REPORT ON A RAPID HYDROLOGIC AND VEGETATION INVESTIGATION

At Anlung Pring Crane Reserve in Kampot province and Boeung Prek Lapov Crane Reserve in Takeo province, Cambodia

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Under suppoted by
Wildfowl & Wetlands Trust

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Acknowledgements

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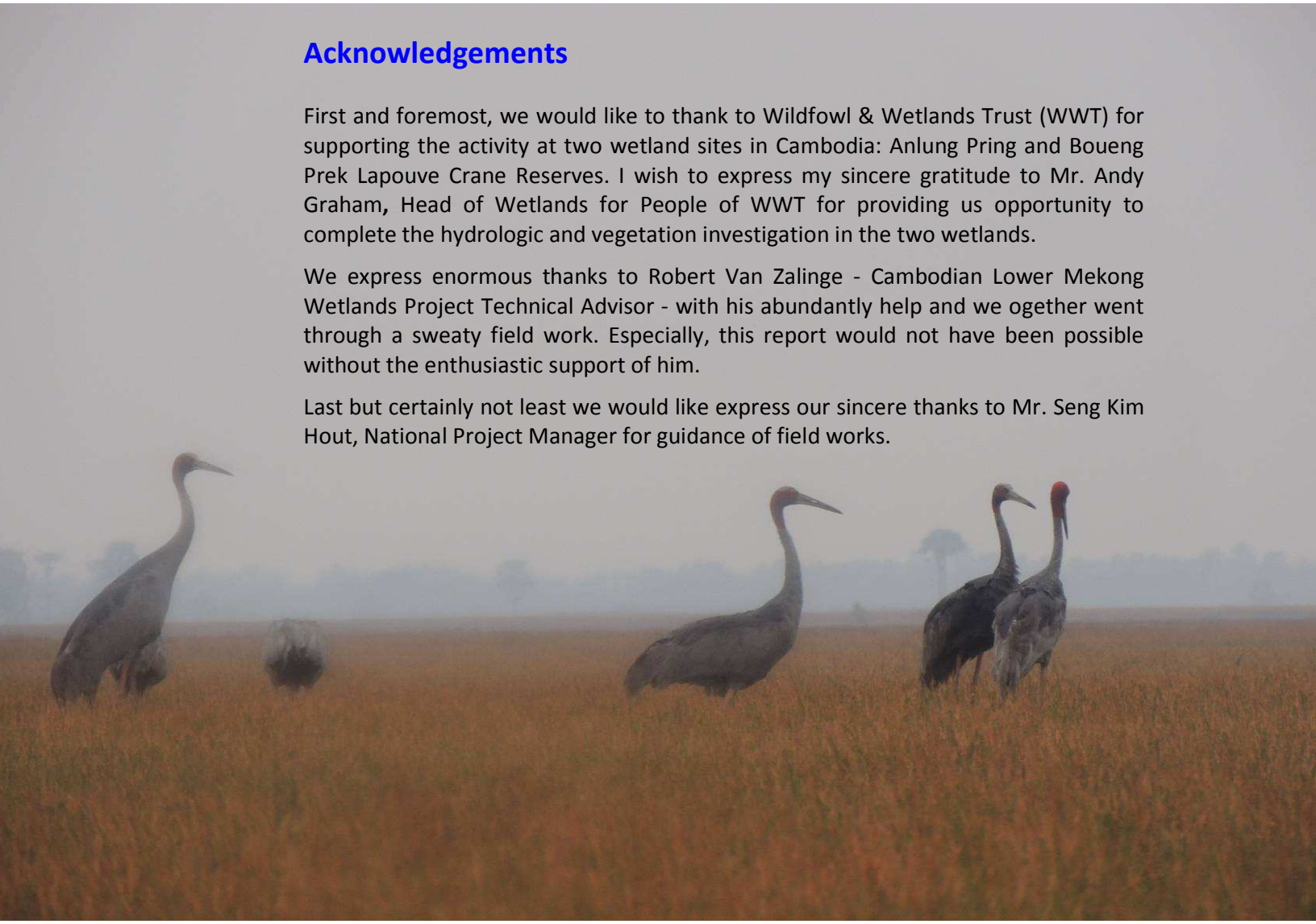
We express enormous thanks to Robert Van Zalinge - Cambodian Lower Mekong Wetlands Project Technical Advisor - with his abundantly help and we ogether went through a sweaty field work. Especially, this report would not have been possible without the enthusiastic support of him.

Last but certainly not least we would like express our sincere thanks to Mr. Seng Kim Hout, National Project Manager for guidance of field works.



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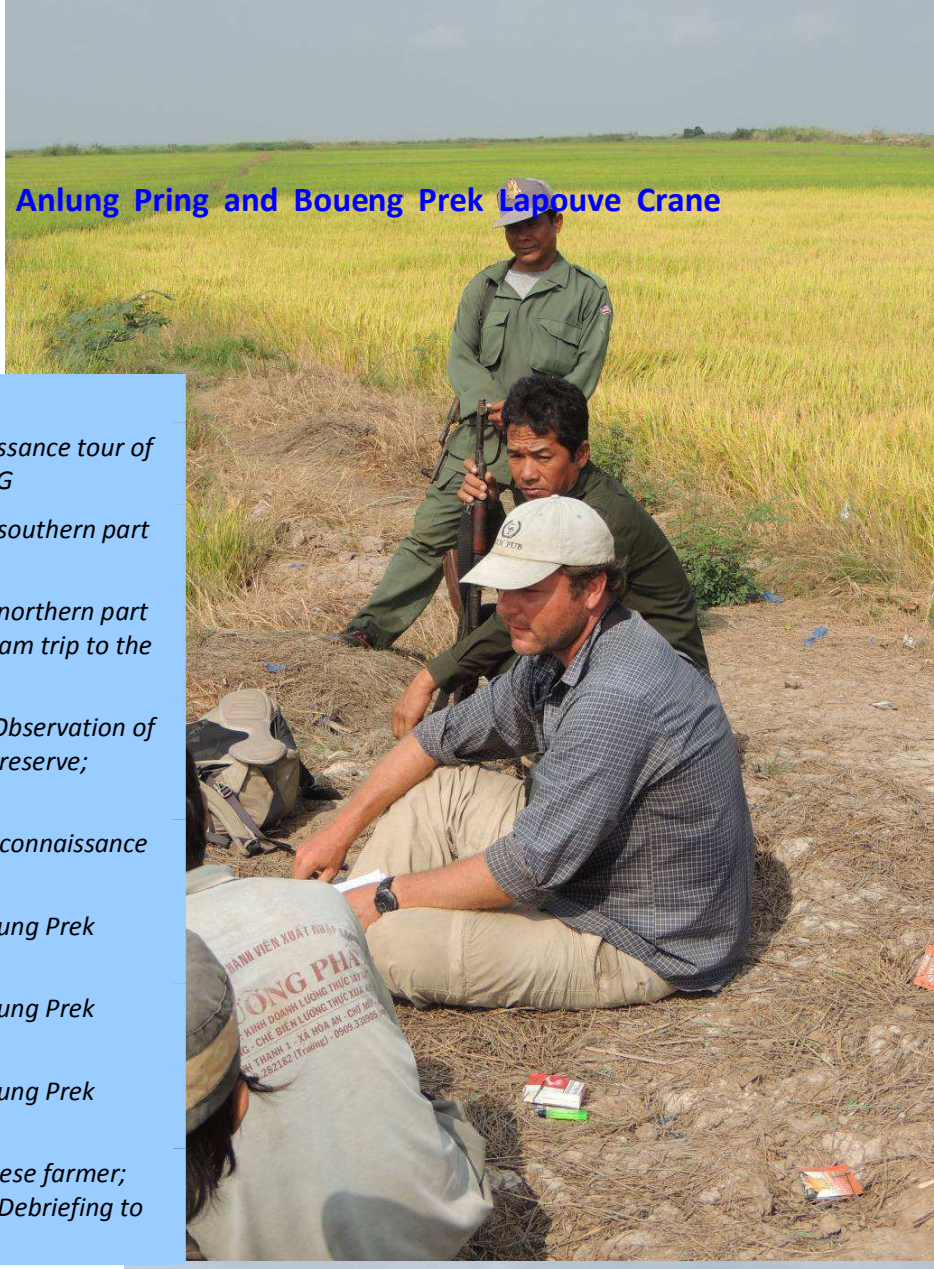
Itinerary of investigation in Anlung Pring and Boueng Prek Lapouve Crane Reserves

Date	Activity
Feb. 20, 2013	*Arrival. General reconnaissance tour of the reserve; PRA with LCG*
Feb. 21, 2013	*Field investigation in the southern part of the reserve*
Feb. 22, 2013	*Field investigation in the northern part of the reserve. Downstream trip to the border with Vietnam.*
Feb. 23, 2013	*PRA with local villagers; Observation of the upstream part of the reserve; Traveling to Takeo*
Feb. 24, 2013	*PRA with LCG; General reconnaissance tour of the reserve*
Feb. 25, 2013	*Field investigation in Boeung Prek Lapouv*
Feb. 26,2013	*Field investigation in Boeung Prek Lapouv*
Feb. 27, 2013	*Field investigation in Boeung Prek Lapouv*
Feb. 28, 2013	*Interview with a Vietnamese farmer; tour to upstream of BPL; Debriefing to Mr. Vanna.*



Surveys in Anlung Pring and Boueng Prek Lapouve

Background

Under WWT commission, a rapid hydro-ecological assessment of two wetland reserve in Cambodia: Anlung Pring in Kampot province and Boeung Prek Lapouv in Takeo province (Figure 1) was conducted by a team of consultants from February 20 to February 28, 2013 (Annex 1).

Figure 1. Location of Anlung Pring in Kampot province and Boeung Prek Lapouv in Takeo province, Cambodia.

Overall objective

The overall objective of the assessment is "*to advise the project on a water management plan for restoration of important plant communities that sustain the Sarus Crane*".
To achieve the overall objectives, the specific objectives are:

1. Understanding the hydrologic features of the site (catchment, climate, land use, geology, soils, and elevations, water inputs, outputs, tidal variation, evaporation, topography, hydrologic units, manage structures, annual water regime, extent and distribution of permanent waterbodies)
2. Understanding the wetland habitats (wetland communities, eco-hydrological requirements of each community—including specific food plants of Sarus Crane)
3. Conclusions and recommendations for management with regards to water level, water quality, soil properties, plant community management, water regulation infrastructures)

Methodology

Hydrology

For the hydrology assessment component, the main method applied was mainly simple field observation, expert judgment, and participatory exercises with local villagers and Local Conservation Groups at the 2 sites, using PRA tools including Historical Timeline, Seasonal Calendar, and Resource Mapping.

Physical features and vegetation

For the soil and vegetation assessment component, the main method was applied as follows:

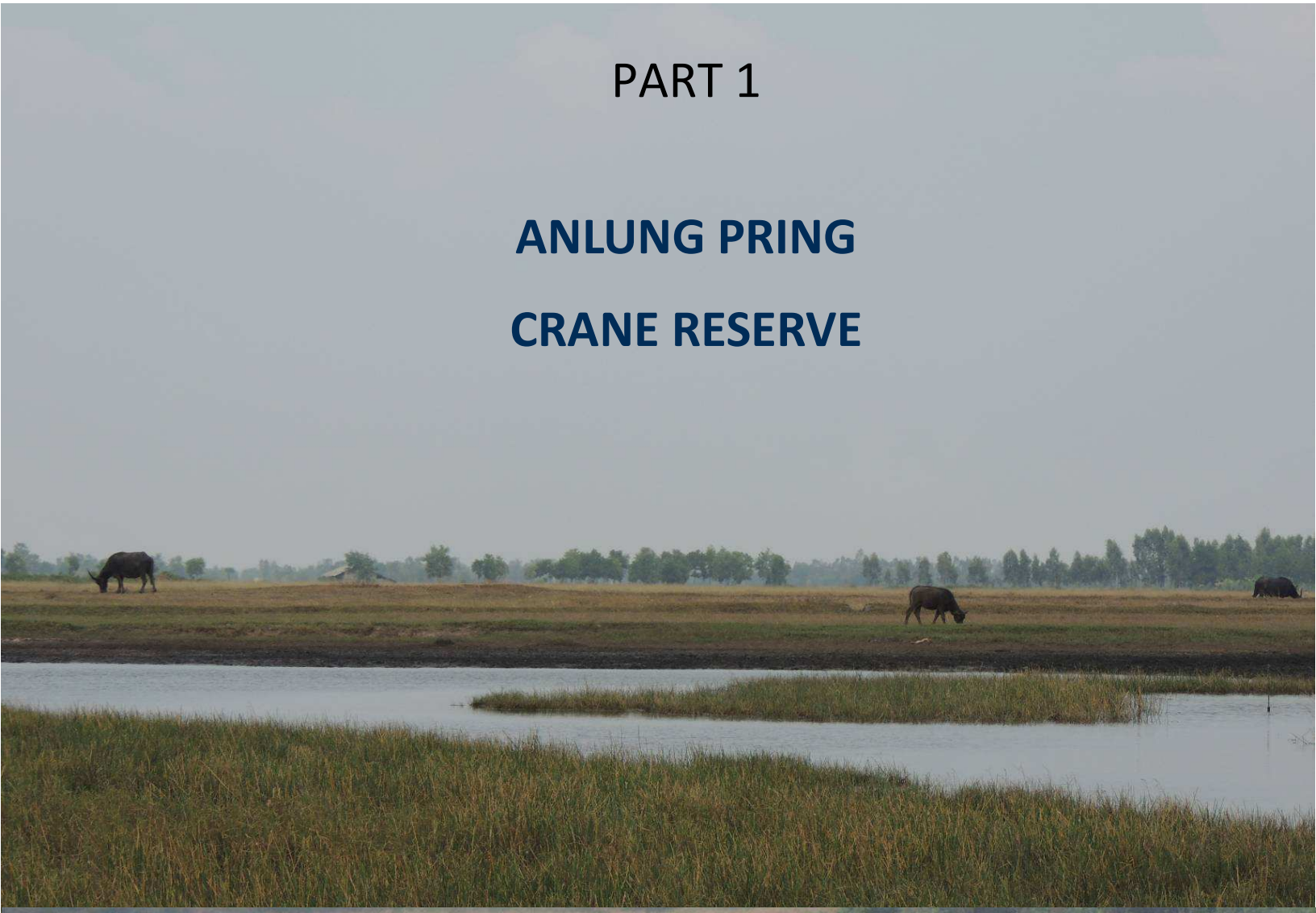
1. Interpretation of Landsat TM7 (2012) and Rapideye (2011 and 2013) to identify diversity of vegetaton communites and distribution of soil types.
2. Field observation at the 2 sites.
    - Ground truthing aimed to record the species and plant communities.
    - Description of soil morphology at some sites was carried out to explain soil characteristics. USDA/Soil Taxonomy is used to classify soil types.
    - Water quality at some ares was tested by field equipment.
3. The data collected by WWT (2012 and 2013) are used in reference for the inventory of plant communities and interpolated topographic maps.
4. Remote sensing and geographic Information system softwares were used for interpolation and mapping of vegetation and other features.

From this point onward, the paper is presented in 2 parts with Part I about Anlung Pring Crane Reserve and Part II about Boeung Prek Lapouv Crane Reserve.

PART 1

ANLUNG PRING

CRANE RESERVE



1. General information

Anlung Pring is alternatively known as Kampong Trach IBA (Important Bird Area)[1]. The IBA is located at the western edge of the Mekong Delta, and comprises an area of seasonally inundated grassland, interspersed with Melaleuca scrubs, along the international border with Vietnam. The IBA is located at the northern extent of the Ha Tien plain, a once extensive area of seasonally inundated grassland and other natural habitats, which extends into Kien Giang Province, Vietnam. Large areas of natural habitat in the Vietnamese part of the Ha Tien plain have been converted into agriculture and aquaculture, while the mosaic of natural habitats in the Cambodian part have been reduced to around 1,000 ha in extent[2].

On 6th January 2011, the Royal Government of Cambodia issued a sub decree (Prime Ministerial Decree) to establish the Anlung Pring Management and Conservation Area for Sarus Crane and Other Birds located in Kampong Trach District, Kampot Province with the total area of 217 ha.

The general location of the site is shown in Figure 2 below.

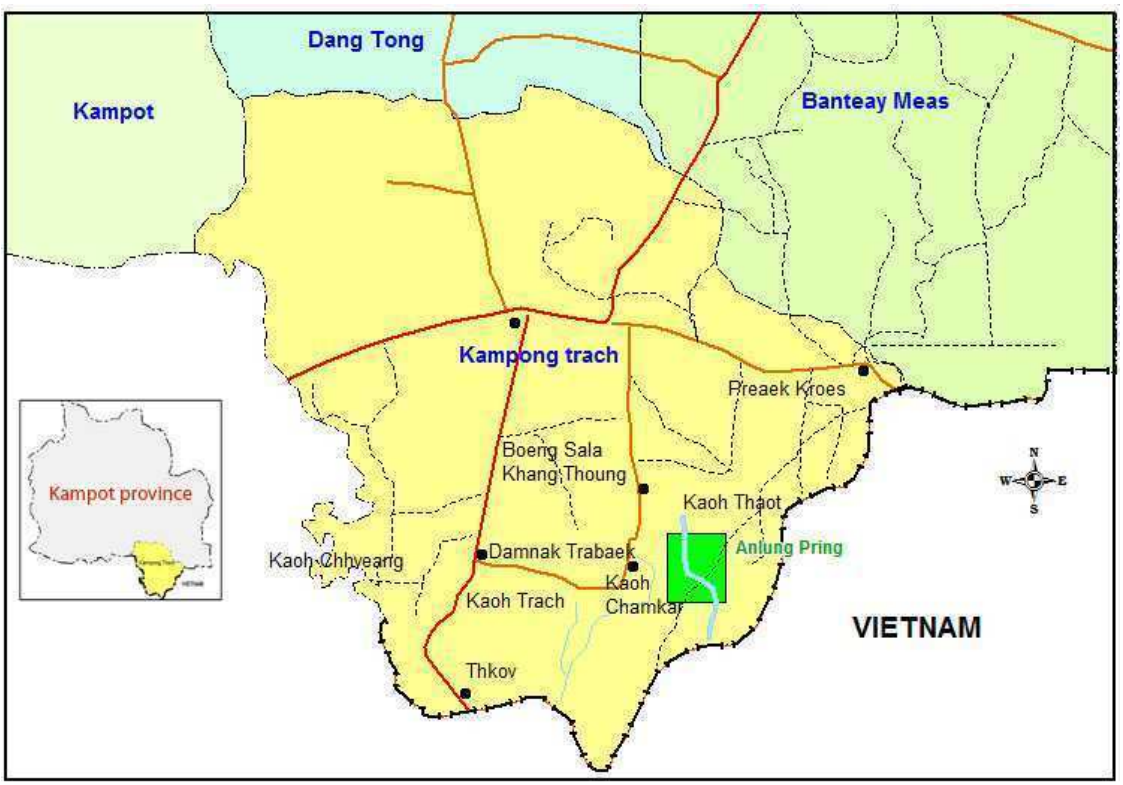


Figure 2. Location of Anlung Pring in Kampong Trach district, Kampot province.

[1] Anlung Pring reserve is sometimes alternatively known as the Kampong Trach IBA. However, the IBA assessment was conducted nearer to the coast, south of the present Anlung Pring reserve. The habitat where the IBA assessment was conducted has been now converted to shrimp aquaculture (Robert van Zalinge, pers.com 2013).

[2] http://www.birdlife.org/datazone/sitefactsheet.php?id=16691

2. Findings

2.1. Hydrology

2.1.1. Catchment and site features

Anlung Pring, located in Kampong Trach district, Kampot province is a stretch of wetland about 4.0 km in length and 450 meters in width. It is part of a floodplain that forms along a shallow river meandering in the north-south direction. The wetland is flanked by high land used for rice cultivation on both sides. The difference in elevation between the surrounding landscape and the average ground within the wetland is about 1-2 meters. The upstream in the north is fed by several branches of small rivers. In the wet season, the river is connected to Giang Thanh River (Prek Ten in Khmer?) at Phumi Tuol Srama. About 1.5 kilometers downstream of the reserve, the Anlung Pring river is connected again to Giang Thanh river that finally pours into the sea at Ha Tien in Vietnam.

In the wet season, as water level rises the river swells up to inundate its flanks. In the dry season, the river shrinks back to the main stream. At the time of observation in February, it was observed that some sections of the main stream were exposed and thus only some sections remain as shallow pools. This annual cycle of swelling and shrinking of the river forms the stretch of floodpain that Anlung Pring is part of.

Upstream of Anlung Pring, the floodplain that Anlung Pring is part of is intersected by several roads (Koh Treak, Ko Koh, and other roads) with small culverts allowing water to pass through downstream in the flood season.

Figure 3: the southern part of the Anlung Pring Reserve (looking south from Koh Treak road)

Anlung Pring itself is divided into 2 parts by a dirt road (Koh Treak road) that was built in 1984. The stretch of road across the river was heavily eroded and broken in sections (possibly due to the big flood in 2000 although this was not mentioned in the PRA) and in 2007 the road across the river was rebuilt and sluice gates placed to allow flood waters to pass through. The northern sector of Anlung Pring is 33 ha, while the southern sector is 184 ha. According to the local old timers, previously both the northern part and the southern part were affected by salinity all year round. After the road was built in 1984 and rennovated in 2007, the northern part gradually became fresh. The southern half of the reserve remains saline and is influenced by daily tide fluctuation from the sea.
Water was observed flowing in from the sea in the south during high tide and flowing out of the wetland during low tide.

Figure 4: The northern part of Anlung Pring Reserve (looking north from Koh Treak road

The water gate at Koh Treak dyke that divides the reserve is operated by the local community group. The gate is closed for the whole time during the dry season. The main purpose of closing the gate, according to the villagers during the PRA exercise, is to prevent salinity from passing north of the road. The gate is opened in the flood season to release excessive flood water to avoid damage to the road.

The PRA exercise with the Local Conservation Group generated the following information about the history of the site.

Table 1: A historical timeline of the site according to the LCG (especially the Prek Kreus Commune Chief)

Timeline	**Description/event**
Around 1965	There were a lot of white shouldered ibis and vultures. They heard crane calls in flight but the cranes did not land in Anlung Pring. There was no land title.
In 2000	Before this year, the site was dominated by Nipa palm. In this year a big flood occurred and killed all the Nipa palm. There was no crane at the site.
In 2002	There were about 6-7 cranes at the sites
2003	Mr. Seng Kim Hout counted 47 cranes
In 2011	A big flood occurred, less than the one in 2000

Figure 5. Koh Treak road dividing the reserve into south and north parts (looking north)

Figure 6. The sluice gate on Koh Treak road that divides the reserve into halves.

Figure 7. Sluice gate on Ko Koh road upstream of Anlung Pring

Figure 8. Further upstream from the reserve (looking north from Ko Koh road) with rice field planted in floodplain

2.1.2. Seasonality

2.1.2.1. Seasonal Calendar

To gain insights into the yearly cycle of the environment and life activities at the site, we conducted a PRA exercise with the Local Conservation Group using the Seasonal Calendar Tool. The result about the seasonality of the area is presented the Table 1 below.

Table 2: Seasonality at Anlung Pring according to the LCG

Topic	Jan	Feb	Mar	April	May	June	Jul	Aug	Sept	Oct	Nov	Dec
Rain					x	x	x	x	x	x	x	
Saline water	x	x	x	x								
Fresh Water						x	x	x	x	x	x	x
Severe acidity					x							
Crane	x	xx	xx	xx	x						x	x
Freshwater fish die	x	x	x	x	xx	x						
Freshwater flood							x	x	xx (>2 m)	xx (>2 m)	x	
High tide		x	x									
Wet rice							x	x	x	x	x	x
Close gate if small flood										x	x	

Interpretation/additional notes:

- Rain season starts in May and lasts till November
- Saline intrusion from Jan to April
- Freshwater from June to December, a month after it rains.
- In May when it first rains, water becomes acidic.
- Freshwater fish die from January to June, especially in May when water becomes acidic.

- Flooding season is from July to November. Deep inundation occurs in September and October. Inundation depths are greater than 2 meters.
- High tide occurs in February and March
- People practice only one crop of rice per year (wet rice season) from July to December.
- The Watergate is closed (after having been opened during peak floods in Sep-Oct) in October to November trying to keep fresh water for use by communities.
- The system has always been like that in the history: brackish water in the dry season and fresh water in the wet season.
- The villagers also reported that big floods occurred in the years 2000, 2001, 2002, 2011. Particularly the big flood in 2000 was said to kill all the Nipa palm plants that used to dominate Anlung Pring. Then a few cranes started to come to the site in 2001 and in large number since 2002.

2.1.2.2. Annual water regime

2.1.2.2.1 The northern part

While the long-term water level monitoring data at Anlung Pring is lacking, the following graph gives a general idea of the monthly water fluctuation of water levels in a typical year (from February 2012 to February 2013) for the northern part of Anlung Pring reserve.

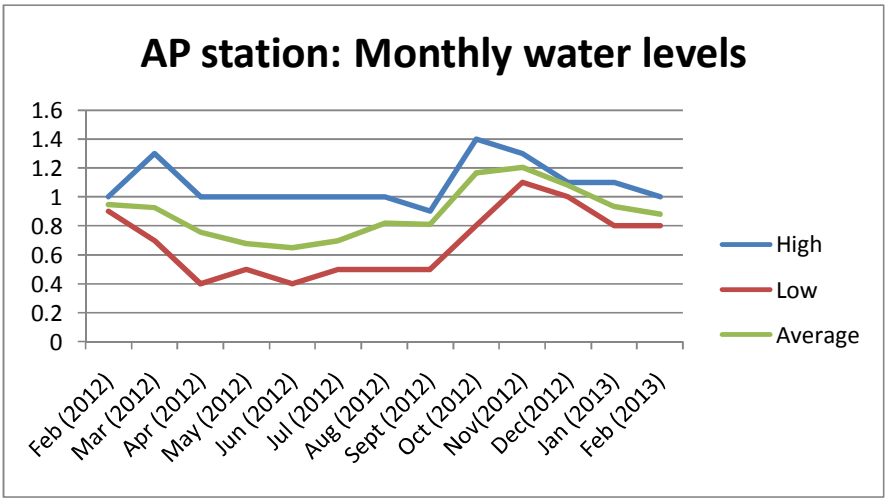


Figure 9: Monthly water levels from February 2012 to February 2013 at the staff gauge in the northern part of Anlung Pring.

The graph was generated based on daily water level readings at the staff gauge installed immediately upstream of the water gate. The daily readings however were taken once a day at different times of the day as convenient so that the maximum and minimum water levels used here not true maximum and minimum water levels but the highest and lowest water levels of the water levels recorded in the month. The average values are the monthly averages of daily readings.

In general, water levels start rising in July-August, peak in Oct-November, and recede afterward to reach lowest values in April-June.

2.1.2.2.2 The southern part

The following graph gives a general idea of the monthly water fluctuation of water levels in a typical year (from February 2012 to February 2013) for the southern part of Anlung Pring reserve.

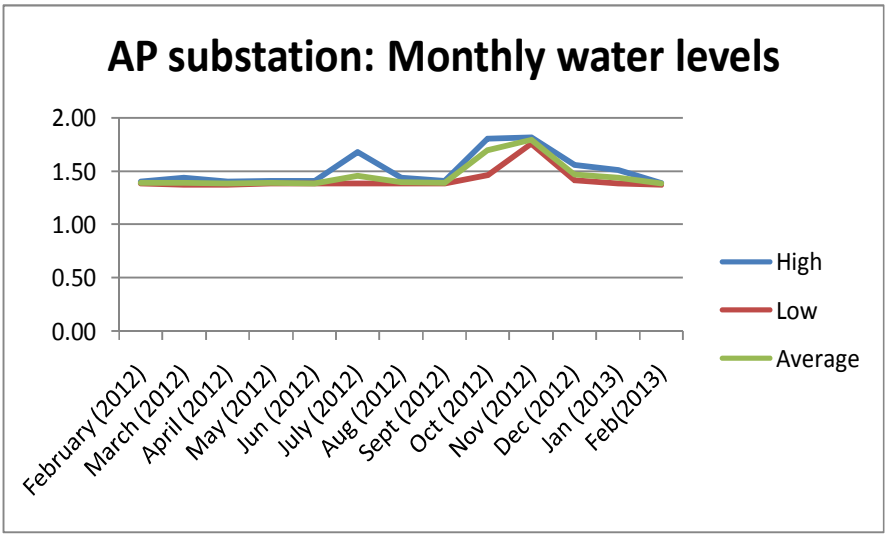


Figure 10: Monthly water levels at the substation in the southern part of Anlung Pring

The graphs were generated based on daily water level readings at the staff gauge installed at the substation at the southern boundary of the reserve. Similar to the water readings in the northern part, the daily readings here were also taken once a day at different times of the day as convenient so that the maximum and minimum water levels used here are not true maximum and minimum water levels but the highest and lowest water levels of the water levels recorded in the month. The average values are the monthly averages of daily readings.

The southern part of Anlung Pring is hydrologically connected to the sea, so water levels are affected by tidal fluctuation on daily basis. Monthly water levels in general rise high in October and November and stay stable for the rest of the year.

2.1.3. Observed field conditions

2.1.3.1. The southern part

It was observed that most of the wetland in the southern part of the reserve was saline and wet. Except near the edges of the central river, most of the ground is exposed during low tide and inundated again during high tide with a sheet of water about 5-10 cm above the ground. The ground was muddy and dominated mainly by *Eleocharis spiralis.*

During the field observation from February 20-23, 2013, more than 300 cranes were feeding at Anlung Pring during the day. The cranes moved between the northern and the southern parts of the reserve several times a day. They seem to start early in the morning from the northern part and moved to the southern part at mid morning for feeding and move back and forth several times. Cranes were seen busy feeding in the central part of the reserve,

south of the sluice gate, but no cranes were seen using the most southern section of the reserve.

At the time of field observation, the whole surrounding landscape was dry and only Anlung Pring remains wet. Besides Sarus Crane, there were also cormorants, egrets and many other water birds. Often, crane families were observed to have 4 members with two youngs, suggesting a high recruitment rate.

In early January 2013, when water in this area was still too wet about 150 cranes stayed in Koh Ta Yoy, next to the border with Vietnam (about 3 km south east of the reserve) (Seng Kim Hout, pers.com. 2013).

At the time of observation, the sluice gate was closed; the water from the seaward part of the gate was about 2-5cm higher than that in the other side. Immediately north of the road, water was also saline, though less saline than the south part of the reserve. Further north water became non-saline but acidic.

It was also reported that in May-June, massive fish die-off usually occur in the southern part due to release of acidity (Seng Kim Hout pers.com. 2013 and PRA exercise with villagers).

Near the coast in Vietnam, south of the southern part of the reserve, most of the land has been converted to extensive low input shrimp farming since 2002. There was information that shrimp farming is expanding toward the reserve from the south.

The most southern part of the reserve contains Eleocharis … which is very tall and forms thick stands. This area is not used by cranes (as observed from field observation, observations from a student studying crane use of Anlung Pring and comments from LCG (boat driver) and project staff (Robert van Zalinge pers.com, 2013).

2.1.3.2. The northern part

Except in the mainstream part of the Anlung Pring river and some other local channels and small depressions where there was still standing water, most of the ground in the northern part of the reserve was exposed by the time of observation.

The southeast corner of the northern reserve, near the water gate, was particularly drier than the rest. Evidence of heavy grazing by water buffalo earlier in the dry season was seen in this corner where the soil was heavily disturbed with buffalo footprints. At the site of heavy grazing, no noticeable change in plant composition was observed.

Further north, except in the main channels and several scattered small channels, there was no standing water on the ground but the soils were still moist. Cranes were seen feeding in this part of the northern reserve.

The villagers, during the PRA exercise, reported that before the Koh Treak road was re-built all of the northern part of the current reserve was also saline. The northern part was dominated by nipa palm which was killed in the partilularly high flood in 2000. The vegetation has gradually become dominated by Eleocharis.

A field of dry season rice was seen north of the Koh Ko road. An increase in agriculture within the floodplain of the river could have a negative impact on water quality, especially if farmers apply agrochemicals.

2.1.4. Crane stay at the reserve

It was reported that cranes started to visit Anlung Pring since 2001 (after the major flood destroyed the nipa palms). Crane counts started in 2004. The following graphs show the statistics of crane counts at Anlung Pring.

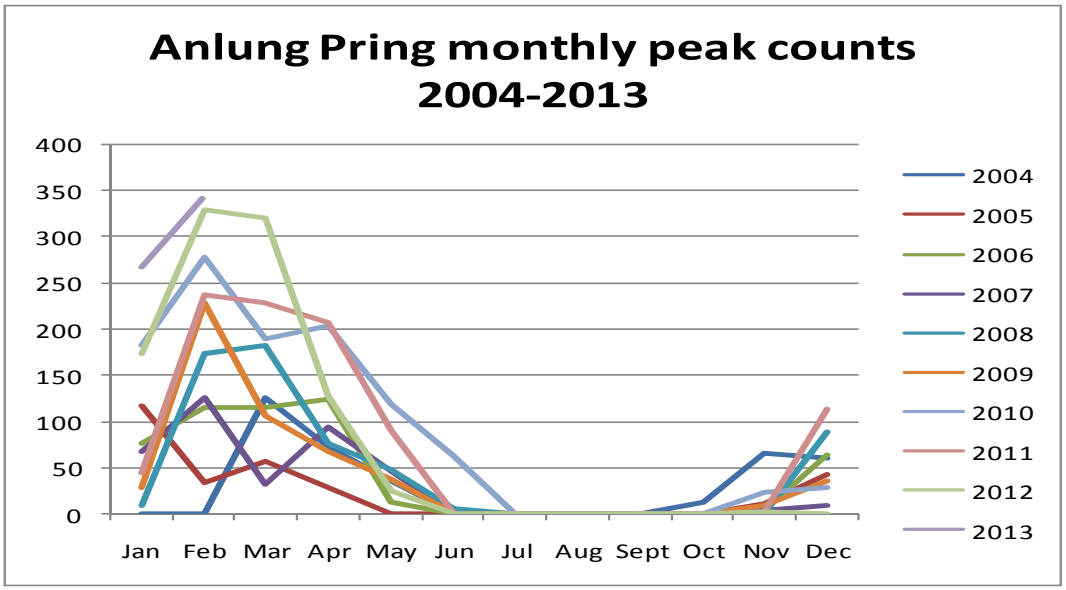


Figure 11: monthly peak counts at AP from 2004 to 2013

The graphs in Figure 3 show that generally the cranes start arriving at Anlung Pring toward the end of the wet season as early as October in small numbers; then the numbers keep rising until peaking around February and March; and decline thereafter until all cranes leave the site by the end of May. The year 2010 was a particular year that the cranes stayed on to June.

- because of habitat change following a major flood in 2000 that destroyed the then abundant nipa palms. The northern part was also gradually "freshenized" with the construction in 1984 and the re-construction of the dyke in 2007. Thus, the presence of the road that fresheninze the northern part and the change of the vegetation from nipa palm to Eleocharis at Anlung Pring were probably all "happy accidents" that created suitable habitat and a freshwater environment to provide drinking water to enable the cranes to use both the saline and the fresh water parts of the reserve for feeding. In addition there is a suitable area for the cranes to roost at Anlung Pring, thus the site, although small in size, covers all the crane's requirements during the non-breeding season.
- As there was no noticeable change in plant composition at the sites of grazing, the concern about buffalo grazing in the reserve is probably not from the direct consumption of the plant biomass but the impact of trampling that disturbed the soil surface. The disturbance of the ground might be beneficial to the cranes as it makes it easier for the cranes to access the tuber of Eleocharis when the ground is still wet.

However, when the ground is exposed, the trampling and the footprints that the buffaloes leave behind will result in more water evaporation, exposure of the potential acidic soils to oxygen leading to oxidation of acidic materials in the soils, and quicker hardening of the soil surface, especially in clay soil areas.

- It was reported that in early January 2013, about 150 cranes used a rice field near the border with Vietnam. It was speculated that this was probably because Anlung Pring was still too wet in January this year, due to a prolonged rainy season that extended well in to November.
- It is not possible now to pinpoint the cause of the death of the 2 cranes whose carcasses were reportedly found in January 2013 in the field. The 2 cranes may have been poisoned when feeding outside the reserve, especially in agriculture field but equally they may also have died of old age. Cranes are known to form life-long pair-bonds, so the 2 cranes might have been a couple of the same age. In the future, if more cranes are found dead then it requires a serious investigation into the causes.
- Toward the end of the dry season/beginning of the wet season when the first rain events occur, soil acidity will be flushed down to low lying areas and remaining water bodies causing high concentration of acidity in the water. The acidic water at this time might cause massive die-off of fish. Water birds tend not to feed on the dead fish but even if they do feed on the dead fish, there should be no problem for the birds. The release of acidity over a large area might cause lack of drinking water for birds if they have no alternative sources.
- Keeping the water gate closed in the dry season is beneficial for the northern part because it maintains fresh water in the pools and the channels and reduces salinity entering the northern part during high tide. However, toward the end of the dry season/beginning of the wet season, there is a dilemma: (i) keeping the gate closed longer into the dry season will prevent concentrated acidity from passing south through the southern channel that might cause massive fish die-off in the southern part of the reserve, but (ii) keeping the gate closed might cause high concentration of acidity in the northern part itself.
- About shrimp farming expansion, at present the extensive low input shrimp farming should not be a problem as they have been doing this since 2002. New excavation, if any, might expose potential acidic soils to the air and activate acidity that can be brought into the reserve with tidal water from the south. When rain comes, if fresh water is released from the north, it can help flushing out the acidity.

2.2. Physical features and plant communities - habitats

Location of observed sites and the reference data obserbed by surveys team of WWT in April 2013 were used for finding natural features in Anplung Pring Sarus Crane Reserve. In addition, useful data of water level reading implemented by WWT in flood season 2012 was used for interpolation of topography features in AnLung Pring (Figure 12).

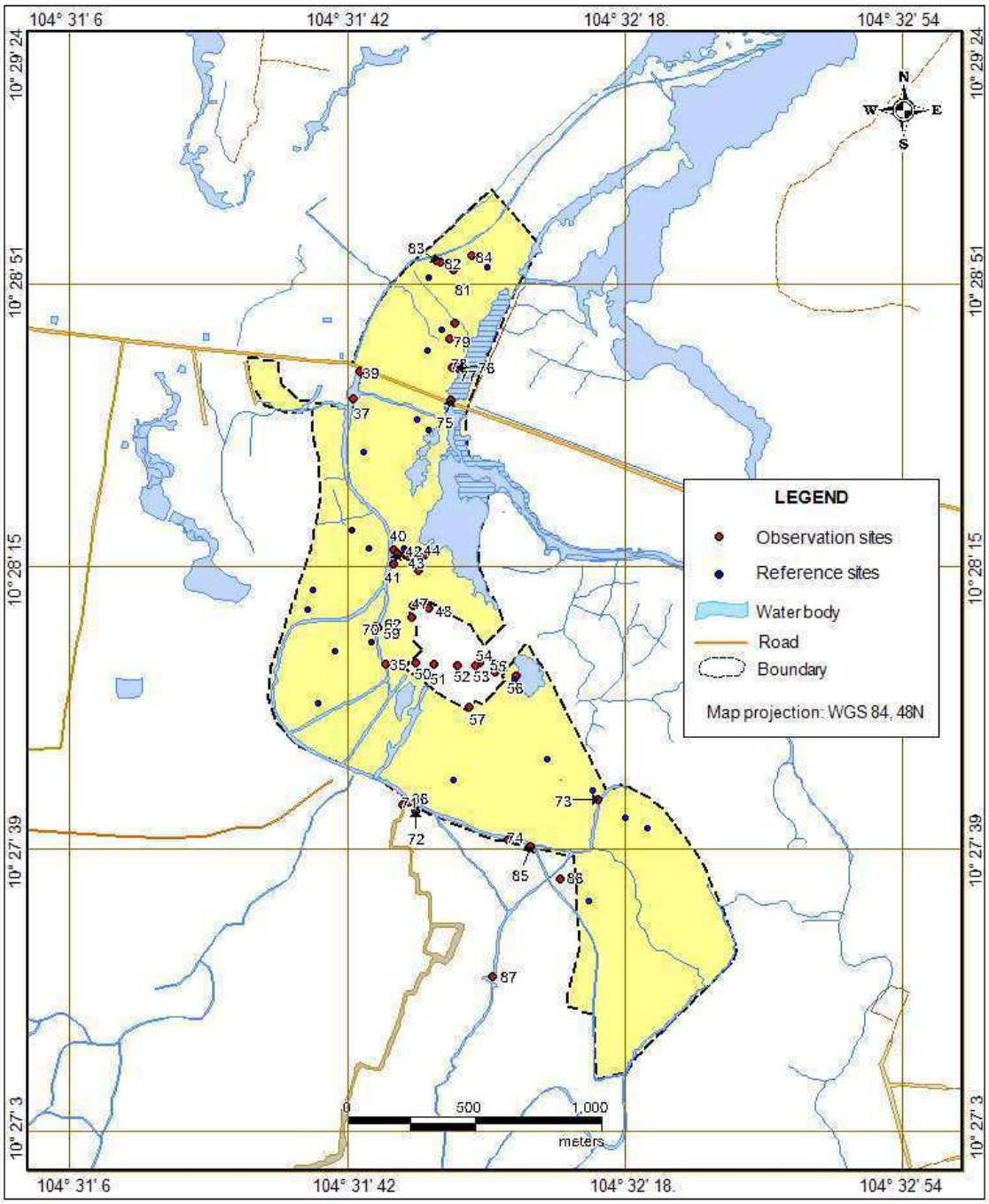


Figure 12. Location of observed sites in Anplung Pring Sarus Crane Reserve, Kampot province. Blue symbols indicated the reference data obserbed by surveys team of WWT in April 2013.

2.2.1. Topography

The topography of the Anlung Pring Crane Reserve is characterized by a combination of the lower young alluvial valley along the channels, from the North to the South of the reserve area, and upland paddy areas surrounding the valleys. Most of young alluvial valley is

extensively flooded in the wet season, but the old alluvial plain only in periods of very high water levels.

Based of topographical map of Kampot provinces (US Army Map Service,1965) and data of season water level reading (WWT, 2012), a topographic map of Anlung Pring was interpolated and showed in Figure 14.

Topography of the older alluvial plain in the ricefields varies from 3 to higher than 5 m, while that of the young alluvial valley is lower, in the range of 1.2 - 2.8 m in height. Due to such a low topography large parts of the young alluvial valley are permanently inundated or under influence of the tidal regime. During the rainy season, due to low-lying terrain over the entire surrounding area the protected areas completely flooded.

Table 3. A range of elevation in Anlung Pring Crane Reserve, Kampot Province

Ord.	Elevation	Area (ha)
1	1.4 - 1.6	0.99
2	1.6 - 1.8	1.67
3	1.8 - 2.0	6.03
4	2.0 - 2.2	12.24
5	2.2 - 2.4	18.93
6	2.4 - 2.6	61.66
7	2.6 - 2.8	93.13
8	2.8 - 3.0	19.63
9	3.0 - 3.2	1.52
10	3.2 - 3.4	0.54
11	3.4 - 3.6	0.12
Total area		**216.46**

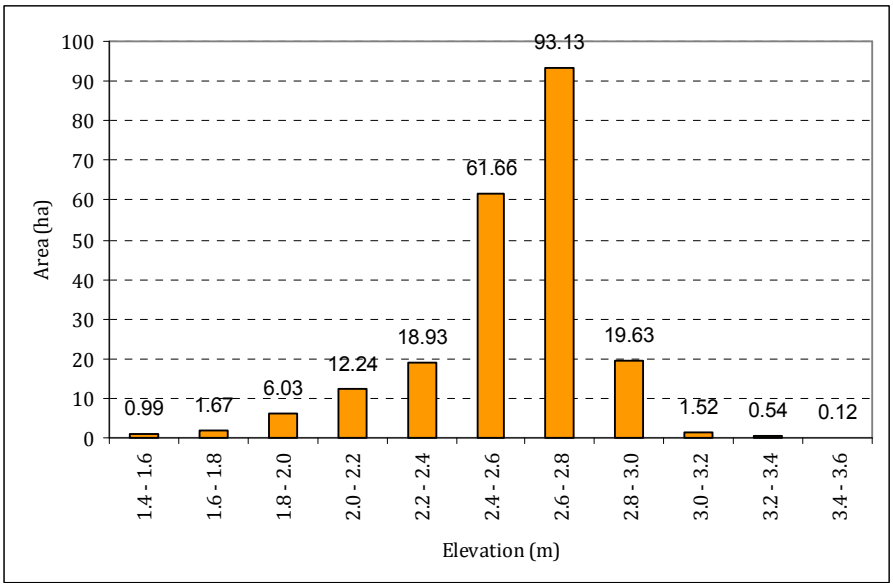


Figure 13. Illustration of elevation distribution in Anlung Pring Crane Reserve, Kampot Province

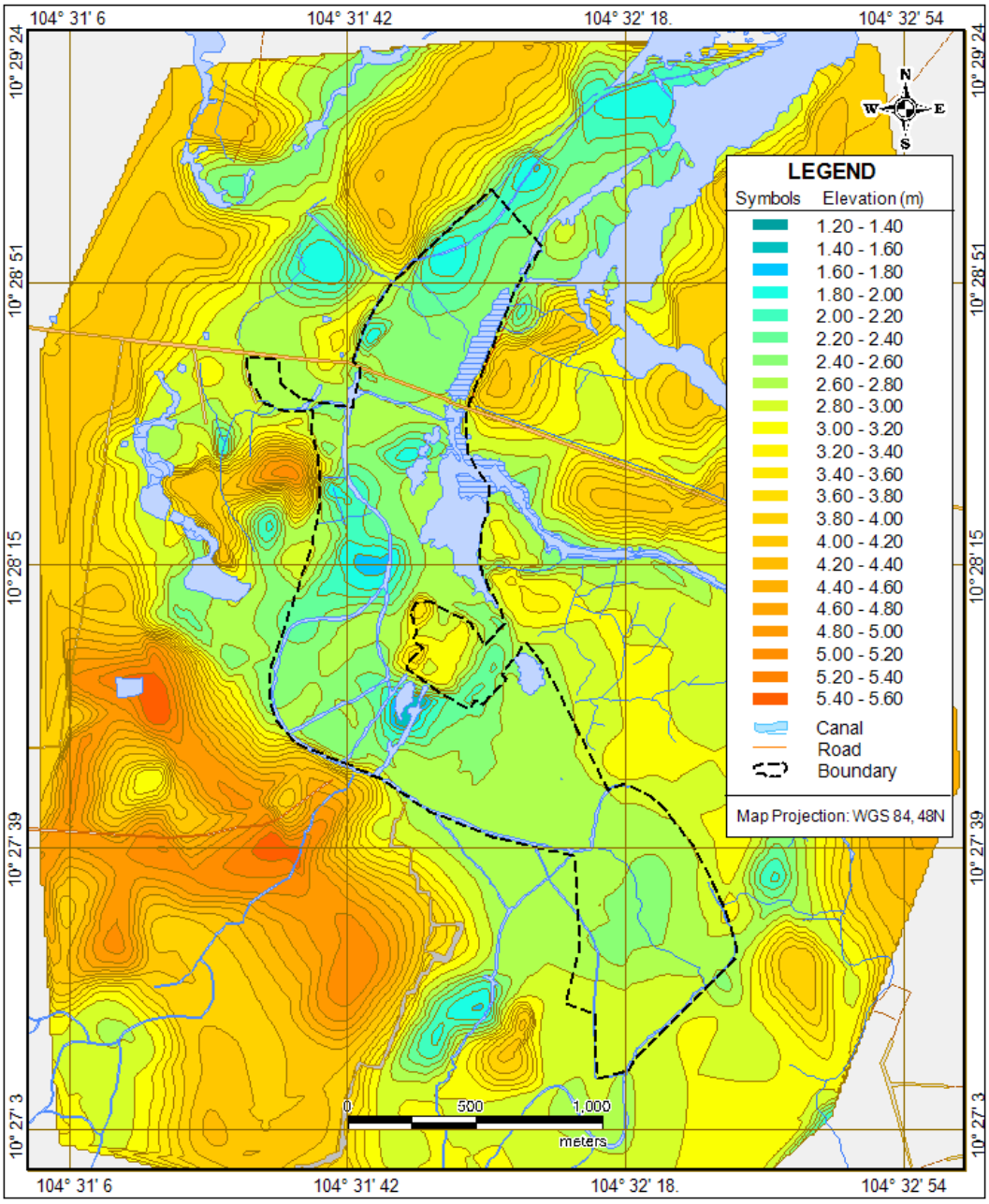


Figure 14. Features of topography in Anlung Pring Crane Reserve, Kampot Province.

2.2.2. Geological features

Geologically, this area was formed by three sediment units: Pleistocene, Late-Pleistocene and Holocene sediments belonging to Quaternary sedimentary rocks and consolidated sediments (VGS, 1991). Based on referenced data and surveys, three sediment units are identified as follows (Figure 15).

- *The Pleistocene* is mainly distributed in the higher terrain in the Anlung Pring area. The grey soils were formed by weathering processes from the Pleistocene sediments,

- *The Late-Pleistocene* is in fact the result of the deposition of material eroded from the higher ground. Much of this sediment is mixed between and along the edge of the Pleistocene sediments. There some older alluvial islands formed from materials of late-Pleistocene appear between the low-lying areas.
- *The Holocene* is a chronostratigraphic period that comes after the Pleistocene. The younger sedimentary material covered in the old sediments. This sedimentary unit is found in the areas of low-lying terrain along the river and canals between the Pleistocene sedimentary areas with higher terrain.

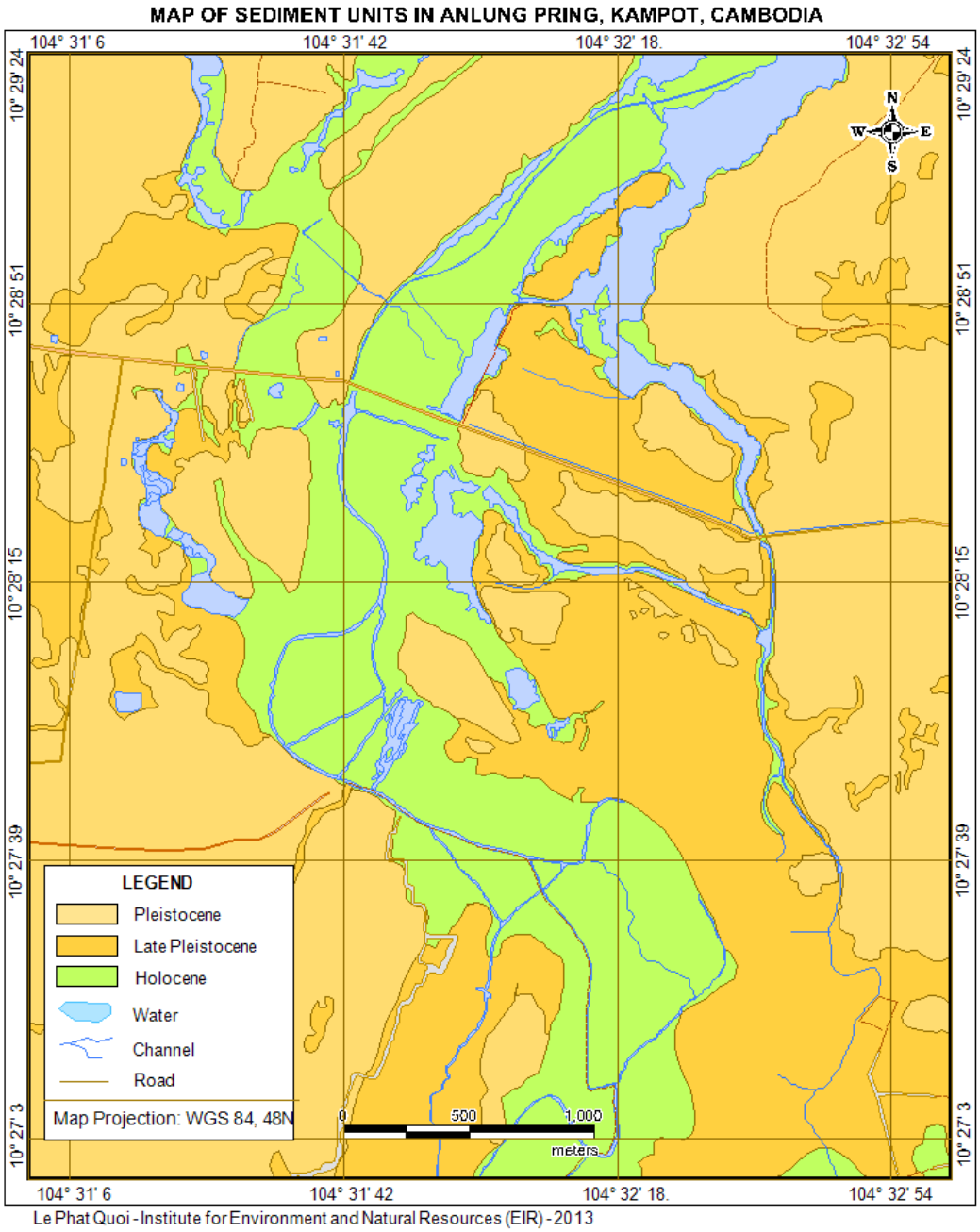


Figure 15 Sediment units in Anlung Pring area, Kampot province

2.2.3. Soil Types

Soil types and their distributions were identified by consulting reference documents (U.S.A.I.D. 1963), satellite image interpretation and soil profiles examined during the field survey. Soils in Anlung Pring are derived from the weathering and erosion of the consolidated materials of old and young sediments.

The research results recorded 8 soils in the area of Anlung Pring and is presented in Figure 17 & 18 and Table 4.

Grey soils (*typic Tropaquults, Umbric Tropaquults and Hydric Tropaquults*) located on higher terrain occupied an area of approximately 25.65 hectares. The soils do not contain pyritic or jarositic minerals and they show a pretty solid ground.

Moderate developed alluvial soils have a sulfuric horizon within 50 – 100 cm from soil surface (*Entic sulfic Tropaquepts*) distributes in the central area of the nothern part, with an area of 16.46 ha. Due to the lowered water tables in the dry season so the pyritic material had to be oxidized to form the acidic alluvial soils.

Slight developed alluvial soils have sulfidic horizon within 50 – 100 cm from soil surface (*Sulfic Tropaquents*) distributes in lower area of the northern part, with an area of 16.76 ha. Due to soil located in lower area, therefore soils are wet throughout the year and pyritic materials have not been oxidized pyrite though its presence within 50 – 100 cm from soil surface.

Hydromorphic alluvial soils have sulfidic horizon within 50 – 100 cm from soil surface (*Sulfic Hydraquents*) distributed mostly in the southern part, with an area of 133.88 ha. Due to influence of flooding or wet throughout the year, therefore soil properties area in underdeveloped state.

A road cuts through protected areas, although there is a water control gate, there is limited water exchange and this could be one of the causes of changes in soil properties in the northern part. During the dry season, a significant amount of water was used for agricultural production and evaporation causing the drier soils. Amount of oxygene penetrated into the soil has resulted in the oxidation of the pyritic mineral (FeS_2) to form Jarositic mineral ($1/3KFe_3(SO)_2(OH)_6$) and acidity increased in the soil and become. Soil riping developed and become harder. Meanwhile, the land in the southern part is influenced by the tide, then most of soils is still wet during the dry season. Therefore, oxidation of pyrite has not been occurred despite its presence observed from 70 cm of soil surface.

In the process of soil formation, Pleistocene and Late-Pleistocene sedimentary units formed Grey soils (Tropaquults/Latosols). Typical greys soils (Typic Tropaquults) were formed in relatively high terrain. Meanwhile the grey soils with humic horison (Umbric Tropaquults) and hydromorphic grey soils (Hydric Tropaquults) occur at lower elevation and are more strongly under influence of the water profile. Alluvial soils or hydromorphic soils were formed from Holocene sediment. Lack of water in the dry season had accelerated the process of soil development.

Two soil profiles were observed in the northern part showed oxidation layer with iron oxides mottles and soil riping obsered within 50 cm of the soil surface. Weak soil structure was identigied and soils become firmer than the soil underneath. Actual acid sulphate soils (Sulfaquepts) recorded were formed from potential acid sulphate soils (Sulfaquents) and

potential acidic alluvial soils that have sulfidic horizon (*sulfic Hydraquents*) through oxidation in the dry season. Jarositic minerals (1/3 $KFe_3(SO)_2(OH)_6$) were identified in soil profiles during surveys (Figure 16), and a sulfidic horizon is still present beneath the sulfuric horizon or within 50-100 cm from the soil surface.

(a) (b)

Figure 16. Features of acid sulphate soils: (a) A sulfuric horizon with jarosite minerals along root channels in acid sulphate soils, and (b) sulfidic horizon with pyrite minerals present beneath the sulfuric horizon or within 50-100 cm from the soil surface (Site 78).

In the southern part, a large area (about 133.88 ha) is alluvial soils with sulfic materials within 50 – 100 cm from the soil surface (*Sulfic Hydraquents*), and potential acid sulphate soils (*Typic Sulfaquents*) are concentrated in low-lying areas and scattered throughout the area (about 19.33 ha). Although pyritic materials are present near the surface, soils are wet from the influence of surface water in most of the year, the pyritic material therefore has not been to be oxidized to form actual acid sulphate soils.

Some terminologies used in the report:

Sulfidic is terminology that mentions to a diagnostic horizon that contains Pyritic mineral (FeS_2) with population must be equal or higher than 18 % in volummne, and thickness of its horizon must be equal or higher than 18 cm. The sulfidic diagnostic horizon is always saturated or wet, therefore there is no oxidation in this horizon. pH value is neutral (pH = 7).

Soils with sulfidic horizon occurs within 50 cm of soil suface classified as *Sulfaquents*. If the sulfidic horizon occurs within 50 – 100 cm, terminology of *sulfic* will be used as prefix of soil great group.

Sulfuric is is terminology that mentions to a diagnostic horizon that contains Jarositic mineral ($1/3KFe_3(SO)_2(OH)_6$), mineral colour is pale yellow (based on Munsell Soil Colour Chart, its colour value is of 5Y8/6). The pH value is equal or less than 3.5. Population of Jarosite mineral must be equal or higher than 18 % in volummne, and thickness of its horizon must be equal or higher than 18 cm.

Soils with Sufuric horizon occurs within 50 cm of soil suface classified as *Sulfaquepts*. If the Sulfurc horizon occurs within 50 – 100 cm, terminology of *Sulfic* will be used as prefix of soil great group.

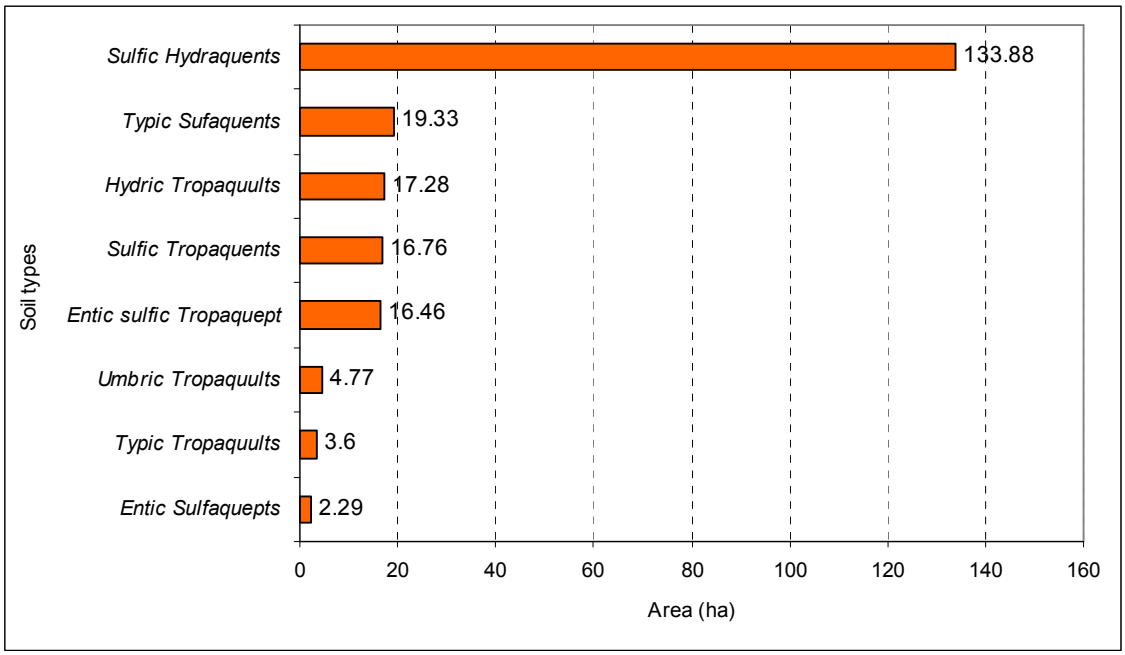


Figure 17. Inlustration of the distribution of soil types in AnLung Pring Crane Reserve in which the alluvial soils with sulfidic horizon occupied the largest area

Table 4. Soil types in Anlung Pring Crane Reserve

	Soil types		Area
	USDA/Soil Taxonomy	**English**	(ha)
1	Typic Tropaquults	Typical grey soils	3.6
2	Umbric Tropaquults	Grey soils with humic epipedon	4.77
3	Hydric Tropaquults	Hydromirphic grey soils	17.28
4	Entic sulfic Tropaquept	Moderate developed alluvial soils with sulfuric horizon	16.46
5	Sulfic Tropaquents	Slight developed alluvial soils with sulfidic horizon	16.76
6	Sulfic Hydraquents	Hydromorphic alluvial soils with sulfidic horizon	133.88
7	Entic Sulfaquepts	Actual acid sulphate soils	2.29
8	Typic Sulfaquents	Potential acid sulphate soils	19.33
		Others	2.13
		Total area	**216.50**

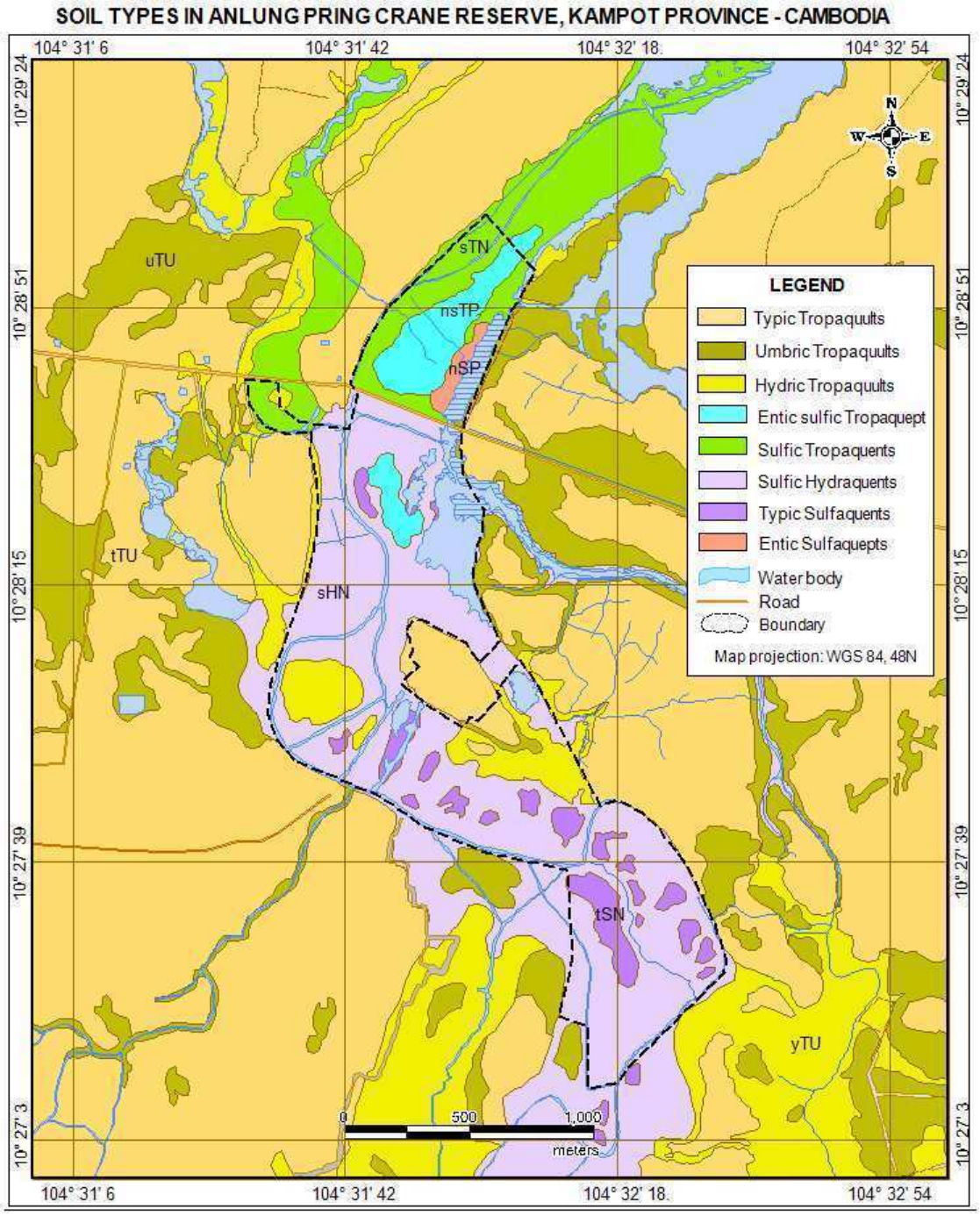


Figure 18. Soil types distribution in Anlung Pring, Kampot Province

2.2.4. Water quality

The Anlung Pring Natural Reserve is located near the western sea of the Gulf of Thailand; this area therefore is affected by saltwater intrusion in the dry season.

Although the natural reserve is a small area, the water quality was variable due to the hydrological management system. A road and sluice gate has been built and the protected area itself divided into two areas: northern and southern parts.

Survey results showed there is significant differences of ground water tables in the northern and southern parts. Average ground water tables in the northern area ranged from 40 - 57 cm of the soil surface, and the presence of iron oxides mottles (geothite) in the soil profile showed lower water tables at the end of the dry season in northern part, while most of the soils in the southern part is still covered by water though only a thin layer of water.

Test results shows surface water in northern part (the north area of the sluice) is more acidic (pH = 3.67 – 5.65), whereas water quality in downstream area was affected by saltwater (pH = 4.71 – 7.10), although the salt concentration was not very high (Table 5). Results of water quality measurements inside and outside of sluice showed a significant difference. The pH value inside of the sluice is of 3.67, while pH value is of 4.71 at the southern part of sluice (at site 75). The area adjacent to the southern boundary of the proteted area, which influenced by brackish water, showed a high pH value (pH = 6.96 – 7.10).

Dissolved oxygen content of surface water in the downstream area is suitable for wild fisheries (4.16 – 5.59 mg/l). Whereas those of surface water in the northern part tends to lower (1.43 – 3.93 mg/l). The decline in dissolved oxygen in the water affects many physiological mechanisms and behavior of fish.

Fish resources is not only food source for the local community, but also as a food source for waterfowl. Reduction of natural fishery may result in a decrease in the population of water birds in this area.

Table 5. Water quality in Anlung Pring Crane Resrve

Site	Water quality					
	pH	Eh	EC	Salt	DO	TDS
		pHmV	mS/cm	%	mg/l	%
Southern						
39	6.19	-8.0	47.0	3.05	4.95	28.6
42	4.84	72	49.4	3.42	5.42	30.2
56	5.54	30	35.3	2.22	5.05	21.5
71	7.10	-54	38.0	2.40	5.59	23.2
73	6.96	-54	40.1	2.55	4.16	24.4
75a	4,71	295	48.8	3.19	4.63	29.8
Northern						
75b	3.67	140	45.9	2.97	2.10	28.0
79	5.65	23	4.24	0.22	3.93	2.70
83	5.60	26	1.34	0.07	1.43	0.85

2.2.5. Vegetation and habitats

2.2.5.1. Species

The short survey recorded 22 species, belonging to 12 families present in the Anlung Pring Crane Reserve and surrounding areas (Table 6).

Most of the reserve is covered by *Eleocharis sp*. grasslands with the following species of Eleocharis in order of abundance: *E. spiralis, E. dulcis, E. philippinensis, E. parvula. Eleocharis attropurpura* found but only individuals in scattered distribution therefore this species does not form the typical plant communities.

E. spiralis and *E. dulcis* distributed in whole wetlands area, whereas *E. philippines* was only found in southern part of the protected area where has still affected by saline intrusion in the dry season. The absence of *E. philippinensis* in the northern part is probably due to the impact of natural environmental change. *E. parvula* was only found in the drier areas of acidic grey soil slopes.

Cynodon dactylon appeared in a wide range of the protected areas, especially in wet areas. It can be found in single species stands or mixed with other plants.

The southern part, being tidal, has plant species considered as indicators of a brackish environment such as *Acanthus ilicifolius, Acrostichum aureum, Sonneratia caseolaris, Nypa fruticants, Fimbristylis sericea*.

Table 6. Main plant species recored in Anlung Pring

No	Family	No.	Species
1	Poacea	1	*Cynodon dactylon* (L.) Pers.
		2	*Eragrostis atrovirens* (Desv.) Trin ex Steud.
2	Cyperaceae	3	*Fimbristylis microcarya* F.v. Mueller
		4	*Fimbristylis miliacea* (L.) Vahl
		5	*Scirpus maritimus* L.
		6	*Fimbristylis sericea* (Poir.) R. Br.
		7	*Eleocharis* spiralis (Rottb.) Roem. & Schult.
		8	*Eleocharis dulcis* (Burm.f.) Trin
		9	*Eleocharis philippinensis*
		10	*Eleocharis parvula* (R. & Sch.) Link ex Pl. :
3	Xyridaceae	11	*Xyris indica* L.
4	Commelibaceae	12	*Commelina benghalensis* L.
5	Convolvulaceae	13	*Ipomoea aquatica* Forssk.
6	Nympheaceae	14	*Nymphaea nouchali* Burm. f.
		15	*Nymphoides indica* (L.) O.Ktze
7	Ceratophyllaceae	16	*Ceratophyllum demersum* L.
8	Acanthaceae	17	*Acanthus ilicifolius* L
9	Pteridaceae	18	*Acrostichum aureum* Linn.
10	Sonneratiaceae (Lythraceae)	19	*Sonneratia caseolaris* (L.) Engl.
11	Arecaceae	20	*Nypa fruticants* Wurm.
12	Myrtaceae	21	*Melaleuca leucadendra* L.
		22	*Melaleuca cajuputi* Powell

2.2.5.2. Habitats

Five units of wetland habitat are recognized: Melaleuca scrub, riverine scrub, seasonally inundated grassland, open water with aquatic plants, and bare land.

Association of species of vegetation forms communities in wetlands. From the results and interpretation of satellite imagery survey, 13 communities of seasonally inundated grassland and two forest communities in the region are divided Anlung Pring (Table 7 and Figure 19 & 20).

Table 7. Plant communities in Anlung Pring Crane Reserve

	Plant communities	**Area (ha)**
	Seasonally Inundated Grass	
1	*Eleocharis spiralis*	23.92
2	*Eleocharis sparilis - Eleocharis dulcis*	17.04
3	*Eleocharis spiralis - Cynodon dactylon*	17.9
4	*Eleocharis spiralis - Cynodon dactylon - Eleocharis philippinesis*	4.28
5	*Eleocharis dulcis - Eleocharis spiralis*	37.58
6	*Eleocharis dulcis - Cyperus sp.- Cynodon dactylon*	1.19
7	*Eleocharis dulcis - Water lily*	2.96
8	*Eleocharis dulcis - Cynodon dactylon*	8.64
9	*Eleocharis philippinesis*	52.13
10	*Eleocharis philippinesis - Cynodon dactylon*	9.5
11	*Cynodon dactylon*	5.29
12	*Cyperus sp.*	1.22
13	*Cyperus sp - Fimristylis sp*	0.32
	Melaleuca Scrub	
14	Dense Melaleuca	8.29
15	Thin Melaleuca	0.54
	Other habitats	
16	Riverine scrub	2.51
17	Water body	22.54
18	Bare land	1.22
	Total area (ha)	**217.07**

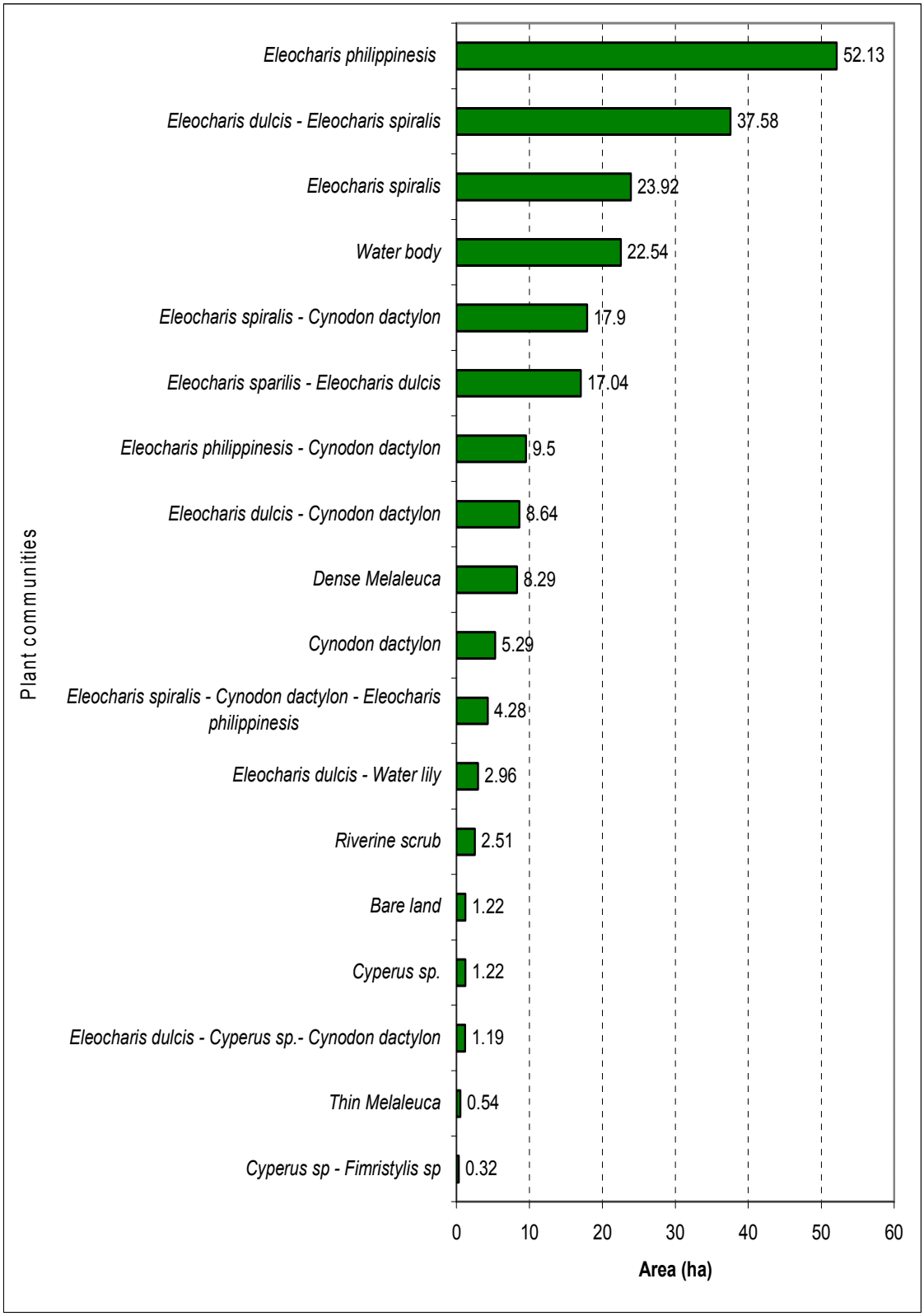


Figure 19. Illustration of plant communities in which Eleochris ducis - E. spiralis is dominant in Anlung Pring Crane Reserve

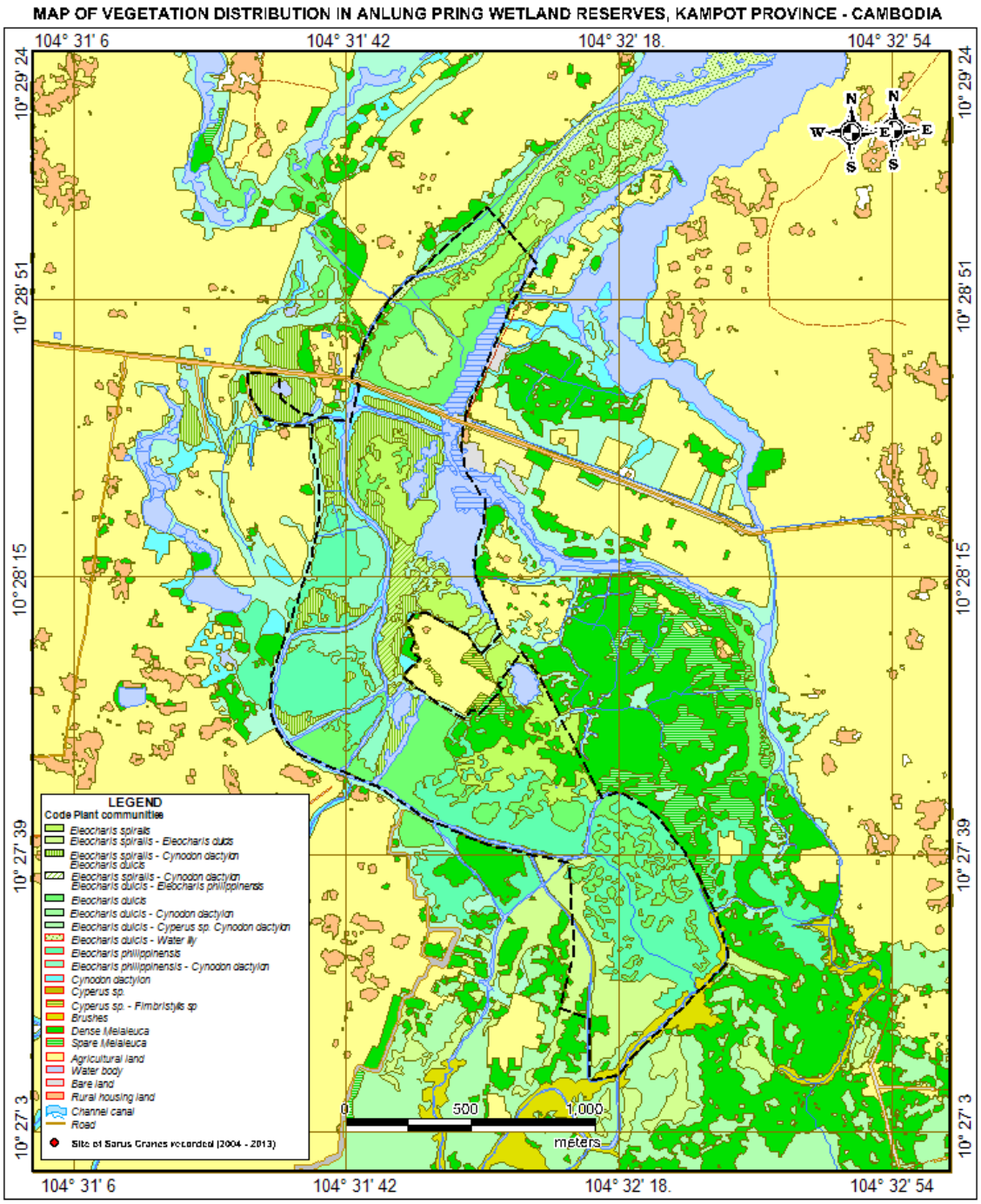


Figure 20. Plant communities in Anlung Pring Crane Reserve, Kampot province

2.2.5.2.1. Melaleuca Scrub

Based on the shape of the Melaleuca trees and the leaves, they can be classified into two species. Melaeuca species with low shape (less than 2 m in height) and many irregular branches is classified as *Melaleuca leucadendron*. This species is found in serve actual acid sulphate soils along the Vietnam - Cambodia border. Although Blake (1968) stated that *M. leucadendron* only appeared in Australia, New Guinea and Molluca, however this species

was recorded in the wetlands of Cambodia by Wilkie and Fortuna (2003) and Schmidt and Thuy (2004). The leaves have a very aromatic odour and essential oil (Tea Tree oil) is distilled from the fresh leaves for medical use.

The other species, *Melaleuca cajuputi* is are common in wetlands, particularly in acid sulphate soils of the Mekong Delta. In Anlung Pring, the species is distributed predominantly in surrounding area of Anlung Pring Crane Reserve. The stems are used in construction and for firewood.

In Anlung Pring both species can be found mixed together in stands consisting almost exclusively of Melaleuca.

Figure 21. Melaleuca habitat with inset photo of the leaves and flower of *M. leucadendron*

2.2.5.2.2. Seasonally inundated grassland communities

Although many species of grass are recognized, *Eleocharis sp.* (*Cyperaceae*) are predominate in the protected area. *Eleocharis sp.* are distributed along the valley where soils are mainly classified as acid sulphate soils (*Entic Sulfaquepts, Typic Sulfaquents*) and acidic alluvial soils (*Sulfic Tropaquents, Entic sulfic Tropaquept, Sulfic Hydraquents*). *Eleocharis sp*. are present as stands of single species or as multi-species communities.

Eleocharis spiralis is common in the area influenced by brackish water and its community distributed mostly in both parts of the conservation area. A single species stand of *E. spiralis*, of 23.92 ha, was found only in the northern part, while communities where *E. spiralis* is dominant have a fairly wide distribution, up to 39.22 ha in total. *Eleocharis spiralis* dominant

communities are: *E. spiralis - Cynodon dactylon, E. spiralis – E. dulcis, E. spiralis - Cynodon dactylon – E. philippinesis* (Table 7). Although the northern part has been blocked by the sluice in few years ago, the soil may srill be affected by salt water in the past.

Eleocharis dulcis is mainly distributed in relatively low-lying areas, especially within Anlung Pring(*E. dulcis* and plant communities wherein it is dominant cover 67.41 ha of AP). *Eleocharis dulcis* communities were identified as: *E. dulcis – E. spiralis, E. dulcis - Cynodon dactylon, E. dulcis - Water lily, E. dulcis - Cyperus sp.- Cynodon dactylon, ,*.

Mono-dominant stands of *Eleocharis dulcis* are found in depressions and along the channels, and *E. dulcis* dominant communities are distributed throughout Anlung Pring. *Eleocharis dulcis - Cynodon dactylon* communities are found along the canal and where the terrain is low and in wet condition.

(a) (b)

Figure 22. Eleocharis grass in acid sulphate soils: (a) *Eleocharis spiralis* and (b) *Eleocharsis dulcis* communities in Anlung Pring Cranes Reserve (Photos taken in March, 2013)

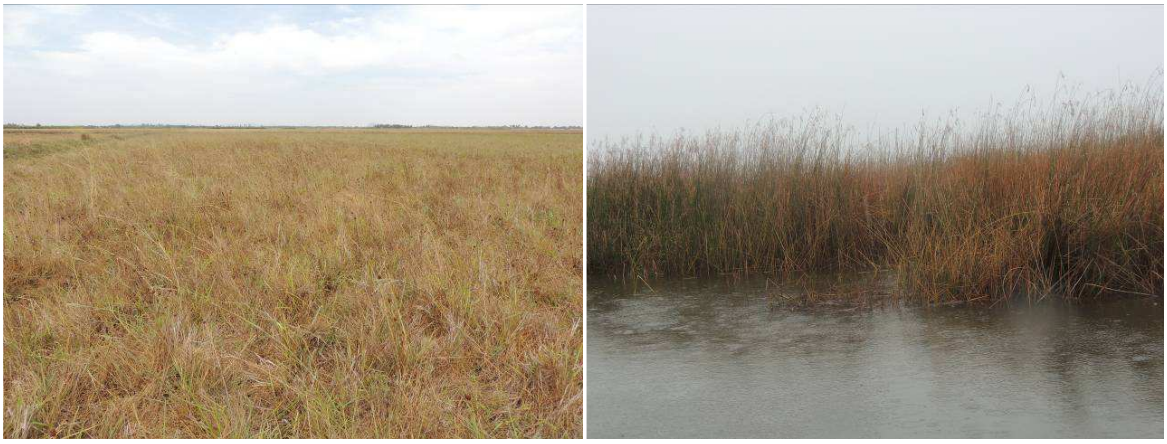
Eleocharis philippinensis, with 4-5 angular spikelets, was found in the southern sector of Anlung Pring, with a total area of about 61.63 ha. This species is mostly found in association with *Cynodon dactylon* (see Figure). According to the data collected by survey team of Phnom Penh University (March, 2013), this species was only found in the southern part but that was not found in the northern part of Anlung Pring.

Figure 23. *Eleocharis philippinensis* community

Cynodon dactylon was found to be widespread in association with other plants in Anlung Pring. The total area of monodominant stands of *Cynodon dactylon* is only of 5.08 ha. With *E. dulcis*, this species of grass is considered as one of the food sources for water buffalo.

Figure 24. *Cynodon dactylon* in Anlung Pring.

Other non-Eleocharis dominated plant communities are limited to small areas of Anlung Pring. *Fimbristylis umbellatus* associated with *Cyperus difformis* was found on slopes of grey soils among the acid sulphate soils, whereas *Cyperus malaccensis* was found in muddy habitat forming a thin band along channels in Anlung Pring. Other species found distributed along channels are *Lepironia articulate* and *Scirpus littoralis (*Bullrush)



(a) (b)

Figure 25. (a) *Fimbristylis umbellatus* - *Cyperus difformis* community on slope of grey soils, and (b) *Scirpus littoralis* along river channel.

2.2.6. Vegetation and Sarus Crane

There is a close relationship between the Sarus Cranes (*Sarus antigone*) and the seasonally inundated grassland habitat of Anlung Pring.

A suitable habitat for Sarus Crane has been depending on food availability. Therefore a wide variety of habitat types depending on food availability, cropping patterns, and other seasonal factors. Their optimal habitat includes a combination of marshes, ponds, fallow lands, and cultivated lands (Meine et al., 1996), and their optimal habitat includes a combination of marshes, ponds, fallow lands, and cultivated lands (Gole, 1991). Therefore, the diet includes aquatic plants, invertebrates, and grains.

Based on the monitoring data of the Sarus Crane (WWT, 2013) recorded the population and spatial distribution of Sarus Cranes within various habitats, but mostly in *Eleocharis* grasslands of the Anlung Pring (Figure 26).

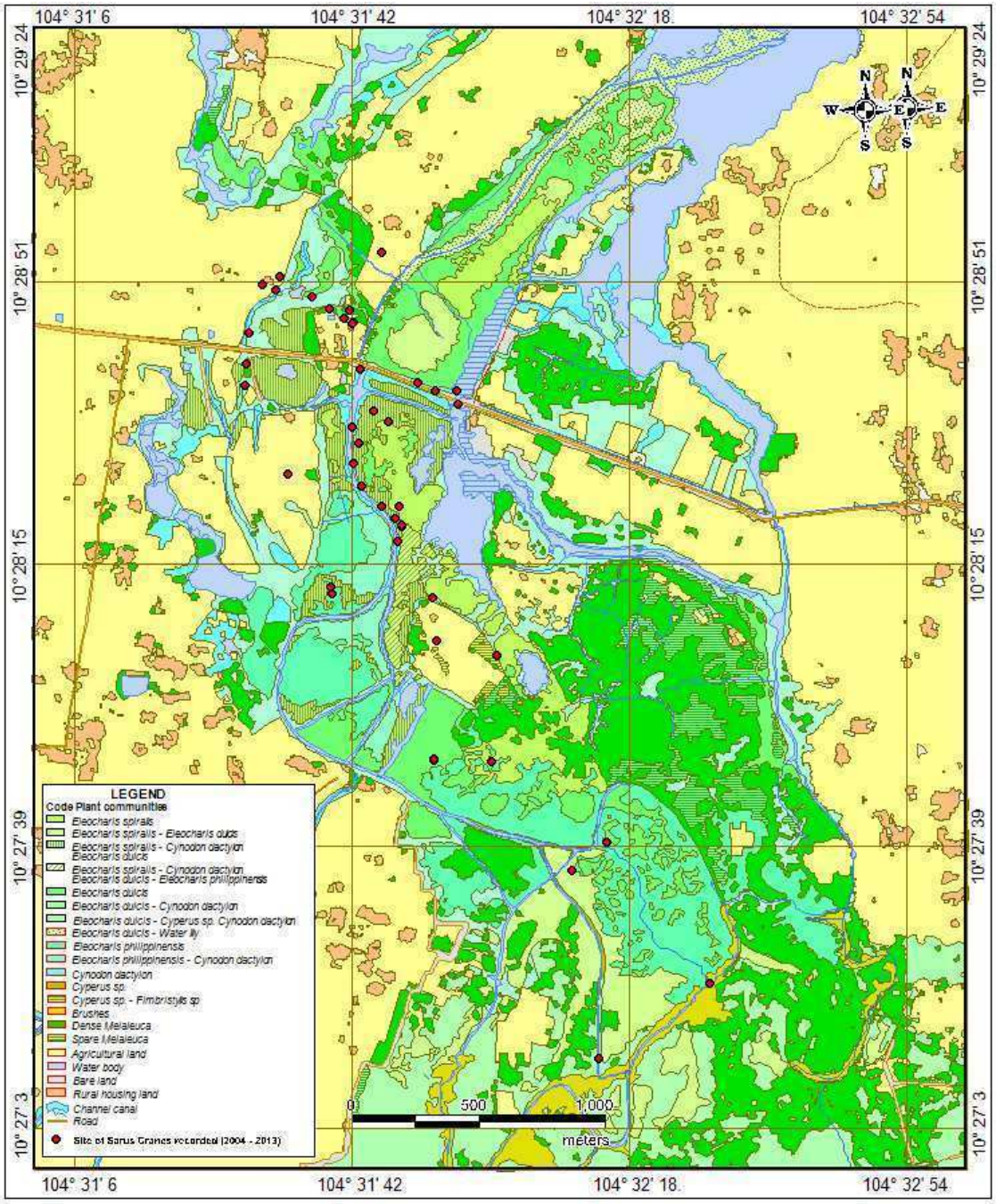


Figure 26. Locations of Sarus Crane appeared in grasslands of Anlung Pring Wetlands have been recorded for the period of 2004 to 2013.

In Vietnam, environmentalists referred to tubers of *Eleochris attropurpurea* as the main food of the Sarus Crane on the wetlands during the dry season. The appropriate water management implemented is aiming to restore certain areas of *Elecharis attropurpurea* to create a habitat for cranes in Tram Chim National Park, Vietnam.. However, Pradip. (2006) stated Sarus Crane focused their foraging on underground tubers of native wetland vegetation such as *Eleocharis spp*.

Some individuals of *Eleocharis atropurpurea* (purple spike-rush) was indentified, its community however was not found in Anlung Pring.

According to scientists in Cambodia, tubers of *Eleocharis spiralis* is considered as one of sources of food for Sarus Crane. However, a study in the Doctor thesis of David Jonathan Rosen (2006) recorded the absence of tubers *of E. spiralis* though it has a long thick rhizomes (2-3 mm thick, scales to 7 mm long

Although there is no document mentioned Sarus Crane used *E. dulcis'* tubers as their food, however the tubers of *E. dulcis* is found with traces of the Sarus Crane foraging (Figure 27). Similarly, an field observation in Tram Chim National Park showed the Sarus Crane foraging in the area of Eleocharis dulcis (Quoi, 2011). Therefore the area of *E. dulcis* communities should be considered as one of important habitats for Sarus Crane in Anlung Pring Crane Reserve.

(a) (b) ©

Figure 27. (a) *Eleocharis dulcis* and (b) its tubes that could be used as food for Sarus Crane. (c) trace of a hole that Sarus Cranes finding the underground E. dulcis' tubers. Photo taken at Anlung Pring. March 2013.

As searching for feeding, Sarus Crane does not dig, but it probes the soil with its long bill. The soil therefore is too dry will results difficulty for them foraging the underground tubers. Soil surveys showed that although the water control system in the northern part of Anlung Pring, a part of Eleocharis grassland was too dry due to the deep water tables (of 64 – 80 cm from the soil surface). In addition, grassland communities are a major food source for water buffalo in this area. However, the frequent movement of them for grazing in the Eleocharis grassland has led to the soil compaction, particularly in heavy clay soils. In such case, soil characteristics will become firmer when dry and not easy for Sarus Crane using their bill to access the underground food.

3. Conclusion and Recommendation

3.1. Hydrological management

That the number of cranes using the habitats in Anlung Pring has kept increasing since 2002 shows that the habitats at the site are functioning well so far.

Therefore, the overall recommendation for the site is that there should be no major habitat interventions at the site. In other words, apply the principle that "*if it's not broken, don't fix it*" to avoid the risk of committing mistakes. Especially, no excavation or construction of any water regulation infrastructures should be done unless it is convincingly necessary to do so.

Other recommendations include:

1. The water gate on Koh Treak road should be kept closed in the dry season. The solution to the acidity dilemma as discussed above might be: if highly concentrated acidity is found in the water in the northern part, the gate should only be opened during high tide so that acidity can be diluted in the south or when there is more fresh water coming from upstream to dilute acidity in the northern part. The impact of the gate operation on fish in the north and the south parts of the reserve should be monitored and adjusted accordingly.
2. To minimize oxidation of soils in the north sector it could be experimented to close the sluice gate earlier (before the flood period is completely ended) to store more water in the dry season. This will need discussion with the water group to see if there are any conflicting interests.
3. Impact of grazing is currently not known. While it is not possible or socially acceptable to ban all grazing, grazing should not increase until impacts are better understood.
4. In the future if shrimp farming in the south changes to intensive farming. There are 2 things that can be done:
    a) In the short and medium term, the profile of the reserve and awareness of the importance of crane protection should be raised so that the government can help to intervene if impacts from shrimp farms are found to be significant in the future.
    b) Even if the south of the south part is polluted, not all is lost. Another dyke similar to the current Koh Treak dyke can be created at the southern boundaries of the reserve to "freshenize" the southern part similar to the current northern part. This option is only a last resort as it will likely lead to a significant deterioration in habitat quality and abundance of food (as it is apparent that the cranes currently prefer feeding in the southern "tidal" sector of the reserve).
5. To avoid pollution coming from upstream, work with local people upstream of Anlung Pring to not practice intensive and chemical-dependent agriculture in the floodplain and provide them with alternatives.

6. Allow for a diversity of habitat, including staging habitats to ensure the cranes have access to habitat in early, middle, and late dry seasons:

    i) The habitat, land use, and land tenure at Koh Ta Yoy where a large population of cranes reportedly used in early the dry season should be explored. If the land is is cultivated and privately owned, which is very likely, arrangement options such as compensation for crop damage by cranes, tourism fees collected from crane watchers, and other incentives for the land owners should be explored with the land owners so that cranes can safely use the habitat as a staging habitat when needed.

    j) The current natural variation in elevation within the reserve is beneficial for the cranes. That the higher parts are exposed earlier while the lower parts become exposed later in the dry season provides the cranes with diverse staging habitats at the site. Levelling the ground should be totally avoided.

    k) The open high ground in the southern part of the reserve currently used by cranes as a roosting area should be left open as such. No trees should be planted in the roosting area as the Sarus cranes are known not to roost in trees.

7. Trial replacing the Eleocharis sp. in the most southern part of the reserve with E. spiralis and E. dulchis

8. Currently, data about the site are lacking thus there is a need for a mornitoring program to document field conditions to help gaining insights into the ecological processes of the site. It is recommended that a monitoring program is designed and implemented to answer the following key questions:

Monitoring questions	Recommended action
Water 1. What are the correlations between the water level readings at the staff gauges and water levels in the field?	1.1 concurrently measure inundation at places in the field representing different elevations and obtain readings at the staff gauges to establish the correlations. 1.2 install a system of piezometers (using small PVC pipes) to monitor ground water levels during the dry season.
Habitat use 2. How many cranes use which locations for how long and when and what are the field conditions there (level of inudnation, soil moistrue, status of vegetation, tuber productivity, etc.,)?	2.1 conduct field checks every 2 weeks from first week of November to last week of June annually; document the numbers of cranes, locations of their feeding, field conditions at the times at the feeding locations including inundation depth or soil moisture and ground water level; status of vegetation and tuber production; etc.,.) 2.2 establish permanent photopoints at key locations representing different feeding areas of the cranes over time during the dry season and take photographs of the habitats from the same angles at times of field checks in 2.1 above.

Fish 3. Does fish die-off occur at the end of the dry season/begining of the wet season? What kind of fish die? How are the water quality paramters (acidity, salinity, DO) at the time?	3.1 at the time of field checks every 2 weeks, check if fish die. If yes, document the time, species of fish that die, estimated amount of dead fish, locations, water quality, weather conditions, source of water inputs to the reserve and possible sources of pollution or acidity.
Grazing 4. What is the impact of grazing on crane use of the reserve	4.1 at the times of field check every 2 weeks, observe if the buffaloes disturb the cranes, if cranes can use the churned grounds left behind by the buffaloes and for how long; note the vegetation and soil conditions at the grazing areas; and compare crane uses of the areas grazed by the buffaloes and areas not grazed by the buffaloes.
Managemnet issues 5. What are the issues that need addressing?	5.1 produce rapid biweekly field reports and annual reports at the end of dry seasons documenting and analyzing information recorded in 2.1 above. 5.2 discuss issues that need addressing and possible measures.

9. To promote science-based management at Anlung Pring, it is recommended that:

    a) an Advisory Body comprising of experienced wetland scientists and practictioners should be established to provide technical advice for the management of habitat at the site.

    b) a technical person should be posted at the site to carry out the monitoring program. The technical person should produce a rapid field report every 2 weeks and an annual report the end of the dry season based on the monitoring results and other direct observations of the field conditions of the site.

    c) research should be carried out on crane feeding to find out the composition of their feed, productivity of tubers of Eleocharis and diversity of soil insects in the southern and the northern parts of the reserve.

3.2. Vegetation and habitats

Although only a relatively small area compared with other natural protected areas the plant communities play an important role in the habitat of the wetlands. The vegetation in Anlung Pring has been covered by seasonally inundated grasslands where species of grasses is predominantly Eleocharis communities of which is considered one of the food sources of Sarus Crane.

Water quality is affected by salinity in the southern part and lack of freshwater reservoirs in the northern part during the dry season and can be difficult to source of drinking water for

Sarus Crane. Thus, a swamp in the northern part for water storage, though artificial, will be useful for creating a healthy habitat for not only Sarus Crane but also for water birds in the dry season.

The hydrological management has not been concerned and invested resulting in grasslands in the northern part became too dry and unsuitable for for Sarus Crane's feeding. Therefore, a suitable hydrology management plan is very necessary to be done and invested to implement conservation of seasonally inundated grassland and water birds, particularly Sarus Crane in Anlung Pring.

PART 2

BOEUNG PREK LAPOUV CRANE RESERVE

A RAPID HYDROLOGIC AND VEGETATION INVESTIGATION

1. General information

Boeung Prek Lapouv is an IBA. The website of BirdLife International provides the following description of the site:

"The IBA comprises an area of seasonally inundated grassland in the floodplain of the Bassac River, which forms part of one of the largest areas of contiguous natural habitat remaining in the Mekong Delta. To the south and east, this area borders Vietnam, where the natural habitat has been almost entirely converted to agriculture. The IBA is inundated for 3 to 4 months each year, during which time a mat of floating vegetation, comprising around 30 aquatic plant species, forms. During the dry season, from December until May, the IBA supports a non-breeding population of Sarus Crane Grus antigone. After Ang Tropeang Thmor (KH001), this is the largest non-breeding population of this species known in Cambodia. The IBA also supports a number of other globally threatened and near-threatened bird species, most notably Bengal Florican Houbaropsis benghalensis. During 2002, the establishment of a Sarus Crane Conservation Area at the IBA was proposed by Department of Forestry and Wildlife"

Location	Cambodia, Takeo
Central coordinates	105° 2.00' East 10° 43.00' North
IBA criteria	A1, A3, A4i
Area	9,276 ha
Altitude	4 - 5m
Year of IBA assessment	2003

Source: Birdlife Data Zone. http://www.birdlife.org/datazone/sitefactsheet.php?id=16690

The following Google image shows the general location of Boeung Prek Lapouv.

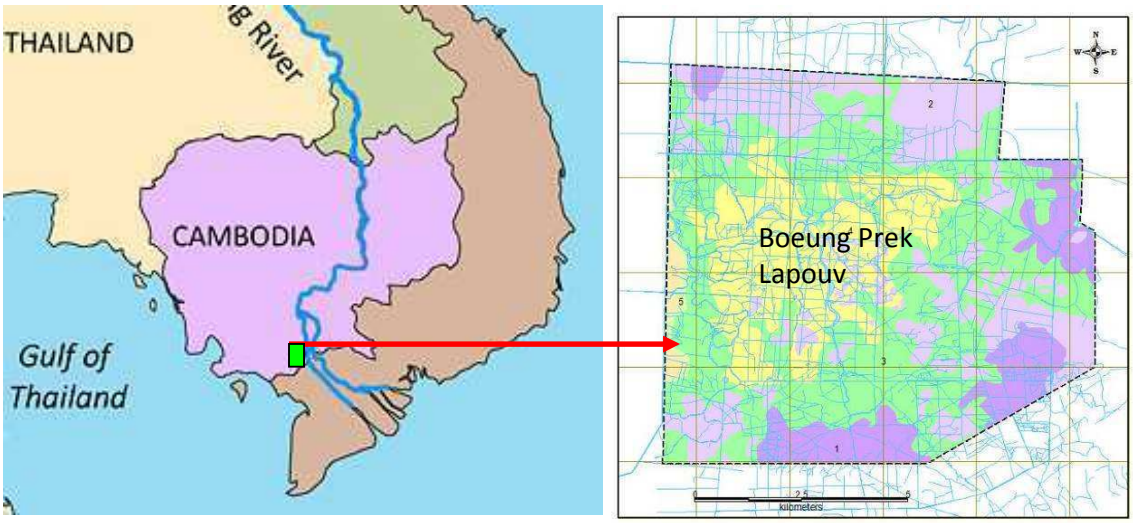


Figure 1: Location of Boeung Prek Lapouv

2. Findings

2.1. Hydrology

2.1.1. Catchment features

The site, essentially a flat area located in Southern Takeo province, is part of the floodplain west of the Bassac River, a branch of the Mekong River. The hydrology of the floodplain and the site is subject to the influence of the hydrology and hydrodynamics of the Mekong River which is characterized by pronounced seasonal variations in flows. In the lower section of the Mekong, water rises in late May with the onset of the rainy season and transforms the large flood plain region into a sheet of muddy water. As water level keeps rising, it peaks in September or October then recedes rapidly until December and then gradually until it reaches the lowest level in April and May. In this system, the Tonle Sap acts as a natural flood retention that absorbs flood water in the flood season and adds to the main channel flow during the dry season.

The graphs bellows shows the hydrographs of the Mekong River at Kampong Cham, in the lower part of the basin.

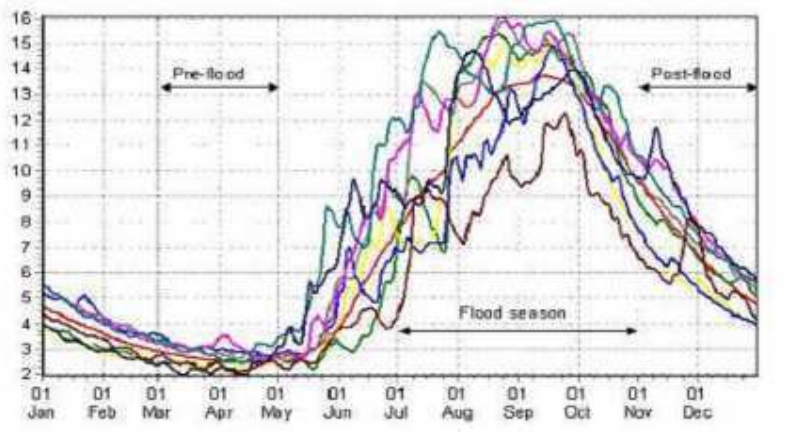


Figure 2: Mekong Flood hydrographs at Kampong Cham (1998 to 2005) (on the vertical axis peak discharges in 1000m3/s)[3]

The graphs below show the average daily discharge of the Mekong for the period 1924-2003.

[3] MRC Flood Management and Mitigation Programme, Component 2: Structural Measures and Flood Proofing Delft Cluster-WWF-MRC 'Roads and Floods' project.

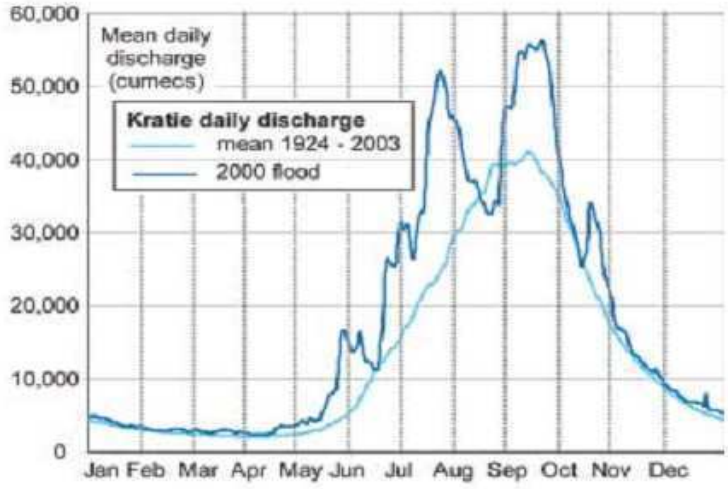


Figure 3: mean daily discharges of the Mekong for the period 1924-2003 and the 2000 flood hydrograph recorded at Kratie[4]

During the flood season as the water in the mainstream rises, the immense flood plain expands as it receives water from the Bassac River and shrinks back again as the water levels recedes in the mainstream.

Within the Mekong Basin, according to MRC[5], Kratie is generally regarded as the point in the Mekong system where the hydrology and hydrodynamics of the river change significantly. Upstream from this point, the river generally flows within a clearly identifiable mainstream channel. In all but the most extreme flood years, this channel contains the full discharge with only local over-bank natural storage. Downstream from Kratie, seasonal floodplain storage dominates the annual regime and there is significant movement of water between channels over flooded areas, the seasonal refilling of the Great Lake and the flow reversal in the Tonle Sap. There is extreme hydrodynamic complexity in both time and space and it becomes impossible to measure channel discharge. Water levels, not flow rates and volumes, determine the movement of water across the landscape. Even in a year when mainstream flows were among the lowest recorded in recent times (1998), the flooded area is vast, amounting to almost 26,000 km2. This figure rose to 45,000 km2 during 2000 when some of the worst flood conditions recorded caused over 800 deaths in Cambodia and Viet Nam. Nonetheless, the floods are essential to the environmental, social and economic fabric of this region, which supports in excess of 25 million people.

The satellite image below shows the extent of flooding in 2009 (an average year) in the Tonle Sap-Mekong Delta area.

[4]Source: http://www.mekonginfo.org/assets/midocs/0001968-inland-waters-overview-of-the-hydrology-of-the-mekong-basin.pdf

[5] Mekong River Commission 2005. Overview of the hydrology of the Mekong Basin. Mekong River Commiison. Vientiane, November 2005. 77 pp.

Figure 4: Extent of flooding in 2009.
(Source: Allan Michaud website. http://allanmichaud.wordpress.com/2011/05/21/satellite-flood-comparison-tonle-sap-2009-10/)

2.1.2. Site features

Boeung Prek Lapouv reserve is essentially a flat floodplain area of 9,305 hectares including a core zone of 919 hectares. Within the reserve, there is a checkerboard system of canals with large parallel canals (such as canals 91,90,..89,..and 96) running in East-West direction intercepted by small parallel canals (such as canals 01,02, etc.,) running in East-West direction. Typically a canal has a low earth levee about 1 meter in height from the ground on one side.
The reserve is hydrologically connected to the Takeo River running in the Northwest-Southeast direction about 1km off the Northeast corner of the reserve. The Takeo River is in turn hydrologically connected to the Bassac River, a branch of the Mekong which runs in the same direction.

The Prek Lapouv channel meandering across the reserve in the Northeast-Southwest direction also connects the reserve to the Takeo River hydrologically. In the dry season, the Prek Lapouv channels exchanges water with the Bassac through Takeo River on daily basis through tidal flows in and out.

The reserve is hydrologically open as there are no ring dykes that surround its boundaries. Water can flow in and out of the reserve almost freely without any major obstructions. The development of the canal system has increased drainage from the reserve causing the

wetland to dry out rapidly at the end of the wet season. The transitional phase between the wet and dry seasons of a typical Mekong floodplain has lost.

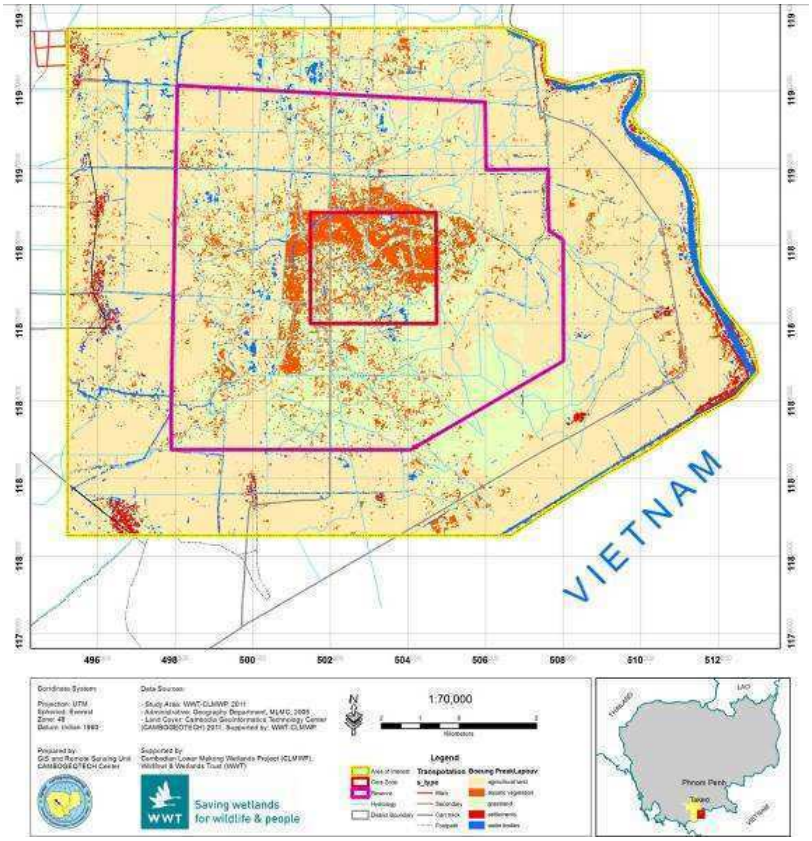


Figure 5: Map of Boeung Prek Lapouv.

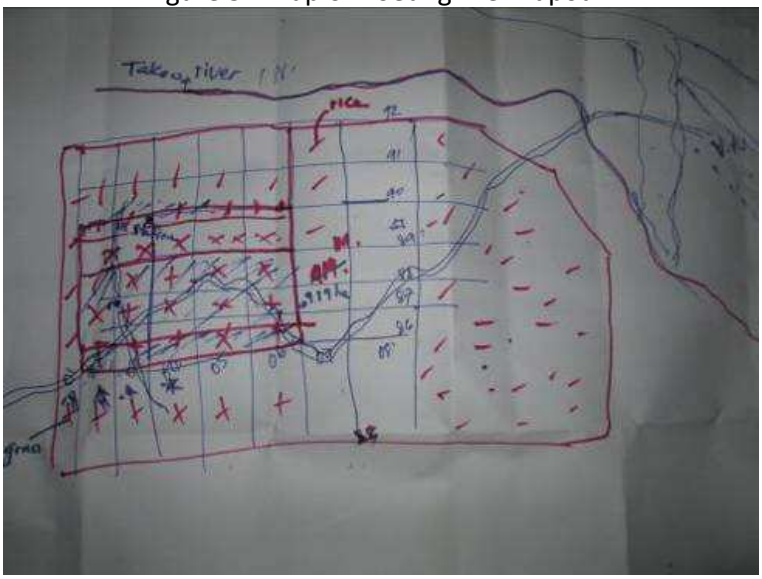


Figure 6: Sketch map of Boeung Prek Lapouv showing the relative positions of the boundaries of the reserve, the core zone, the checker board canal system, the Prek Lapouv channel and the Takeo River.

Figure 7: Prek Lapouv channel running through the reserve and also connected to Takeo River which in turn is connected to the Bassac

Figure 8: Takeo River connected to the Bassac River and the BPL reserve.

Figure 9: one of the major parallel canals that run through the reserve in the East-West direction

To understand the past changes in the wetland area, we conducted a PRA exercise with the Local Conservation Group and a group of local villagers. The PRA exercise with the Local Conservation Group at Boeung Prek Lapouv gave the following information about the history of the site:

Table 1. A timeline history of Boeung Prek Lapouv

Timeline	Features/Events
1955	The site was dominated by flooded forest
1979	Flooded forest started to decline
1981-1991	People planted deep water rice
1983	The locals built some small canals
1987	Major canals dug connected to Bassac River
1991	Some cranes (about 4-5) were seen
2002	Crane population started to increase

Meanwhile, the PRA exercise with the villagers gave the following information:

Timeline	Features/events
Before 1975	The ground was much wetter in the dry season
1975-1979	Small canals such as 01,03,03,04, etc., were built
1986	About 10-20 cranes were seen
1991-1998	EU irrigation project dug the system of canals. Now water comes in through canal 90 and Prek Lapouv channel faster than before.

2.1.3. Seasonality

2.1.3.1 Seasonal calendar

The PRA with the villagers gave the following information about the seasonality of the site.

Table 2: A seasonal calendar of BPL

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Rain												
Flood										peak		
Rice												
Crane												
dry season inundation before canals					10cm of standing water							
Fishing												

Interpretation notes:

- Rain season starts in May and end late October, peaking in August-September.
- Flood season starts in July and ends late December, peaking in October.
- Rice crop in fields from Jan to May (depending on year, e.g. in mid-March 2013 crop already harvested due to early planting, R van Zalinge pers. com. 2013).
- Crane uses of the reserve from middle of December to end of March
- Before the presence of the canal system, water was presence in the area of the current reserve almost year round:
    - From January to end of April the field was still inundated.
    - By February some areas were still knee-deep.
    - By May, there would be still 10cm of standing water in the field.
- Before, the cranes stayed in the reserve from November to March and come back again in June when it is flooded again, but now fewer come back for the second time.

2.1.3.2. Annual Hydroperiod

The water level records at BPL only exist from June 2012 to February 2013. The following graphs give a general idea of the fluctuation of water levels over the course of one year.

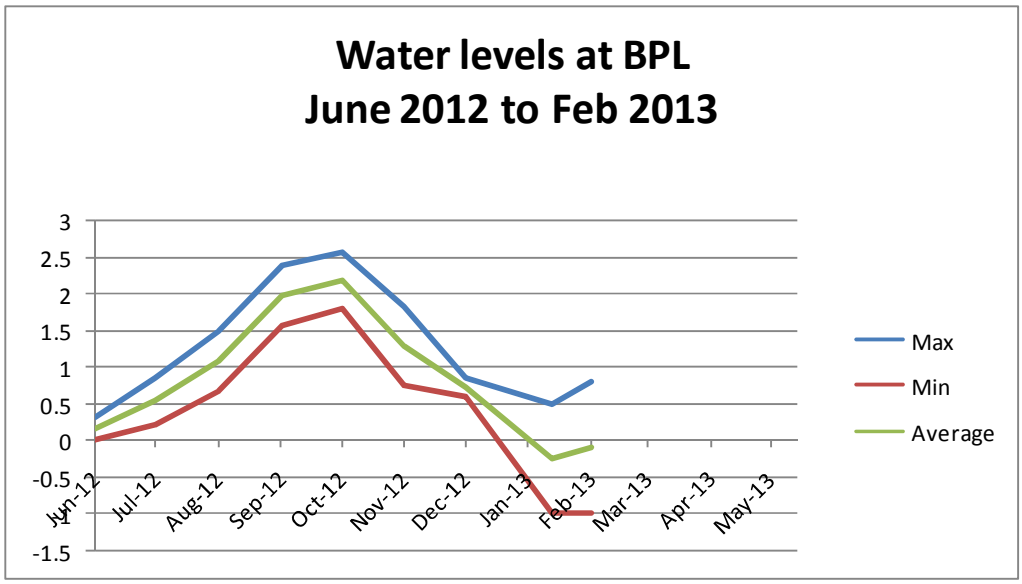


Figure 10: month max and min water levels at BPL

Note: The graphs are generated from the monthly max and min water levels at the staff gauge at the office of BPL. The daily water readings were done at different times of the day as convenient, thus the max and min water readings are not true maximum and minimum water levels at the site but the highest and lowest values of the available data series.

Generally, water starts rising in June-July, peaks at October, and decline thereafter. The influence of the tides is more pronounced in the dry season than in the wet season as the difference between the max water levels and the min water levels widen.

2.1.4. Observed Field conditions

At the time of observation from February 25 to February 28, 2013, except for the Prek Lapouv channel that runs through the reserve the area receives tidal flows from the Bassac on daily basis, yet most of the ground in BPL was dry or very dry. The groundwater table was far from the ground surface in most of the places (around 45-65cm). Water levels recede quickly at the beginning of the dry season (Seng Kim Hout per.com, 2013).

The majority of the area of BPL is dominated by tall reeds and grasses. Before 2002, most of the reserve was covered with short grasses but now tall reeds and grasses have replaced the short grasses (Eleocharis spp.) (Seng Kim Hout, Per.com., 2013) rendering much of the area not suitable as habitat for the cranes.

One of the reasons of the change of vegetation from short grasses to tall grasses and reeds is explained as that grass burning by local villagers for hunting or by accident that helped keep the tall grasses down has been stopped since 2003 by the reserve authority.. Buffalo grazing was also banned at around the same time.

Several years ago, it was observed that a lot of water lily in the field came back after burning and now water lily is disappearing because of the absence of frequent burns (Mr. Vanna, site manager of the reserve, Pers. Com., 2013).

At the time of observation, however, small scattered burns were seen in a few places in the reserve. At the small burnt patches, Mimosa pigra were seen sprouting up abundantly.

Mimosa pigra invasion is a serious issue at BPL as the plant was seen scattered almost throughout the reserve, especially on the dykes, at the edges, and areas where the vegetation communities were disturbed by fires.

The vegetation at BPL at the time of observation was showing signs of water shortage. Only the deep rooted reeds and shrubs were still green. The short grasses were turning brown or withering. Parts of dead water lilies were found on the ground.

The overall condition of the site is that the habitat for cranes is badly degraded. No cranes were seen in the reserve as all have left the reserve by the time of the observation.

Since 2011, cranes have shifted their feeding area to a new feeding area as some burns occurred in this new area in the dry season of 2012.

Figure 11: Tall grasses have replaced short grasses in a large part of BPL rendering habitat unsuitable for the cranes.

Figure 12: withering plants on dry ground

Figure 13: scatter open places providing feeding habitat for the cranes

Figure 14: Mimosa pigra is commonly found in BPL

The villagers also gave information about the following trends in the recent 10 years

Table 3: Past trends of resources at BPL, according to villagers

Topic		Reason
Water birds	↓	Because rice field expansion and use of pesticides, bird trapping
Fish	↓	
Rain in dry season	↓	
Flood		Don't know
Drought	↑	
Crane		Fewer than last year
Water lily	↓	Out-competed by other plants
Eleocharis		Same

2.1.5. Crane stay at the reserve

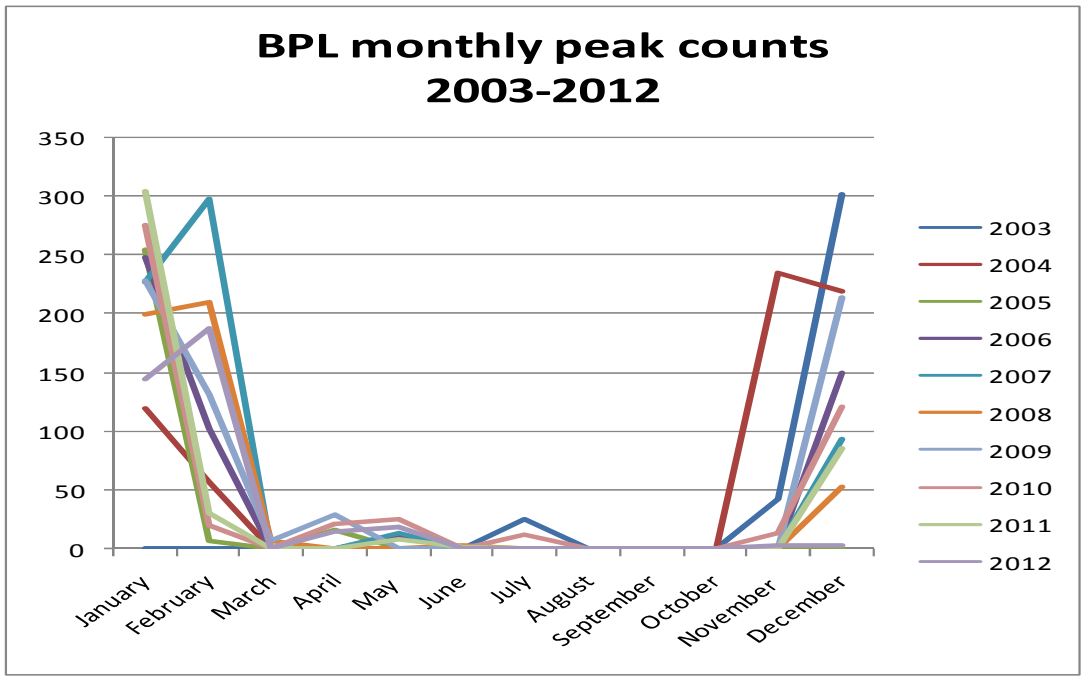


Figure 15: Monthly peak counts at BPL from 2003 to 2012

The graphs show that in general the cranes arrive at the reserve as early as November, peaking around January-February and stay on till end of February.

After the first departure around February, the cranes come back to BPL for the second time in a year toward the later part of the dry season as shown in figure 16 below.

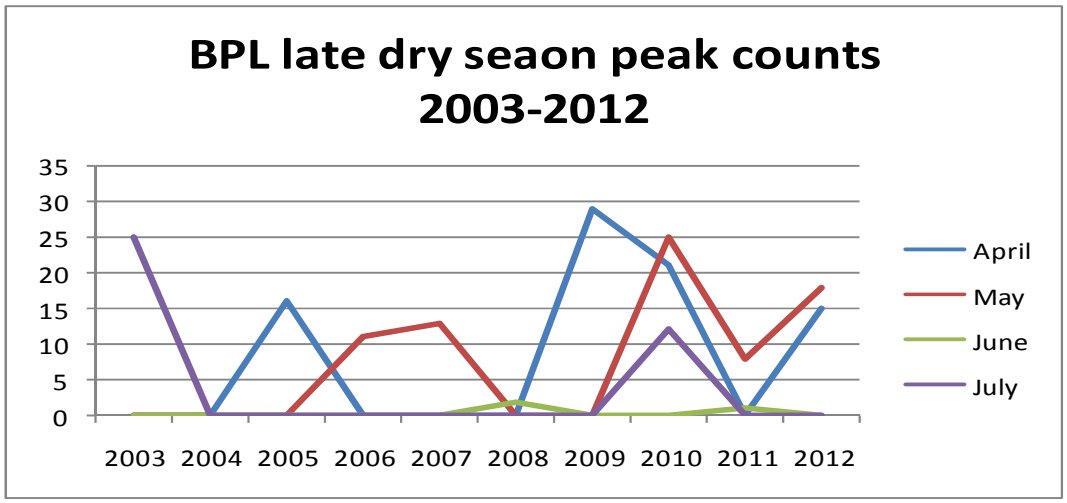


Figure 16: Late dry season peak counts at BPL. Cranes come back to BPL for the second time in a year from middle to the end of the dry season (no declining trend is observed in contrast to what was reported by villagers, yet the numbers are very low).

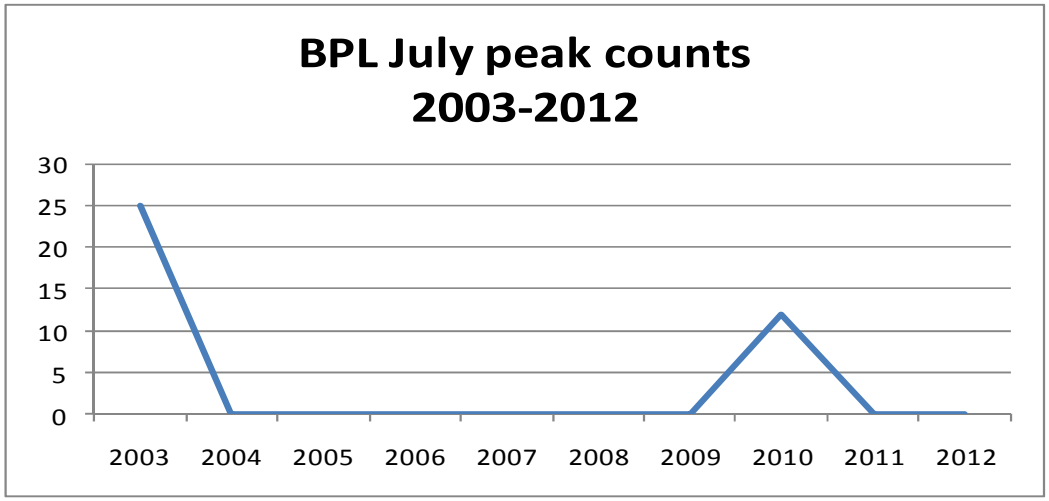


Figure 17: July peak counts at BPL 2003-2012

The years 2003 and 2010 were the only 2 years that saw cranes present at BPL in July. In 2010, all cranes left the reserve in March, came back again in small numbers (21 and 25) then left again in June and came back again in July with only 12 cranes.

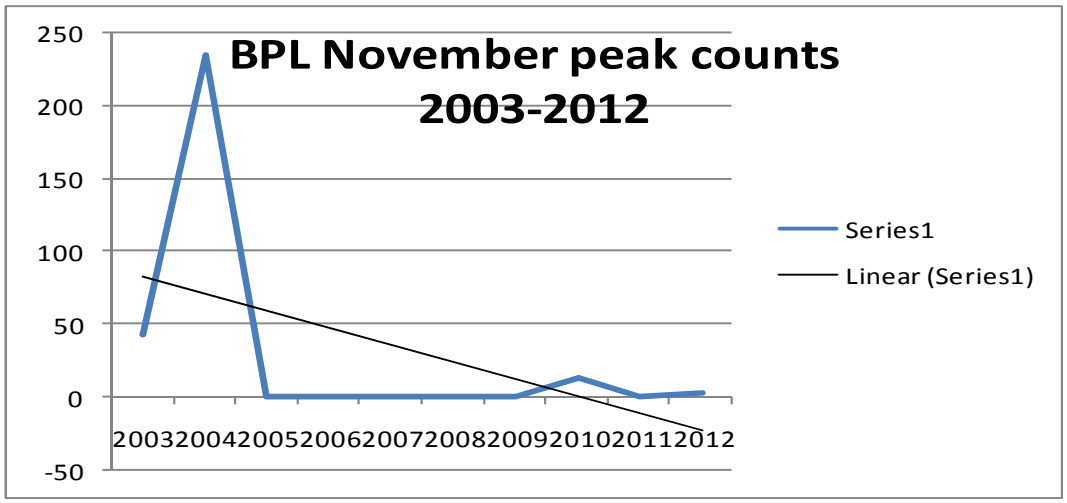


Figure 18: November peak counts at BPL from 2003 to 2012

Figure 19 shows that cranes arrival at BPL in November declined rapidly and has remained low since 2004.

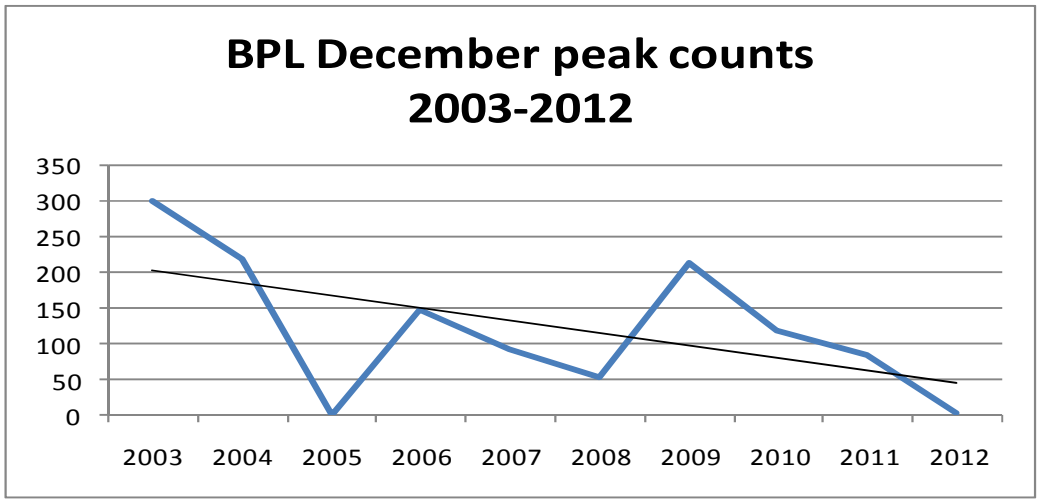


Figure 19: December peak counts at BPL from 2002 to 2012

The figure also shows a declining trend of crane presence at BPL in December. Especially in 2012, crane population in December has reached zero.

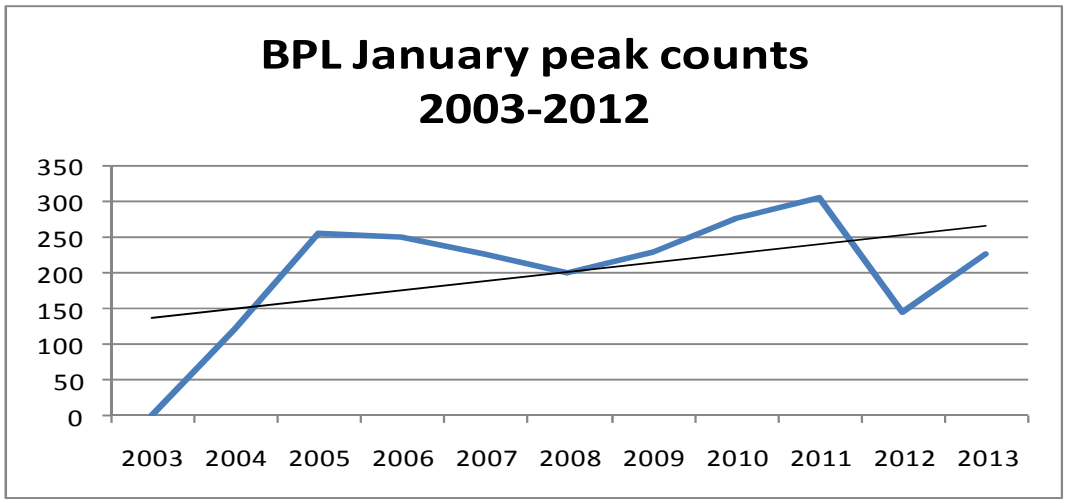


Figure 20: January peak counts at BPL from 2003 to 2013

The overall trend of number of cranes using BPL in January is increasing though there are yearly fluctuations.

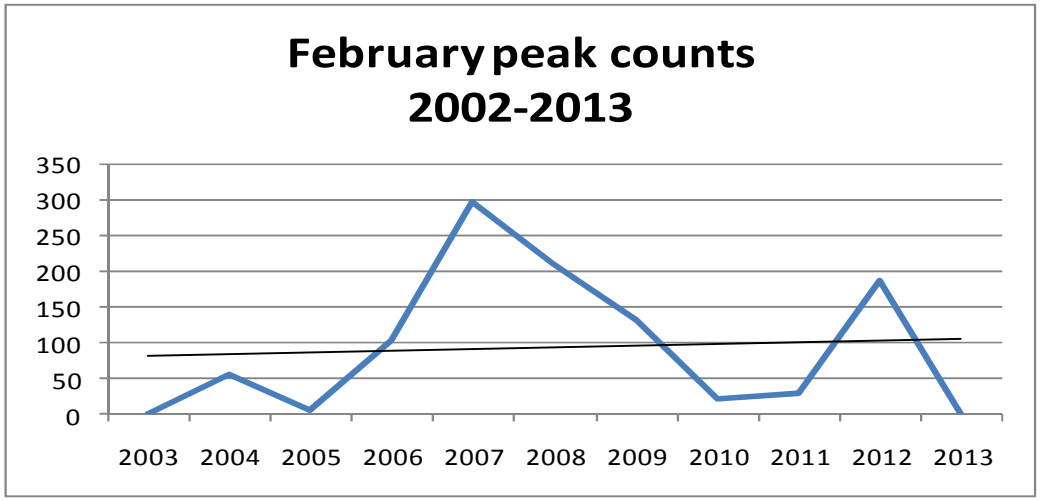


Figure 21: February peak counts at BPL from 2003 to 2013

The long-term trend of crane presence in BPL in February from 2003 to 2013 is increasing but the recent sub-trend from 2007 to 2013 is decreasing. Especially in 2013, no cranes were present in the reserve in mid-February.

Cranes counts in November has come down to zero since 2005 (except 2010 (dry year, why) with 13 cranes and 2012 with 3 cranes). Cranes count in December also shows a declining trend (except 2009 with 212 cranes) and has come to zero in 2012. Annual maximum was particularly low in 2012 (187 while the average was 231) below the minimum of 2008 (210 cranes).In 2010 (a particularly dry year in the Mekong region) the number of cranes that stayed on in February was only 20.

2.1.6. Crane feeding

No cranes were at the reserve so we could not observe their feeding behavior. Evidence of crane feeding, probe holes and feeding holes, could be seen on the ground. The pattern is that there are many small probing holes around a main feeding hole that were continually enlarged by the cranes using their bills.
The feeding evidence near the pulled up, dead and dry water lily plants suggest that the cranes were feeding on the tubers or the tender basal stems of water lilies. Feeding evidence was also found in areas of Eleocharis and areas without any Eleocharis or water lilies. This suggests that the cranes were also feeding on the tubers of Eleocharis and something else, probably soil insects.

Figure 22: Evidence suggesting crane feeding on water lily.

Figure 23: Feeding holes and dead water lily suggesting crane feeding on water lily

Figure 24: Evidence suggesting crane feeding on Eleocharis tubers

Figure 25: Feeding evidence in an area without water lily or Eleocharis suggesting that the cranes were feeding on something else, probably soil insects when the ground was wetter earlier in the dry season.

Figure 26: Feeding evidence in an area without water lily or Eleocharis suggesting that the cranes were feeding on something else, probably soil insects.

2.1.7. Discussion

The main issue in BPL is that the duration of stay of the cranes at the reserve is short, though annual maximum count remains stable.

It is important to view the issue of BPL in the context of the larger landscape, the Takeo – Bassac floodplain:

1. The hydrology of the whole Takeo floodplain has changed due to the presence of the canal network. While there are no data of the hydrology in the past of the Takeo-Bassac floodplain[6], it is obvious that the development of the network of canals for agriculture development, especially those during 1983-1987 have changed the hydrology of the floodplain. Based on the description of the past conditions by the local villagers during the PRA exercise and the observed current conditions, the speculated changes include:
    - The flows from the river to the floodplain have changed from a sheet flow regime to a more channelized regime since the presence of the canal network on the floodplain.
    - As a result, in the flood season flood water from the river now rushes into the floodplain at a very fast pace through the canals and after breaching the channel levies.

[6] The name of the floodplain is "invented" here by the author for convenient reference.

- And, at the end of the flood season, water is drained out from the floodplain faster than before, causing the floodplain to become drier faster.
- Meanwhile, the extensive checkerboard canal system within the reserve further contributes to water loss from the reserve by draining sub-surface water out of the soil, increased open surface evaporation, and intersecting ground water table.

2. The early change in hydrology of the floodplain with the associated disappearance of the flooded forest landscape that gave rise to the appearance of the grassland was probably what accidentally created a favorable environment that attracted the cranes to BPL in the first place. However the issue began later on when more and bigger canals were developed. Water is now drained out rapidly from the wetland at the beginning of the dry season causing the habitats to dry out too quickly and thus the duration of stay of the cranes at the reserve in the dry season has been shortened.
3. At the same time, the habitats for cranes at BPL have since been degraded. Many of the open spaces of the short grass areas have been replaced by tall dense vegetation not suitable as habitat for the cranes. The replacement of the short grass, open spaces with the tall, dense vegetation is probably due to: (i) the area is excessively dry in the dry season so that the deep rooted reeds and shrubs are favored over the shallow rooted short grasses and (ii) burns by local villagers for hunting that created open spaces annually in the dry season for the re-emergence of the short grasses has been stopped.
4. The tall dense vegetation is also not good for fish productivity as it can be impenetrable for fish.. The thickly accumulated dead biomass layer on the ground will tend to deplete dissolved oxygen in the water during the decomposition process, especially in a stagnant system. Fortunately, BPL is still a hydrologically open system so that water can exchange with the surrounding floodplain and the Bassac River so that the oxygen depletion effect is not yet serious.

The success of wetland hydrology restoration is often accomplished by documenting changes in wetland hydro-period before and after restoration. Ideally, post-restoration hydro pattern would approach those that existed before site degradation[7]. However, for the case of BPL, while understanding of the past hydrology conditions and changes are essential, the objective of the "hydrology restoration" in this case should not be to restore the hydrologic conditions of the floodplain before the existence of the canal network because it is (a) not possible given the change in the larger landscape (b) not desirable for the cranes. The objective, therefore, should be to improve moisture conditions in the dry season to a certain extent to extend the period within the dry season that the habitats at BPL can support the cranes.

While it is not possible to restore the hydrology of the whole floodplain, measures can be undertaken to improve hydrologic conditions of the reserve locally.

[7] Kevin K. Moorhead, David W. Bell, Rachael N. Thorn (2008). Floodplain Hydrology After Restoration of a Southern Appalachian Mountain Stream. Wetlands 28(3):632-639. 2008. http://link.springer.com/article/10.1672%2F07-100.1

2.2. Physical features and plant communities

To record tyical features of nature and plant communities in BPL being a large area of wetlands, short transects were coducted during surveys (Figure 27). Each study site, some key features were recorded for mapping of plant communities and soil characteristics and water quality that is used for wetland asseement.

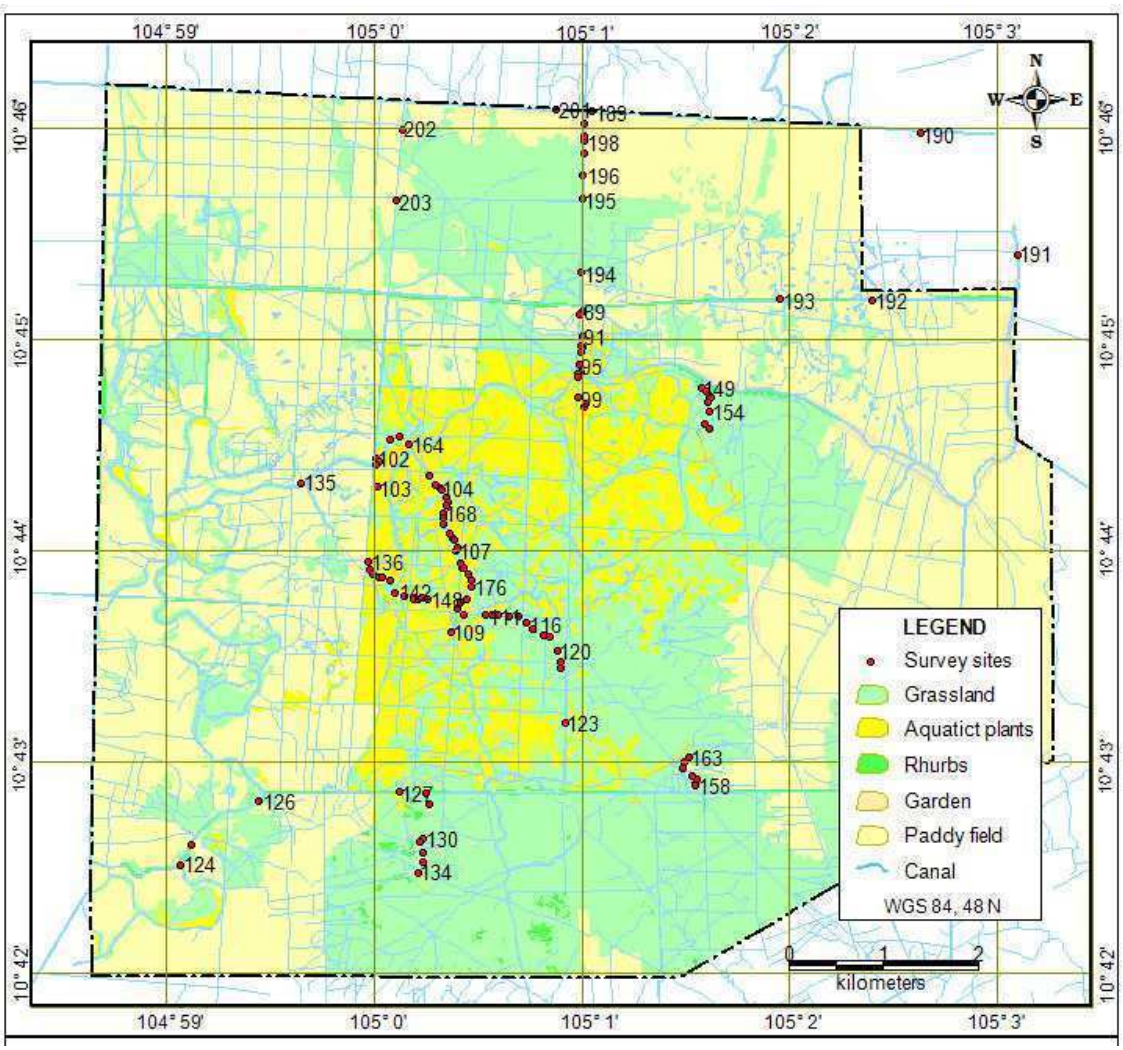


Figure 27. Survey sites taken in Boeung Prek Lapouv in March, 2013

2.2.1. Physical features

2.2.1.1. Topography

The topography of the Boeung Prek Lapouv is characterized by riverine plains where the terrain is considered to be quite flat that is extensively flooded in the wet season.

Based of topographical map of Kampot provinces (US Army Map Service,1965) and data of season water level reading (WWT, 2012), a topographic map was interpolated and showed in Figure 29. The figure does not have the absolute accuracy, but for a glimpse of the

topographical features of wetlands in Boeung Prek Lapouv. The elevation of whole area varies from 0.8 – 2.6 m, therefore this area is also considered as flood plain where is completely inundated in the flood season. Topography ranges from 1.4 to 2.0 covers is covered the largest area of protected area, with a total area of about 6,590.97 ha (Table 4 and Figure 28). Many canals and ponds within the area have created a local low-lying areas where water level was high in the flood season (Figure of WWT, 2012).

Table 4. Range of elevation in Boeung Prek Lapouv, Takeo province

Ord	**Elevation (m)**	**Area (ha)**
1	0.90 - 1.10	22.01
2	1.10 - 1.25	78.95
3	1.25 - 1.40	378.07
4	1.40 - 1.55	1,254.95
5	1.55 - 1.70	1,984.51
6	1.70 - 1.85	2,192.55
7	1.85 - 2.00	1,158.96
8	2.00 - 2.15	803.13
9	2.15 - 2.30	315.02
10	2.30 - 2.45	132.58
11	2.45 - 2.60	40.35
	Total area (ha)	**8,361.08**

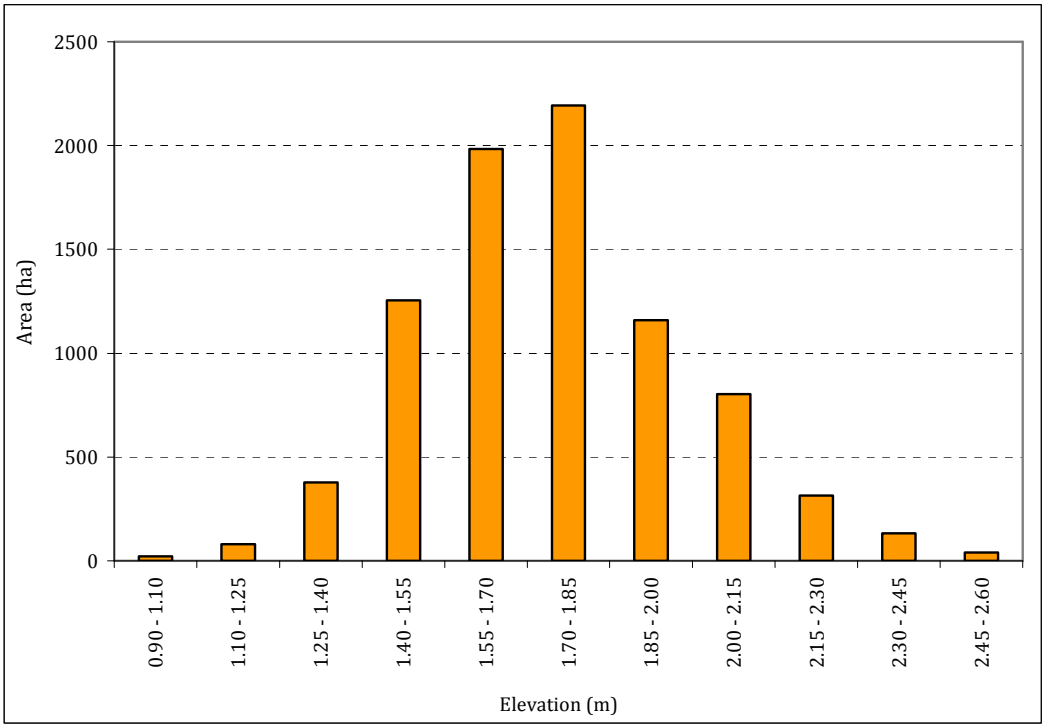


Figure 28. Range of elevation in Boeung Prek Lapouv, Takeo province

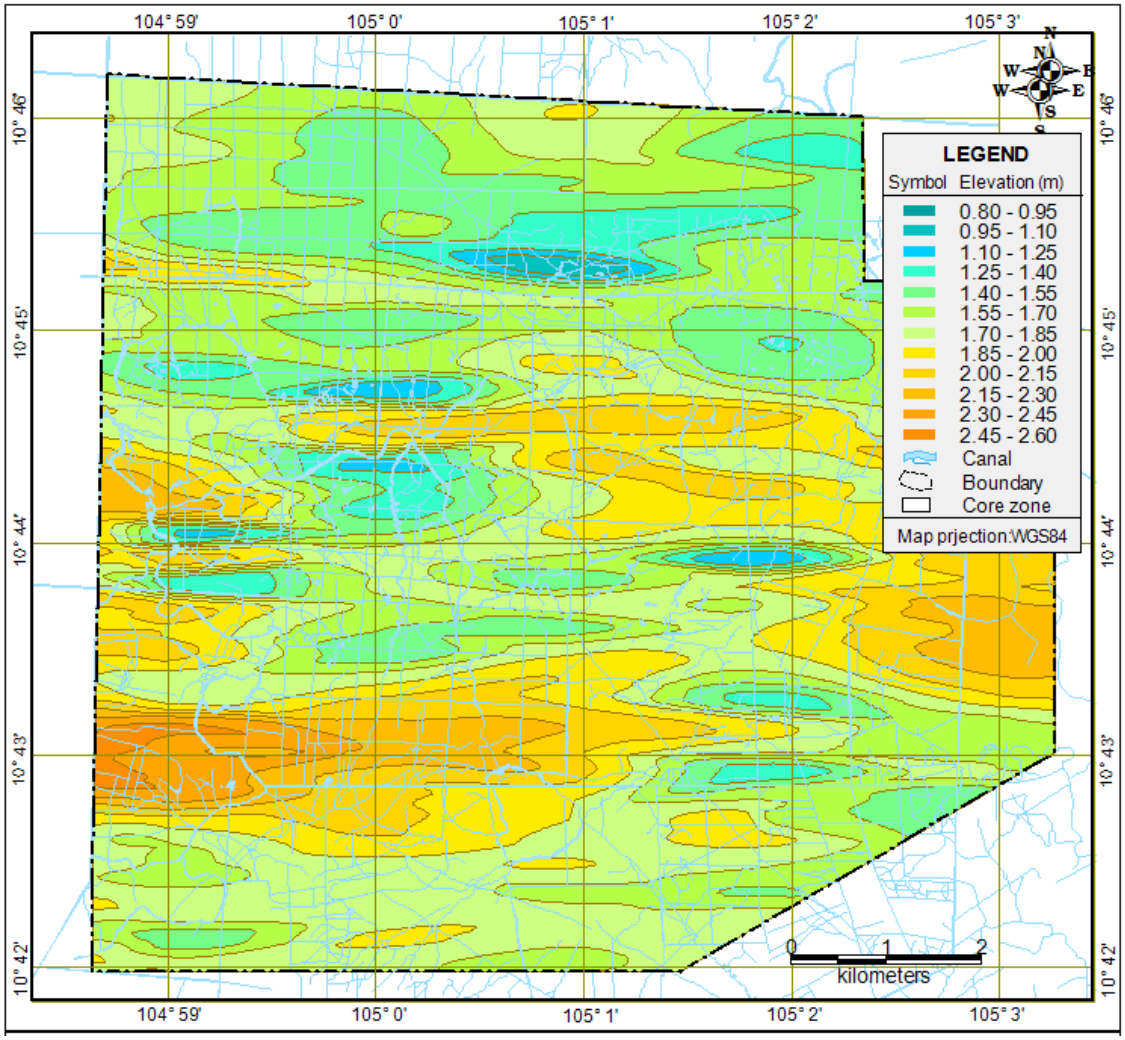


Figure 29. Topographical features in Boeung Prek Lapouv

2.2.1.2. Geological features

Geologically, this area was formed by Holocene deposits, with Quaternary sedimentary rocks and consolidated sediments being deposited over time as parent materials and forming the upper soil levels in Boeung Prek Lapouv.

Holocene deposits have been created by transgressions followed by regressions in Holocene times. On the basis of the origin of materials there are two types of Holocene sediment in this area (BRGM, 1973, Tien, et al, 1991).

- Swampy-marine sediments.(abQ_{iv}). These sediments are distributed at low reliefs between natural levees (along Bassac river and old alluvium in the Plain of Reeds in Vietnam and Cambodia. These sediments are also sometimes covered by alluvial sediment.
- Tidal flat sediments (amQiv) formed from alluvial materials transported through tidal processes.. The alluvial materials are deposited in backward area of the levees and covered on the areas formed from the swampy-marine sediments

The different sedimentary materials have formed different soil types through a process of weathering.

2.2.1.3. Soil characteristics

Soils in Boeung Prek Lapouv are mainly derived from the weathering young sediment and colluvial materials resulting from erosion in higher areas. Soils in Boeung Prek Lapouv have been characterized as dominantly strongly well drained by dense canal network that has played an important role in soil development and the formation of different soil types in this area.

Some soil profiles observed was not enough data to point out exactly of soil types distribution, but can be able to make a few remark on the nature of the land. Depending on the occurrence of sulfuric and sulfidic horizon, the general soil distribution can be subdivided in to 5 soil types, in which including the soils without occurrence of jarositic and pyritic material in the soil profile.

Alluvial soils without sulfuric and sulfidic horizons and alluvial soils with sulfuric and sulfidic horizons, and acid sulphate soils in Boeung Prek Lapouv were mentioned by Takeo Provincial Department of Agriculture (Seng Kim Hout, 2004). As applied FAO/Unesco system, soils with sufidic and/or sulfuric horizons were classified as Thionic Fulivisols (similar with Sulfic Tropaquents and Sulfaquepts in USDA/Soil Taxonomy).

Although the soils are young with limited profile development, the dense canal network facilitates drainage and causes weathering of soils in dry season. Therefore, most soils types belong to the group of developing alluvial soils (Inceptisols). Soil profiles observed contained a B sub-horizon where the weathering of materials had taken place. Formation and accumulation of iron compounds such as Geothite (FeO(OH)) and Heamtite (Fe_2O_3) was observed in this B sub-horizon as a result of fluctuation between wet and dry condition and salt of aluminium sulphate ($Al_2(SO_4)_2$ precipitated on soil surface was recorded. Soil texture is between clay and silt clay (Figure 30).

(a) (b)

Figure 30. a) Jarosites in B horizon in APL, and b) Aluminium sulphate (Al2(SO4)2) was precipitated after being calipilary to the soil surface in the dry season.

Entic Tropaquepts

Survey results showed that the area located at middle elevation in the north, near to older alluvial soils, are alluvial soils covered with colluvium (Site 95). The thickness of young alluvium ranges from 50 – 80 cm from the soil surface. Soils containing a B-horizon with soil ripping were classified as e*ntic Tropaquepts* (Site 96, 113).

Acid Sulphate Soils

Some typical acid sulphate soil types were identified in Boeung Prek Lapouv, which includes acid alluvial soils and actula acid sulphate soils. Landscape of acid sulphate soil with iron hydroxides ($Fe(OH)_3$) on the soil surface and typical grass such as *Eleocharis dulcis, Ischaemum indicum* were recorded in many places in BPL (Figure 31).

Figure 31. Acid sulphate soils in lowlands of BPL area.

a) Sulfic Tropaquents

Found in locally depressed areas with a thick alluvial layer that contains pyritic minerals (FeS_2) within 50 to 100 cm from soil surface though not in high density (Site 130). These soils are considered as *sulfic Tropaquents*.

If these soil types containing sulfidic materials is drained or if sulfidic materials are otherwise exposed to aerobic conditions, the sulfides oxidize and form sulfuric acid. The pH value, which normally is near neutrality before drainage or exposure, may drop below 3.

b) Bathi-sulfic Tropaquents

Similar soils in which a sulfidic horizon occurred at depths of more than 100 cm of soil surface are classified as *bathi-sulfidic Tropaquents/Tropaquenpts* (Site 147).

c) Entic Sulfaquepts

A considerable area is delineated as acid sulphate soils in which a sulfuric horizon occurred within 50 – 100 cm of the soil surface, but without a high density of jarositic minerals (1/3 $KFe_3(SO)_2(OH)_6$), and with a sulfidic horizon at a depth over 95 cm from soil surface (Site 131). The pH value of surface water tested is very low (pH = 3.01) and high electric conductivity (EC = 5.520 mS/cm). *Eleocharis dulcis* and *Ischaemum indicum* were found to occur in this soil type.

(a) (b)

Figure 32. Some typical acid sulphate soil features recorded in BPL:

a) Jarosite mottles (pale yelow -2.5Y^8/6) appeared in developed soil horizon along with geothite (FeOOH) – yellow and strongre yellow and Hematite (Fe_2O_3) – red colour were formed from hydrolysis process; and b) Subsoils containing pyritic materials (FeS_2) within 70 – 150 cm from soil surface.

d) Sulfic Hydraquents

Low lying soils along canal in which the sulfidic horizon occurrs at a depth of more than 50 cm of the soil surface and the soil is undeveloped and permanently saturated due to the influence of canal water.

2.2.1.4. Water quality

Water resources in this area is provided mainly from the Bassac River, therefore surface water quality in canals is normally only slightly acidic, except in areas with actual acid sulphate soils. Water quality was mostly tested along rivers and canals that transport water through Boeung Prek Lapouv (see figure 32). Most water quality parameters tested were suitable for fresh water biodiversity.

Figure 33. Canal network inside is main water body in the dry season of the protected area of Boeung Prek Lapouv.

Surface water in central channels of reserve area with prolific aquatic vegetation showed a pH value of 5.4 and higher (site 182, 183, and 184) (Table 5). Such pH values are suitable for fish.

Low flow rates and an abundance of aquatic plants could be reasons for slightly low values of dissolved oxygen, but such values should not affect fish negatively.

Table 5. Surface water quality in Boeung Prek Lapouv

Site	Water quality parameters					
	pH	Eh	EC	Salt	DO	TDS
		pHmV	mS/cm	%	mg/l	%
90	7.14	-65	0.201	0.01	4.90	0.131
123	5.33	33	0.314	0.01	5.14	0.202
131	3.01	182	5.520	0.30	5.53	3.480
181	4.71	78	0.240	0.01	3.51	0.155
182	5.41	34	0.230	0.01	3.10	0.149
183	5.68	16	0.222	0.01	3.75	0.143
184	5.86	12	0.229	0.01	3.83	0.149
191	6.46	-3	0.166	0.01	4.93	0.108

2.2.2. Plants and habitats

2.2.2.1. Species

There is an abundance of plant species in Boeung Prek Lapouv. Although only a short survey, there are 64 species belonging to 22 families recorded in this wetlands (Table 6). Of these, two families have the largest number of species: Poaceae (grasses) and Cyperaceae (sedges) (Table 6 and Figure 38). The plant spcecies with main growth habitats are classified as grass, tall grass, shurb, liana, semi-aquatic and aquatic, and tree (Table 7).

Table 6. List of numbers of families and plant species recorded in Boeung Prek Lapouv Wetlands, Takeo Province

Family	Species			Growth habitat
	No.	Scientific	English	
Grass				
Acanthaceae	1	*Ruellia tuberosa* L.	Minnie Root, Fever Root, Snapdragon Root	Herb
Amaranthaceae	2	*Alternanthera sessilis* RBr	Sessile joyweed	Forb/herb
Asteraceae	3	*Sphaeranthus indicus* L.	East Indian Globe Thistle	Herb
	4	*Blumea lacera* (Burm.f.) DC.	Blumea.	Herb
Boraginaceae	5	*Heliotropium indicum* L.	Indian turnsole, Indian heliotrope	Forb/Herb
Cyperaceae	6	*Fimbristylis microcarya* F.v. Muell	Unknown	Herb
	7	*Fimbristylis sp.*	Unknown	Herb
	8	*Fimbristylis miliacea* (L.) Vahl	Globe fringerush,	Herb/ Graminoid
	9	*Cyperus difformis* L.	Variable flatsedge	Graminoid
	10	*Cyperus compactus* Retz.	Vernacular	Graminoid
	11	*Cyperus rotundus* L.	Purple nutsedge, Nutgrass	Graminoid
	12	*Cyperus digitatus* Roxb	Finger Flatsegde	Graminoid
	13	*Cyperus elatus* L.	Flatsedge	Graminoid
	14	*Cyperus iria* L.	Rice flat sedge	Graminoid
	15	*Scirpus maritimus* (L.)	Alkali	Herb
Poaceae	16	*Cynodon dactylon* L. Pres	Couch grass, Bermudagrass,	Graminoid

Family	Species			Growth habitat
	No.	Scientific	English	
	17	*Eragrostis atrovirens* (Desv.)	Thalia lovegrass, Wiry lovegrass	Graminoid
	18	*Brachiaria mutica* (Forssk.) Stapf	Para Grass, Buffalo grass	Graminoid
	19	*Echinochloa crusgalli* L.)P.Beauv	Barnyard Grass	Graminoid
	20	*Echinochloa pyramidalis* (Lam.)	Antelope grass	Graminoid
	21	*Eleusine indica* (L.) Gaertn.	Goose grass	Graminoid
	22	*Echinochloa stagnina* (Retz.) P.	Hippo Grass	Graminoid
	23	*Ischaemum indicum* (Houtt.) Merr.	Batiki bluegrass	Graminoid
	24	*Hymenachne acutigluma* Steud.	Water straw grass, Trumpet grass.	Graminoid
	25	*Ischaemum rugosum* Salisb	Wrinkle duck beak, Saromacca grass	Graminoid
	26	*Chloris barbata* Sw.	Swollen finger grass, Purple top chloris.	Graminoid
	27	*Leersia hexandra* Sw.	Club-head Cutgrass	Graminoid
	28	*Paspalum scrobiculatum* L.	Kodo millet	Graminoid
	29	*Panicum repens* L.	Torpedo grass	Graminoid
	30	*Oryza rufipogon* Griffiths	Wild rice, Wild red rice, Brownbeard rice.	Graminoid
	31	*Sclerachne punctata* R.Br	Unknown	Graminoid
	32	*Leptochloa chinensis* (L.) Nees.	Asian Sprangletop, Red Sprangletop.	Graminoid
	33	*Echinochloa colonum* L. Link	Jungle rice, Jungle rice grass.	Graminoid
	34	*Hemarthria longiflora* (Kook.f)	Unknown.	Graminoid
	35	*Saccharum spontaneum* L.	Kans grass, wild sugarcane	Graminoid
	36	*Phragmites vallatoria* (L.) Veldkamp	Tropical reed	Subshrub Shrub
Semi-aquatic				
Ceperacea	37	*Cyperus malaccensis* L.	Shichito matgrass	Herb
	38	*Scirpus grossus* L.f.	Giant Bulrush	Herb
Oxalidaceae	39	*Oxalis corniculata* L.	Creeping woodsorrel,	Forb/Herb
Aquatic				
Asteraceae	40	*Enydra fluctuans* Lour..	Limnophyte	Herb
Ceratophyllaceae	41	*Ceratophyllum demersum* L.	Hornwort, rigid hornwort,	Forb/Herb
Commelibaceae	42	*Commelina benghalensis* L.	Bengal dayflower	Forb/Herb. Weed
Menyanthaceae	43	*Nymphoides indica* (L.) O.Ktze	Water Snowflake	Forb/Herb
Nelumbonaceae	44	*Nelumbo nucifera* Gaertn.	Sacred lotus	Forb/Herb
Nympheaceae	45	*Nymphaea pubescens* Willd	Pink Water lily	Forb/Herb
	46	*Nymphaea nouchali* Burm. f.	Red and blue water lily	Forb/Herb
Onagraceae	47	*Ludwigia stolonifera* (Guill)	Seedbox	Herb
	48	*Ludwigia adscendens* (L.) Hara	Waterpimrose	Herb
Poacea	49	*Coix aquatica* Roxb	Job's Tear	Herb
Polygonaceae.	50	*Polygonum hydropiper* L.	Marshpepper knotweed	Forb/Herb

Family	Species			Growth habitat
	No.	Scientific	English	
Pontederiaceae	51	*Eichhornia crassipes* (Mart.) Solms	Water hyacinth	Forb/Herb
	52	*Monochoria hastat* (L.) Solms	Pondweed, Arrowleaf False Pickerelweed	Forb/Herb
Salviaceae	53	*Salvinia cucullata* Roxb	giant water fern	Forb/herb
Sphenocleaceae	54	*Sphenoclea zeylanica* Gaertn.	Gooseweed, Chickenspike	Forb/herb
Liana				
Convolvulaceae	55	*Ipomoea aquatica* Forssk.	Water spinach	Vine, Semi-aquatic
	56	*Ipomoea rupens.* L	Binweed	Vine
	57	*Merremia umbellata* Subsp	Vine blossoms	Hogvine
	58	*Aniseia martinicensis* (Jacq.) Choisy	White Jacket	Forb/Herb
Shurbs				
Euphorbiaceae	59	*Phyllanthus reticulatus* Poir.	Black-Honey Shrub	Deciduous shurb
Fabaceae	60	*Sesbania sesban* (Jacq)	Sesban	Tree/Shurb
	61	*Mimosa pigra* L.	Giant sensitive plant	Shurb
Rubiaceae	62	*Morinda citrifolia* L.	Great morinda, Cheese fruit, Indian mulberry	Tree-Shrub
Trees				
Myrtaceae	63	*Melaleuca cajuputi* L.	Swamp tea tree	Tree
Rubiaceae	64	*Neolamarckia cadamba* (Roxe.)	Kadam	Tree

Some species of Poaceae and Cyperaceae are widely distributed, from depression areas to higher areas, are: *Ischaemum indicum, Ischaemum rugosum, Hymenachne acutigluma, Fimbristylis miliacea, Leersia hexandra*. *Scirpus grossus, Cyperus malaccensis* and *Cyperus trialatus* were found along canals.

Figure 34. A typical grassland (*Echinochloa stagnina* - Poaceae) in Boeung Prek Lapouv.

Species such as *Phragmites vallatoria*, *Saccharum spontaneum, Sesbania sesba* are distributed over higher terrain, such as along the banks of canals. The invasive alien species *Mimosa pigra* was found in many higher areas.

Wild rice (*Oryza rufipogon*) was found in some areas in BPL. According to scientists, the greatest value of this species of rice is as a genetic resource to create hybrid varieties that have the ability to withstand harsh conditions and plant diseases.

Figure 35. Wild rice (*Oryza rufipogon*) distributes in some areas in Boeung Prek Lapouv

While many species of *Eleocharis sp*. were found in Anlung Pring then there was only *Eleocharis dulcis* was found in acid sulphate soils and acidic low lands in Boeung Prek Lapouv.

Still seems confused in identifying the species of *Eleocharis dulcis* to refer to its tubers (roots) as food for Sarus Crane. According to Ho (2003), there are two species of *Eleocharis dulcis*, the common one in the Plain of Reeds was classified as *Eleocharis dulcis* (Burm.f.) Hensch and the rest named as *Eleocharis dulcis* (Roxb) Koy that is grown for food because of its relatively large tubers..

Most of aquatic plant species distributed dominantly in water body of canals and also depression areas where can hold water for a longer period of time than other areas. Some typical aquatic species are recognized as *Nelumbo nucifera, Nymphaea pubescens, Nymphaea nouchali, Nymphoides indica, Polygonum hydropiper*, *Ceratophyllum demersum, Ludwigia adscendens, Salvinia cucullata. A*lthough as a species of aquatic plants, *Polygonum hydropiper* presents can stay in the soils just enough moisture, so they are found in areas near the canals and in of low-lying land even in the dry season while lotus and water chili were died by no surface water. Many small channel inside the protected area, though no longer in use, so it facilitated to store a certain amount of water for aquatic plants to expand their living area in the dry season. Therefore the living mass of these aquatic plants forms the main component of the floating mat in water areas.

Based on the references and interview of local people, many species of aquatic plants appear in flooding season. Since the short survey was carried out in the dry season it surely could not be recognized by all species of aquatic plants in the nature reserve.

Some species of tall grasses such as *Phragmites vallatoria*, *Saccharum spontaneum, Sesbania sesba* distributed over higher terrain, such as along the banks of the canals and the mound. Even alien species *Mimosa pigra* was found in many higher areas.

Liana species such as *Ipomoea aquatica, Ipomoea nil, Merremia umbellate, Aniseia martinicensis* distributed widely in the wetlands, commonly *Ipomoea aquatica* was found over a different range terrain.

There are only two species of wood trees found as *Melaleuca cajuputi* and *Neolamarckia cadamba.* However, they only appear in a few scattered seats in the nature reserve. There are some species of shrubs were identified, however only *Phyllanthus reticulatus* and *Morinda citrifolia* are predominant and distribute along the bank of canal and the mound.

(a) (b)

Figure 36. a) A clump of Kadam tree (*Neolamarckia cadamba*) is used as a rest of stocks, and b) *Morinda citrifolia* distributes scattered in Boeung Prek Lapouv.

2.2.2.2. Plant communities

Three units of wetland ecosystems are recognized: scrub/forest, seasonally inundated grassland and open water with aquatic plants. The general map of plant communities is showed in Figure 37 and detail plant communities is showed in map scale 1:10,000 (seperated map).

The results of satellite image interpretation show plant communities representing seasonal inundated grasslands, aquatic vegetation and shrubs make up a large area of BPL (Figure 37 and 38). There are 29 units of land covers including plant communities with typical domibant specices showed in Table 7

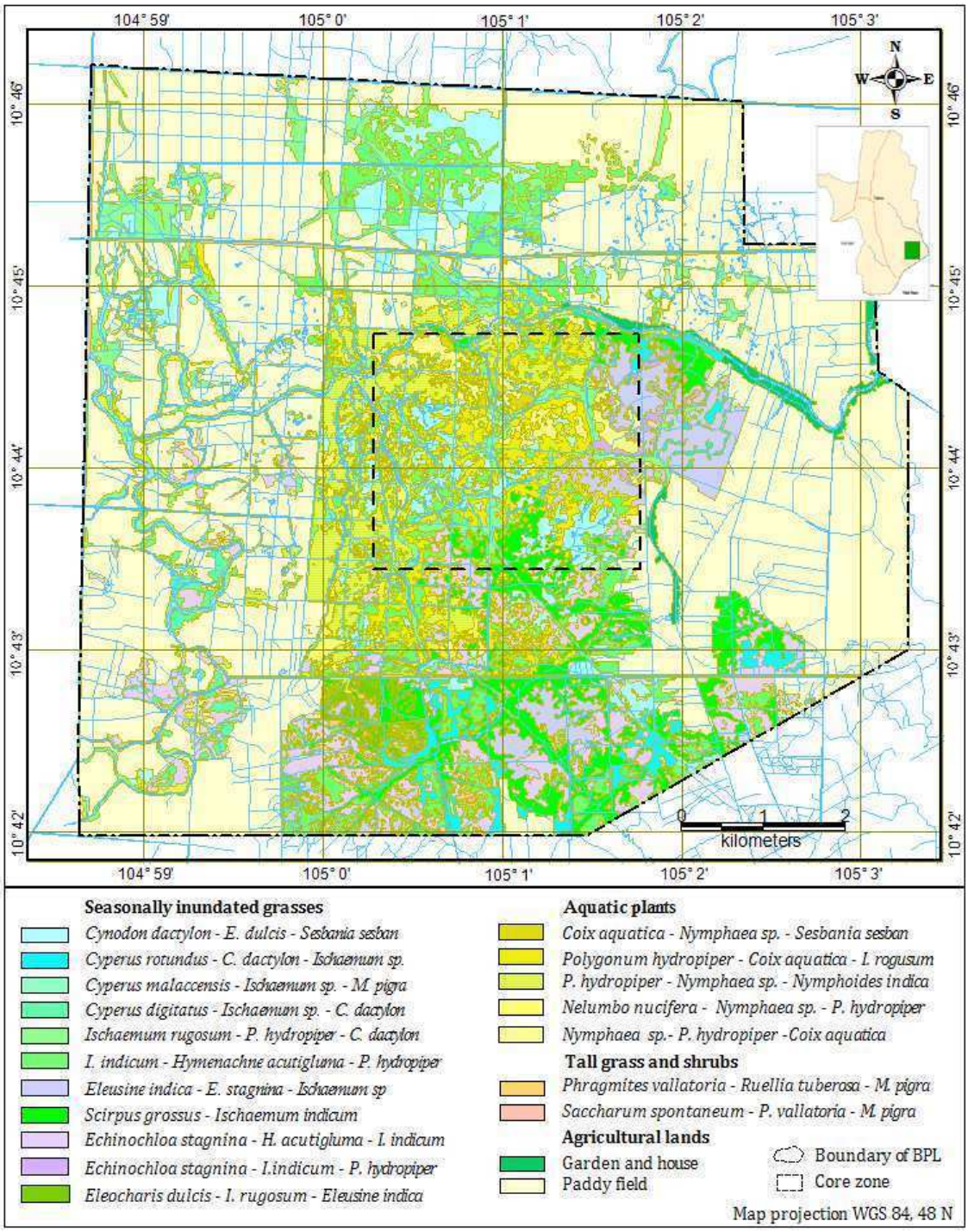


Figure 37. Distribution of major plant communities in Boeung Prek Lapouv Crane Reserve, Takeo province.

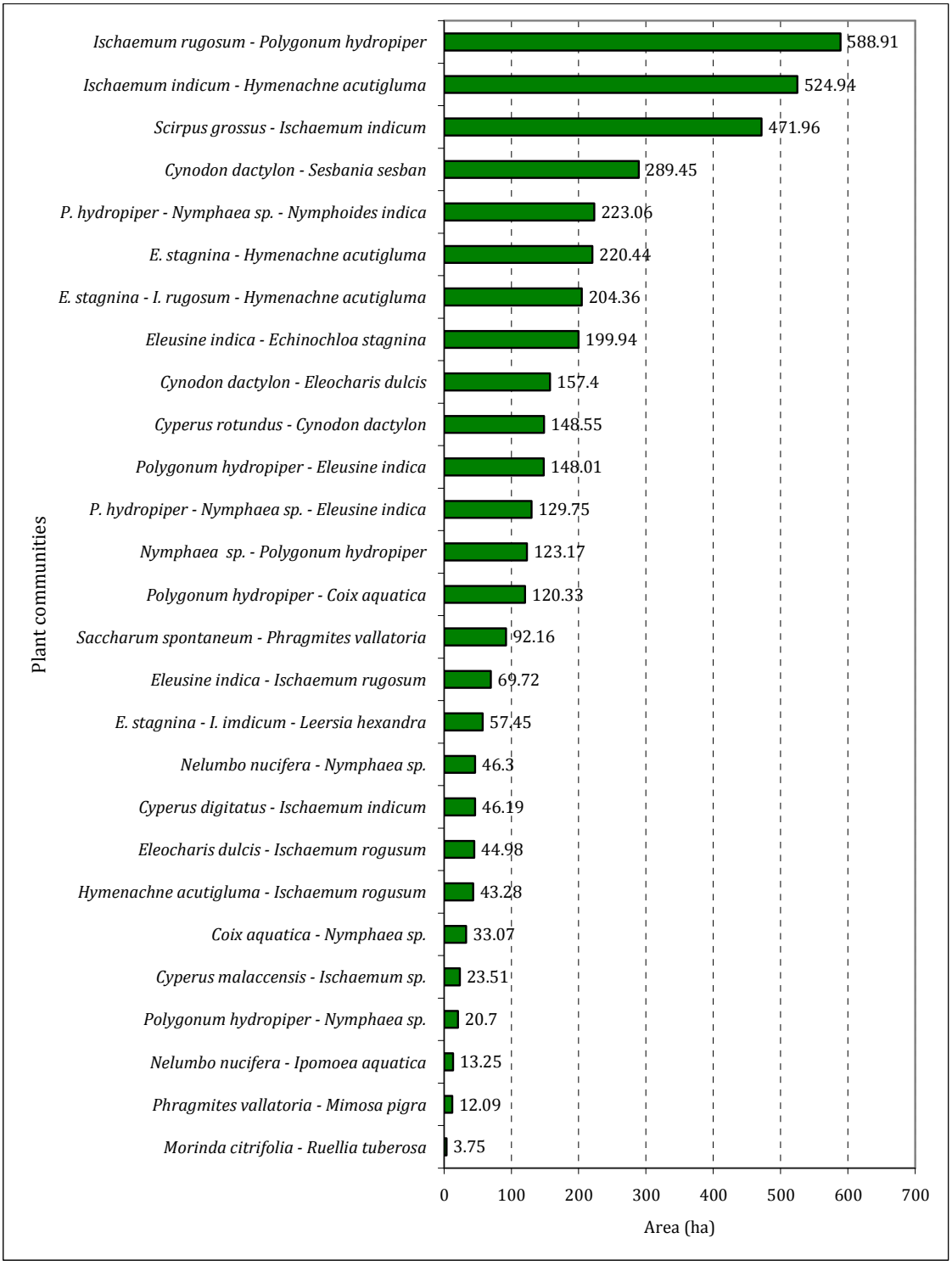


Figure 38. Ranges of area of plant communities in Boeung Prek Lapouv Crane Reserve

Table 7. Land covers with plant communities in Boeung Prek Lapouv Crane Reserve. Takeo Province

	Plant communities and plant species				Area (ha)
	Plant species in high population		Plant species in low population		
	Seasonally inundated grassland				**3,091.08**
1	*Cynodon dactylon*	*Sesbania sesban*	*Ludwigia adscendens*	*Polygonum hydropiper*	289.45
2	*Cynodon dactylon*	*Eleocharis dulcis*	*Ischaemum sp.*	*Nymphaea sp.*	157.4
3	*Cyperus rotundus*	*Cynodon dactylon*	*Ischaemum sp.*	*Mimosa pigra*	148.55
4	*Cyperus malaccensis*	*Ischaemum sp.*	*Mimosa pigra*		23.51
5	*Ischaemum rugosum*	*Polygonum hydropiper*	*Cynodon dactylon*		588.91
6	*Cyperus digitatus*	*Ischaemum indicum*	*Cynodon dactylon*		46.19
7	*Ischaemum indicum*	*Hymenachne acutigluma*	*Polygonum hydropiper*		524.94
8	*Eleusine indica*	*Echinochloa stagnina*	*Ischaemum sp*	*Leersia hexandra*	199.94
9	*Eleusine indica*	*Ischaemum rugosum*			69.72
10	*Scirpus grossus*	*Ischaemum indicum*	*Cyperus sp.*		471.96
11	*Echinochloa stagnina*	*Hymenachne acutigluma*	*Eleusine indica*	*Cynodon dactylon*	220.44
12	*Echinochloa stagnina*	*Ischaemum imdicum*	*Leersia hexandra*		57.45
13	*Echinochloa stagnina*	*Ischaemum rugosum*	*Hymenachne acutigluma*		204.36
14	*Hymenachne acutigluma*	*Ischaemum rogusum*	*Polygonum hydropiper*		43.28
15	*Eleocharis dulcis*	*Ischaemum rugosum*	*Eleusine indica*		44.98
	Aquatic plants				**857.64**
16	*Coix aquatica*	*Nymphaea sp.*	*Sesbania sesban*		33.07
17	*Polygonum hydropiper*	*Nymphaea sp.*	*Eleusine indica*		129.75
18	*Polygonum hydropiper*	*Nymphaea sp.*	*Nymphoides indica*	*Hymenachne acutigluma*	223.06
19	*Polygonum hydropiper*	*Coix aquatica*	*Saccharum spontaneum L.*		120.33
20	*Polygonum hydropiper*	*Eleusine indica*	*Ischaemum rogusum*	*Hymenachne acutigluma*	148.01
21	*Polygonum hydropiper*	*Nymphaea sp.*	*Nymphoides indica*	*Hymenachne acutigluma*	20.70
22	*Nelumbo nucifera*	*Nymphaea sp.*	*Polygonum hydropiper*		46.30
23	*Nelumbo nucifera*	*Ipomoea aquatica*	*Saccharum spontaneum*		13.25
24	*Nymphaea sp.*	*Polygonum hydropiper*	*Coix aquatica*	*Sesbania sesban*	123.17
	Tall grasses and shrubs				**108.00**
25	*Phragmites vallatoria*	*Mimosa pigra*	*Sesbania sesban*		12.09
26	*Saccharum spontaneum*	*Phragmites vallatoria*	*Mimosa pigra*		92.16
27	*Morinda citrifolia*	*Ruellia tuberosa*	*Cyperus difformis*	*Mimosa pigra*	3.75
	Agricultural land				**4,219.62**
28	Fruit trees				68.97
29	Paddy				4150.65
	Total area (ha)				**8,276.34**

Within seasonally inundated grassland, four plant communities are recognized:

- *Ischaemum sp - Leersia hexandra*; This plant community has quite a broad distribution of about 350 ha in the middle elevational range. Besides the two species of *Ischaemum* grass and *Leersia hexandra* that are most abundant, there are other species interspersed, such as *Echinochloa stagnina, Chloris barbata, Eleusine indica*.

Figure 39. Community of *Ischaemum sp - Leersia hexandra* in BPL.

- *Echinochloa stagnina - Leersia hexandra*; This plant community is distributed predominantly at middle elevation especially along slopes of canals and small mounds. As the distribution is on higher terrain, there are species of shrubs and tall grass associated with this community such as *Phyllanthus reticulates, Morinda citrifolia, Saccharum spontaneum,* and liana species such as *Ipomoea nil*, *Merremia umbellate*.

- *Eleocharis dulcis*; Clusters of *Eleocharis dulcis* are sometimes found within *Ischaemum sp - Leersia hexandra* grasslands. The area of each cluster is not large, however it distributed fairly common to form a complex piece of grassland in the south of the nature reserve. Soil profile showed most of land is actual acid sulphate soils and acidic soils.

- *Eleocharis dulcis – Ischaemum sp*. There is a large area in the south and south-west of the reserve (Figure). Although two species *Eleocharis dulcis – Ischaemum sp*. are predominant, some other species such as *Eleusine indica, Leersia hexandra, Chloris barbata, Cynodon dactylon* are found in association.

Figure 40. *Eleocharis dulcis – Ischaemum sp*. community in acid sulphate soils in BPL

There are many small and shallow swamps which receive acidic water from the surrounding area resulting in the appropriate environment for the development of *Eleocharis dulcis.*

- The *Cyperus* plant community is widely distributed and occupies a considerable area of the reserve, about 760 ha. Most of this community occurs in low lying areas along the canals and in small ponds. Dominant species are *Cyperus malaccensis, Scirpus grossus*, *Scirpus mucronatus*. Waterlogged soils are a suitable environmental factor for this community.

  Some species of grass were recorded in association with the Cyperus community such as *Ischaemum indicum*, *Ischaemum rugosum, Panicum repens*. In drier areas, there are also some other species of Cyperaceae identified as *Fimbristylis microcarya, Fimbristylis miliacea, Cyperus difformis, Cyperus compactus, Cyperus rotundus, Cyperus elatus.*

Figure 41. Cyperus community in Boeung Prek Lapouv.

- *Saccharum spontaneum - Phragmites vallatoria*; the community distributed along the bank of canals and higher terrain. The banks of the canal network built before establishment of BPL are covered by *Saccharum spontaneum* and *Phragmites vallatoria*. *Mimosa pigra* has also intermingled in this community and its population is quite high in some areas.

Figure 42. Community of *Saccharum spontaneum - Phragmites vallatoria* in BPL

- Scrub complex; distributed in higher areas along the banks of canals and higher terrain. Plant community comprising predominantly of *Morinda citrifolia.* and *Phyllanthus reticulatus*. The grass beneath the scrub canopy comprises of *Ruellia tuberosa*, *Cyperus difformis*, *Pluchea indica*, *Cynodon dactylon*, *Heliotropium indicum*, and liana species as *Ipomoea nil, Merremia umbellate*. *Mimosa pigra* was also found scattered in the shrub community.

Figure 43. Shrubs complex in Boeung Prek Lapouv.

- *Nelumbo nucifera* (Lotus) – *Nymphaea* sp. (Water lily); distributed not only in the area of water bodies but also in seasonal depressions. Lotus was found in some open water areas along natural channels and irrigation canals, but was absent in depression areas among grasslands.

Figure 44. Lotus community in open water habitat in Boeung Prek Lapouv.

The lotus and water lily plant community comprises some typical aquatic species as *Nelumbo nucifera, Nymphaea pubescens* and *Nymphaea nouchali*. Other aquatic species were also identified as *Nymphoides indica*, *Ceratophyllum demersum*.

- Water lily (*Nymphaea* sp.) was found commonly in small depressions within the grassland (even though they had died at time of survey due to lack of water in the dry season, decomposing stems were found).
- Water hyacinth (*Eichhornia crassipes*) was also commonly found in open water body along the canals.
- Trees; there are not many trees at present. There are a few Melaleuca tree stands among the vast grasslands, and a few Kadam tree (*Neolamarckia cadamba*) still stand by the banks of the natural channels.
- Mimosa (*Mimosa pigra*) an invasive alien species is already present in many places in Boeung Prek Lapouv. It is especially dominant on high-mid elevations where the soil has been disturbed such as on embankments. Its expansion may have hazardous effects on the natural ecosystem.

The core zone of Boeung Prek Lapouv, which was designed as a square of 934 ha where there are 21 plant communities covered about 928.48 ha in which total area of seasonally inundated grass communities is of 496.72 ha and that of aquatic plant is of 420.99 ha. Each plant community with two dominant species associated with other species in low population showed in Table 8.

Two plant communities are dominant: *Polygonum hydropiper - Eleusine indica, Ischaemum rogusum - Hymenachne acutigluma*, and other nine plant communities are from 41.21 – 85.88 ha: *Polygonum hydropiper - Coix aquatica, Polygonum hydropiper - Nymphaea sp., Eleusine indica - Echinochloa stagnina, Scirpus grossus - Ischaemum indicum, P. hydropiper - Nymphaea sp., Ischaemum indicum - Hymenachne acutigluma, C. dactylon - Sesbania sesban, C. dactylon - Eleocharis dulcis, and Nymphaea sp. - Polygonum hydropiper* (Figure 45).

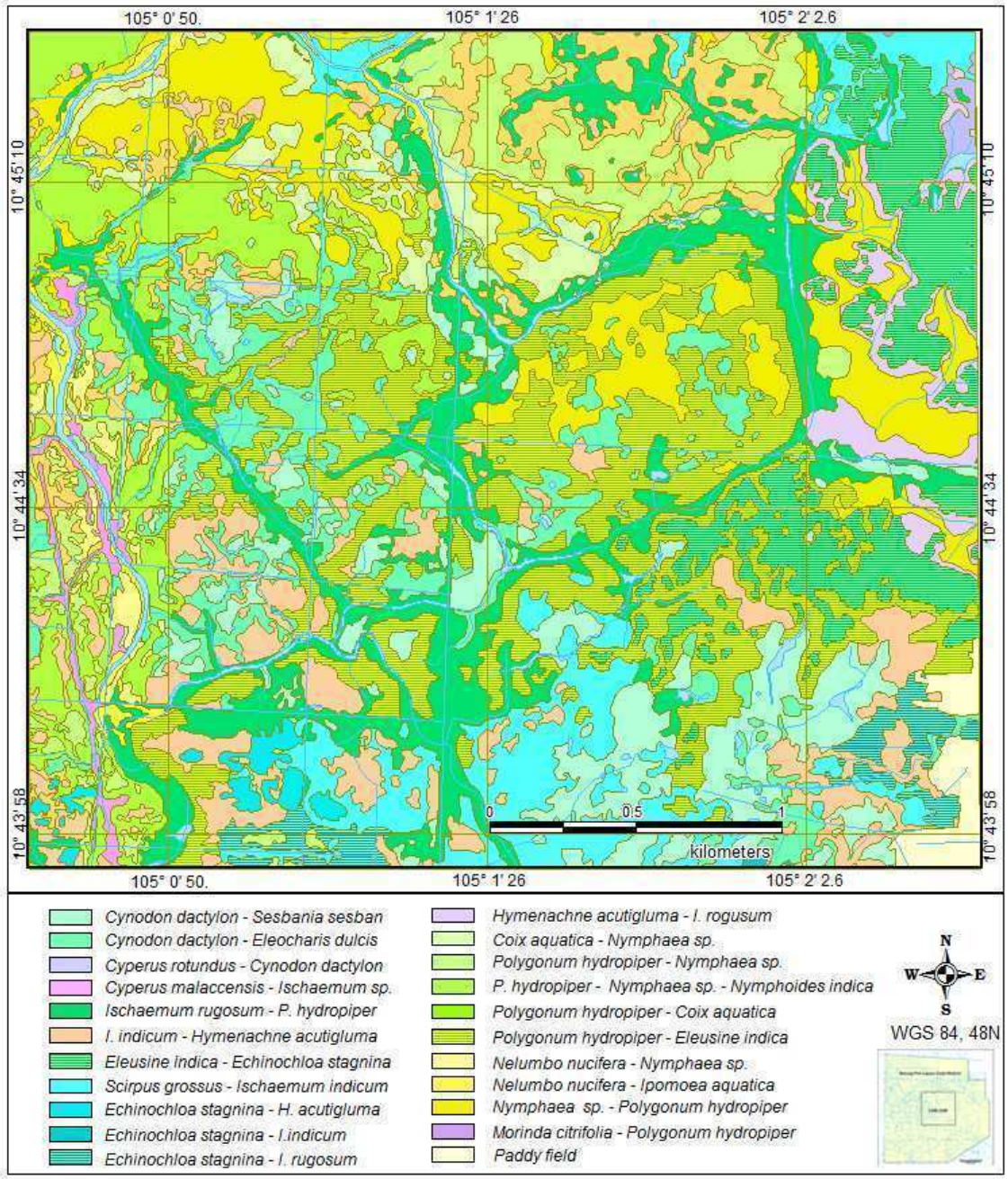


Figure 45. Distribution of plant communities in core zone of BP

Table 8. Plant communities in core zone of Boeung Prek Lapouv Crane Reserve

	Plant communities				Area (ha)
	Plant species in high population		Plant species in low population		
	Seasonally inundated grasslands				**496.72**
1	*Cynodon dactylon*	*Sesbania sesban*	*Ludwigia adscendens*	*Polygonum hydropiper*	70.33
2	*Cynodon dactylon*	*Eleocharis dulcis*	*Ischaemum sp.*	*Nymphaea sp.*	72.27
3	*Cyperus rotundus*	*Cynodon dactylon*	*Ischaemum sp.*	*Mimosa pigra*	3.18
4	*Cyperus malaccensis*	*Ischaemum sp.*	*Mimosa pigra*		8.67
5	*Ischaemum rugosum*	*Polygonum hydropiper*	*Cynodon dactylon*		116.08
6	*Ischaemum indicum*	*Hymenachne acutigluma*	*Polygonum hydropiper*		64.39
7	*Eleusine indica*	*Echinochloa stagnina*	*Ischaemum sp*	*Leersia hexandra*	59.62
8	*Scirpus grossus*	*Ischaemum indicum*	*Cyperus sp.*		60.54
9	*Echinochloa stagnina*	*Hymenachne acutigluma*	*Eleusine indica*	*Cynodon dactylon*	7.25
10	*Echinochloa stagnina*	*Ischaemum imdicum*	*Leersia hexandra*		0.46
11	*Echinochloa stagnina*	*Ischaemum rugosum*	*Hymenachne acutigluma*		13.91
12	*Hymenachne acutigluma*	*Ischaemum rogusum*	*Polygonum hydropiper*		20.02
	Aquatic plants				**420.99**
13	*Coix aquatica*	*Nymphaea sp.*	*Sesbania sesban*		26.81
14	*Polygonum hydropiper*	*Nymphaea sp.*	*Eleusine indica*		47.38
15	*Polygonum hydropiper*	*Nymphaea sp.*	*Nymphoides indica*	*Hymenachne acutigluma*	62.25
16	*Polygonum hydropiper*	*Coix aquatica*	*Saccharum spontaneum L.*		41.21
17	*Polygonum hydropiper*	*Eleusine indica*	*Ischaemum rogusum*	*Hymenachne acutigluma*	141.81
18	*Nelumbo nucifera*	*Nymphaea sp.*	*Polygonum hydropiper*		7.08
19	*Nelumbo nucifera*	*Ipomoea aquatica*	*Saccharum spontaneum*		8.57
20	*Nymphaea sp.*	*Polygonum hydropiper*	*Coix aquatica*	*Sesbania sesban*	85.88
	Shrubs				**0.05**
21	*Morinda citrifolia*	*Ruellia tuberosa*	*Cyperus difformis*	*Mimosa pigra*	0.05
			Total area		**917.76**

Table 8. Plant communities in core zone of Boeung Prek Lapouv Crane Reserve

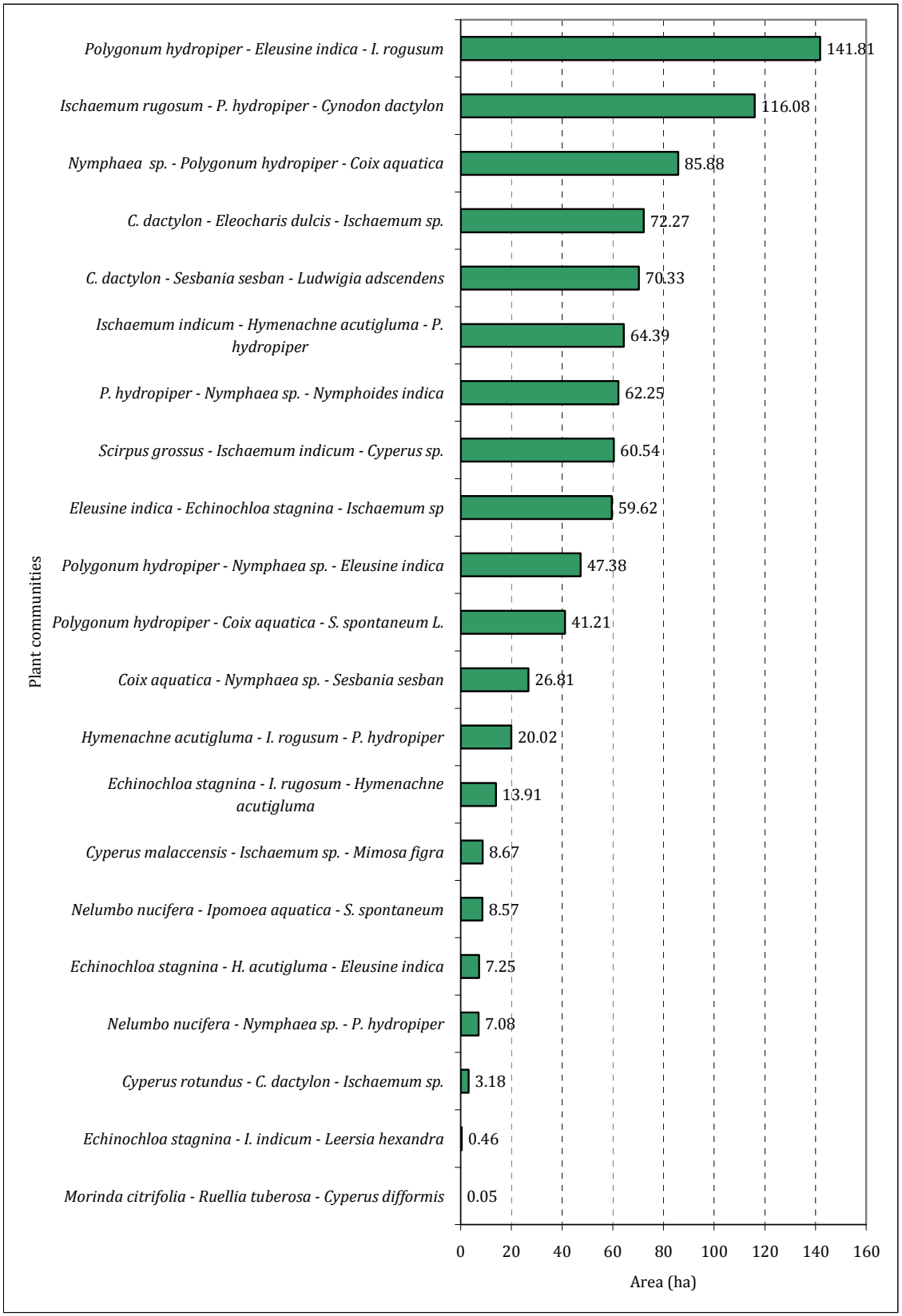


Figure 46. Plant communities in core zone of Boeung Prek Lapouv Crane Reserve

2.2.3. Vegetation communities and birds

For Sarus Cranes, implementation of the protection and rehabilitation of *Eleocharis dulcis* and Water lily areas (especially Water lily growing in depressed areas in grasslands) should be taken into account. However, other bird species and wetland biodiversity can also be restored to former levels by managing water levels, influencing soil and water properties and vegetation..

Floodwater also rises and falls faster in Boeung Prek Lapouv as compared to areas further downstream. A dense network of canals without dikes for water management has resulted in the loss of large amount of water during the dry season. The area is therefore quite dry during the dry season except for some small channels and ponds located within the area. Seasonally inundated grasslands should have two alternating seasons in the growth and development of it, however as water table levels drop too deep from the soil surface resulted in soil too dry will be unfavorable factors for the healthy ecosystem. Although many Water Lily communities distributed in many swamps and small shallow ponds within grasslands where cranes often be back for feeding in the dry season, however, the bed of clay or silty-clay soils become too firm as water loss and drier has caused the most problems for the Crane to access the water lily 's tubes lying underneath of the ground. Sarus Crane returned back to this area in search of food as the soil is still moist and flied away as the soil is too dry can prove such a case.

As mentioned on the food sources for Sarus Cranes on the important wetlands in the Mekong Delta, Triet (2004) stated degradation of crane feeding sites in the Mekong Delta may also be making it increasingly difficult for cranes to feed at the key sites for long periods of time. Cranes have stopped feeding at Boeung Prek Lapouv in the mid-late dry season since 2004, likely due to the drier conditions that still prevail today and that are progressively becoming more severe.

Aquatic community being abundant in Boeung Prek Lapouv plays an important role for the water birds living and foraging, particularly in the dry season. Some swamps and shallow ponds where are appropriate for the growth of lotus and water lily. Therefore, the proper management of water for maintaining and expanding the area of swamps will create health habitats for water birds, especially cranes will spend more times in this wetlands.

A too dry grassland will result in a poor habitat for water birds. During the survey, many water birds concentrate in open water area of canals, but can hardly see any birds appeared to be on dried grasslands. Expansion of waterlogged areas such as artificial wetlands by dikes systems for suitable water management will facilitate an increase the areas of habitats for waterfowl during the dry season. Similarly, the variety of and population of waterbirds increased significantly after an applying appropriate water management to restore the swamps at U Minh Thuong National Park in Kien Giang (Quoi, 2012).

Natural channels network within protected area is the open water habitat for many species of freshwater fish. Natural fisheries are important not only for people but also are food sources for waterfowl. Thus, restoration of these water areas will create better habitat of waterbirds. The expansion of grass species such as *Ischaemum sp., Panicum repens* along the edge of the channels has reduced surface water habitat areas in this area.

Seasonally inundated grassland with species of grasses such as *Ischaemum sp*., *Echinochloa stagnina* well developed and they have a significant height that can be impediments for

many species of water birds coming this area for shelter and feeding. The initiative burning of grasslands will need to be carried out in the dry season for the purpose of reducing the thickness of the grass layer and vegetation residues can be a source of food for fish in the flood season.

3. Conclusion and recommendations

3.1. Hydrological management

There are four main issues to be addressed at BPL:

1. Wetland drying out too rapidly at the beginning of the dry season
2. The replacement of the short grass and open habitats with tall, thick vegetation rendering habitat unsuitable for cranes.
3. The invasion of mimosa pigra
4. Wetland loss in the buffer zone due to encroachment

To address issues 1-3 and in part also issue 4, the following management actions are recommended:

1. Prepare experimental hydro-ecological restoration plots and monitor the outcomes for 3 years. The details of the recommended experimental plots are described in 4.1 below.
2. Conduct a hydro-ecological monitoring program at BPL. The details of the monitoring program are described in 4.2 below.
3. Burns by villagers should be allowed and prescribed burns should also be conducted by the management of the reserve. However, one or two weeks after each burn, Mimosa pigra will sprout up abundantly from the soil seed bank. A team of local laborers should be hired to eradicate mimosa seedings at the burnt sites in the dry season.
4. Mimosa pigra should be kept in check. Normally, M. pigra usually invades where the local vegetation communities are disturbed. As Mimosa pigra seeds are carried downstream with Mekong flows, it is not possible to eliminate the plant but should be kept in check with a long-term Mimosa control program.
5. It is strongly recommended that tall dykes, especially tall dykes that enclose the reserve and isolate the reserve from the surrounding or those that fragment the habitat of the reserve hydrologically should be avoided now and in the future. As discussed earlier, tall dykes will create stagnant water conditions in which decomposition of accumulated dead biomass will be slowed down as biological oxygen demand (BOD) will increase and result in depletion of dissolved oxygen (DO) in the water, a condition not favorable for fish productivity. The tall dykes will also prevent fish eggs and fingerings from the Mekong waters to come into the floodplain environment of the reserve during the wet season. At the same time, the thickly accumulated biomass layer will render the habitat not suitable for cranes.
6. Further channel construction within the reserve should be avoided as canals will fragment habitats and increase water losses from the reserve in the dry season

through increased outflows, increased open surface evaporation, and lowering the water table.

7. To promote science-based management at the site, an Advisory Body comprising of experienced wetland scientists and practitioners should be established to provide technical advice to the management of the reserve on periodic basis.

3.1.1 Recommended Experimental plots

It is recommended that at least 2 hydro-ecological habitat management plots be conducted and monitored

a. Objective

The objective of the experimental plots is to provide habitat for Sarus Crane and water birds in the dry season through experimenting localized hydrologic restoration in the field.

b. Target

The target is to provide suitable habitat to enable the Sarus crane to stay on at the reserve to at least the middle of April. To achieve this, the hydrologic target is that by the end of March, water level is at approximately the ground level but with no standing water on the ground.

d. Site selection

To provide sufficient habitat for the visiting crane population to BPL, the plots should be sufficient in size. It is recommended that the plots should be 50-100 hectares each. Factors that should be taken into account in selecting the sites for the plots include:

- Accessibility for monitoring. The selected sites should be within a walk distance or adjacent to a canal accessible by boat.
- Use of existing low dykes to save on the cost.
- Of the 2 selected plots, one should be aimed for promoting water lily and the other for Eleocharis to provide a diversity of feeding habitats for the cranes.

3.1.2 Design and construction

A periphery low dyke should be constructed to enclose the plot. The dyke should only be made of the soil from the excavation of the associated canal. To ensure water retention capacity of the plot, the canal should be on the outside of the dyke or in other word. The construction of the dykes for the experimental plots should be done manually to avoid noise disturbance to the cranes and to provide employment to the locals.

The dykes should be low to allow flood water overtopping in the flood season to enable water exchange and to take in fish eggs and fingerlings from the Mekong flood water. But at the same time, the dyke should be tall enough to retain enough water to achieve the target moisture at the end of March as discussed above. It is recommended that the dyke should

be 1 meter tall from the ground to the top to enable retaining a layer of 1 meter of water at the end of the flood season. This layer should be sufficient to accommodate for water losses through evaporation (about 5-6mm/day for about 3 months) and leakages. The width of the dyke should be about 1 meter at top. The dyke should be built at early dry season when the soil is till wet enough so that it is easy to compact. The soil of the dyke should be compacted right away after excavation to reduce leakages through the dyke. Also, to reduce leakage through the foot of the dyke, the top soil layer with high organic contents and thus high hydraulic conductivity should be removed and set aside before further excavation. The top soil that has been removed and set aside should be placed on top of the dyke after completion in order to facilitate growth of vegetation on the dyke.

Small permanent sluice gates or temporary openings can be made on the dykes of the experiment plots to allow water in when water level is still below the tops of the dykes. The sluice gates or openings will help flushing out of organic matters from the plots. The downside is that building the sluice gates with concrete can be expensive while temporary openings will be inconvenient for management as the openings will need to be sealed when flood water recedes in order to retain water in the plots.

Ideally, the experimental plots should be placed in the buffer zone, along soft boundaries between wetland and rice fields so that the dyke can form a hard boundary and prevent encroachment in that area.

3.1.3 Habitat management within the experimental plots

Within the plot, all Mimosa plants should be removed including young sprouts before the flood season. If there is a thick layer of accumulated dead biomass and tall grass in the plot, it should be burnt to create open space to facilitate establishment of water lily, Eleocharis, and short grasses. Note that after burn an abundance of Mimosa will sprout up from the seed bank in the soil. Thus it is necessary that the burnt areas must be revisited several times to eliminate all the Mimosa sprouts. While Eleocharis will be able to re-establish itself easily, water lily reestablishment should be assisted through replanting if necessary.

3.1.4 Monitoring and evaluation of the experimental plots

The processes and the outcomes of the experimental plots must be monitored for evaluation purpose. A monitoring trip should be made to the plots every two weeks.

1) Water levels, water quality, and rate of water loss

In each of the plots, a staff gauge should be installed at the lowest accessible point to monitor the surface water level. As the plots are in the field away from the station, daily readings are not logistically feasible, water readings should be obtained on weekly basis from the end of the flood season when water level is at the level of the top of the periphery dykes of the plots.

Also in each of the plots, a system of several piezometers should be installed at different locations representing a gradient of elevation within the plot. The piezometers can be made of simple PVC pipes (34mm in diameter) inserted to 1 meter deep from the soil. Small holes

should be made in the lower 30cm part of the pipes to allow ground water to flow into the pipes. Readings of the distances from the ground levels to the water table in the pipes should be obtained on weekly basis. Note that the readings of the ground water levels in the piezometers are to be done when the surface water level has receding from the ground levels rendering readings of the staff gauges no longer possible. Piezometer readings should start when ground water level is at the ground level until the end of the dry season when water raises up to the ground level again.

pH and DO of surface water should also be measured in the surface water and the ground water (in the piezometers) during the dry season. pH is important for detecting acidity released from the soil while DO is important for aquatic life as accumulation of organic matters will tend to demand for DO in water.

At the headquarters of BPL reserve, a simple rain gauge should also be established and rainfall readings should be obtained for any rain events that happen during the dry season. As the dry season rains might affect ground water levels, acidity release from the soils, and vegetation status in the experiment plots, the data of dry season rainfall should be linked to the field monitoring data to detect patterns. The following table provides a suggested template for water level reading log.

Table 9. Suggested template for water level reading log

Date	Surface water level (cm above the ground)	Ground water level (cm below the ground)	Rate of water level reduction (cm/day)

The periphery dykes should also be checked on weekly basis for leakages. Any visible leakages of water through the periphery dikes should be sealed.

2) Vegetation monitoring:

Status of vegetation in the plots should be monitored every 2 weeks. The following parameters are recommended for monitoring:

i) Species, estimated density, percentage, and coverage of the plants within the plots. This can be done by using 1mx1m quadrants along permanent transects covering different plant species within a plot.

ii) General observation of the status of the vegetation: what species seem doing well and what species not.

iii) Take pictures from the same position of the same frame at each observation from the permanent photopoints established at each experiment plot.

3) Crane and water bird monitoring

Crane and water birds monitoring should also be done every 2 weeks. The following information should be documented:

a. Date and time of observation

b. Number of cranes and other species of water birds

c. First day of crane use of the plots, length of stay.

d. Specific location of crane use in the plots and field conditions of the locations (water level, moisture, species and status of vegetation, water quality, etc.,)

e. Feeding behavior of the cranes and water birds (kinds of food, time of feeding, feeding evidence on the ground etc.,)

4) Reporting:

Every 2 weeks, by the end of the field monitoring day, a rapid field condition report should be written and submitted to the management of the reserve. The rapid field monitoring report should contain monitoring data on water, vegetation, cranes and birds as mentioned above, other field observations, thoughts on issues and recommendations for management actions.

At the end of every dry season, an annual report should be prepared based on the rapid reports and provide overall evaluation of the experiment plots and recommendation for scaling up or corrections. Correlations between crane numbers and lengths of stay in the experiment plots and the field conditions (water level and quality, vegetation status) should be analyzed in the rapid and annual dry season reports.

3.1.5 Overall Field Monitoring Program

Besides the morning in the experimental plots, a monitoring program should also be conducted for the entire reserve on monthly basis. A monitoring program should be designed and implemented to answer the following monitoring questions.

Table 10: Suggested Monitoring questions and actions

Monitoring questions	Recommended action
Cranes: 1. when do they first arrive at the reserve? 2. which areas in the reserve do they use at different times over the course of a year? 3. what is the length of crane stay at the reserve?	Crane counts at every 2 weeks and note the locations of the habitats that they use at diferent times in the reserve
Field conditions: 1. What are the depths of inundations or ground water levels and soil moistures of the habitat locations when cranes use them? 2. What are the water quality values at the habitat locations when cranes use them? (pH, DO) 3. What is the status of vegetation at the habitat locations when cranes use them? (species, health status, tuber productivity, etc.,)	conduct field checks every 2 weeks from first week of November to last week of June annually; document the numbers of cranes, locations of their feeding, field conditions at the times at the feeding locations including inundation depth or soil moisture and ground water level; status of vegetation and tuber production; etc.,.) establish permanent photopoints at key locations representing different feeding areas of the cranes over time during the

	dry season and take photographs of the habitats from the same angles at times of field checks in 2.1 above.
Status of mimosa Distribution and density of mimosa	Periodic image interpretations of distribution of mimosa Ground check on distribution and density of mimosa.
Burn and Grazing What is the impact of burns on cranes and water birds	Field checks every 2 weeks and document crane and other bird uses of burnt areas (date of burn, date of observed crane presence in the burnt areas, status of vegetation, level of inundation, soil moisture, ground water table) Observe if buffaloes disturb cranes Observe if cranes can use areas disturbed by buffalo grazing.
Habitat Management Issues: What are the issues that need addressing?	produce rapid biweekly field reports and annual reports at the end of dry seasons documenting and analyzing information recorded. discuss issues that need addressing and possible measures that should be undertaken.

3.2. Plant communities and habitats

This area is one of the few natural wetlands remaining in the Plain of Reeds and is regarded as a remnant of its original biodiversity.

Sarus Cranes have received the most attention in conservation of wetlands in the Plain of Reeds. However, many other important species whose abundance are surely an important aspect of biodiversity conservation in Boeung Prek Lapouv should also be paid more attention.

A significant area of acid sulphate soils would also be appropriate areas for expansion of *Eleocharis* grasslands where will be suitable one of the few feeding grounds for Sarus Cranes. Abundance of swamps within the protected area is potential area of expansion of indispensable aquatic habitats for waterbirds in the dry season. However, hydrological management systems have not been invested resulting in the degradation of natural ecosystems and biodiversity itself.

A model of appropriate management of hydrology for protection and rehabilitation of wetlands ecosystems and biodiversity should be taken into account and done before expanding to the area of the nature reserve.

Mimosa (*Mimosa pigra*) as invasive alien species already present in many areas. This species will compete habitat of native species. As the density increases, it will cause damage to natural ecosystems in protected areas. Consequently, there should be plans to limit the spread of this species in Boeung Prek Lapouv.

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Annex 1. Soil Profile Description

1.1. Soil profile description in Anlung Pring

Soil Profile at Site 78
Water level: - 64 cm.
Plants: *Eleocharis spiralis – E. dulcis*
Soil classification: Entic Sulfaquepts
Soil condition: Dry
Landscape: Eleocharis grass

Ah: 0 – 22 cm; Silty loam mixed with high amount of decomposed organic matter, black; abundant small grass roots; grass residues mixed in soil matrix; moist; non-plastic and non-sticky to slightly sticky, unripe.

A/B: 22 – 31 cm; Loam mixed with decomposed organic matter; black mixed with brown streaks; few small roots; few dark brown iron (oxides) hydroxides mottles; medium spores; moist; slightly sticky; ripe.

Bj: 31 – 63 cm: Silty clay; brown; yellow jarosite mottles along root channels and pores, about 27 %; few channel spores; firm; very plastic and sticky; moist; half-ripe to ripe.

Bg: 63 – 65 cm: Silty clay; dark brown; few dark brown iron (oxides) hydroxides mottles; few channel spores; very plastic and sticky; moist; unripe

Cr: 63 – 150 cm: Silty clay; dark grey; pyritic minerals mixed with clay materials; very few fine spores; very plastic and sticky; wet; unripe

Soil Profile at Site 84
Water level: - 35 cm.
Plants: *Eleochris dulcis – E. spiralis*
Soil classification: Sulfic Tropaquents
Soil condition: Moist
Landscape: Eleocharis grass

Ah: 0 – 14 cm; Silty loam mixed with high amount of decomposed organic matter; black; abundant small grass roots; medium spores; moist; non-sticky, half-ripe.

A/B: 14 – 21 cm; Loam mixed with decomposed organic matter; brown; few small roots; few dark brown iron mottles; small and medium spores; moist; slightly plastic and sticky; ripe.

Bg: 21 – 51 cm; Silty clay; light brown; few brown iron iron (oxides) hydroxides mottles; few channel spores; very plastic and sticky; moist; half-ripe to unripe.

Cr_1: 51 – 81 cm; Clay loam; semi-decomposed organic matter; dark grey; few small channel pores; wet; very plastic and sticky; unripe.

Cr_2: 81 – 150 cm; Clay; dark grey; pyritic minerals; very plastic and sticky; wet; unripe.

Soil Profile at Site 58
Water level: + 2 cm.
Plants: *Eleochris dulcis – E. spiralis*

Ah: 0 – 24 cm; Silty loam mixed with high amount of decomposed organic matter; black; abundant small grass roots; medium spores; wet; non-sticky, unripe.

B/C: 24 – 42 cm; Loam mixed with low mount of semi-decomposed organic matter; dark brown; small grass roots; few small pores; wet; slightly sticky; unripe.

Cr: 42 – 100 cm; Slity clay, few decomposed organic matter, dark grey; very few small pores; wet; very sticky; pyritic minerals; unripe.

Soil Profile at Site 87
Water level: - 43 cm.
Plants: *Eleochris spiralis*

Ah: 0 – 34 cm; Silt mixed with high amount of decomposed organic matter; black; abundant small grass roots; medium spores; moist; non-sticky, half-ripe.

A/B: 34 – 45 cm; Silt cloam mixed with few decomposed organic matter; brown; few small roots; small and medium spores; moist; slightly plastic and sticky; half-ripe.

C/B: 45 – 76 cm: Silty clay; light brown; few channel spores; moist; very plastic and sticky; unripe.

Cr: 76 – 150 cm; Clay; dark grey; pyritic minerals; wet; very plastic and sticky; unripe.

2.2. Soil profile description in Boueng Prek Lapouve

Soil Profile at Site 89
Water level: > 80 cm.
Plants: *Echinochloa stagnina, Morinda citrifolia, Cynodon dactylon*

Ah: 0 – 37 cm; Clay loam mixed with decomposed organic matter; black; abundant small grass roots; medium spores; moist; non-sticky, ripe.

Bg_1: 37 – 50 cm: Clay; young alluvial mixed with collouvial materials; very light grey; few yellow and brown iron iron (oxides) hydroxides mottles; few medium spores; very plastic and sticky; moist; firm; ripe.

Bg_2: 50 – 100 cm; Clay; very light grey; colluvial materials; few yellow and brown iron mottles; medium small spores; moist; very plastic and sticky; firm; ripe.

Soil Profile at Site 95
Water level: - 47 cm
Plants: *Echinochloa stagnina, Morinda citrifolia, Saccharum spontaneum*
Soil condition: dry, depression
Soil classification: Palesulfic Tropaquepts
Landscape: Grassland in low area

A: 0 – 14 cm; Clay; brown; few small grass roots; abundant brown ion (oxides) hydroxides in matrix and inside pores; firm; slightly moist; plastic and sticky in moist; ripe.

Ah: 14 – 50 cm; Silt mixed with decomposed organic matter; very dark grey; small grass roots; medium small spores along root channels and pores; moist; slightly plastic and sticky; ripe.

Bg_1: 50 – 82 cm; Clay; light grey; few yellow, brown (gethite) and red (hematite) mottles in medium pores; medium spores; moist; very plastic; firm; ripe.

Bg_2: 82 – 131 cm; Clay; dark grey; few dark yellow iron (oxide) hydroxides mottles along channel pores; medium spores; moist; very plastic and sticky; firm; ripe to half-ripe.

Cr: 131 – 170 cm; Clay mixed with few dark brown organic matter; dark grey; ; few plant residues and semi-decomposed organic matter; pyritic minerals; wet; very plastic and sticky; unripe.

Soil Profile at Site 93
Water level: - 47 cm
Plants: *Cynodon dactylon, Ipomoea aquatica*

Ah: 0 38 cm; Silt mixed with high amount of decomposed organic matter; very dark grey; abundant small grass roots; medium small spores; moist; non-sticky, ripe.

Bg_1: 38 – 70 cm; Clay; grey with dark grey streaks; some brown iron iron (oxide) hydroxides mottles along root channels; medium spores; moist; very plastic and sticky; firm; half-ripe to ripe.

B/C: 70 – 78 cm: Silty clay; brownish grey; few small channel spores; few plant residues and semi-decomposed organic matter; moist to wet; very plastic and sticky; half-ripe.

Cr: 78 – 180 cm: Clay; dark grey; ; few plant residues and semi-decomposed organic matter; pyritic minerals; wet; very plastic and sticky; unripe.

Soil Profile at Site 122
Water level: - 75 cm
Plants: *Cynodon dactylon, Nymphaea pubescens, Eleusine indica.*

A: 0 – 41 cm; Ah: 0 – 50 cm; Clay loam mixed with few organic matter; dark grey; small grass roots; medium small spores; moist; slightly sticky, ripe.

1Bg: 41 – 92 cm; Clay loam mixed with few fine sands; brown; few brown iron iron (oxides) hydroxides mottles in medium pores and soil matrix; medium spores; moist; very plastic; soft; slightly plastic and sticky; unrire to half-ripe.

2Bgj: 92 – 165 cm; Clay loam mixed with fine sands; light grey; few yellow jarosite mottles along root channels and pores, about 5 - 7 %; few channel spores; soft; moist; very plastic and sticky; half-ripe to ripe.

2B: 165 – 180 cm; Clay loam mixed with fine sands; light grey; colluvial materials from older alluvial; moist; plastic and sticky; ripe.

Soil Profile at Site 148
Water level: - 73 cm
Plants: *Leersia hexandra*, *Eleusine indica, Cynodon dactylon, Hymenachne acutigluma*

Ah: 0 – 42 cm; Silt loam mixed with decomposed organic matter; dark grey; abundant small grass roots; medium coarse spores; firm; moist; plastic and sticky to slightly sticky in moist, ripe.

Bg_1: 42 – 58 cm; Clay; brownish grey; few yellow iron iron (oxide) hydroxides mottles in medium pores; medium spores; moist; firm; slightly plastic and sticky in moist; ripe.

Bg_2: 58 – 120 cm; Clay; brown; few yellow iron iron (oxide) hydroxides mottles in medium pores; medium spores; moist; firm; slightly plastic and sticky in moist; half-ripe.

Cr: 120 – 180 cm; Clay; dark grey; ; few plant residues and semi-decomposed organic matter; pyritic minerals; wet; very plastic and sticky; unripe.

Soil Profile at Site 130
Water level: - 74 cm
Plants: *Eleochris dulcis, Cynodon dactylon, Eleusine indica*
Soil condition: Dry
Soil classification: Sulfic Tropaquepts
Landscape: Eleochris grass

Ah: 0 – 26 cm; Silt mixed with decomposed organic matter; very dark grey; abundant small grass roots; medium small spores; moist; non plastic and sticky to slightly sticky, ripe.

Bg_1: 26 – 52 cm; Silty clay; light brown; medium yellow and brown iron iron (oxides) hydroxides mottles in medium pores and soil matrix; medium spores; moist; soft; slightly plastic and sticky; half-ripe.

Bgj_2: 52 – 75 cm; Silty clay; brown; few yellow jarosite mottles along root channels and pores, about 7 %; few channel spores; soft; moist; very plastic and sticky; unripe to half-ripe.

Bg: 75 – 90 cm; Silty clay mixed with organic matter; brown; few channel spores; soft; wet; very plastic and sticky; unripe. Perdysis propertiy.

C_1: 90 – 110 cm; Silty clay mixed with organic matter; dark brown; few channel spores; very soft; wet; very plastic and sticky; unripe.

C_2: 110 – 145 cm; Clay mixed with organic matter; dark grey; ; few plant residues and semi-decomposed organic matter; pyritic minerals; wet; very plastic and sticky; unripe.

Soil Profile at Site 131
Water level: - 54 cm
Plants: *Eleochris dulcis, Eleusine indica, Mimosa pigra; Cyperus difformis*
Soil conditionL Dry
Soil classification: Sulfic Tropaquepts
Landscape: Grassland

Ah: 0 – 36 cm; Silt loam mixed with decomposed organic matter; very dark grey; abundant small grass roots; medium small spores; moist; non plastic and sticky to slightly sticky, ripe.

Bg_1: 36 – 54 cm; Silty clay; light brown; medium yellow iron iron (oxide) hydroxides mottles in medium pores; medium spores; moist; soft; slightly plastic and sticky; half-ripe to ripe.

Bjg_2: 54 – 87 cm; Silty clay mixed with organic matter; dark brown; few yellow jarosite mottles along root channels and pores, about 10 %; few channel spores; soft; moist; very plastic and sticky; unripe to half-ripe.

B/C: 87 – 95 cm; Silty clay loam; brownish grey; few small channel spores; few semi-decomposed organic matter; moist to wet; very plastic and sticky; half-ripe.

Cr: 95 – 170 cm; Clay; dark grey; ; few plant residues and semi-decomposed organic matter; pyritic minerals; wet; very plastic and sticky; unripe.

Soil Profile at Site 163
Water level: - 57 cm
Plants: *Fimbristylis miliacea,, Cynodon dactylon, Eleocharis dulcis*
Soil condition: Dry
Soil classification: Sulfic Tropaquepts
Landscape: Grassland

Ah: 0 – 27 cm; Silt loam mixed with decomposed organic matter; very dark grey; small grass roots; few brown iron mottles in posers; medium small spores; moist; non plastic and sticky to slightly sticky, ripe.

A/B: 27 – 34 cm; Silt cloam mixed with few decomposed organic matter; grey mixed with back treaks; few small roots; small and medium spores; moist; slightly plastic and sticky; ripe.

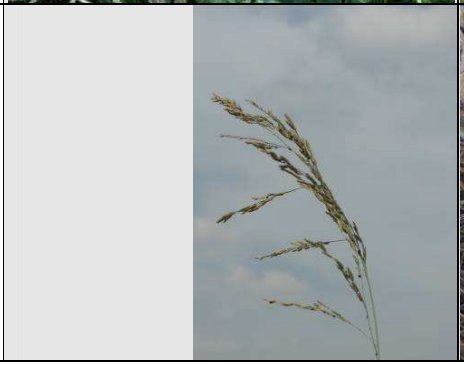
Bg: 34 – 68 cm; Silt cloam mixed with few decomposed organic matter; grey; few small grass roots; brown iron iron (oxide) hydroxides mottles in spores soil soil matrix, about 25 %; small and medium spores; moist; slightly plastic and sticky; ripe.

Bg_2: 68 – 92 cm; Clay; grey; few small grass roots; brown iron (oxide) hydroxides mottles in spores soil soil matrix; small and medium spores, about 40 %; moist; slightly plastic and sticky; ripe.

Cr: 92 – 160 cm; Clay; dark brownish grey; semi-decomposed plant residues and organic matter mixed in soil matrix; pyritic minerals; wet; very plastic and sticky; unripe.

ANNEX 2. LIST OF SPECIES OF VEGETATION IN WETLANDS OF ANLUNG PRING 9KAMPOT) AND BOEUNG PREK LAPOUV (TAKEO) – CAMBODIA

2.1. Main species of flora in Anlung Pring area, Kampot Province, Cambodia

No	Name			Photo	
	Family	Scientific	English		
1	Poacea	*Cynodon dactylon*	Couch grass		
2	Poacea	*Eragrostis atrovirens* (Desv.) Trin ex Steud.	Thalia lovegrass, Wiry lovegrass		

No	Name			Photo
	Family	Scientific	English	
3	Cyperaceae	*Fimbristylis microcarya* F.v. Mueller	Fringerush	 
4	Cyperaceae	*Fimbristylis miliacea* (L.) Vahl Fimbristylis littoralis	Grass-like fimbristylis, Lesser fimbristylis	 

No	Name			Photo
	Family	Scientific	English	
5	Cyperaceae	*Scirpus maritimus*	Alkali	 
6	Cyperaceae	*Fimbristylis sericea* (Poir.) R. Br.	Fringerush	 

No	Name			Photo	
	Family	Scientific	English		
7	Cyperaceae	*Eleocharis* spiralis (Rottb.) Roem. & Schult.	Unknown		
8	Cyperaceae	*Eleocharis dulcis* (Burm.f.) Trin	Water chestnuts		

No	Name			Photo
	Family	Scientific	English	
9	Cyperaceae	*Eleocharis philippinensis*	Unknown	 
10	Cyperaceae	*Eleocharis parvula* (R. & Sch.) Link ex Pl. :	Dwarf spikerush, small spikerush and hairgrass	 

No	Name			Photo
	Family	Scientific	English	
11	Xyridaceae	*Xyris indica*	Indian yellow-eyed grass	 
12	Commelibaceae	*Commelina benghalensis*	Dayflower	 

No	Name			Photo
	Family	Scientific	English	
13	Convolvulaceae	*Ipomoea aquatica*	Water spinach	 
14	Nympheaceae	*Nymphaea nouchali* Burm. f.	Water lily	 

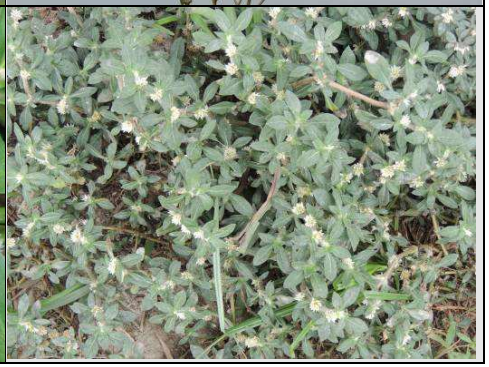
No	Name			Photo
	Family	Scientific	English	
15	Menyanthaceae	*Nymphoides indica* (L.) O.Ktze	Water snowflake	 
16	Ceratophyllaceae	*Ceratophyllum demersum*	Common hornwurt	 

No	Name			Photo	
	Family	Scientific	English		
17	Acanthaceae	*Acanthus ilicifolius* L.	Holly-leaved acanthus, Sea Holly, and Holy Mangrove		
18	Pteridaceae	*Acrostichum aureum* Linn.	Golden Leather Fern		

No	Name			Photo
	Family	Scientific	English	
19	Sonneratiaceae (Lythraceae)	*Sonneratia caseolaris* (L.) Engl.	Mangrove apple, Crabapple Mangrove	 
20	Arecaceae	*Nypa fruticants* Wumrb.	Nipa palm	 

No	Name			Photo	
	Family	Scientific	English		
21	Myrtaceae	*Melaleuca leucadendra* Synomym: *Melaleuca leucadendron* L.	Cajeput tree		
22	Myrtaceae	*Melaleuca cajuputi* L.	Swamp tea tree		

2.2. Main species of flora in wetlands of Boeung Prek Lapouv, Takeo Province, Cambodia.

No	Name				Photo	
	Family	Scientific	English	Growth habit		
1	Acanthaceae	*Ruellia tuberosa* L.	Minnie Root, Fever Root, Snapdragon Root and Sheep Potato	Herb		
2	Amaranthaceae	*Alternanthera sessilis* RBr	Sessile joyweed	Forb/ herb		

3	Asteraceae	*Sphaeranthus indicus* L.	East Indian Globe Thistle	Herb		 
4	Asteraceae	*Blumea lacera* (Burm.f.) DC.	Blumea.	Herb		
5	Asteraceae	*Enydra fluctuans* Lour..	Limnophyte	Herb		

6	Boraginaceae	*Heliotropium indicum* L.	Indian turnsole	Forb/ Herb		
7	Ceratophyllaceae	*Ceratophyllum demersum* L.	Hornwort, rigid hornwort, coon's tail	Forb/ Herb		
8	Commelibaceae	*Commelina benghalensis* L.	Dayflower	Forb/ Herb Weed		

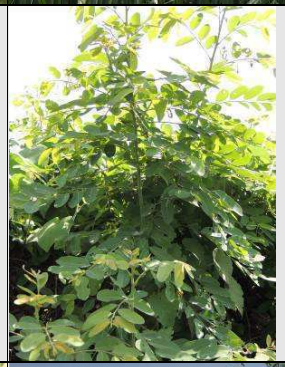
9	Convolvulaceae	*Ipomoea aquatica* Forssk.	Water spinach	Vine, Semi aquatic		
10	Convolvulaceae	*Ipomoea rupens* L	Binweed	Vine		
11	Convolvulaceae	*Merremia umbellata* Subsp.	Vine blossoms	Hogvine		

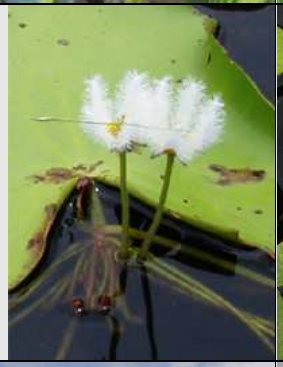
12	Convolvulaceae	*Aniseia martinicensis* (Jacq.) Choisy	White Jacket	Vine Forb/ Herb			
13	Cyperaceae	*Fimbristylis microcarya* F.v. Mueller	Unknown	Herb			
14	Cyperaceae	*Fimbristylis sp.*	Unknown	Herb			

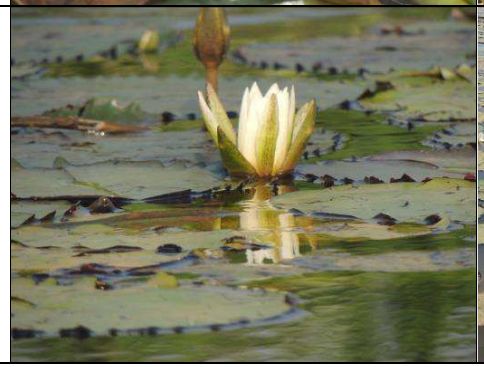
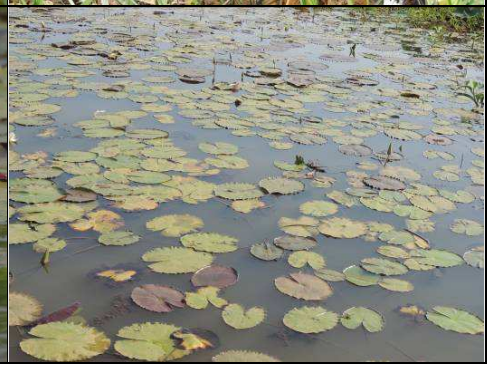
15	Cyperaceae	*Fimbristylis miliacea* (L.) Vahl	Globe fringerush, Grasslike fimbry.	Herb/ Graminoid		
16	Cyperaceae	*Cyperus difformis*	Small Flower Umbrella-	Graminoid		
17	Cyperaceae	*Cyperus compactus* Retz.	Vernacular	Graminoid		

18	Cyperaceae	*Cyperus rotundus* L.	Purple nutsedge, Nutgrass	Graminoid		
19	Cyperaceae	*Cyperus digitatus* Roxb	Finger Flatsegde	Graminoid		
20	Cyperaceae	*Cyperus elatus* L.	Flatsedge	Graminoid		

21	Cyperaceae	*Cyperus iria* L.	Rice flat sedge	Graminoid		
22	Cyperaceae	*Cyperus malaccensis* L.	Shichito matgrass	Herb		
23	Cyperaceae	*Scirpus maritimus* (L.)	Alkali	Herb		

24	Cyperaceae	*Scirpus grossus* L.f.	Giant Bulrush	Herb		
25	Euphorbiaceae	*Phyllanthus reticulatus* Poir.	Black-Honey Shrub	Deciduous shurb		
26	Fabaceae	*Sesbania sesban* (Jacq)	Sesban	Tree/ Shurb		

27	Fabaceae	*Mimosa pigra* L.	Giant Mimosa	Shurb		
28	Menyanthaceae	*Nymphoides indica* (L.) O.Ktze	Water Snowflake	Forb/ Herb		
29	Myrtaceae	*Melaleuca cajuputi* L.	Swamp tea tree	Tree		

30	Nelumbonaceae	*Nelumbo nucifera* Gaertn.	Lotus	Forb/Herb		
31	Nympheaceae	*Nymphaea pubescens* Willd	Pink Water lily	Forb/Herb		
32	Nympheaceae	*Nymphaea nouchali* Burm. f.	Red and blue water lily, Blue star water lily	Forb/Herb		

33	Onagraceae	*Ludwigia stolonifera* *Ludwigia hyssopifolia* (G. Don) Exell	Seedbox	Herb		
34	Onagraceae	*Ludwigia adscendens* (L.) Hara	Waterpimrose	Herb		
35	Oxalidaceae	*Oxalis corniculata* L.	Creeping woodsorrel, Procumbent Yellow-sorrel or Sleeping Beauty	Forb/ Herb		

36	Poacea	*Cynodon dactylon* L. Pres	Couch grass, Bermudagrass, Devil grass.	Graminoid		
37	Poacea	*Eragrostis atrovirens* (Desv.) Trin ex Steud.	Thalia lovegrass, Wiry lovegrass	Graminoid		
38	Poacea	*Brachiaria mutica* (Forssk.) Stapf	Para Grass	Graminoid		

39	Poacea	*Echinochloa crusgalli* (L.)P.Beauv	Barnyard Grass	Graminoid		
40	Poacea	*Echinochloa pyramidalis* (Lam.) Hichc	Antelope grass	Graminoid		
41	Poaceae	*Eleusine indica*	Goose grass	Graminoid		

42	Poaceae	*Echinochloa stagnina*	Hippo Grass or Creeping Paddy Weed	Graminoid		 
43	Poaceae	*Ischaemum indicum* Merr	Batiki bluegrass	Graminoid		
44	Poaceae	*Hymenachne acutigluma*	Water straw grass, Bamboo grass, Trumpet grass.	Graminoid		

45	Poaceae	*Ischaemum rugosum* Salisb	Wrinkle duck beak, Saromacca grass	Graminoid		
46	Poaceae	*Saccharum spontaneum* L.	Kans grass	Graminoid		
47	Poaceae	*Coix aquatica* Roxb	Job's Tear	Herb		

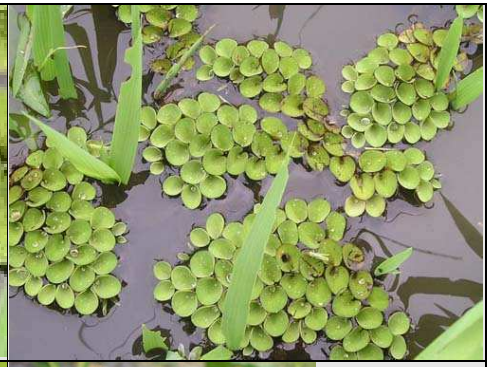
48	Poaceae	*Phragmites vallatoria* Synomym: *Phragmites karka* (Retz.) Trin. ex Steud	Tropical reed	Subshrub Shrub		
49	Poaceae	*Chloris barbata* Sw.	Swollen finger grass, Purple top chloris.	Graminoid		
50	Poaceae	*Leersia hexandra* Sw.	Club-head Cutgrass	Graminoid		

51	Poaceae	*Paspalum scrobiculatum* L.	Kodo millet	Graminoid		
52	Poaceae	*Panicum repens* L.	Torpedo grass	Graminoid		
53	Poaceae	*Oryza rufipogon*	Wild rice, Wild red rice, Brownbeard rice.	Graminoid		

54	Poaceae	*Sclerachne punctata* R.Br	Unknown	Graminoid		
55	Poaceae	*Leptochloa chinensis* (L.) Nees.	Asian Sprangletop, Red Sprangletop.	Graminoid		
56	Poaceae	*Echinochloa colonum* L. Link	Jungle rice, Jungle rice grass.	Graminoid		

57	Poaceae	*Hemarthria longiflora* (Kook.f) A Camus.	Unknown. Species of this genus are aquatic or semi-aquatic.	Graminoid		
58	Polygonaceae.	*Polygonum hydropiper* L. *Polygonum tomentosum* Wild.,	Marshpepper knotweed	Forb/ Herb		
59	Pontederiaceae	*Eichhornia crassipes*	Water hyacinth	Forb/ Herb		

60	Pontederiaceae	*Monochoria hastata*	Pondweed Arrowleaf False Pickerelweed	Forb/ Herb		
61	Rubiaceae	*Morinda citrifolia* L.	Great morinda, Cheese fruit	Tree Shrub		
62	Rubiaceae	*Neolamarckia cadamba* (Roxe.) Bosser	Kadam	Tree		

63	Salviaceae	*Salvinia cucullata* Roxb	Giant water fern	Forb/ herb	 
64	Sphenocleaceae	*Sphenoclea zeylanica* Gaertner	Gooseweed	Forb/ herb	 

2.3. List of species of vegetation grouped by families in Boeung Prek Lapouve, Takeo Province

Family		Names of species		
No.		No.	Scientific	English
1	Acanthaceae	1	*Ruellia tuberosa* L.	Minnie Root, Fever Root, Snapdragon Root
2	*Amaranthaceae*	2	*Alternanthera sessilis* RBr	Sessile joyweed
3	Asteraceae	3	*Sphaeranthus indicus* L.	East Indian Globe Thistle
		4	*Blumea lacera* (Burm.f.) DC.	Blumea.
		5	*Enydra fluctuans* Lour..	Limnophyte
4	Boraginaceae	6	*Heliotropium indicum* L.	Indian turnsole
5	Ceratophyllaceae	7	*Ceratophyllum demersum*	Hornwort, rigid hornwort, coontail
6	Commelibaceae	8	*Commelina bengalensis* L.	Dayflower
7	Convolvulaceae	9	*Ipomoea aquatica* Forssk.	Water spinach
		10	*Ipomoea rupens.* L	Binweed
		11	*Merremia umbellata* subsp	Vine Blossoms
		12	*Aniseia martinicensis*	White Jacket
8	Cyperaceae	13	*Fimbristylis microcarya* F.v. Mueller	Unknown
		14	*Fimbristylis sp.*	Unknown
		15	*Fimbristylis miliacea* (L.) Vahl	Globe fringerush, Grasslike fimbry.
		16	*Cyperus difformis*	Small Flower Umbrella-
		17	*Cyperus compactus* Retz.	Vernacular
		18	*Cyperus rotundus*	Purple nutsedge, Nutgrass
		19	*Cyperus digitatus* Roxb	Finger Flatsegde
		20	*Cyperus elatus* L.	Flatsedge
		21	*Cyperus iria* L.	Rice flat sedge
		22	*Cyperus malaccensis* L.	Shichito matgrass
		23	*Scirpus maritimus* (L.)	Alkali
		24	*Scirpus grossus* L.f.	Giant Bulrush
9	Euphorbiaceae	25	*Phyllanthus reticulatus* Poir.	Black-Honey Shrub
10	Fabaceae	26	*Sesbania sesban* (Jacq)	Sesban
		27	*Mimosa pigra* L.	Giant Mimosa
11	Menyanthaceae	28	*Nymphoides indica* (L.) O.Ktze	Water Snowflake
12	Myrtaceae	29	*Melaleuca cajuputi* L.	Swamp tea tree

Family		Names of species		
No.		**No.**	**Scientific**	**English**
13	Nelumbonaceae	30	*Nelumbo nucifera*Gaertn.	Lotus
14	Nympheaceae	31	*Nymphaea pubescens* Willd	Pink Water lily
		32	*Nymphaea nouchali* Burm. f.	Red and blue water lily, Blue star water lily
15	Onagraceae	33	*Ludwigia stolonifera*	Seedbox
		34	*Ludwigia adscendens* (L.) Hara	Waterpimrose
16	Oxalidaceae	35	*Oxalis corniculata* L.	Creeping woodsorrel, Procumbent Yellow-sorrel
17	Poacea	36	*Cynodon dactylon* L. Pres	Couch grass, Bermudagrass, Devil grass.
		37	*Eragrostis atrovirens* (Desv.) Trin ex Steud.	Thalia lovegrass, Wiry lovegrass
		38	*Brachiaria mutica* (Forssk.) Stapf	Para Grass
		39	*Echinochloa crusgalli* (L.)P.Beauv	Barnyard Grass
		40	*Echinochloa pyramidalis* (Lam.) Hichc	Antelope grass
		41	*Eleusine indica*	Goose grass
		42	*Echinochloa stagnina*	Hippo Grass or Creeping Paddy Weed
		43	*Ischaemum indicum* Merr	Batiki bluegrass
		44	*Hymenachne acutigluma*	Water straw grass, Bamboo grass, Trumpet grass.
		45	*Ischaemum rugosum* Salisb	Wrinkle duck beak, Saromacca grass
		46	*Saccharum spontaneum* L.	Kans grass
		47	*Coix aquatica* Roxb	Job's Tear
		48	*Phragmites vallatoria* (L.) Synomym: *Phragmites karka* (Retz.)	Tropical reed
		49	*Chloris barbata* Sw.	Swollen finger grass
		50	*Leersia hexandra* Sw.	Club-head Cutgrass
		51	*Paspalum scrobiculatum* L.	Kodo millet
		52	*Panicum repens* L.	Torpedo grass
		53	*Oryza rufipogon*	Wild rice, Wild red rice, Brownbeard rice.
		54	*Sclerachne punctata* R.Br	Unknown
		55	*Leptochloa chinensis* (L.) Nees.	Asian Sprangletop, Red Sprangletop.
		56	*Echinochloa colonum* L. Link	Jungle rice, Jungle rice grass.
		57	*Hemarthria longiflora* (Kook.f) A Camus.	Unknown.
18	*Polygonaceae.*	58	*Polygonum hydropiper* L.	Marshpepper knotweed
19	Pontederiaceae	59	*Eichhornia crassipes*	Water hyacinth

Family		Names of species		
No.		No.	Scientific	English
		60	*Monochoria hastate*	Pondweed, Arrowleaf False Pickerelweed
20	Rubiaceae	61	*Morinda citrifolia* L.	Great morinda, Cheese fruit
		62	*Neolamarckia cadamba* (Roxe.) Bosser	Kadam
21	Salviaceae	63	*Salvinia cucullata* Roxb	giant water fern
22	Sphenocleaceae	64	*Sphenoclea zeylanica*	Gooseweed