.

2.1 Climate and rainfall data

Monthly data on temperature, humidity, wind velocity and sunshine duration are available from weather stations at major airports like Banjarmasin and Palangkaraya. Average values over a number of years can be used to calculate the potential evapotranspiration according to the modified Penman method (FAO, 1986). Together with rainfall figures these data can then be used for crop water balances to assess agro-climatic suitability and/or crop water requirements. However, the data should be used with care, as there are often gaps in the records and data quality has not been assured. For the hydrological modeling by the EMRP project an estimated average actual evapotranspiration of 3.7 mm/day, adjusted for groundwater depth, was considered sufficiently accurate. For agricultural assessment, however, a monthly or at least seasonal differentiation is required.

Annual and monthly rainfall records are available fro several stations, see Table 2.1. Annual rainfall decreases from over 2500 mm/year in the northern part of the EMRP area to less than 2000 mm/year in the coastal areas south of Kuala Kapuas. The data show important variations from place to place which, however, besides representing climatic variations may also be due to differences in data quality. There are often gaps in the record, and the data should be handled with care. Recent land use changes and forest/peat burning may have an impact on rainfall patterns, and present rainfall might be somewhat different from past records.

Station No.	Station Name	Period	J	F	M	A	M	J	J	A	S	O	N	D	Year
	Historical records														
298	Buntok	1880-1941	322	274	331	312	221	173	107	99	113	176	307	321	2756
306a	Marabahan	1917-1941	318	253	283	211	160	128	71	75	95	103	206	264	2167
306b	Kuala Kapuas	1917-1941	298	252	325	277	135	127	68	63	86	112	213	254	2210
312	Banjarmasin	1879-1941	323	298	302	217	158	143	90	82	100	129	216	311	2369
	Recent records														
	Buntok	1983-2006	323	232	284	242	235	168	113	80	126	175	304	320	2502
	Palangkaraya	1978-2006	327	278	308	322	239	180	110	97	131	181	342	332	2846
	Kuala Kapuas	1983-2002	283	193	211	204	170	111	90	63	66	156	187	273	2007
	Palingkau	1983-1999	240	163	131	227	96	83	81	69	101	173	230	263	1857
	Banjarmasin														
	EMRP area, 50-percentile driest years														
	Northern part	1982-2006	282	220	219	226	163	115	73	54	63	126	237	267	2045
	Southern part	1982-2006	250	192	195	160	136	81	53	36	41	111	167	242	1663

Table 2.1 – Average monthly rainfall

Through an analysis of available records the Master Plan study assessed representative monthly rainfall for the northern and southern part of the EMRP area, as shown in Table 2.1. The minimum monthly rainfall in a 1-in-2 dry year (50 percentile), a 1-in-4 dry year (25 percentile) and a 1-in-10 dry year (10 percentile) have been determined from an analysis of data from stations with long-term (> 20 years) records, see Figure 2.1.

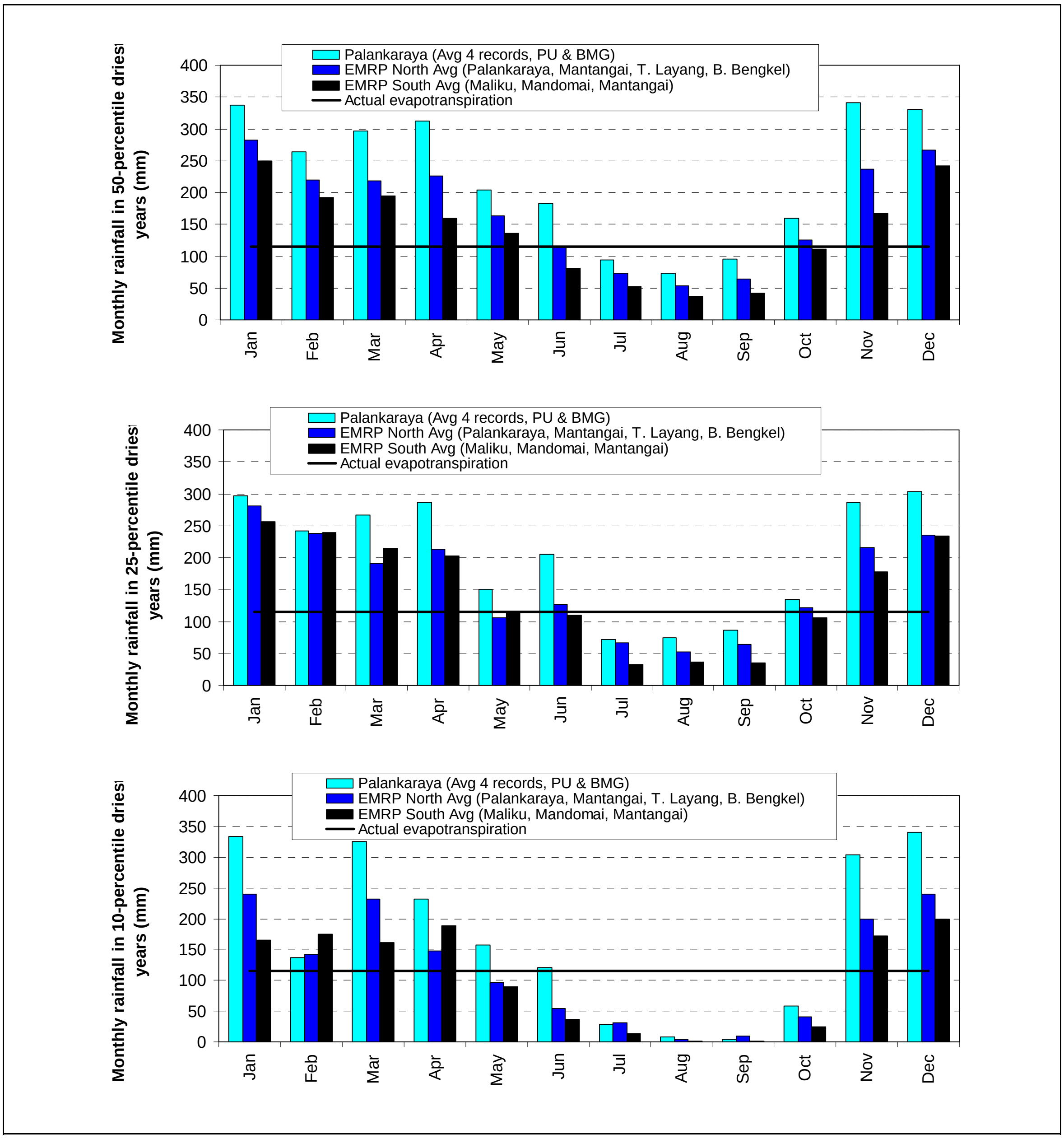


Figure 2.1 – Percentile driest monthly rainfall (1984-2006)

Note: The percentiles were approached by first ranking annual rainfall, then calculating monthly averages for percentile groups. Ranking by seasonal rainfall might give somewhat different results.

Source: Master Plan study, Hydrology report.

The agro-climatic classification of Oldeman et al. (1980), based on average monthly rainfall, classifies almost the entire area as C2, i.e. with 2 to 3 consecutive dry months (<100 mm/month) per year and 5 to 6 wet months (>200 mm/month) which makes the area suitable for rainfed rice cultivation.

Daily rainfall is recorded at a number of stations in and upstream of the EMRP area by PU and BMG, but only a few of the records can be used for analysis as most have too many data gaps and show poor data quality when cross validated. Moreover, distribution of stations over the area is uneven, with only very few stations near the coast and in the mountains. A review of the available records and their quality is given in Table 2.2. The records are available in the Master Plan database. It appears that complete and reliable long-term records are only available from four stations in Palankaraya or further north, and none in the EMRP area itself.

For an analysis of peak rainfall within the EMRP area records of stations further east, in South Kalimantan province (Banjarmasin, Marabahan), should be analyzed as well. Although rainfall there may be somewhat influenced by hills further east, the records are considered more representative for the lower part of the EMRP area than the data of Palangkaraya and stations up north.

				Coverage data (%)				
Location	*Source*	*From*	*Until*	*Jan 76-Dec 80*	*Jan 81-Dec 90*	*Jan 91-Dec 00*	*Jan 00-Apr 08*	*Quality (last decade)*
Maliku	PU	1-Jul-84	30-Apr-08	n.a.	51	93	65	May be useful
Mandomai	PU	1-Jan-84	30-Apr-08	n.a.	59	90	100	May be useful, P too low over 2000-2003
Mantangai	PU	1-Nov-82	30-Apr-03	n.a.	73	94	32	May be useful
Tamiang Layang	BMG	1-Feb-96	5-Jul-07	n.a.	n.a.	39	89	Can not be used, P too low
Bereng Bengkel	PU	1-Apr-80	10-Sep-07	15	93	88	51	May be useful
Palangkaraya	PU	1-Jan-76	30-Apr-08	100	94	100	100	Can be used
Palangkaraya	BMG	1-Jan-78	20-May-08	60	100	100	100	Can be used
Kuala Kurun	PU	1-Jan-81	30-Apr-08	n.a.	98	100	100	Can be used
Timpah	PU	1-Nov-83	24-Apr-08	n.a.	67	95	98	Can be used
Buntok	BMG	1-Jan-02	30-Sep-07	n.a.	n.a.	61	81	May be useful
Buntok	PU	1-Jan-77	31-Mar-08	75	99	93	100	Can not be used, P too high
Tampa	BMG	1-Jan-81	31-Aug-99	n.a.	64	77	n.a.	Can not be used, no data
Takaras	PU	1-Nov-83	30-Apr-08	n.a.	72	94	100	May be useful

Table 2.2 – Daily rainfall records
Note: 'May be useful' means that records are incomplete and short. 'Cannot be used' means that quality of the data is insufficient.
Source: Master Plan study, Hydrology report.

2.2 Tides

The sea tides along the coast of Central Kalimantan are mainly diurnal, which means one high and low water each day. Especially around neap tide a second high and low water may develop. The tidal range varies from 1.20 m at neaptide to 2.50 m at springtide.

Tidal predictions for the mouth of the Barito River are available from tide tables published annually by the Indonesian Navy. The predictions can also be calculated from tidal constants with software like Rampas, T_Tide, or others. The Master Plan study has determined new tidal constants for the mouth of the Barito, Kapuas, Kahayan and Sebangau rivers based on an analysis of hourly water-level registrations at those locations during varying periods in 1981. The results for the most important tidal constituents are given in Table 2.3.

Besides the 14-day spring/neap tide cycle, there are two long-term fluctuations in tides which have an impact especially on tidal irrigation possibilities (see Figure 2.2):

(1) An annual fluctuation in the height of daily high and low waters. Predictions for the Barito river mouth show that in December and June tidal high waters are some 20 to 40 cm higher, and low water-levels some 20 to 40 cm lower, than in March and September/October. Very high spring-tide levels in December are known from other places in Indonesia as well.

(2) An 18.5 year cycle in tidal fluctuations. This cycle influences especially the springtide levels, and reached a peak in about 2007 with average spring high waters in the mouth of the Barito River some 22 cm higher than during 1997.

Both fluctuations are illustrated in the figure below.

Location	Tidal constituent							
	M2	N2	S2	K2	K1	P1	O1	M4
Barito River mouth	0.322	0.075	0.024	0	0.645	0.183	0.306	0.036
114.48223 -3.47602	185.6	161.0	113.3	0	344.2	342.0	306.9	292.4
Kapuas River mouth	0.372	0.101	0.056	0	0.695	0.198	0.324	0.024
	159.8	120.3	87.3	0	343.6	341.4	282.1	243.9
Kahayan River mouth	0.374	0.080	0.047	0.041	0.704	0.200	0.315	0.033
114.07264 -3.32251	171.0	135.5	84.6	114.2	345.2	347.4	285.2	268.6
Sebangau River mouth	0.471	0.112	0.109	0.056	0.697	0.206	0.317	0.027
113.60696 -3.14267	175.9	135.9	92.9	86.3	341.5	338.1	275.6	264.2

Table 2.3 – Tidal constants determined by EMRP project
Source: Master Plan Hydrology cluster

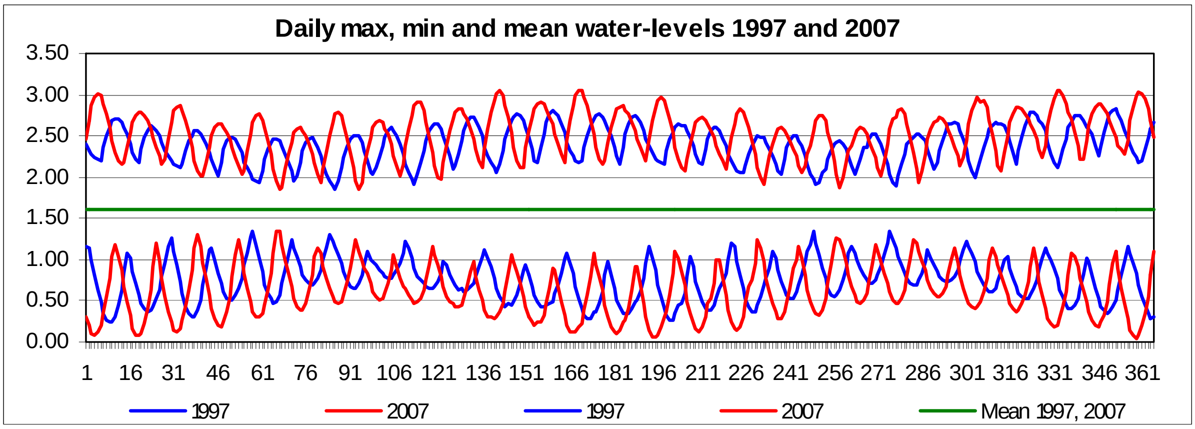


Figure 2.2 – Tide predictions at mouth of Barito River for 1997 and 2007
as calculated with the Rampas computer program. The graphs show the 14-day neap-springtide cycle, annual fluctuations, as well as the 18 to 19 year cycle (2007 was at a peak, 1997 near a low in that cycle).

The tidal predictions do not account for seasonal fluctuations caused by meteorological or other influences. These influences cause variations in mean sea level, called Mean Sea Level Anomaly, of 15 to 20 cm, with high values around May and June and low values from December to March along the south coast of Kalimantan.

2.3 Topography

Topographic maps of the area at scale 1:250,000 and 1:50,000 are available from Bakosurtanal. Elevation data on these maps, however, are not detailed enough for design purposes.

In the framework of the CKPP and Master Plan studies a Digital Elevation Model or DEM has been prepared of the EMRP area. Elevations are expressed in meters above an estimated mean sea level, the precise relation to mean sea level is not known. While the model gives a good picture of the overall relief of the area, the accuracy is in the order of 1 m and the model therefore cannot be used for design purposes. However, it could serve as a first indication, and to some extent as a check on more detailed surveys: if the latter would greatly deviate from the DEM then survey errors should be suspected.

To relate the DEM to actual field levels, a network of benchmarks has been established in the area and their coordinates and elevations were determined by a DGPS survey carried out by staff from Bakosurtanal. However, several elevations proved to be inaccurate and more surveys are needed to correct these. Table 2.4 lists those benchmarks to which either topographic transects or long-term water-level registrations have been tied which could be useful to future studies in the area. In Lamunti and the adjacent Block A NW peat area the benchmarks have been related to each other by conventional leveling surveys.

BM code	Desa	Location	Coordinates		Elevation (1)	Transect and/or water-level data expressed in the same reference level as the BM (1)
			latitude	longitude		
Benchmarks related to transects						
- Block C South						
BM 16	Pangkoh III	Kahayan	-3.01621080	114.14463503	1.856	CIMTROP transect 2
- Dadahup east						
BM 25	Palangkau B	Barito	-2.66005533	114.78902064	5.850	Andik transect 2
- Dadahup west						
BM 47	Dadahup	Canal??	-2.57391126	114.66196253	6.035	Pepen transect 3
- Lamunti and Block A NW peat area						
BM 28-D	Manusup	Kapuas	-2.68669189	114.44088413	4.976	) Ican transect 1, Ican) transect 2, Ika transect) 1, Pepen transect 1and) 2, Pepen transect 4,) Andik transect 1,) Diver A6040
BM 29/BPN	Mantangai	Kapuas	-2.50291094	114.49775964	8.100	
BM 30	Katunjung	Kapuas	-2.34477972	114.40232466	8.426	
BM 33/WI			-2.23394895	114.60764671	8.427	
BM 43-D	Lamunti C2	Canal	-2.66777152	114.49032167	8.368	
Benchmarks related to Divers (water-level recorders)						
BM 5-D	Bantanan??	Sebangau	-2.93199614	113.87490341	3.642	Diver
BM 20-D	Pangko	Jl. Maliku	-2.95286328	114.03986665	7.056	Diver
BM 22-D	Kuala Kapuas	Murung	-3.01755234	114.40005201	3.953	Diver A6084
BM 28-D	Manusup	Kapuas	-2.68669189	114.44088413	4.976	Diver
BM 33-D	Rangga Ilung	Barito	-2.32073294	114.87609298	8.824	Diver A6099
BM 40-D	Buntoi	Kahayan	-2.80798897	114.20201947	3.693	Diver A6168
BM 41-D	Pangkoh III	Canal	-3.00450374	114.09763083	1.711	Diver A6031
BM 42-D	Dadahup	Canal	-2.68188349	114.68404735	5.596	Diver A6248
BM 43-D	Lamunti	Canal	-2.66777152	114.49032167	8.368	Diver A6040

Table 2.4 – Benchmarks established by EMRP

(1) Reference levels are approximately equal to MSL, but are different for each of the four transect areas and for each of the diver locations.

Note: Benchmarks should be carefully checked on stability if used for future surveys. Other benchmarks have been established as well during EMRP study, but are not related to transects or water-level data.

Note: Most diver registrations started in August 2007.

In addition, the CKPP and Master Plan teams have surveyed elevations along a large number of transects in the area. The DEM produced by the Master Plan combines all these data with the DGPS survey results, selected SRTM data and laser-altimetry data for two west-east transects in the northern part of the EMRP area. The results, all in the EMRP data base, could be used for comparison with and as a check on future detailed topographic surveys in the areas concerned.

Cross sections of the major rivers traversing the area have been collected by the Master Plan study from various sources and additional river as well as canal cross sections have been measured. The results are included in the database.

Numerous topographic surveys and mapping exercises have been carried out in the past in parts of the EMRP area for specific project purposes. Reference levels used for these surveys were often tied to nearby short-term river level registrations, but none have been tied to long-term records or to mean sea level. The surveys were mostly also not tied to reference levels of previous surveys carried out in or near the area. Some of the mapping exercises were not based on field surveys but used elevation data derived from air photos or satellite images, a process known to be not very accurate in the flat lowland areas. While moreover the accuracy of many field surveys is doubtful, the results should be used only with great care.

2.4 Hydrology

River levels

Long-term hourly water level records are available for several places along the downstream reaches of the Barito (4 stations), Kapuas (2), Kahayan (3) and Sebangau River (2) for various periods in between 1979 and 1983. At the time the records were tied to nearby benchmarks, but except for the stations along the Barito the benchmarks were not related to each other, neither to mean sea level or to reference levels of topographic surveys. Although there are large gaps in the records, they give a good insight in neap-springtide fluctuations and seasonal variations in river levels in the tidal stretch.

Continuous water-level registration is carried out at two stations within the EMRP area, both on the Kahayan River:

- Kahayan at Palangkaraya, outside the tidal influence in the wet season, with observations now done one-time daily from 1980 to present;
- Kahayan at Mentaren, close to the weir in Mentaren village, within the tidal zone and with observations 3-times daily from 1999 to present.

Short-term water-level registrations have been carried out by numerous projects in the area, often combined with topographic surveys. Most the records cover periods of a few weeks at most, and reference levels are mostly unknown making the records of limited value. Water-level recording to support preparation of the Master Plan started in August 2007 by the CKPP project and is still ongoing at several places along the main rivers and canals. The data are published in the Master Plan project's database.

Where registrations were carried out simultaneously at several places along a river, information regarding damping of the tidal fluctuations can be deduced from them. If such simultaneous records are expressed in the same reference level as used for a topographic survey, the records can serve as a check on the accuracy of the survey results. For example, if the data expressed in the reference level would show that water-levels go down in upstream direction, then there clearly is something wrong with the measurements. See also Section 3.2.

Hydrological model
A hydrological computer simulation model of the main rivers and the larger canals in the area has been prepared by the Master Plan team using the Sobek software package. The model is available at Water Resources Research Center (Puslitbang Pengairan) in Bandung where staff has been trained to operate the model. The model simulates flows and water-levels along the main rivers from rainfall over the catchment area of the river, using the tidal sea-level fluctuations at the river mouth as the downstream boundary. Unfortunately, the relations between the simulated water-levels and land elevations are not accurately known, which limits the usefulness of the simulation results for design purposes. The model can help to assess boundary conditions for the simulation of flows through canal systems branching off from the river, see Table 2.5.

Water quality
Besides salinity intrusion into the downstream river reaches, the water quality of the main rivers is no impediment to agricultural development. The extent of salinity intrusion in a typical dry season is shown in Figure 3.2 (1‰ level, which is the limit for drinking water). In smaller streams originating from peat areas the water may be acid and brown or black coloured rendering it unsuitable for drinking purposes. Although not directly harmful to crops, such peat water is less suitable for flushing of canals to remove acidity from an area.

River	Location	River depth (m)	River width (m)	Tidal spring-tide range (m)		MWL during wettest month above MWL dry season (m)	Maximum flood level above MWL dry season (m)	Remarks
				Dry season	Wet season			
Barito	River mouth	7	2760	2.40	2.40	0.20	1.20	
	Murung junction	9	660	1.50	0.60	1.20	2.30	
	Mengkatib	15	300	1.50	0.15	4.20	4.70	km 188
Mengkatib	River mouth	10	132	1.80	1.40	0.80	1.70	
	Dadahup	11	70	1.80	1.30	1.00	1.80	app. km 35
	upstream			0.20	0.10	2.00	2.50	
Kapuas	River mouth	7	1800	2.40	2.30	0.20	1.30	
	Kuala Kapuas	12	860	2.20	2.20	0.30	1.50	
	Mantangai	12	250	2.20	2.00	0.80	2.00	
	SPI canal	12	250	2.20	1.10	1.70	2.50	
Kahayan	River mouth	7	2150	2.40	2.30	0.20	1.30	
	Maliku	22	400	2.20	2.30	0.20	1.40	
	Jabiren	13	250	2.40	2.30	0.40	1.90	
	Palangkaraya	11	340	0.70	0.10	3.20	4.70	

Table 2.5 – Estimated river level fluctuations at various locations
Note: Tidal range = the difference in elevation between daily tidal high water and low water.
MWL = mean water-level
Source: Data from Sobek simulation. Accuracy of water-levels 0.5 to 1.0 m, higher accuracy close to river mouths.

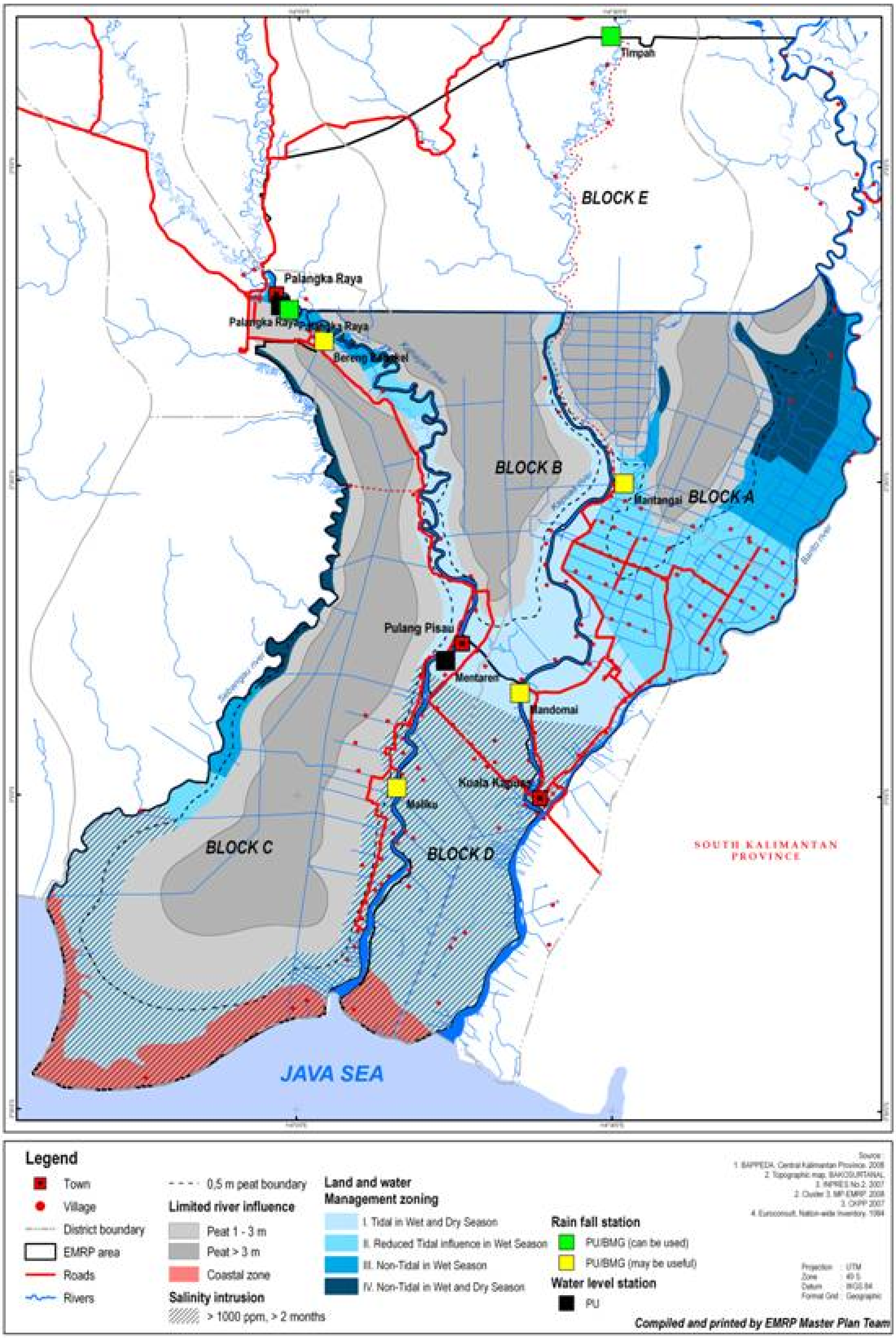


Figure 3.2 – Extent of tidal intrusion and salinity intrusion, and location of Government operated rainfall and water-level stations

2.5 Soil data

A soil map at scale 1:100,000 has been prepared of the entire area in 1998 by the Research Center for Soils and Agroclimate in Bogor (Puslittanak, 1998). Although outdated for the peat soils, for the development zone the map still provides valuable information. Soil surveys have also been carried out in the past by local consultants or universities as part of SID studies. These surveys cover a particular scheme or project area only and are of variable quality. The available information indicates that the soils are very similar to those in the lowlands of South Kalimantan province where more detailed studies have been carried out in the past.

Soils in the development zone are predominantly swamp clay soils, in places with a peaty top layer. Before reclamation, often a thicker peat layer was present but as a result of drainage and frequent burning most of the peat has disappeared. The mineral soils are generally well suited to cultivation of wetland rice, as well as other food- and tree crops depending on drainage conditions. Soils are not all ripened yet, even many years after reclamation, and exposure and oxidation of pyrite in the subsoil still causes high acidities in some areas. Through lateral groundwater flow or interflow the acids tend to accumulate in areas with a slightly lower position, where moreover possibilities for drainage are more limited. In some areas of South Kalimantan pH values of less than 3.0 have been measured, but such extreme acidity has not been reported from the EMRP area.

During the past few years much attention has been given to investigating the peat soils in the EMRP area. A fairly accurate peat depth map has been prepared by the CKPP/Master Plan studies, and is shown in the Master Plan study main report. It appeared that the peat soils are characterized by a relatively low hydraulic permeability in the order of 1 m/day, which is low compared to peat soils elsewhere in Indonesia. For more details and for other characteristics of the peat soils in the area reference is made to the Master Plan hydrology report and the project's database.

3 SURVEYS AND INVESTIGATIONS

Survey requirements for area development in lowlands differ from survey requirements in uplands mainly in the field of hydrology and soils. Of prime importance is to establish the relation between the topographic field levels and the daily and seasonal water-level fluctuations in the rivers bordering the area. The so-called hydro-topography determines the possibilities for drainage as well as for water supply to the area.

This chapter follows to a large extent the Technical Guidelines on Swamp Land Development, Volume II – Surveys, Investigations and Designs, revised edition ISDP, 2000. Table 3.1 lists the survey requirements for detailed (re-)design together with the most important use to be made of the survey data. More details on the specific requirements in the EMRP area are given in the following section of this chapter.

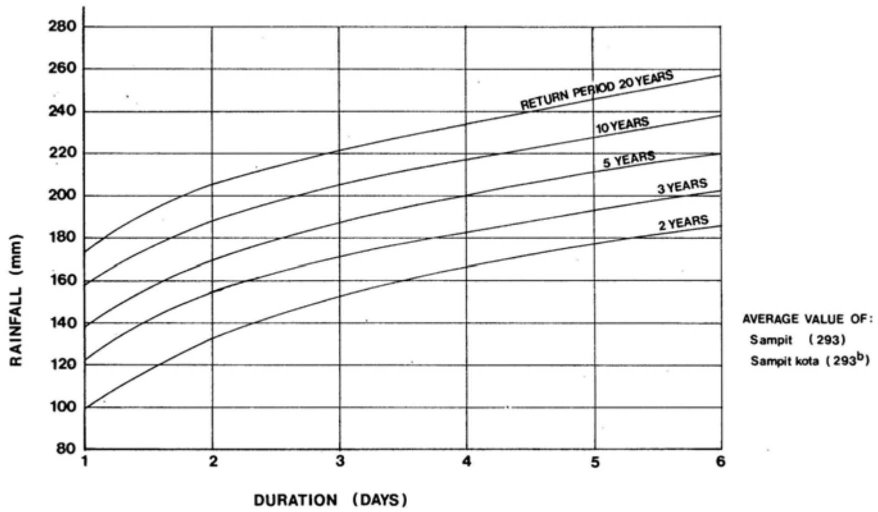
3.1 Climate and rainfall

Climate and rainfall data are available from the Meteorological and Geo-physical Service (Badan Meteorologi dan Geofisika). Many of the data regarding the EMRP area have been included in the Master Plan database, see Section 2.1. Climate data are useful for assessing the agricultural suitability and for calculating monthly evapotranspiration values

Monthly rainfall data should be used to assess optimal cropping seasons and to establish crop water balances and where relevant irrigation requirements.

Daily data should be used for a statistical analysis of peak rainfall to determine peak drainage requirements. Rainfall duration-intensity curves need to be established (see e.g. PU, 1986, van der Weert, 1995), an example is shown in Figure 3.1 based on rainfall data from Sampit. In the EMRP area only Palangkaraya and stations to the east (Banjarmasin) have a sufficiently long daily record for such an analysis. While peak rainfall calculated from the Palangkaraya data could represent the north of the EMRP area, the central and southern parts of the area could better be represented by Banjarmasin or a combination of Palangkaraya and Banjarmasin values. The methodology to translate the maximum rainfall into design drainage flows is described in the Technical Guidelines (ISDP, 2000).

Figures 3.1 – Rainfall intensity-duration curves



Survey item	To be processed into	Required for
Topography		
Existing maps, air photos, satellite images	Base map, 1 : 5,000	Presentation of survey results and designs
Construction of benchmarks Basic frame mapping	Benchmark coordinates and elevation	Corrections to base map, reference for survey lines and future surveys
Spot heights: 2 per hectare	Contour-line map, DEM (25 cm interval)	Drainage possibilities Flood protection requirements Tidal irrigation possibilities
Longitudinal and cross sections of existing and new canals and roads	Longitudinal and cross section drawings	Re-design of canal system
Cross sections of small rivers and creeks	Cross section drawings	Re-design of hydraulic system Design of bridges and/or closure dams
Situation surveys of existing and proposed new structures	Detailed situation maps	(Re-)design of structures
Climatology		
Long-term climatologic data	Reference evapotranspiration	Crop pattern and crop water balance
Long-term monthly rainfall data	Reliable monthly rainfall	Crop pattern and crop water balance Drainage requirements
Long-term daily rainfall data	Rainfall duration-intensity curves	Peak drainage requirements
Hydrology		
Long-term hourly water-levels in main rivers surrounding the entire hydrological unit	Maximum HW, wet season 25% HW, cropping season MW and LW, peak of wet season MW and LW, dry season Minimum LW, dry season Boundary conditions for hydraulic model	Flood protection Tidal irrigation possibilities, hydro-topography Drainage wet season crop Drainage dry season crop Navigability Hydraulic model of canal system
Short-term hourly water-levels, simultaneous at various places in rivers and canals	Damping of daily HW and LW	Tidal irrigation possibilities Drainage possibilities Check on topographic measurements Calibration of hydraulic model
Flooding: extent, depth, duration, frequency	Flood map	Design of flood protection
Flood marks along rivers and canals, local information	Depth of flooding	Design of flood protection
Salinity measurements, local information	5%0 and 1%o boundary wet season, dry season	Boundary for tidal irrigation Drinking water supply
Sediment samples	Grain size analysis	Building material
pH measurements in canals, local information	Acidity map	Re-design of hydraulic infrastructure Model calibration
Agricultural soil survey		
Soil augering to 1.20 m depth: .... per hectare	Soil classification and mapping: - Map of soil classes - Map of peat thickness - Map of pyrite depth - Map of present land use - Map of (ground)water depth - Map of soil ripeness classes	))) Soil potentials and constraints))))
Soil sampling for laboratory analysis	Soil classification and mapping Soil fertility, pyrite depth, ripeness	Soil potentials and constraints
Soil profile pits	Soil classification and mapping	Soil potentials and constraints

Table 3.1 – Survey requirements

Survey item	To be processed into	Required for
Soil mechanical surveys - for major structures		
Cone penetration tests Soil friction (vane) tests Triaxial tests	Spoil bearing capacity	Structure design (foundation)
Soil sampling at various depths for laboratory analysis	Soil bearing capacity Slope stability Soil compaction	Structure design (foundation) Canal design Expected land subsidence
- for minor structures		
Soil augering for visual observations	Soil classes	Design of seepage protection
Inventory of existing infrastructure (see also Topography)		
Collection of previous designs, maps, profiles, inventories	Inventory of existing infrastructure	Basis for re-design
Field inspection of all canals, structures, roads	Present condition of infrastructure, causes of poor performance	Basis for re-design
Interview with the water users on: - condition, problems of the hydr. infrastr. - past efforts to improve the situation - proposals, suggestions	Bottlenecks, options for system improvement	Re-design
Local consultations		
Village-level participatory needs assessment	Lists of prioritized needs	Re-design
Village-level meetings to explain plans, discuss design and implementation, receive suggestions and comments	Minutes of meetings, with desired options for system improvement	Re-design
Analysis of successful experiences in and around the area	Options for system improvement	Re-design

Table 3.1 – Survey requirements (continued)

3.2 Topography

Survey requirements and methods

Requirements and specifications for topographic surveys follow existing standards on density of observations and accuracy of the measurements, see e.g. ISDP 2000. At least two spot heights per ha are required for detailed designs. In addition to conventional field surveys use could be made of DGPS measurements which have a high accuracy if correctly implemented. Another accurate but costly new methodology is offered by airborne laser scanning (ALS) technology or Lidar. An accuracy of +/–15 cm could be achieved over large distances.

Benchmarks

A network of concrete benchmarks serves as control and reference points for the current as well as for future topographic surveys:

- Minimum density is one benchmark every 500 ha
- Existing benchmarks may be used if still in good and stable condition
- Location of benchmarks should be considered in relation to the basic frame mapping and in relation to future use to be made of the benchmarks, e.g. for staking out of canal alignments, location of structures etc.
- The benchmarks shall be installed in a safe location, away from river banks, and above highest flood level.
- Additional benchmark need to be installed near all water-level stations

- Benchmark construction will follow existing standards, though in peat areas foundation poles should extend down to the mineral soil to prevent lowering of the benchmark as the peat soil subsides.

Project Reference Level

Topographic surveys should preferably be linked to one of the benchmarks established by the CKPP and Master Plan surveys of which the approximate elevations relative to mean sea level are known (see Table 2.4). The benchmark should be carefully checked to make sure it is still in its original position. Using one and the same reference level for the entire area EMRP area has obvious advantages for comparison of survey results, for establishing links to water-level stations, for accurate hydraulic calculations etc.

If it would not be possible to link a particular survey to one of these existing benchmarks a local reference level may need to be established temporarily, based on a separate master benchmark. If well established, this benchmark, and hence the results of the survey, could then possibly at a later stage still be tied to the overall reference level.

The topographic survey should always include benchmarks established by previous surveys in the area, so that those survey results can also be linked to and compared with the new data. This applies in particular to benchmarks related to water-level stations with long-term records

Checks with water-level data

Because accurate elevations (< 20 cm) are essential for design and construction of hydraulic infrastructure, and because areas are very large hence long survey lines, and survey conditions difficult (dense vegetation, soft soils) it is essential to compare topo survey results (elevations) with water-levels recorded simultaneous during at least one full tidal cycle at various locations. If unlikely differences appear (e.g. water-levels in one location higher than those in a more upstream location), a re-survey is called for.
Along canals with (almost) zero flow velocity, the water-level in the canal will be practically horizontal and this can also serve as a check on nearby elevation surveys.

Measurement of river and canal cross sections

As stated in Section 2.3 data on river and canal cross sections have been collected in the EMRP database and no additional surveys are required.
Additional canal cross sections should be measured where these are not available at regular intervals of 1 km (depending on geometry of the canal network). All sections should be linked to the PRL. The data will support hydraulic calculation for redesign of the infrastructure and will be used for determining quantities of earth works if changes in the existing canal dimensions are required.

Basemap

The survey results will be used to prepare a base map of the area at scale 1:20,000 and 1:5,000. In addition, a map of the entire hydrological unit in which the area is located will be prepared at scale 1:20,000 to 1:40,000 using existing maps and/or satellite images

3.3 Hydrology

River levels

The river level fluctuations determine the boundary conditions for all aspects of water management in the areas. Their daily and annual fluctuations, as well as maximum flood levels, should preferably be assessed from long-term water-level observation. Unfortunately, such records are practically non-existing in the area and no permanent water-level recording stations are present. During surveys for re-design, river-levels should be recorded during a continuous period of at least 14 days (a full neap-springtide cycle) in both the wet season and the dry season near main drain outlets. The results should then be carefully compared with results from previous surveys, with tidal predictions, with modeling results, and with field observations and information from local people in the area to assess the longer term fluctuations.

During a period of at least 25 hours (one tidal cycle) but preferably longer, water-levels should be observed simultaneously at various locations along the main rivers and canals to assess the variations in tidal fluctuations.

The hydrological river model prepared by EMRP can evidently be of great help in determining the fluctuations. River flows and water-levels can be simulated and from the results the parameters as mentioned in Table 3.1 can be determined. However, model results should always be compared and combined and with local measurements to ensure their accuracy.

Canal water-levels

In areas with serious drainage or water circulation problems measuring the canal water-levels during one or more tidal cycles of 25 hours at various locations simultaneously might help to determine the cause of the problems. Such measurements are often also important for calibration of computer models of the hydraulic system, see Chapter 5.

Salinity

Saline river water (> 5‰) cannot be used for (tidal) irrigation, but otherwise salinity intrusion does not pose serious threats to agricultural development. Salinity exceeding 1‰ makes the water unsuitable for drinking purposes. The boundary of the salinity intrusion into the main rivers is fairly well known, certainly by the local people in the area. Additional measurements could be made, especially in canals or tributaries where less information is available, but otherwise no elaborate surveys are required.

Acidity

Improved drainage and inevitable lowering of groundwater levels in the dry season will cause oxidation of pyritic soil material. High amounts of acids and other elements toxic to crops are released which have to be leached out from the soil and, after entering the drains, have to be flushed out of the canal system to the river. Water circulation though the canal system and sufficient drainability are therefore essential and can be promoted by a proper design of the canal system layout including flow regulating structures.

In places where acidity-related problems have been identified by the needs assessment, pH measurements should be carried out along the canals at regular time intervals and local people should be interviewed to assess seasonal changes and variations in acidity over the past years. Automatic recorders (divers) could be installed to measure the pH combined together with water-level recording, and such registrations could be very useful to determine changes brought about by future infrastructure improvement works.

River floods
Within the fully tidal zone river flooding is rarely perceived as a major problem because the flooding last a few hours per day around spring-tide only, and flooding depth is a few dm at most. Even though, village areas may need to be protected by a low flood protection embankment.
Upstream of the tidal zone river floods are more serious, and may last for weeks or months. In the absence of long-term water-level records related to topographic elevations, flooding depths and durations should be surveyed by observation of flood marks along rivers and canals, and by interviewing people living near the canal or river bank. The height of the flood marks above the average ground level in the area should be assessed. At crucial places flood marks should be included in the topographic survey, or should be tied by separate measurements to the topographic reference level or MSL.
The hydrological model developed by the EMRP could also help to assess maximum flood levels, but cannot provide absolute values.

3.4 Soils and soil mechanics

Soil surveys in the developed areas are mainly for the purpose of agricultural assessments and are not further dealt with in this note.

Soil mechanical surveys are required for all major structures. The procedures are fairly standard, and reference is made to various textbooks or the PU Irrigation Design Standards (PU 1986). A summary of required investigations for lowland areas is given in the Guidelines (ISDP 2000).

For minor, tertiary structures usually no soil mechanical investigations are done. However, soil augerings to a depth of 4 m are strongly recommended to check whether high soil permeabilities can be expected (indicated e.g. by the presence of soft clay or sand layers) requiring adjustments of designs to prevent seepage around or below the structure.

3.5 Inventory of existing hydraulic infrastructure

A detailed inventory is required of all present infrastructure items and their condition. Existing maps, inventories and as-built and/or design drawings will be used as a start. Actual length and cross sections of major canals and embankments as well as situation mapping of main structures are already mentioned as part of the topographic survey. Using pre-prepared checklists and copies of the base map, the inventory will in particular aim to:

- Update the existing maps and inventories of canals with their embankments, culverts, bridges, and control structures, including any additions or alterations made by the government or by the water users themselves. Particular attention should be paid to accurately map interconnections between canals.
- Describe the current condition and functioning of all items and any repair needs (embankment slips, sedimentation, leakage around structures, malfunctioning of gates, state of maintenance, etc. etc.).

The inventories should preferably be made together with (representatives of) the water users, who best know the conditions in the area. It should well be part of the needs assessment required before re-design work can start (see Figure 1.3). The inventory offers good opportunities to discuss also other relevant water management issues with the users, such as extent and depth of flooding and/or tidal irrigation, acidity, over-drainage, lack of drainage, past attempts to improve the situation, O&M activities by the government and the users, etc. Relevant information should be noted down on the inventory forms and where possible drawn on maps of the area.

3.6 Local consultations

Prior to the start of the design process a participatory needs assessment should be carried out. The assessment should be guided by experienced social facilitators (e.g. from a NGO or university) but competent technical people and PU field staff should participate as well to make sure that the outcome is realistic and addresses the underlying causes of perceived problems. The assessment could well be used to improve the system inventory mentioned above. Results of past discussions or requests for assistance forwarded by the community, e.g. through the Musrenbang or PNPM process, should be carefully reviewed.

At the start of the re-design process the local communities should be informed about exact objectives, scope and timeframe of the design work, and should be given the opportunity to forward any suggestions and comments. During the field surveys informal contacts with the communities will contribute further useful information on local conditions and aspirations.

Further consultations at village level are recommended after the field surveys have been completed and initial ideas about the re-design have been laid down in a so-called draft system plan. A simplified summary of the survey findings and system plan should be given to the participants well before the meeting so that they have time to reflect on these. Participants in the discussions should include local government representatives, field staff, as well as technically competent agency staff to ensure that proposed solutions really address the underlying problems. After agreement on the system plan, the design work can proceed.

Final consultations will take place after draft detailed designs have been prepared, to explain the designs to the community and to receive their comments. Again, simplified design drawings and cost estimates should be given to the participants some time before the meetings to reflect upon. During the consultations also the implementation of the work could be discussed, including a possible local contribution to the work and/or participation of the community in the construction process.

The consultations take considerable time and will raise the total SID costs. However, these costs are always low compared to the costs of building infrastructure which will not serve its purpose.

3.7 Hydro-topography

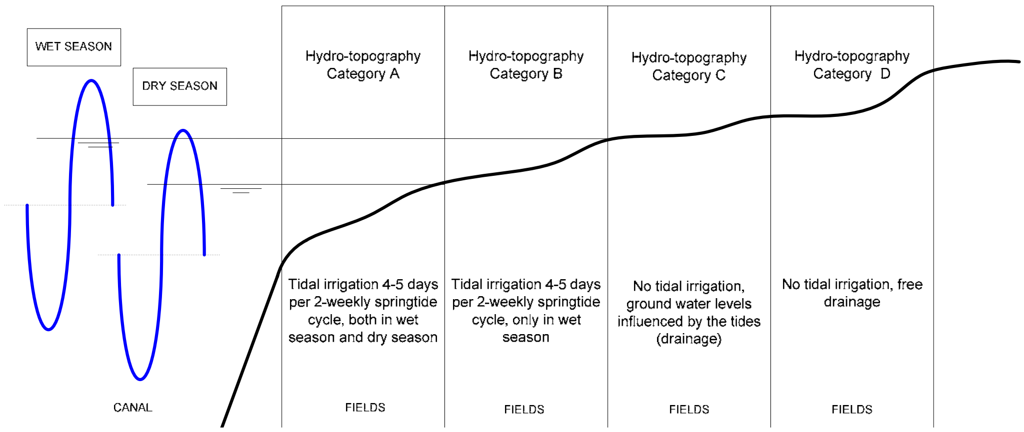
The relation between tidal high water-levels and the land elevation is of crucial importance for agricultural development. Where the high water rises above the land tidal irrigation of rice fields is possible (provided the water is not saline), while for dryland or tee crops flood protection would be required. This makes the low-lying tidal lands particularly suitable for wetland rice. Because tidal flooding last a couple of hours per day only, to be really effective the tidal flooding should occur regularly, i.e. at least during 4 to 5 days in a typical 14-day neap-springtide cycle. Four hydro-topographic land classes are distinguished, see Box 3.1. Within the canal system, as more lands get flooded, damping of the tidal wave takes place, and tidal high water-levels decrease away from the river. To reduce this decrease and to increase the extent of tidal irrigation, large canals are recommended in these areas.

Box 3.1 Typology of tidal lowlands
Source: Euroconsult et al, 2008b

The tidal lowlands of Indonesia are divided into four hydro-topographic classes. The classes are based on land elevations in relation to tidal water-levels in the nearest open water course (river or canal). The tidal water-levels are in turn determined by the sea tides and the damping of the tidal wave in the river and canal system.

The four hydro-topographical classes are:

- Class A. Tidal irrigated areas where the fields can be flooded at least four to five times at high tide during a 14- day spring tide cycle in both wet and dry cropping seasons, and where tidal supply provides sufficient leaching for proper soil and water quality
- Class B. Tidal irrigated areas where the fields can be flooded at high tide at least four to five times at high tide during a spring tide cycle only during the wet cropping season and where less water is available to maintain soil and water quality
- Class C. Areas just above tidal high water, where the fields cannot be flooded at high tide but where the tides still influence groundwater levels, and where leaching of the root zone from acids and toxicants depends entirely on rainfall and percolation through controlled drainage
- Class D. Higher areas where the fields are not subject to tidal influence.



3.8 Drainability

Drainability is defined as the depth to which the groundwater can be lowered by the drainage system under normal (i.e. non-peak) rainfall conditions. During peak rainfall a temporary rise of the groundwater above this level is allowed.

The drainability of a particular area is determined as follows (ISDP 2000, Euroconsult et al., 2008b):

(1) The drainage base is the typical tidal water-level at the main drain outlet in the river during the month with the highest river stages in the growing season of the crop.
(2) The rainfall to be drained is the 1-in-5 year highest monthly rainfall during that month; the rainfall is assumed to be evenly distributed over the whole month.

(3) Under these conditions, and using preferably hydraulic modeling, either the average groundwater depth in the field or the average water-level in the tertiary canal is calculated. In case of the latter, a head difference of 10 cm is added between ground water-level and canal water-level. The depth of the groundwater below field level is the drainability.

(4) An reasonable estimate of the drainability can be made with steady flow formula (Manning) and using as drainage base the average water-level at the drain outlet with a drainage time of 12 hours per day. Typical head losses within the canal system are:

- head loss in primary and secondary canal:	5 cm/km
- head loss in tertiary canal:	10 cm/km
- head loss at structures and transition from one type of canal to another:	5 – 10 cm

NB. The drainage time of 12 hours per day is adequate for areas close to the river but may need to be gradually reduced for areas further away from the river.

Criteria for minimum required drainability are as follows (ISDP 2000, DID 2001):

Rice	30 cm
Dryland crops	30 – 60 cm
Houselots	30 – 60 cm
Tree crops	60 cm

Calculation example

For an area at 3 km from the river, the total head losses based on the above assumptions are in the order of 3 x 5 = 15 cm in the main canals, 15 cm in the tertiary system and 10 cm between groundwater level and canal water-level, or in total 40 cm. For rice requiring a drainability of 30 cm, the difference in elevation between field level and drainage base should hence be 40 + 30 = 70 cm, and for tree crops 40 + 60 = 100 cm.

If the above criteria are not met, the design will have to be adjusted. Options to improve or counter balance poor drainability include:

- Reduce the head loss in the canal system between field and river by changes in layout and capacity of the canal system:
  - Increase canal dimensions;
  - Add new short-cut canals;
  - Move the drain outlet or add a new drain outlet further downstream along the river where tidal fluctuations are bigger.
- Change land use to traditional rice varieties; treecrops such as gelam (*Melaleuca cajuputi*), sago or others that can stand long periods with high (ground)water tables)
- Install water control structures with automatic flapgates to prevent drainage water re-entering the canals during high tide. Calculations and field experience show, however, that the effect of structures for this purpose is rather limited and can improve the drainability by a few dm at most.
- The ultimate solution might be pumping, as practiced in polders elsewhere in the world. However, because of the high rainfall in Indonesia pumping costs would be very high and economically not feasible for low-income rural settlements.
- And finally it might decide not to develop the area, if all above options prove to be not feasible.

4. SYSTEM PLANNING AND DETAILED DESIGN

4.1 Initial steps

As mentioned in Chapter 1, before re-design of an individual scheme or area can start it is recommended that the following steps are completed:

- ***Review of successful experiences***
  Most farmers are already living for a long time in the area and have tried to develop their land as good as possible. Besides failures, in almost every scheme there are also success stories which can provide valuable lessons for the re-design. The reasons for the success, and whether or not conditions on these farms and/or measures adopted by these farmers are replicable in other parts of the scheme, should be carefully assessed.

- ***Regional hydraulic improvement plan***
  Schemes are no isolated hydraulic units anymore, and to identify possible improvements the designer has to look beyond the narrow scheme boundaries. The entire area delineated by natural hydrologic boundaries (rivers, coasts) should be viewed as a whole for which a hydraulic plan, or at least a broad view regarding future improvements should be available. The re-design of individual schemes has to be embedded in such a broader plan.

- ***Participatory assessment of the hydraulic infrastructure***
  Small variations in topography or soil conditions can make big differences for crop growing and water management. Even with the most detailed surveys these variations cannot be mapped out accurately. This calls for a participatory assessment of field condition and of the present and required (or desired) infrastructure. However, the assessment should always be assisted by competent technical staff to avoid that proposals are forwarded which do not really address the underlying problems. For example, acidity is an important issue but proposals aimed at maintaining permanent high water-levels in the canal to avoid further acidification would be counterproductive.

4.2 Design criteria

To ensure consistency in the designs and the adherence to desired design standards, a number of design criteria have to be formulated before the start of the design work. Design criteria include parameter values and calculation procedures which apply equally to any part of the design. A summary is given in Table 4.1, based on criteria given in the Technical Guidelines. The criteria are a guideline only and may have to be adjusted to individual areas or to suit specific requirements. Some may not be applicable while other may have to be added.

As no design documents of the existing schemes in the EMRP area have yet been found, it is not known whether the original designs adhere to these criteria or not. If field conditions appear to be different one should be careful not too rigidly try to adopt the criteria.

Criterion	Location	Value	Unit	Remarks
Drainability	Rice fields Dryland crops Tree crops Oil palm Acacia crassicarpa Pineapple	30 30 - 60 60 60 - 75 70 - 80 75 - 90	cm cm cm cm cm cm	Figures the same as those adopted in Serawak. For calculation procedures see Section 3.7.
Storm drainage	Rice areas Food crops, home yards Tree crops areas Economical areas Peat land forests	4.9 6.3 4.9 15.0 0.4 ???	l/sec/ha l/sec/ha l/sec/ha l/sec/ha m3/sec/km2	Figures from South Sumatra. See Section .....
Drainage base	Outlet of main canals in river	Average daily MWL during wettest month	m+PRL	For preliminary calculations only. Detailed calculations based on water-levels during full tidal cycle.
Flood protection safety	Areas subject to river floods	1 in 25	years	
Tidal irrigation	All canals in Class A and B lands			See Section 3.6
Navigation	Canals with: - major navigation function - minor navigation function	 24 12	 hours/day hours/day	 one vessel, 3 m wide, draught 1 m do.
Tertiary canals	Spacing Maximum length	200 - 300 1,500	m m	Each field should have direct access to a tertiary canal.
Width of farm roads	Tertiary units	2	m	Most farm plots should have direct access to a farm road
Bridge clearance	Navigation, primary canals Secondary canals	2 1	m above mean HW in wet season m above mean HW in wet season	
Free board	Flood embankments Navigation, primary canals Secondary canals	0.75 0.75 0.30	m m m	
Side slope, canals	Navigation, primary canals Secondary canals Tertiary canals	1 : 2 1 : 1.5 1 : 1	- - -	Applies only to new canals. Side slopes of existing canals should mostly be left untouched.
Side slope, embankments	Embankment > 2 m high Embankment 1-2 m high Embankment < 1 m high	1 : 2 1 : 1.5 1 : 1	- - -	
Berm width	Navigation, primary canals Secondary canals Tertiary canals	5 3 2	m m m	
Roughness coefficient	Canal depth < 2 m Canal depth 2-3 m Canal depth > 3 m	25 30 40	k-Manning k-Manning k-Manning	
Maximum flow velocity	All canals All structures	0.70 2.00	m/sec m/sec	
Subsidence	Peat soils Mineral soils	10 - 20 2 - 4	cm/year cm/year	
Over-height for embankment construction	Unripe, half ripe clay soils Ripe clay soils	30 - 50 15 - 30	% %	

Table 4.1 – Design criteria
Adapted from Technical Guidelines on Swamp Land Development Volume II (ISDP 2000).

4.3 System Planning

General issues to be considered in the design of the hydraulic infrastructure much depend on the prevailing land and water conditions, see Table 4.2. It should be realized that within one scheme conditions may vary considerably from place to place, and one should be careful with adopting standard designs over any large area.

Table 4.2 – Design considerations hydraulic infrastructure

Condition	Issues to be Considered	Infrastructure requirements
All swamplands	Drainage of excess rainfall	Drain spacing at 200 m
	(Ground) water level control	Water control at farm level
River/canal tidal in dry and wet season, daily LW > 1 m below ground level	Potential for tidal irrigation	Wide open canals
	Protection against tidal flooding	Low embankments
River/canal tidal in dry and wet season, daily LW < 1 m below ground level during part of the year	Improved drainage	Drainage structures at tert/sec level
	Protection against tidal flooding	Low embankments
River/canal tidal in dry season only	Flood protection	High embankments
	Improved drainage	Drainage structures primary level, pumping
	Alternative drainage outlets	Long drainage diversion canals parallel to river and connecting downstream
River/canal outside tidal range	Same	Same
Deep peat and conservation areas	Prevent drainage	Physical separation of development and conservation areas
	Hydrological restoration	Block existing canals, physical separation of development and conservation areas
Deep peat, tree crops	Minimize drainage	Structures in canals
	Subsidence and future drainability	No or only few permanent structures
Shallow peat	Minimize drainage	Structures in canals
	Subsidence and future drainability	No or only few permanent structures
Adapted management zone along conservation	Minimize drainage	Structures in canals
Acidity	Water circulation	Double-connected canals at all levels
	Canal flushing/one-way flow	Flap-gate structures tert/sec level
	Soil leaching	Tata Air Mikro (TAM)
Salinity	Need to prevent salinity intrusion	Flapgate structures at tert/sec level

Based on the inventory of the available infrastructure and he needs assessment, maps scale 1 : 10,000 or 1 : 20,000 will be prepared showing:

- All existing canals, streams, rivers, water control structures, bridges, jetties
  Particular attention need to be paid to accurately indicate whether tail ends of canals are connected to another canal or not.
- Flood protection embankments
- Existing roads and paths, and canals that are used for transport
- Village centers and location of main services
- Houselot areas, farm holdings
- Present land use
- Water management aspects: areas with tidal irrigation, river flooding, acidity, drainage problems, and other results of the needs assessment

If a regional hydraulic improvement plan has been made as a separate exercise, the results should be incorporated as well. All planned changes and different options will be indicated on these maps and serve as basis for the first round of consultations. Preferred options, together with initial draft designs of structures, cross sections of canals, embankments, roads and possibly others items together form the System Planning.

4.4 Flood protection

Tidal flooding

The duration of tidal flooding is limited to a few hours per day, and mostly only during days around spring-tide. If the depth of flooding does not exceed 2 to 3 dm, farmer-made field bunds are sufficient. With deeper flooding, embankments need to be constructed, their height depending on the expected maximum flood level and required freeboard. In the design an over-height will be given to allow for subsidence of the subsoil and fill material, even if the latter is well compacted during construction. See Table 4.2. Where the embankment has to be crossed by canals, either a control gate has to be installed or the embankment will be extended all along that canal. The choice should take into account other functions of the canal (e.g. navigation) and evidently a cost comparison.

Flooding by runoff from adjacent areas

Flooded by runoff from adjacent (conservation) areas, like peat domes, should be prevented by either a collector drain or a protection embankment to divert the runoff to the drainage system. Dimensions should be based on an expected maximum flows which for peat domes has been estimated at 0.4 m3/sec/ha, see the EMRP Hydrology report. To avoid negative effects of the drainage on water-levels in the peat dome, a protection embankment is in most cases likely to be preferred above a collector drain.

River floods

Flooding by high river stages is the most serious type of flooding, it normally lasts for days, weeks or even months and it needs to be prevented “at all costs”. For agricultural areas without habitation a safety against a 1-in-25 year flood is normally considered sufficient as no direct danger to people is involved. For village areas a higher safety level may be adopted. The flood protection will consist of a dike with the required height and gates at locations where canals have to cross the dike.

An important choice has to be made regarding the location of the dike, either along the river or at the primary, secondary or tertiary level inside the area:

- ***Dike along the river or along outer boundary of developed area***
  Pro - Shortest alignment
  - Least number of structures required
  Contra - Large structures in primary canals required
  - Structures hindering navigation
  - Remote location, difficult access for inspection, maintenance and repair
  - Embankment may infringe on river flood plain, further raising river levels
  - A breach in the dike will affect a large area
- ***Dike at primary, secondary or tertiary level***
  Pro - Smaller structures required
  - Navigation in main canals remains possible
  - Easy access for inspection, maintenance and repairs
  - A breach in the dike will affect smaller areas
  - Embankment construction can make use of the canal excavation spoil

Contra - Longer alignment
- Number of structures increases

River flooding is most severe in the north-east of Block A, the Dadahup and Jenamas area. Flood waters from the Barito River enter the area though open connections between the river and the canal system, and possibly also over land or through natural creeks. Flood water also reportedly comes down sometimes from the north through the long north-south running ex-PLG canals. In recent years the Government has planned flood protection works here at secondary level, i.e. around secondary blocks with gates in the tertiary canals, which seems an appropriate choice. However, open connections to the Barito may have to be closed as well.

4.5 Canal System Layout

4.5.1 General considerations

The required canal system depends largely on the hydrological conditions and the planned land use. The focus of the design in relation to hydro-topographic classes and cropping patterns is shown in Table 4.3. However, where possible the design should allow for flexibility in land use as even in typical rice areas farmers at some moment may want to shift to dryland or tree crops.

HYDRO-TOPO-GRAPHY	CROPPING PATTERN	FOCUS OF INVESTIGATIONS	FOCUS OF WATER MANAGEMENT DESIGN
A	WS wet rice DS wet rice	Storm drainage WS rice Drainability WS rice Tidal irrigation DS rice Flood protection WS	Optimize tidal supply, hence large canals, dense canal network, double connected canals. Flood protection *Local varieties*: open canal system *HYV rice*: structures at tertiary/quaternary level for water-level control
A (saline in DS) B	WS wet rice DS palawija	Storm drainage WS rice Storm drainage DS palawija Drainability WS rice Drainability DS palawija Tidal irrigation WS rice Flood protection WS	Optimize tidal supply, hence large canals, dense canal network, double connected canals. If necessary: flood protection *Local varieties*: open canal system *HYV rice*: structures at tertiary/quaternary level for water-level control and/or water retention, salinity control
C, D	WS dry rice or palawija DS palawija	Storm drainage WS crop Flushing, water circulation Pump irrigation (Recharge groundwater)	Optimize drainability and leaching/flushing hence double connected canals, sufficiently deep, with structures at sec./tert. level. Pumps at tertiary level
C, D	Tree crops	Storm drainage WS tree crop Drainability WS tree crop (Recharge of goundwater)	Optimize drainability and leaching/flushing hence double connected, deep canals, and dense system of quaternary drains. Structures at boundary with rice areas to control water-levels.

Table 4.3 – Design for improved water management

In the EMRP areas with already an existing canal system the re-design will likely focus on:

- Improving drainability
  - double connected canals (within as well as between schemes)
  - densely spaced tertiary canals
  - large canal flow capacity to reduce head losses within the system
  - shortest flow path from field to primary canal and river
  - possibly relocation of drain outlet further downstream along the river
  - water control structures which can be operated for drainage
- Improving water circulation for leaching and flushing of acids
  - double connected canals (within as well as between schemes)
  - where possible making use of inflow from outside the area
  - water control structures which can be operated for one-way flow
- Improving possibilities for tidal irrigation in A and B lands
  - large canal flow capacity to reduce head losses in the system
  - densely spaced canals
  - open canal system (no structures which normally introduce additional head loss)

Other aspects to be taken into account in the design:

- Subsidence will lead to lower land levels and reduced drainability in the future
- Existing creeks or small streams crossing the area have in the past often been ignored by designers, or only simple closure dams were proposed. In practice closing these natural drains often proved very difficult. They could be either left open, and flood protection embankments designed around them, or they could be closed by a dam with (flapgate) structures to allow drainage without causing damage to the dam.
- Normally no bottom gradients are applied to canals in tidal swamp lands. Cross sections are varied in steps of 25 cm for the bottom level and 50 cm for the bottom width. All tertiary canals usually have the same uniform cross section.
- Fill requirements for embankments may in places override otherwise required canal dimensions.
- Side slopes of existing canals, especially those already stabilized and vegetated, should be left in tact. The vegetation should be kept short but not uprooted. The practice of periodic canal maintenance by excavator risks to unnecessarily widen the (tertiary) canals, hence making future routine maintenance much more difficult.
- Road network: with roads constructed most conveniently on the canal embankments, the layout of the canal system is closely linked to the development of the road network. Optimum access, including small roads along the tertiary canals for farm tractors and small trucks, should be planned with a minimum of canal crossings to save costs.

Some suggestions for re-design of the canals in the EMRP areas are shown in Figures 4.1 to 4.3, and are discussed below.

4.5.2 Fork systems Block D (Development Zone)

The entire Block D of the EMRP area forms one hydrological unit, an island even, in which besides local settlements and transmigrant systems of the typical fork layout, some large canals have been constructed by the EMRP. It is strongly recommended that the entire Block is seen as one hydrological unit for which a separate hydraulic improvement plan is to be drafted.

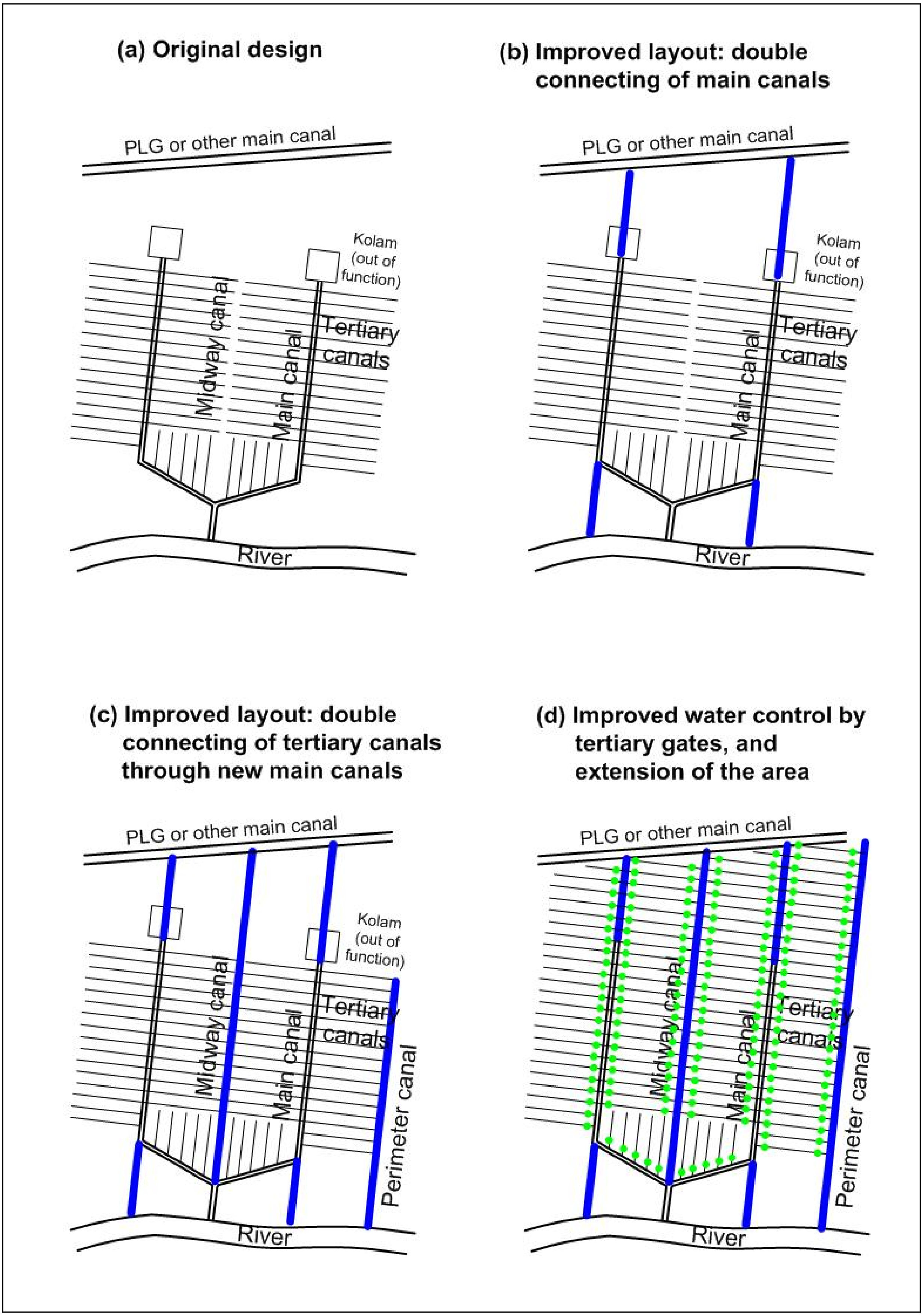


Figure 4.1 – Possible system improvements: fork systems in Block D

The dead-ended main and tertiary canals of the fork systems prevent any water circulation. Stagnant flow at the end of the canals leads to deteriorating water quality and weed growth, and insufficient tidal fluctuations are a likely cause (depending on the local topography) of poor drainage conditions. Possible solutions are shown in Figure 4.1. Double connecting the main and tertiary canals would allow the tide to enter from both sides. Double-connecting also opens the possibility of the often propagated one-way flow system through the tertiary to remove acid water. In that case flapgate structures would have to be added. The presence in Block D of the large ex-PLG main canals offers good opportunities to double-connect also the main canals of the fork systems, to both the river and to the PLG canal. Preliminary calculations of this option have been reported by Schultz et al. (1998) and confirmed the potential positive effect on water circulation in the canal system. An open canal system, without gates, might be most suitable for the low areas with tidal irrigation in the south of Block D. For the somewhat higher areas better water control is needed if high yielding varieties are to be grown, or improved drainage is needed if the farmers want to change to tee crops. In both cases water control structures would be needed, either in the main canals or in the tertiaries. Figure 4.1(d) shows them in the tertiary canals.

4.5.3 Fork systems Block C (Adapted Management Zone)

Although the canal system layout is similar to the fork systems in Block D, field conditions here are very different. The systems are laid out on the foot of the peat dome between the Kahayan and the Sebangau rivers, with appreciable gradients in the main canals. Connecting the ends of these canals to the north-south running ex PLG canal might increase water flow from that canal through the fork system, but being peat water it will not improve water quality in the system. Far more serious, however, is the fact that such connections would drain water out of the peat dome which hence is doomed. If the peat dome is to be preserved, the ex-PLG canals and any connections already made to the river should as much as possible be closed. Options for water management improvement are shown in Figure 4.2, Government Systems, and include:

- Abandoning the upper part of the scheme with deep peat soil. If people are still living here they should be re-settled. The tertiary canals can be left as they are. Without further maintenance they will gradually be closed by overgrowing vegetation.
- The main canal should be blocked at the boundary between the peat area and the developed area in order to maintain high (ground) water-levels in the peat lands. A series of several blocks may be needed with small head differences over each block (20 to 40 cm) to reduce the risk of seepage and piping through the peat soils around the blocks. The blocks can be made either of concrete or masonry (costly because of deep foundation needs) or by a wooden frame filled with earth. Such a box dam, however, does not last long and may have to be re-built after 5 to 7 years.
- A protection embankment or low dike is needed across the area in case of large overland flows from the peat dome to the cropped fields. In many cases, however, the first tertiary below the secondary blocks will be sufficient to intercept the flow and divert it to the main canal. In that case no additional embankment will be needed.
- In the developed area close to the boundary with the conservation area land use may have to be adapted to withstand permanent high groundwater-levels
- The water management system in the developed area can now be improved in a way similar to the fork systems in Block D. Double connecting main canals is not an option, but perimeter drains could be added to double connect the tertiaries; these perimeter canals could possibly serve an adjacent scheme as well. Next, tertiary gates could be introduced.

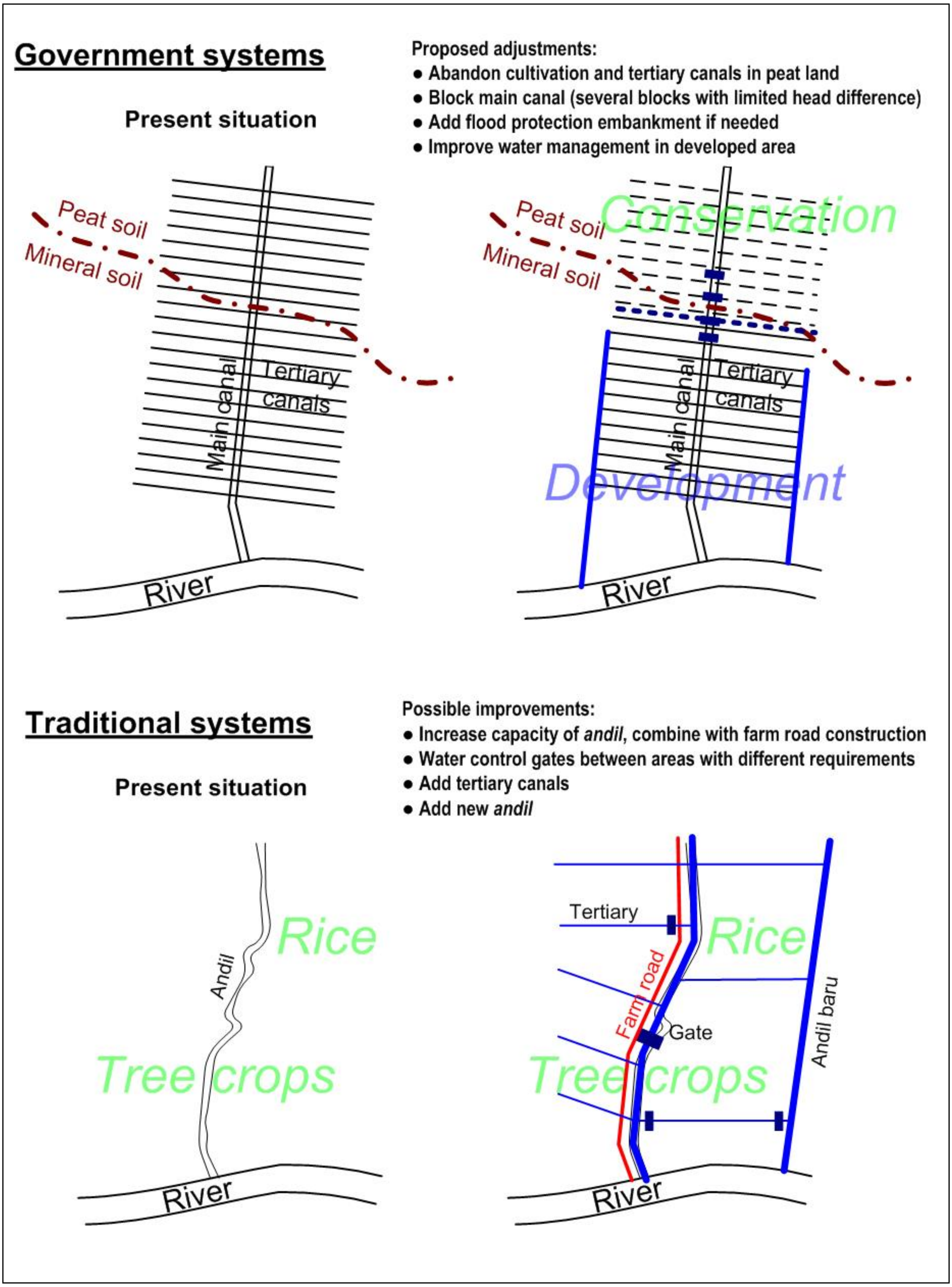


Figure 4.2 – Possible system improvements: Government systems in Adapted Management Zone and traditional systems

4.5.4 Traditional systems (Development and Adapted Management Zone)

The autochthonous water management systems consist of *andils*, or small canals, extending from the river several km land inward. Mostly excavated by hand and/or following old creeks they are often rather shallow and in places tortuous. Water control is often problematic as structures are either non-existant or made of perishable material. Another disadvantage of the systems is the lack of road access, which in the government schemes is provided by the embankments along the straight canals. Possible improvements of the systems include:

- Straightening and deepening the canals
- Adding tertiary drains perpendicular to the *andil*
- Adding water control structures in either the *andil* or the tertiaries
- Construction of farm roads along the canals

Connecting the tail of the *andil* to other canals (e.g. those of transmigration schemes) should be investigated as well. It might add (irrigation) water to the *andil*, but in the wet season it could cause flooding, while the water quality of the inflowing water may be less than that of the *andil*. It goes without saying that any intervention in the *andil* systems should be thoroughly discussed with the owners and users of the *andil*. In fact, in many cases the people have clear ideas about system improvements and the kind of government support they would desire.

4.5.5 Lamunti and Dadahup area (Development Zone)

The original design consists of a rectangular grid of primary and secondary canals in open connection with a collector canal surrounding the development area and running parallel to the main rivers. At several places the collector canal is connected to the river through large sluice structures to control the in- and outflow. The secondary canals are spaced 2.5 km apart, and may be up to 15 km long. Tertiary canals within the blocks are 2.5 km long and spaced 600 m apart, and a tertiary unit hence covers 150 ha or some 60 farmers. Many tertiary canals are connected alternating to a secondary either at its northern end or at its southern end, in line with the original concept of separate supply and drainage canals. Most farm plots have no direct access to a tertiary canal, nor to a farm road, and they depend for water management and access on their neighbours, see Figure 4.3(a).

A first requirement will be to check the adequacy of the main canal system through hydraulic modeling based on accurate topographic and hydrological data. In view of the large distances from the area to the river and the wide spacing of the secondary canals, drainability and soil/water quality improvement through leaching and flushing is critical and additional main canals may be needed. They may also be needed to reduce the considerable length of the tertiary canals, see below. Drainage in both areas is likely best directed to the south and west, i.e. for the Dadahup area to the Murung and Mengkatib rivers and for Lamunti to the Kapuas where wet-season river levels are lower than in the Barito..

Most of the large sluice gate structures in the primary/secondary canals are out of order. Before any decision on their rehabilitation is taken, the need for these structures should be thoroughly investigated and tested by hydraulic modeling. At the downstream, southern end of the area there is likely to be less need for the structures than further north where they may serve a flood protection function. If the structures are not needed anymore, it might be considered to remove their remnants entirely as these are likely to cause additional head loss for water flows though the canals, as is the case with some of the bridges in the area which are narrower than the canal width.

Because the tertiary spacing of 600 m is considered too wide for proper water management, the Government has added 3 m wide quaternary drains perpendicular to the tertiaries, spaced 200 or 400 m apart. In this system each farm plot has direct access to a quaternary canal (Figure 4.2(a), right-hand side). Connecting the quaternaries at both ends to a tertiary may well support drainage and water circulation but a disadvantage is that it makes individual water control per tertiary unit impossible. The risk is that all water will flow through the quaternaries from a (slightly) higher tertiary to a lower one unless a large number of gates are installed in the quaternaries. The quaternary canals also block access from the village area to the farm plots and installation of small bridges is required.

An alternative improvement of the original tertiary design is shown in Figure 4.2(b). Additional tertiaries are installed in between the existing ones to reduce the tertiary spacing to 200 m or 300 m (the latter would still leave some farm plots in the middle without direct access to a canal). In this way, each tertiary can be operated independent of other tertiary canals. Bridges across quaternaries are avoided although an additional bridge in the hamlet area will be required where the new tertiary crosses the village- or access road. With long tertiaries of 2.5 km, water management in the middle of the secondary block may still be problematic. In that case cutting the tertiaries into half by adding a secondary canal midway the existing secondaries should be considered.

4.6 Water Control Structures

Except for canals which cross flood protection embankments, the need for water control structures or gates in lowland canals is not always clear-cut. The structures alone, even if well constructed and operated, will not raise agricultural production unless accompanied by improved farming practices. Any decision on installing gates should be based on a careful consideration of the need for it in close consultation with the users.

Canal structures in the lowlands serve several purposes:

- Flood protection
- Increase drainage capacity of the canal, by closing the gate during high tide and opening again during low tide
- Controlled drainage, i.e. maintaining water-level at a certain depth to allow for soil leaching while preventing over-drainage and exposure of pyrite
- Flushing and improving water quality of a canal by regulating in- and outflow
- Water retention and supply, by opening the gate only when outside water-levels are higher than those inside the canal
- Preventing saline water from entering the canal.

In most cases a structure will serve one purpose during one part of cropping season, and another function during another part of the season. If installed near the junction of canals with different bottom levels, the bottom drop can be built into the structure, hence preventing erosion in the canal with the higher bottom level.

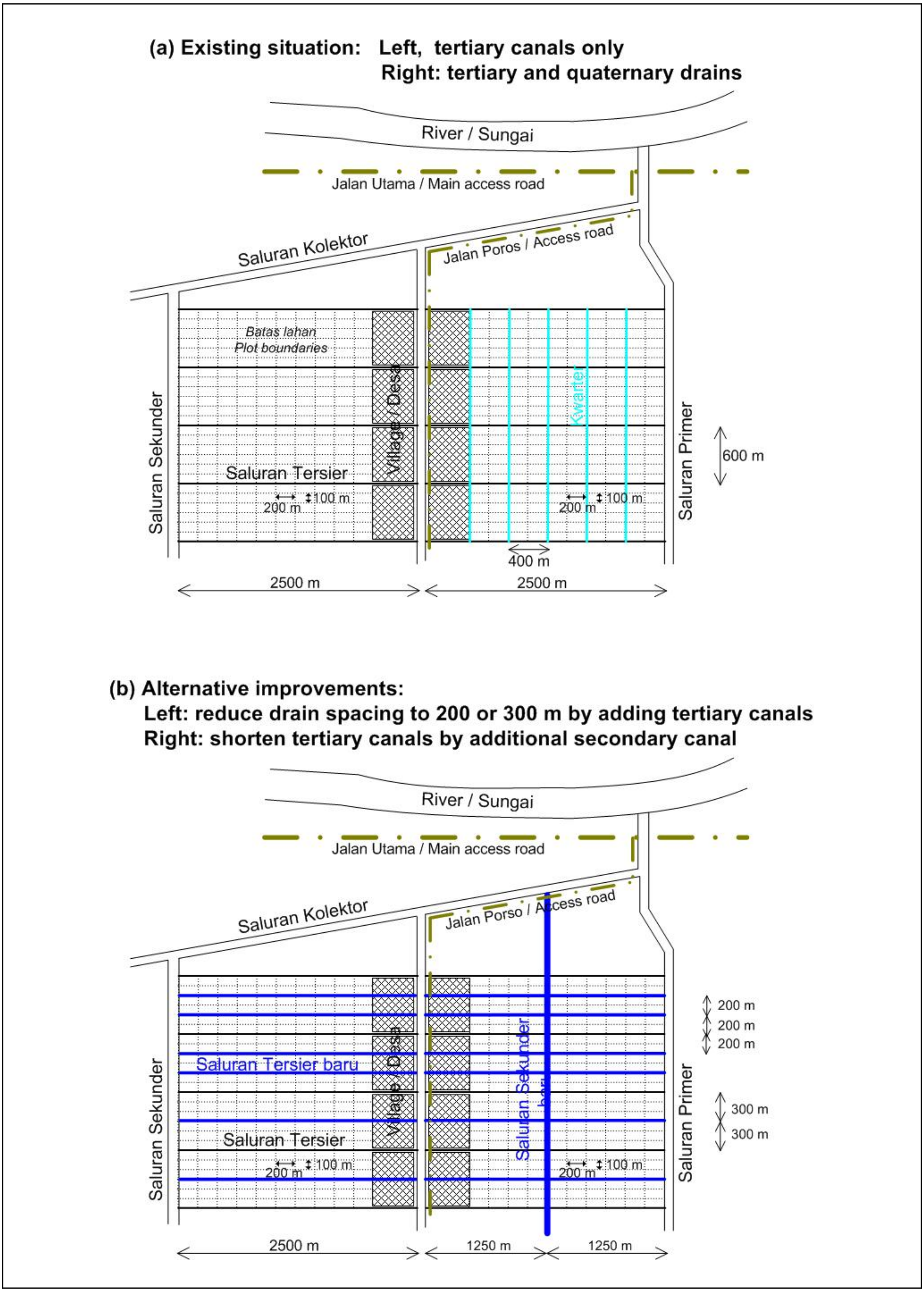


Figure 4.2 – Possible system improvements: Lamunti and Dadahup schemes

Basically three types of gates can be used in the canal structures: stoplogs, sliding gates and flapgates, each with its advantages and disadvantages, see Table 4.4.

Type of gate	Best used for	Advantages	Disadvantage
Stoplogs	- Controlled drainage - Water retention	- simple construction - simple maintenance	- stoplogs get lost - leakage between logs - operation increasingly difficult in larger canals
Sliding gate (underflow)	- Water retention - Block inflow (floods, saline water, acid water)	- simple operation	- complicated construction - sensitive to poor maintenance - underflow, therefore poor water-level control
Flap gate	*Drainage gate:* - Maximum drainage - Block inflow - One-way canal flow *Supply gate:* - Water retention, supply - One-way canal flow	- automatic operation - allows for maximum drainage - automatic operation - allows for maximum water retention, supply	- complicated construction - sensitive to debris in the canal (trash racks can only partly prevent this)
Combination (e.g. stoplogs and flap gate)	Depending on gate types	- high flexibility	- slightly more expensive

Table 4.4 – Gate types for water control structures

Except for the large primary canal structures of the ex PLG area, structures in lowlands are so far mostly limited to tertiary canals. Experience with such structures is in many cases disappointing, which is believed to be due to two main causes:

(1) Seepage around the structure

The peaty or half-ripe clay soils often have high permeabilities, leading to seepage when trying to maintain a head difference over the structure. In other places sandy soil layers at shallow depth have the same effect. Continued seepage causes erosion and ultimately collapse of the structure. The process is sometimes accelerated by repeated mechanical canal maintenance, which, by scraping the canal side-slopes, gradually widens the canal while the width of the structure remains the same.

The seepage can be reduced by increasing the length of the structure, which of course will raise the costs. Where also a road crossing over the canal is required, the two could well be combined, the structure hence benefiting from the length of the road culvert to reduce the water-level gradient over the structure. Another option is installing plastic sheets or geo-membrane on the canal bottom and side-slopes before and/or after the structure.

(2) Difficult operation

Structures are often located far from housing areas making frequent gate operation, and certainly twice daily operation in case tides would require this, almost impossible. In practice, gate settings are rarely adjusted more than a few times per season, hence not making the best possible use of the structure. Automatic flapgates which can be used either for “supply only” or for “drainage only” have in some cases been successfully installed. In principle no operation is required other then changing the position of the flap on either supply or drainage, but in practice regular attention is needed to prevent dirt from blocking the flaps.

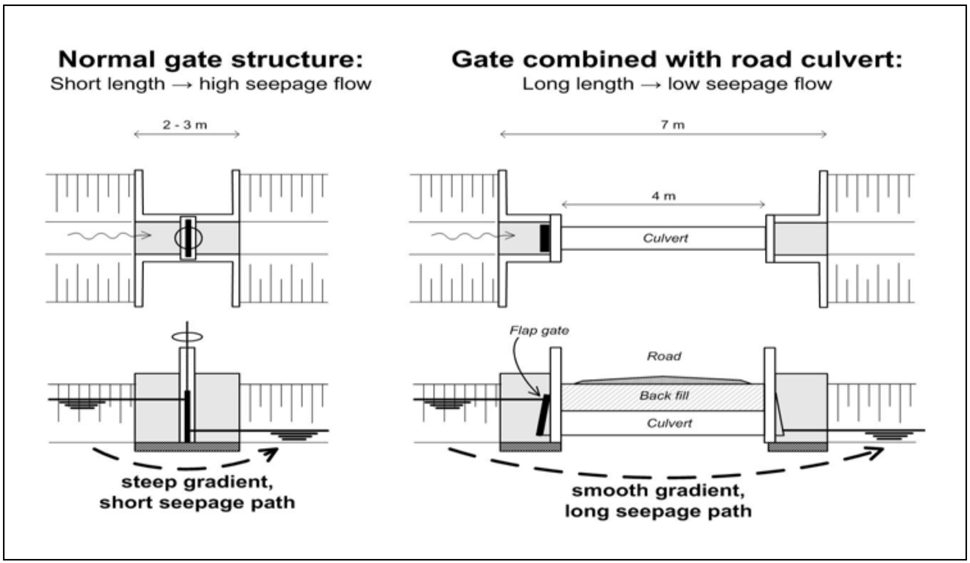


Figure 4.4 – Reducing seepage by increasing the length of a structure

Construction materials

Another choice to be made concerns construction materials and construction methods. With good quality wood becoming scarce, materials to be used include concrete/masonry, ferro-cement, and fiber-glass, plastics etc. These are compared in Table 4.5. Of course, a combination of materials in one structure is well possible. Gates within the structure are mostly made of wood reinforced with iron strips, and placed in an iron frame. Flapgates for smaller (tertiary) structures are conveniently made of fiber-glass.

Type of material	Advantages	Disadvantage
Wood	- light weight - well suited for construction by the community	- good quality wood increasingly scarce or expensive - not long-lasting
Concrete, or concrete frame in combination with masonry	- material strength - ease of construction - well suited for construction by the community	- quality control under field conditions may be difficult
Ferro-cement	- light weight - good quality control of prefab elements	- expensive - vulnerable during transport - complicated installation
Fiber-glass, plastics	- light weight - good quality control of prefab elements	- weak material strength - limited durability - expensive

Table 4.5 – Construction materials for water control structures

Community participation in construction

Water control structures will normally be constructed by a contractor, but for small tertiary gates community participation in the construction is highly desirable. The advantages are often better workmanship, better adjustment to local conditions and preferences, and a sense of community ownership of the structure. Design details should in this case also be intensively discussed with the community and take into consideration the availability of local materials and craftmanship.

Summarizing structure design

Summarizing, important issues to consider for design of structures include:

- Main purpose of the gate
- The water management needs as indicated by the water users
- Location (depending on water management needs but also on access for ease of operation and the use of the canals for transport)
- Type of gate
- Sill level depending on drainage requirements, topography and expected subsidence
- Combine with road crossing?
- Combine with canal bottom drop?
- (Sub-)soil conditions and seepage prevention
- Costs and availability of construction materials
- Available workmanship and possibilities for quality control
- Implementation method (local community or contractor)

4.7 On-farm water management systems

Improvements of the hydraulic system will only be effective if at the same time farming practices are improved. Besides agronomic issues, not dealt with here, from a water management point of view the most important issues are:

(1) On-farm water management systems
or Tata Air Mikro (TAM). The main purpose is to ensure uniform distribution of available water, to avoid too deep flooding, to retain water during critical periods and assure adequate drainage when needed, and to promote soil leaching by water infiltration into the soil rather than surface runoff. The systems consist of field bunds, quaternary and in-field drains, while sometimes small gates are installed as well. Standard designs are available from the Dinas Pertanian.

(2) Mechanical land preparation
in already sufficiently ripened soils. Ploughing will greatly facilitate water infiltration and soil leaching, and also helps the fermentation of weeds or stubble remaining in the field from the previous crop. In the lowlands of South Sumatra high yields are obtained with early ploughing, in September, well before the start of the rainy season and at least one month before harrowing and planting. Operating the tertiary canal on drainage during this period promotes the fermentation process as well as soil leaching by the first rains.

(3) Synchronized planting in compact areas
Synchronized planting of all fields in a tertiary unit not only helps to combat pests and diseases but is also important for on-farm water management to avoid conflicting requirements between farmers who want to drain their fields and other who want to keep water-levels high.
Abandoned fields (*lahan tidur*) form a breeding place for rats and other pests, and cultivated areas should as much as possible form compact blocks. Land consolidation may be required to allow other farmers to plant the fields abandoned by their owners.

4.8 Reporting, mapping

Table 4.6 gives an overview of the drawings and reports to be prepared on the re-design of the hydraulic infrastructure. The surveys and investigations (see Chapter 3) should be reported separately and are not included in the table.

Report / map	Contents	Remarks
Design maps	1 : 20,000 scale situation maps with existing and designed infrastructure 1 : 5,000 scale situation map with existing and designed infrastructure	Entire area Re-designed areas only
Design drawings	Long. sections (scale hor. 1:5,000, vert. 1:100) Cross sections (scale hor. 1:100, 1:200, vert. 1:100)	
Design report	Detailed description of design methods, calculations procedures, assumptions, risks	
Technical specifications	Earth works Concrete works, ferro-cement, reinforcements Steel works Timber works	
Bill of Quantities and cost estimates	Unit rate analysis Work volumes per construction item Cost estimates	
Final report	Executive summary Summary of survey activities and results Summary of local conceptions, successful experiences Summary of options considered and agreed upon Design of proposed infrastructure Economic analysis and EIA if needed Recommendations	

Table 4.6 – Detailed design documents

5. HYDRAULIC MODELING

5.1 The aim of hydraulic modeling

Hydraulic modeling can be an important supportive tool in the redesign process as schematized in Figure 1.3. It can be used in the following ways:

- To validate the data collected and the results of field surveys and to check their consistency;
- To analyze the actual situation and to help define current problems;
- To evaluate and compare performance of different options for the layout of the hydraulic system with respect to:
  - Flooding
  - Drainage
  - Irrigation
  - Acidity
  - Salinity

Hydraulic modeling is no aim in itself and can only be useful if combined with data collection and analysis and if embedded in a participative design process.

5.2 Model set-up and required data

A large number of software packages exist for hydraulic modeling. For preparation of the EMRP Master Plan the hydrology, hydraulics and flooding in the area have been modeled with Deltares' Sobek modeling package (see www.sobek.nl). Other packages with similar functionality can also be used to support the design process. Examples include DuFlow, DHI's MIKE package and USGS' HEC-RAS package (although not all these packages include combined functionality for hydraulics, flooding and water quality). It is recommended to use standardized software instead of tailor-made software to ensure quality control and reproducibility. It is important to include the following considerations in the selection of a model package:

- Availability of trained staff to setup, calibrate and apply the modeling software.
- Cost, availability and support for the modeling software.
- Possibility to combine one-dimensional canal hydraulics with two-dimensional overland flow hydraulics for simulation of floods and tidal irrigation (where flooding and tidal irrigation are issues to be analyzed).
- Possibility to combine hydraulic and water quality modeling (where acidity and salinity are issues to be analyzed).

Due to the relatively low hydraulic conductivity found for the peat and clay soils in the EMRP area, the contribution of sub-surface flow to overall flow will be limited. Therefore coupling with groundwater flow models is not necessary to support the design process. However, sub-surface flow from the field to the lowest level drains should be included in the calibration of the rainfall-runoff coefficients.

Hydraulic modeling to support the redesign process should start with modeling of the actual situation, including:

1. The actual lay-out of the canal system and the actual dimensions of the canals.
2. The existing structures, their dimensions, state and operation.
3. The actual topography, preferably available as a Digital Elevation Model (DEM) with an accuracy of 10-20cm.

For system planning, the hydraulic model should include the entire hydrological unit or Integrated Management Unit (IMU), i.e. the area encompassed by linked canals and the whole catchment draining to these canals. This can also include areas outside the Development Zone. The upstream boundary will therefore be a catchment boundary determined by topography. The downstream boundarie(s) will be formed by the rivers and/or the sea.

Downstream boundary conditions should be described in the hydraulic model as time series of water-levels. These can be obtained by water level measurements at these locations and/or by the results of the river hydraulic model prepared in Sobek in the framework of the EMRP Master Plan Project as described in the Technical Report on Hydrology of the Master Plan study. Even without a Sobek license, the results of this model can be presented and extracted from the project database with the demo version available from www.sobek.nl.

To support the preparation of detailed designs, a separate model(s) for part(s) of the IMU can be constructed, using results of the model for the whole IMU as boundary conditions.

For larger IMUs it might take too much time to setup and run a model including all canals down to tertiary or quaternary level. In this case, a detailed model including all canals for a part of the area can be used to derive run-off specifications for secondary or tertiary blocks, and the smaller canals can then be omitted from the schematization for the whole IMU.

Hydraulic modeling should provide results for typical 14-day spring-neap cycles in both wet and dry season. Daily rainfall data for periods of at least 20 days should be available from measurements to eliminate errors in the first days of the model simulation.

For drainability assessment as defined in Section 3.8 the 1-in-5 year highest monthly rainfall should be determined for that month of the growing season during which river-levels are highest.

For flooding assessment a rainfall event with a probability of 0.04 per year (a 25 year return period) should be constructed as input for the model based on available long term precipitation time series and recent, local information. Initial conditions for water-levels should reflect normal wet season conditions (as obtained from the simulation for the wet season).

5.3 Model calibration

The model setup for the actual situation should be calibrated for 14-day spring-neap cycles in both wet and dry season. For the same periods the following data should be available:

- Water-level measurements with preferably an hourly frequency at different locations (in the river near the connections with the IMU, upstream of structures and in primary, secondary, tertiary and quarternary canals).
- Where relevant measurements of salinity and acidity at different distances from the river.

Calibration of the water-levels can best start with the locations closest to the river in the dry season, working from here upstream the canals, and followed by the wet season simulation. The major coefficients for calibration are the canal roughness (mostly for the dry season) and the rainfall-runoff parameters (mostly for the wet season). Parameterization of the rainfall-runoff can differ according to the model used.

It might be possible to roughly calibrate results from flood simulations on flood marks, local knowledge on flood extent, depth, frequency and duration and on remote sensing data of flood extent. Significant differences between simulated and observed flooding will most likely be caused by either the simulated river water-level or the DEM used. Model parameters such as surface roughness will mostly have less influence on the results.

The major coefficient for calibration of the water quality model is the dispersion coefficient.

As part of model calibration it is important to execute a sensitivity analysis of the model for the most important parameters with values within a reasonable range. Results of the sensitivity analysis should be included in the report. If model results for all parameter settings within the predefined reasonable range deviate significantly from measurements (outside the range of 10-20cm for water-levels), significant problems exist in the data and/or the model and should be corrected before the model is used to evaluate designs. Sensitivity analysis, correlation analysis between model parameters and parameter optimization can be supported by tools such as UCODE_2005 and PEST.

5.4 Evaluation of different designs under different scenarios

The calibrated hydraulic model can be used to evaluate and optimize the design. A first design can be developed from the actual situation and the model can be used to simulate the hydraulics for both the typical wet and dry season, the 1-in-5 years highest monthly rainfall in the wet and dry season and the 1-in-25 years flood event, resulting in the following output:

1. Maps of maximum flood depth and flood duration for the 1-in-25 years event.
2. Maps of wet and dry season drainability based on the water level in the tertiary canals for the 1-in-5 year highest monthly rainfall.
3. Maps of wet and dry season potential for tidal irrigation indicated by the number of times per 14-day spring tide cycle that the surface can be flooded at high tide.
4. Map of the dilution and removal of acidity in the canals by flushing.
5. Map of saline intrusion into the canals.

Information from the maps can be aggregated into tabular information, such as areas per class of flooding, drainability, tidal irrigation, acidity and salinity. This enables comparison between results for different designs.

Based on the results for the first design, the number, location and dimensions of canals, embankments and structures can be adjusted resulting in a new design which can be evaluated.

The long term sustainability of a design can be tested by modification of the input to reflect expected climate change (mainly effecting precipitation, evapotranspiration and sea and river water levels, see Chapter 7) and subsidence (mainly effecting the DEM and the elevation of canal beds, embankments and structures).

6. TRIALS AND DEMONSTRATIONS

Past efforts at rehabilitation of hydraulic infrastructure in lowland schemes have often been disappointing and did not lead to the expected increase in agricultural production. Designs may have been inappropriate or not adapted to the local situation, the infrastructure improvements were not accompanied by simultaneous improvements in farming practices, farmers may have been unsure how to make best use of the new infrastructure, or may have been reluctant to take the risk of changing their known and tested practices. But even if all these factors are accounted for success is not guaranteed.

The best way would be to try out the improvements in pilot areas before applying them on a large scale. A programme of field trials should be implemented where various land and water management practices are tried out. If for example structures at tertiary level are desired, these should be tested out in one or two tertiary units first, both in terms of design (gate type, prevention of underflow) and in terms of operation, before being applied at a larger scale. The same with installation of on-farm water management systems and introduction of other improved practices, like synchronized planting, mechanical land preparation, use of improved varieties, etc. In order to try out these practices, to learn from experience, and to demonstrate what works well to the community at large, farmer field schools could be established. The farmers themselves will implement the trials, while the agencies (Pertanina, PU) will provide assistance, disseminate information, give demonstration, organize exchange visits to other areas etc. The field schools could also be the focus for other agricultural extension activities, for strengthening farmer groups and water user organizations, for organizing canal maintenance, for joint input supply or processing and marketing activities etc.

Evidently, system improvement programmes cannot wait until such trials have been completed which takes years. Nevertheless, it is highly recommended that such trials are started at the earliest possible date. Besides for the direct benefits mentioned above, the results of the trials will also support future system improvements, according to the gradual process of improvement and adjustments of the hydraulic infrastructure illustrated in Figure 1.2.

Practical guidelines how to set up the field schools are given in various publication of the Dinas Pertanian, see e.g. www.pla.deptan.go.id. Valuable experience with similar kind of integrated development has also been gained in pilot areas of projects, such as the IISP, LWMTL and STLD projects in South Sumatra, the ISDP project in Jambi, Riau and West Kalimantan, and several others.

7. EFFECTS OF CLIMATE CHANGE

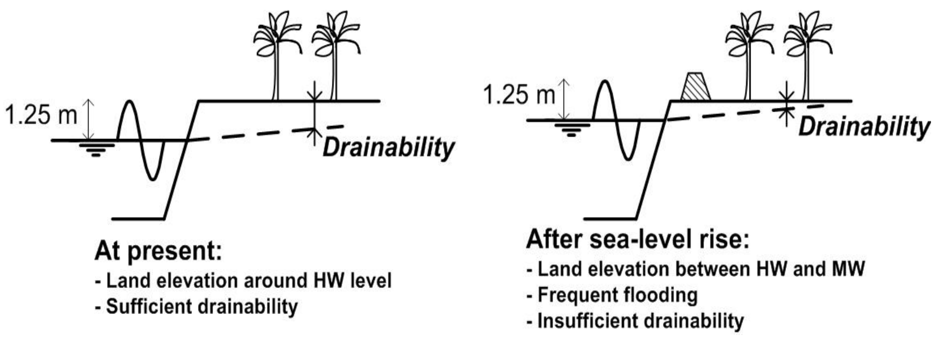
The magnitude of climate change in the decennia ahead is uncertain, but certain trends have been clearly recognized. These trends are expected to affect conditions in the Indonesian lowlands in the following way:

A rise in temperatures
A rise in temperature alone may not have serious impacts on conditions in the lowlands, but in combination with changes in rainfall may affect agricultural growing seasons

Changing rainfall patterns
The total annual precipitation is likely to become more variable, and may be accompanied by a shift in seasonal rainfall patterns. Studies (IPCC 2007) suggest that the onset of the rainy season will be delayed. Droughts may become more severe and peak rainfall in the wet season may rise. This will have direct impact on cropping seasons, and a shorter wet season with more peaky rainfall will increase the risk of rainfed farming.

Changing river hydrology
Together with land use changes in the river basins, the changing rainfall patterns are expected to cause lower dry-season flows, which in turn will cause increased salinity intrusion and reduced opportunities for tidal irrigation. Peak flows in the wet season are likely to rise, and protection dikes against river floods will have to be raised.

Rise in sea levels
Probably the most serious consequence of climate change for the Indonesian lowlands is the rise in sea levels. Expected to be this century in the range of 0.18 to 0.59 cm globally, for Indonesia a rise of 0.65 has been predicted (Bappenas 2004). Large parts of the lowlands which are typically situated at an elevation about equal to spring-tide high water, would require protection embankments with an average height of 1.40 m (65 cm rise plus freeboard).
But even more serious will be the reduced drainability. Drainability is defined as the elevation difference between the land and the drainage base minus unavoidable head losses in the drainage system (see Section 3.8). The elevation of the land being around spring-tide HW, or about 1,25 m above MSL, and with the drainage base assumed to be equal to MSL, a sea-level rise of 65 cm would reduce the drainability of areas close to the river (zero head losses) from 1.25 m to 0.60 m. Further away from the river, where head losses in the drainage system have to be taken into account, drainability will become increasingly worse. Tree crops become virtually impossible to be grown in the tidal lowlands other than on the river bank, and away from the river drainage of foodcrops and even rice becomes jeopardized unless pumped drainage is introduced.



The hydraulic modeling as described in Chapter 5 can well be used to evaluate the effects of certain changes in rainfall and/or sea levels on the river hydrology and on the drainability of the area.

However, due to the big uncertainties involved in predicting climate change, it seems too early to take possible effects of climate change into consideration for re-design of existing settlements. For planning of new settlements it might be prudent to avoid the lowest areas and to locate villages and houselots only in the highest parts of the landscape.

The uncertain effects of climate change make accurate monitoring of rainfall and water-levels even more important, in order to identify and quantify any changes or trends as early as possible, and be able to implement protective measures.

8. MONITORING AND EVALUATION

8.1 Monitoring at regional level

From Chapter 2 it is clear that there is a serious lack of basic data regarding the EMRP areas. In particular missing, and crucial for (re-)design of the hydraulic infrastructure, are accurate hydrometric data (tide and river levels) related to a topographic network. The Master Plan study has established a series of benchmarks in the area with elevations expressed approximately in MSL but further verifications are urgently needed. Other surveys in the area often establish their own project reference level, and relates this at best to short-term water-level recordings in the nearby river and not to results of other studies. Results of those surveys, even if accurately implemented, remain therefore of limited value.

It is strongly recommended that permanent water-level recording stations are established in the main rivers. Small electronic recorders (divers) could be easily installed in pipes attached to bridge pillars or jetties, far cheaper than the stand-alone platforms built in the river for past mechanically operating water-level recorders. The records should be expressed in the same reference level as used for the topographic data. A more accurate mean sea level can then be determined, and seasonal and annual changes in water-levels can be monitored, together with salinity or other characteristics of the water. Further recommendations on rainfall and hydrological monitoring in the EMRP area are given in the Master Plan Technical Report on Hydrology.

8.2 Monitoring at scheme level

Within the rehabilitated schemes, it is recommended that monitoring of land and water parameters is concentrated on the proposed trial and demonstration areas (Chapter 6). The following parameters are important:

- Daily rainfall
- Groundwater-levels (daily) and water quality (weekly)
- Canal and river water-levels: daily observations in the tertiary canal, supported by occasional hourly measurements during 24-hours simultaneously in the tertiary canal, main canal and river. Ground- and canal water-levels should all be expressed in the same reference level.
- Crop growth and cultivation practices: for all fields in the trial area data on variety, time of planting and harvesting, and yield should be recorded. For selected fields a full crop husbandry diary should be kept, from date and method of land preparation up to post harvesting activities and sale of the produce.

The local water user organizations should from the start be involved in the monitoring. The results have to be reviewed seasonally, plot into tables or graphs and compared with data from other fields and/or from previous years. The data should be discussed with the water users in order to get a clearer understanding of the real issues at hand. The data will support conclusions about the effectiveness of the implemented land and water management practices and will help to identify what further adjustments would be desirable.

8.3 Maintenance monitoring

The condition of the hydraulic infrastructure should be monitored continuously by the O&M staff as well as by the water user organizations. Consistent use by the field staff of the Maintenance Record Book (*Buku Catatan Pemeliharaan*) is recommended in which any damage, malfunctioning or other repair or maintenance needs observed in the field are recorded together with a rough estimate of quantities/costs and urgency of the repair work required.
If well maintained and kept up to date, these records will form a sound basis for higher level staff to decide on mobilization of manpower and materials needed for the repair, as well for preparation of next year's O&M plans and budgets.

The implementation of maintenance activities should evidently be closely monitored but this is beyond the scope of the present note.

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USEFUL WEBSITES

www.pla.deptan.go.id	Direktorat Jenderal Pengelolaan Lahan dan Air, Ministry of Agriculture. Many guidelines on agricultural land and water management.
www.pu.go.id/balitbang/	Badan Penelitian dan Pengembangan PU (Development Research Organization of Public Works Department). Many technical standards and guidelines.
http://sda.pu.go.id	Information on water resources, irrigation and swamp schemes. Site still under development.
www.sobek.nl	Website on the Sobek software package for hydraulic modeling
www.kalteng.go.id	Website of the Central Kalimantan provincial government, with among others information about the Mamangun dan Mahaga Lewu village development program, and links to the Kabupaten websites.
www.eelaart.com	Website on experience with development of Indonesian tidal lowlands for agriculture.

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Jl. Taman Suropati No.2,
Jakarta 10310

www.bappenas.go.id

Bappeda Central Kalimantan
Secretariat Inpres 2/2007

Jl. Diponegoro 60,
Palangka Raya 73111,
Kalimantan Tengah

www.kalteng.go.id

Royal Netherlands Embassy

Jl. H.R. Rasuna Said Kav. S-3,
Kuningan
Jakarta 12950

indonesia.nlembassy.org

Euroconsult Mott MacDonald

S. Widjojo Centre, lt. 3
Jl. Sudirman Kav. 71
Jakarta 12190

www.euroconsult.mottmac.com

Deltares | Delft Hydraulics

P.O. Box 177
2600 MH Delft
The Netherlands

www.wldelft.nl