Initial Environmental Examination

April 2017

Myanmar: Third GMS Corridor Town Development Project
“Mon State” (Part 2B of 4)

Zone I and Zone II are the furthest zones and the weight to collect is important due to their density of population and the presence of the main markets.

As markets are generating a lot of wastes in a specific area (main containers at the corner of the markets), it is important to ensure an efficient collection by a large capacity truck such as compaction truck. The leachates rapidly generated by the important amount of organics would be properly maintained as compaction trucks are impervious.

As streets are narrow in Zone I and II, the private solid waste collection could be completed by two 7m3 dumpers in a first phase and two more in a second phase.

Zone III, IV and V will be densified according to the urban planning proposed by DUHD. However it is expected less densified areas than in historical zones I and II. Then larger dumpers would be able to work in these zone.

The truck duration is estimated 15 years corresponding to the first phase. Then the second phase must be include a truck renewal and additional trucks to face the increase of waste generation.

	First phase (2018 – 2030)			**Second phase (2030 -2040)**		
	Dumper Small	Dumper Large	Compactor	Dumper Small	Dumper Large	Compactor
Zone I	1	-	1	2	-	2
Zone II	1	-			-	
Zone III	-	1	-	-	2	-
Zone IV	-	1	-	-	2	-
Zone V			-	-	1	-

Improvement of collection practises

- Improve collection points, especially at the main markets. Remove mobile carts and replace them with containers.
- Improve the overall collection rate.

Improvement of the Primary collection consists of the following proposed elements:

Table 3-30: Improvement Primary Collection

Item	Description	Subdivision	Number to purchase
i)	Small containers 240 ltr in 3 different colours for the three different separation waste streams: for each	Green colour containers for organics;	56

Item	Description	Subdivision	Number to purchase
	ward two collection points (28 Wards)	Blue colour containers for recyclables Yellow containers for reject waste	56 56
ii)	Aluminium containers 1100 ltr for siting at small size collection points. Two different containers for separating organics and rejected waste.	Aluminium container with large text on site: ORGANICS Aluminium container with large text: ONLY REJECTS WASTE	28 28
iii)	Transport containers content 3 m3 for collecting with hooklift trucks	Steel containers 3 m3 hooklift system	28
iv)	Collection trucks for above containers	Small trucks with lift system for 240 ltr and 1100 ltr containers Hook lift Truck for 3m3 steel containers	2 2
v)	Compactor for market areas	16 m3 compaction truck	1

It should be noted, that each truck can transport different containers with separated organics, recyclables and reject waste. This means that the truck is not dedicated to one separate waste stream but will be used in a multi-functional way (however never mix the waste streams in one truck load or one container load).

The number of trucks is based on the first phase implementation phase Short Term till 2020. It is obvious when the new waste management systems will be fully implemented, more trucks are required. This is assumed taken place in the next Phase, Medium Term 2025 -2030.

RECYCLING

The recycling system will be further improved for higher efficiency in separating the recyclables. Two sectors are distinguished:

- Informal Sector;
- Formal Sector.

Informal Sector

To improve the informal collection sector, it is important that the today's recyclable collectors are getting familiar with the new introduced upgraded integrated solid waste management system.

Awareness campaigns, information how to deal with recyclable collection in a Healthy and Safe manner are important issues for the informal sector. To improve this behaviour regular meetings and information leaflets will be provided to the informal collection sector and the public.

It is estimated that during the implementation of this first Phase Short Term project, communication meetings and leaflets information will be provided.

Formal Sector

To improve the recyclables collection rate from about 16% to about 20%, more involvement of the Formal Sector is required. More collection will be implemented throughout the following measures:

Table 3-31: Improvement measures Recycling Sector

Item	Description of purchase or implementation	Subdivision	Number
i)	Formal sector: Introducing at schools, township offices and other official buildings the separation and recovery of recyclables using 3 different colour containers	recyclables (“dry waste”): 240 ltr containers Blue compost (“wet waste”): 240 ltr containers Green reject waste: 240 ltr containers Yellow	28 28 28
ii)	Adding aluminium containers 1100 ltr at specific collection Points in town for deposit recyclables by the public	Additional Recycling containers 1100 ltr, 1 in each ward	28
iii)	Adding some extra 3m3 containers in the most populated wards of town	Additional containers 3m3 hook lift system in most populated wards	15

Note: it is however possible to introduce small containers of 40 or 60 ltr, to be placed inside buildings especially dedicated for “dry” waste (=recyclables) and reject waste, while composting containers can be placed outside the building easy accessible for the public. These smaller containers are not estimated in this project but could easily be purchased at the municipality own initiative.

COMPOSTING

Two proposed systems will be introduced in the town:

- Backyard Composting;
- Construction of a Composting Plant.

Backyard Composting

Backyard composting will only be introduced in the peri-urban areas of the town and for houses with large gardens.

At the moment the public is not acquainted with composting. Therefore training and information is required to assist the potential house owners with backyard composting. In this project it is estimated to implement “Instruction and Awareness

Programs for Backyard composting". This may be executed in conjunction with the recyclables awareness programs.

Construction of Compost Plant

The following main constructions are estimated for the first Phase composting of 25% of the generated waste till 2025. The design capacity is 65 tons/day. The follow-up phase to compost 40% of the waste generated is not estimated in this project as capital Investment. The capacity prognosis for this second phase is about 120 ton/day. However, extensions of the compost plant are included in the land surface areas. Purchase of Equipment is selected on 40% composting quantities, like Front-end loader, conveyor belts and trommel screens.

Some of the civil works are included in the Landfill design as they will be used for both operations. The following items are included in the landfill design and landfill cost estimate: Access Roads, Guard house and entrance, fencing around the site including perimeter roads, weighbridge and on-site gravel roads.

WORKS: The composting Plant for Mawlamyine will have the following main items to be constructed as Works:

- Construction of Sorting Area: concrete pad with drainage system
- Construction composting pad: concrete pad with drainage system
- Construction of "monsoon" cover over composting area: hangar style roof
- Construction Maturing (Curing) area, concrete pad
- Construction of Storage area ready Product: concrete based area with hangar style roof
- Offices, sanitation building, equipment and trucks storage.

SUPPLIES: Equipment to be purchased as Supplies:

- Front-end loader: 1
- Trommel screen, capacity max.15 tons/hour: 1
- Conveyor belts different lengths and width: 5
- Magnetic Ferro remover: 1
- Mixer and Grinder, max capacity 15 tons/hour: 1
- Final automatic screens <10mm

The following table presents the required areas for each part of the compost plant. The detailed calculation is presented in the Appendices.

Table 3-32: Required Areas for Compost Plant Phase 1 Mawlamyine

Compost Plant Item	Unit	Total
Design Capacity	**tonnes/day**	**65**

Compost Plant Item	Unit	Total
Sorting Area	m^2	500
Composting pad	m^2	4,000
Maturing pad	m^2	1,600
Storage Area	m^2	4,000
Subtotal	m^2	10,100
Mech. Equipment area	m^2	2,000
Total	m^2	12,100
Total ha. (/10,000m^2)	ha	1.21
Total acres (2.4691m^2)	acres	3.00

A lay-out of the compost plant is provided in the Appendices.

CONTROLLED LANDFILL

Waste quantities

For designing the capacity of a landfill, the waste quantities which will be landfilled during the life span of the landfill are calculated. The lifespan proposed of the Mawlamyine landfill is till 2040. The calculation is based on several important prognoses for the long term. It should be noted that landfill capacity values will undergo revision during operation of the landfill when waste quantities delivered at the site vary from the generation rates estimated prior to the start of landfill operations.

The following prognoses are taken into account for calculating the waste quantity going to the landfill:

- Population growth in Mawlamyine from 258,809 in 2015 to 424,603 in 2040
- Quantity per capita from 0.55 kg/c/day in 2015 to 0.9 kg/c/day in 2040
- Separation rates for composting fractions of 25% of collected wastes in 2020 to 40% of collected wastes starting in 2026;
- Recyclables recovery rate from approx. 16% of collected waste in 2015 to 20% of collected wastes in 2020;
- Collection of generated waste from 55% in 2015 to 92% in 2025 and finally to 98% in 2040.

The total rejects waste to be landfilled after the separation of the recyclables and organics from the generated waste is 1,174,000 tonnes during the lifespan of the landfill in 2040.

The calculation of the waste quantities to be landfilled is shown in Table 3-33. The complete excel sheet with the detailed quantities calculation is presented in the Appendices.

Table 3-33: Waste disposal quantities 5-years projections

Year	Population	Waste generated ton/day	Waste not collected ton/day	Recyclables ton/day	Compost ton/day	Disposal ton/day	Disposal waste ton/year
2015	258 860	171	91	13	-	67	24 500
2020	286 084	213	21	38	48	105	38 500
2025	316 172	262	21	48	96	96	35 200
2030	349 424	319	19	60	120	120	43 700
2035	386 173	385	15	74	148	148	53 900
2040	426 788	461	9	90	181	181	65 900
					Total in 25 years		**1,174,000**

The table above shows that after implementation of the first Phase of the project with improved collection system and start of the Compost Plant (with 25% composting of the collected wastes the first 5 years), the disposal quantities increases mainly due more collection of the waste in the town with a reduced amount of not-collected waste quantities. After 2025 when the second phase of Composting (to 40% of the collected waste) will be implemented, the quantities increase mainly due to population growth and higher quantities of waste generation per capita per day.

The total calculated waste for disposal in 25 years is 1,174,000 tonnes. This quantity will be disposed in several landfill cells. The required surface area and level of landfill cells is presented in the next paragraph.

LANDFILL AREA AND LANDFILL CELLS

The following quantities and area surfaces are calculated for the landfill area. The waste of the existing dumpsite will be removed to the new controlled landfill. An estimate quantity of 100,000 m3 is added to the total waste generation (existing dumpsite area is about 2.5 ha, waste level approx. 4.00 m).

Table 3-34: Total Landfill Disposal area and Landfill Cell I area

Mawlamyine Landfill Item	Unit	Total
Waste generated till 2040	m^3	1,174,000
Existing waste dumpsite estimate	m^3	100,000
Total estimate 2040 LF	m^3	1,274,000
Cover material +30%	m^3	382,200
Total Capacity LF 2040	m^3	1,656,200
Average height	m	12
Area for landfill waste	m^2	138,000

Mawlamyine Landfill Item	Unit	Total
Calculated area (trapezium shape)	m^2	146,300
Infrastructures (roads, offices etc.): 15%	m^2	21,945
Total m2	m^2	168,245
Total ha. (/10,000m2)	ha	16.80
Total in acres (2.4691m2)	acres	41.54
First CELL I		
Total number of Cells	No.	5
Percentage landfilled in Cell I	%	20
Quantity waste in Cell I	m^3	330,814
Area required Cell I:	m^2	175 x170m: 29,750
Cell I in ha.	ha	3.00
Cell I in acres	acres	7.35

See for the detailed calculation the excel sheets in the Appendices.

A controlled landfill will be constructed at the same site location as the existing dumpsite. The construction will be as described in the previous section.

Leachate Treatment

As indicated previously, Leachate Treatment in this project includes the following:

- Recirculation back into the landfill;
- Passive evaporation to the atmosphere (often through holding ponds or storage lagoons)
- On-site physical and biological treatment.

The sequence as mentioned above will be utilized for the treatment of leachate, this depending on the rainfall/day.

Capacity of a leachate storage and treatment pond by full evaporation method:

The area of a landfill Cell is 3 ha. However to ensure good leachates management and reduce storm water intrusion, it should be divided in 6 months to 1 year lifespan sub-cells. The amount of 330,000 m3 (cell I capacity including coverage) will be reached in 5 years. Then a sub-cell should have an area of 3 ha/5 = 6,000 m^2.

The leachate discharge estimate is a complex calculation involving several parameters such as rainfall, evaporation, but also waste absorption, humidity, temperature, etc.

As a first approach, it is considered here only rainfall and evaporation (source DMH data from 2011 to 2015). The estimated area under use is one sub-cell so 6,000 m^2.

	Average rainfall (mm/month)	Storm water volume (m3/month)	Average evaporation (mm/month)	Surface needed for full evaporation (m^2)
January	5	33	125	260
February	0	1	133	9
March	24	144	170	847
April	30	180	172	1045
May	428	2569	240	10714
June	858	5147	227	22629
July	1120	6720	253	26556
August	1269	7615	291	26177
September	785	4709	270	17427
October	170	1023	146	6983
November	31	188	128	1470
December	37	222	126	1757
Calculation for a year	4759 mm/y	28551 m3/y	2283 mm/y	12507 m^2 (average)

Note: The above calculation is not including the surface of the leachate pond. The leachate pond should be covered by a roof in order to reduce the inflow from storm water

To conclude, a leachate removal by evaporation would involve a wide leachate pond (12 ha at least) with a covering roof.

Then a leachate treatment plant has to be considered.

Two samplings were done at the leachates outlet of the existing dump site:

- Sampling in September 2015: BOD = 160 / COD = 740
- Sampling in July 2016: BOD = 400 / COD = 900
- Both results reveal a high concentration in Iron and Nitrogen and a lower concentration in Phosphates.

However these samplings should be completed by additional samplings before designing the leachates treatment plant. In addition, the leachates production estimate should be more detailed by analysing the humidity rate in the wastes in dry and rainy season.

In a first approach, the treatment plant would have an average flow of 80 m^3/d or 2400 m^3/month or 29 000 m^3/year. During the rainy season the storm water reaches 27 000 m^3 (From May to September (5 months)) then the basin would need to accept 27 000 – (5*2400) = 15000 m^3. Including 20% of evaporation, the minimum volume of the basin is 12000 m^3.

A 4000 m² leachates pond by 3 m deep would allow a simple evaporation process in dry season and an average treatment of 80 m^3/d.

The municipal septage trucks are currently tipping wastewater into the dump site. The leachate treatment plant would be an advantage to treat both leachates and septic tanks effluents.

- WORKS: The following main structures are estimated for Works:
  - Access road, width 7.50 m for heavy trucks;
  - Perimeter fence 2.00 m high;
  - Guard house with barrier;
  - Weighbridge 40 tons;
  - On-site roads (gravel); 3.00 width;
  - Construction of landfill Cell no. I, about 330,000 ton capacity (calculation details in next paragraph and in Appendices;
  - Perimeter survey road, width 3.50 m for normal vehicles;
  - Leachate storage pond with treatment;
  - Environmental Monitoring wells; 6 pc
  - Offices and sanitary buildings;
  - Power supply and water supply connections.
- SUPPLIES: The following Landfill Equipment are required for Supplies:
  - Bulldozer 185 kW (248 HP) for transfer and compacting of waste;
  - Small 4-wheel drive truck tractor for on-site transfer of daily cover soil;

It should be taken into account, that only the first landfill Cell no. 1 will be constructed during this phase. Future landfill Cells have to be constructed according to the following scheme:

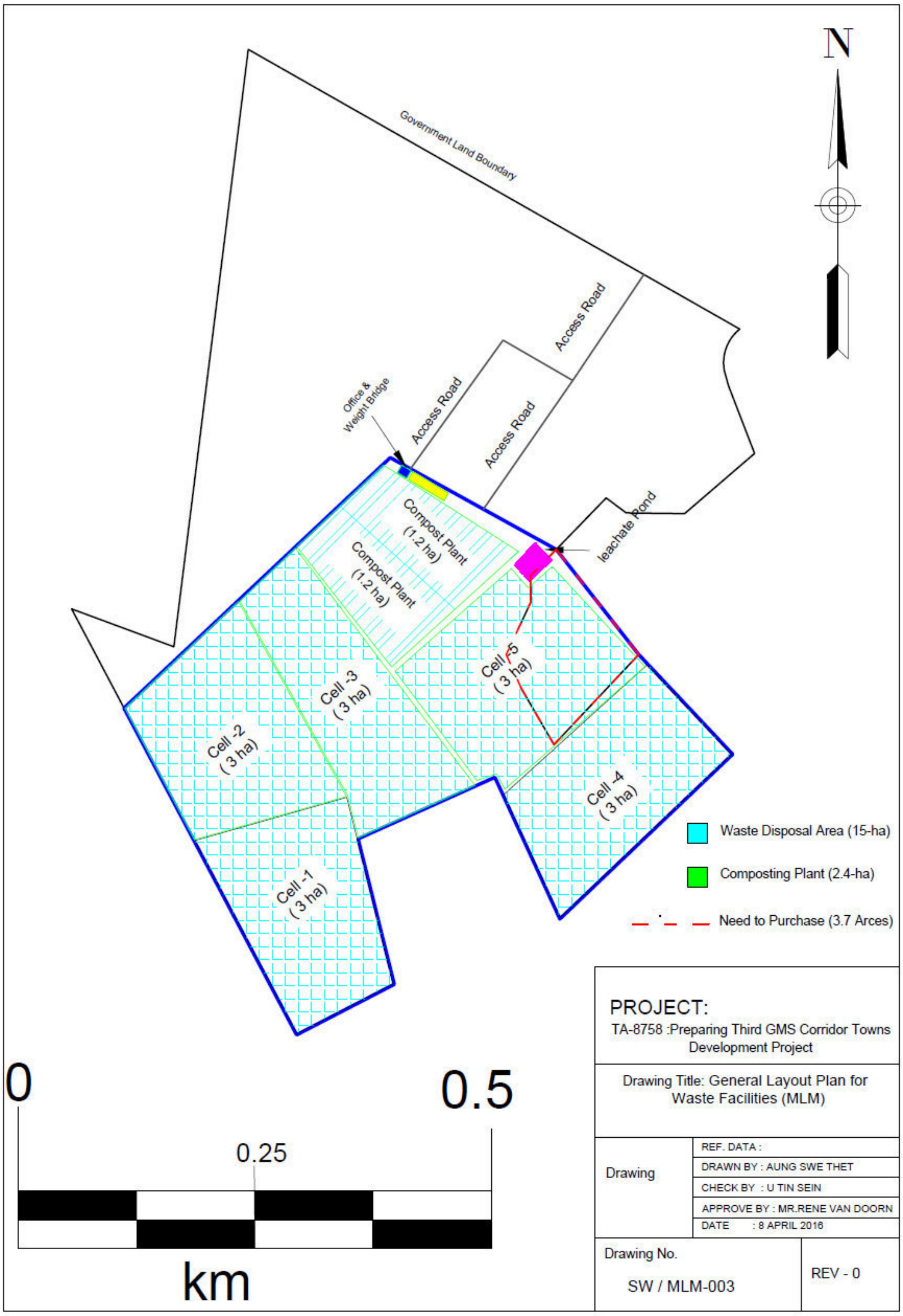
Table 3-35: Planning Construction of new Landfill Cells at Mawlamyine Landfill

Landfill Cells	Construction Year
Landfill Cell no. 1 (implemented in this project phase)	2018
Landfill Cell no. 2	2020

Landfill Cell no. 3	2025
Landfill Cell no. 4	2031
Landfill Cell no. 5	2036

It is usual that after construction of the controlled landfill with implementation of a weighbridge, much more details about quantities and materials recoveries are collected. New analyses and updates for future expansions are required on a regular basis to anticipate for measures to be taken on time.

Figure 3-49 Proposed site plan of the landfill cells and the composting plant



3.4 Cultural Heritage

Mawlamyine currently has a rich built history which many other urban centers in the region have lost in their rapid desire to move to a "modern" city. There is a short window of opportunity (perhaps 5 years) during which there is time to conserve much of this heritage and then use or convert this resource to attract tourists and create related sustainable employment directly as guides/historians and indirectly through extra generated income in hotels, restaurants and travel related businesses. Several buildings currently in government use have the potential to be converted into more efficient and more appropriate working spaces better suited to modern needs. It would certainly be a cultural disaster to lose many of the old buildings and their settings. To do so would mean that Mawlamyine would become just another Asian city with little individual character or special reason to visit.

The country's tourism industry has seen major growth in recent years, in part brought about by economic and political reforms that have made the country an attractive tourism and investment destination. Myanmar officially recorded 1.06 million and 2.04 million international arrivals in 2012 and 2013 respectively. Figures released by the Union of Myanmar Travel Association (UMTA) show that 3.08 million visitors entered Myanmar in 2014, of which 1.95 million entered at land border points.

Figures for Mawlamyine show significant annual increases from 2011 – 14 of 32% for international and 18% for local visitors.

The 2013 – 2020 Tourism Master Plan (prepared by the Ministry of Hotels and Tourism) projects that there will be 7.5 million inbound visitors by 2020. If even a small proportion of these people visited Mawlamyine it would produce a massive boost for the local economy. Many of these tourists can now be more adventurous as the country becomes considered more safe and accommodating, while many restrictions on travel have also been lifted. The completion of the upgraded road link from the Thai border at Myawaddy/Mae Sot will further encourage visitors to Mawlamyine en route to Yangon or to the new destinations opening up to the south on the way to Dawei and beyond.

Mawlamyine has a number of attributes that provide it with plenty of potential to be a major historical attraction in its own right. These include:

- Its wide range of distinctive and strategically located religious buildings including the Kyaik Thanlan pagoda (erected in 875 A.D), U Zina pagoda (3rd century B.C according to legend) and the Mahamuni pagoda (1904).
- Its connection with two famous authors, namely Rudyard Kipling (briefly in 1889) in association with the Kyaik Thanlan temple, and George Orwell (as a policeman in the 1920's) where his mother's maiden family name of Limousin is still commemorated in Lainmawzin Street;
- Its wealth of colonial secular and religious buildings, many of which are in need of significant renovation, and which are associated with Mawlamyine's position as capital of British Burma from 1826 to 1852 and then one of the busiest ports in South East Asia;
- Its relatively relaxed environment compared to the hustle and bustle of Yangon;
- Its attractive location on and views over the Thanlwin River which makes it an ideal location as a base for exploring the surrounding regional attractions (e.g. several world renowned caves and Mount ZweKabin north towards Hpa-An: and the reclining Buddha at Win Sein Taw Ya, Second World War memorials at

Thanbyuzayat, as well as the town of Kyaikkami with its Yele Paya, all south of Mawlamyine).

- The potential of Belu Kyun (Ogre Island) and its cottage industries (slates, rubber bands, smoking pipes, walking sticks, pens, bracelets, bamboo articles) which are focused on a number of small villages. The island will become more accessible once the new bridge to the mainland is constructed and once the government decides that security is not an issue to prevent visitors staying overnight in future.

Mawlamyine is currently a Neglected Attraction. The UMTA also reported that there were 19 officially registered motels/hotels in Mawlamyine with a total of 553 beds. Of the 59 recorded locations in Myanmar, Mawlamyine was 14th in the list of bed numbers, behind places such as PyinOoLwin (933 beds), Taunggyi (676) and Kalaw (636). This suggests that Mawlamyine, with the 5th largest urban population in Myanmar (2014 Census), is not currently fulfilling its full potential in attracting neither national nor international visitors.

There is concern within the country that rapid unchecked development is already harming the physical and cultural environment in sensitive areas. A recent article in Myanmar Insider (Volume 2 – Issue 16 – March 2015) noted the suspension of 5 projects in Yangon which were considered to be located too close to the city's cultural heritage, including the Shwedagon Pagoda. The Myanmar Engineering Society is to investigate if they harm the environment and the projects' continuation will be based on their report. In April 2015, the GoM released two heritage protection bills[1] that would help better protect heritage buildings and objects. The 1957 Antiquities Act has been modified and separated into these two bills in order to improve legal protection for heritage structures and heritage objects. The bills would protect "*more than 100-year-old buildings and antiquities across the country—either above or below the ground and water—that have historic, cultural, artistic, antique and archaeological values*." Penalties for damaging, removing or destroying heritage buildings and objects would be tougher than under the 1957 Act. The Protection and Conservation of Ancient Buildings Bill says anyone who destroys or damages protected buildings could face prison terms of between 1 – 7 years.

The project recognizes that it is necessary to demonstrate that heritage buildings can be used (in their current form or as a conversion) to generate/raise economic activity by using them in a more efficient and more financially viable manner. It is not enough to appeal to an owner's good will. Owners must be convinced that a heritage building can be made more valuable/useful as it is rather than any other alternative potential use following its demolition. This argument will require the aid of both inducements and controls. Inducements may well be financial, in terms of assistance (and professional advice) to repair and/or convert the building to a more beneficial use.

[1] Protection and Conservation of Ancient Buildings Bill and Protection and Conservation of Antiquities Bill

Controls might take the form of land use controls and prohibition of demolition of selected heritage buildings.

For Mawlamyine as a whole the purpose of any assistance would be to support the government's serious intention to raise the quality and future longevity of its built heritage which would then attract more visitors and investors to acquire and convert selected buildings to more economic uses (e.g. boutique hotels, restaurants and professional offices). When successful, and at some point down the line it might be appropriate for the MSG to propose the inclusion of the town as a World Heritage Site[2]. That would lead to additional worldwide interest and increase the numbers of visitors to the area.

In order to demonstrate how the Restoration Fund can be initiated and used to renovate and to make buildings more efficient and useable, the Project is proposing a pilot study based on the General Administration Department (GAD) complex in U Zina Phayar Street as depicted by the red line in **Figure 3-50**. The building is currently subject to a tender for minor renovation works including painting, roof repairs and electrical upgrading. The current Administration building was originally the Courthouse and was shown on maps dating from 1876-77. The new and current Courthouse (to the left) was a later addition, probably in the late 1800's.

SCENARIOS

Three Scenarios have been considered for the future of the GAD building as shown on **Table 3-36** : "Do Minimal"; add Mezzanine floor; and Demolish and replace with a new construction.

Table 3-36: GAD Building Scenarios Considered

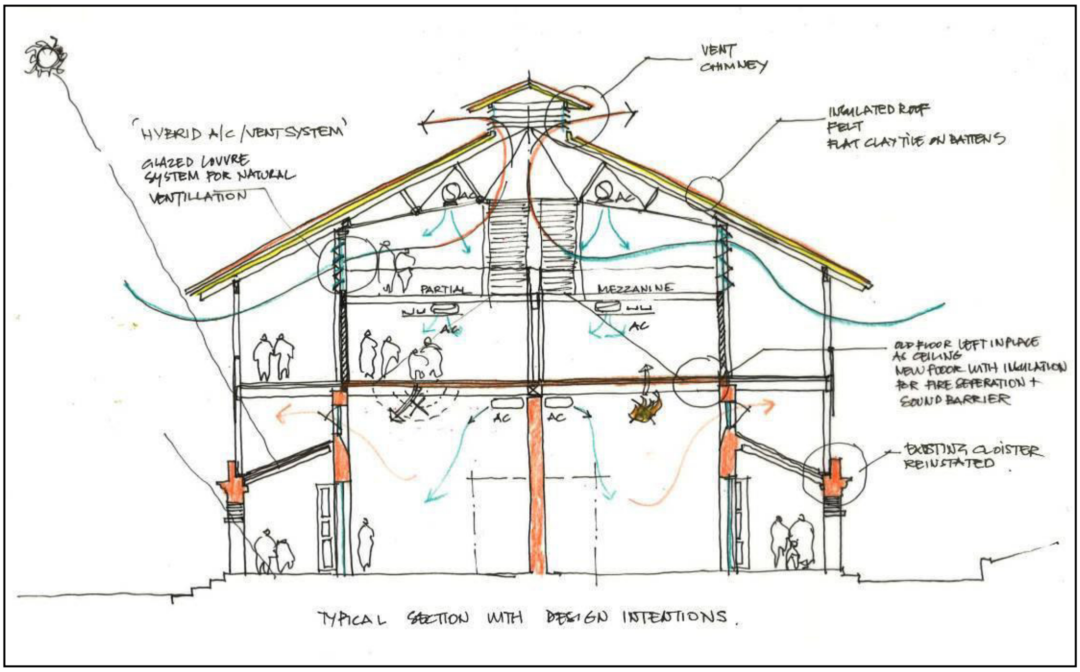
One Stop Shop - District Level		**Scenario 1 - "Do Minimal"**		**Scenario 2 - Mezzanine Rehabilitation**		**Scenario 3 - New Construction**	
		Composition	**MMK Million**	**Composition**	**Million**	**Composition**	**Million**
Description		- Rehabilitation of existing building. - Efficiency improvements to accommodate all departments, excluding Education. - Courtyard enhancements		- Rehabilitation of existing building, including mezzanine. - Efficiency improvements to accommodate all departments. - Courtyard enhancements		- Demolition of existing building. - New Building to accommodate all departments. - Courtyard enhancements.	
Total Development Cost	MMK Million	1,547,925,935	94.4%	1,679,444,735	94.4%	3,904,942,500	93.5%
Financing Cost	MMK Million	91,200,000	5.6%	98,860,000	5.6%	272,300,000	6.5%
Total Loan Amount	% of proportion	1,639,125,935	100%	1,778,304,735	100%	4,177,242,500	100%
Amount USD (at MMK 1300/USD)		**1,260,866**		**1,367,927**		**3,213,263**	
Loan interest rate	p.a.	4.0%		4.0%		4.0%	
Inflation rate	p.a.	6.6%		6.6%		6.6%	
NPV and IRR Comparison		NPV	IRR	NPV	IRR	NPV	IRR
Financial		1,491,601,052	7.9%	3,094,694,735	10.8%	107,926,990	4.1%
Economic (Threshold IRR 12%)		(19,869,203)	11.9%	725,448,807	15.6%	(1,644,460,903)	7.4%

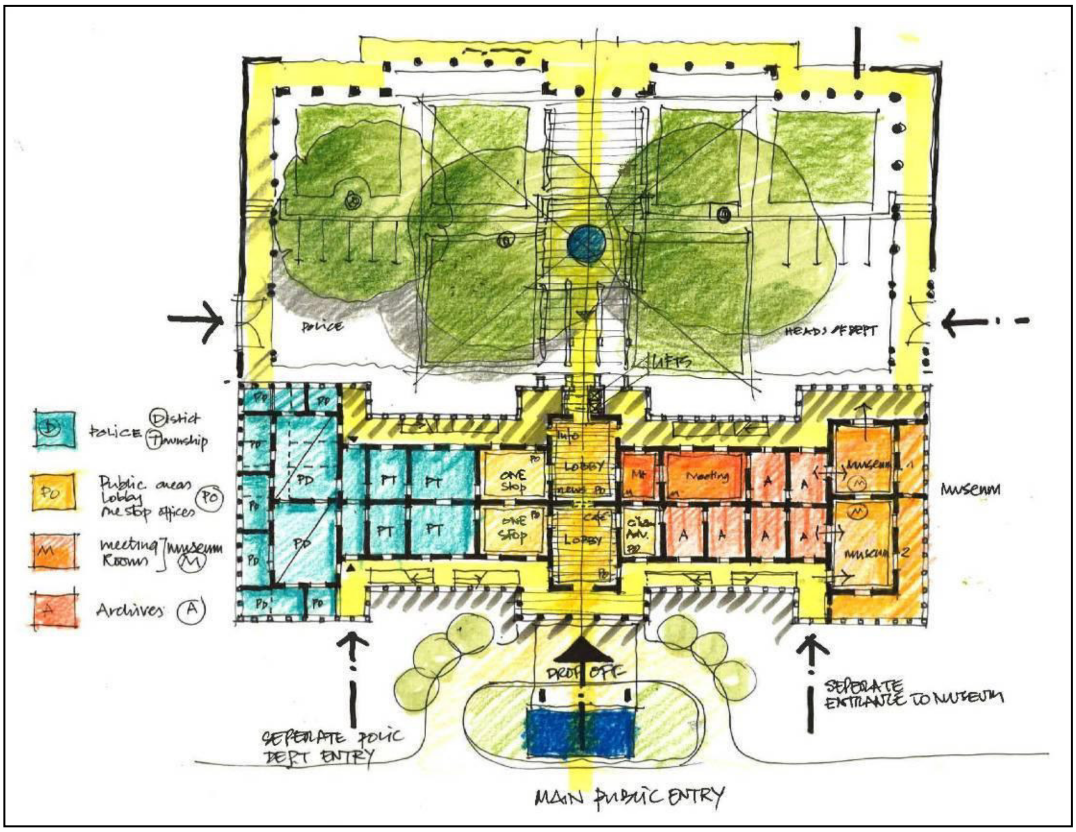
[2] The example of Levuka, an historic port town in Fiji is very similar to Mawlamyine in its history and setting although Mawlamyine has significantly more varied buildings/culture and a longer more interesting history. Levuka was granted World Heritage listing in 2013. See http://whc.unesco.org/en/list/1399 for more details.

The figures show that it would be substantially more expensive to demolish (USD 3.2 million) and rebuild the complex to incorporate the same number of people and functions compared to the preferred Scenario 2 which would add more space (USD 1.4 million). There would be little cost difference (USD 0.1 million) in a "Minimal" compared to an approach which incorporated a mezzanine floor to the second floor to provide more useable office space. A number of concept ideas as to how the complex could be designed are shown on **Figure 3-51**.

Figure 3-50: General Administration Complex U Zina Phayar Street

Figure 3-51: Concept Plan for Renovation of GAD Building (Scenario 2)





The Third GMS Project in Mon State will fund the rehabilitation of the former Court House built in the mid-1800's. The building is presently used as an Administrative Building by the GAD for Mawlamyine Township. The rehabilitation anticipates the re-organisation of the internal volume to continue to serve as a government office building. The courtyard between the building and the new courthouse will also be restored. The building is reported as being in good structural condition regarding civil works considering its age.

This pilot rehabilitation would promote best practice in heritage restoration in Mawlamyine and serve as a model for future interventions.

Figure 3-52: View of GAD building proposed to be rehabilitated under the project

View of Administration Complex U building to be rehabilitated

Same

3.5 Associated Facilities

In Mawlamyine, JICA is providing a grant for the construction of a water treatment plant (slow sand filter) for the water supplied from the Shwe Nat Taung reservoir, with the rehabilitation of a section of the pipeline between the WTP and the Kan Thone Kan storages. JICA and ADB projects are interlinked for the water supply of Mawlamyine and they must be considered as associated facilities.

An environmental and social due diligence (ESDD) has been carried out by the GMS3 TA 8758 Consultant from 16 to 30 November 2016. By the time the GMS3 PPTA final report is submitted and approved, the JICA water supply component for Mawlamyine **will be completed and will not be anymore an associated project but an associated existing facility**. As such, further steps shall now focus on GMS3 water supply component adaptation with regard to optimization of linked project operation for the full benefit of Mawlamyine Township.

The ESDD identified opportunities to improve the combined operation of the two water supply systems, in order for the city to take full benefit from the existence of two water treatment plants and to better secure 24/7 water supply quantity and quality. An interconnection between both systems shall be investigated at the time of the detailed design as well as an emergency chlorination unit at KTK storage.

Similarly, the proposed distribution area for the GMS3 project shall be adjusted as required at the start of the detailed design in order to take full consideration of the distribution area under JICA project Phase 2, not yet defined at the time of the due diligence, to avoid any risk of overlapping.

Despite its evident non-compliance with ADB SPS regarding its preparation and implementation, the JICA WS sub-component for Mawlamyine resulted hopefully in insignificant environmental and social impacts. The sub-project, therefore, does not appear to involve any kind of reputational risk to ADB funding on environmental safeguards and will not hamper the operation of the GMS sub-project.

ESDD report is attached to the present IEE as a Supplementary Document.

4 BASELINE SITUATION

4.1 Regional Geology, Soils and Seismicity

From the geomorphologic and tectonic point of view, Myanmar can be subdivided into four major tectonic provinces which are north-south trending linear belts, these are from east to west (I) Shan-Tanintharyi Block (II) Central Cenozoic Belt (III) Western Fold Belt, and (IV) Rakhine Coastal Belt. Both Mon and Kayin States fall into the eastern Shan-Tanintharyi Block (I).

Figure 4-1 illustrates that the main rock types found in Mon state are soft rocks, and Mawlamyine is mainly composed of bedrock continuously covered by at least 6 meters of alluvial deposit soils while Hpa-An area has soft rocks such as sandstone, shale, limestone and conglomerate. The rock types found around the area of Myawaddy are mainly hard rocks including limestone and dolomite, schist and granite.

Regarding soil types, Mawlamyine region mainly consist of Gleisoil which normally occurs on wide range of unconsolidated materials, mainly fluvial, marine and lacustrine sediments of Pleistocene or Holocene age (**Figure 4-2**). They are found in depression areas and low landscape positions with shallow groundwater. Red-brown forest soils, together with mountain red brown forest soils, primitive crushed stone soils are found in Southern Mon and Kayin. Lateritic soils and laterites are found at altitude below 100m above sea-level.

Figure 4-1: Geology of Myanmar

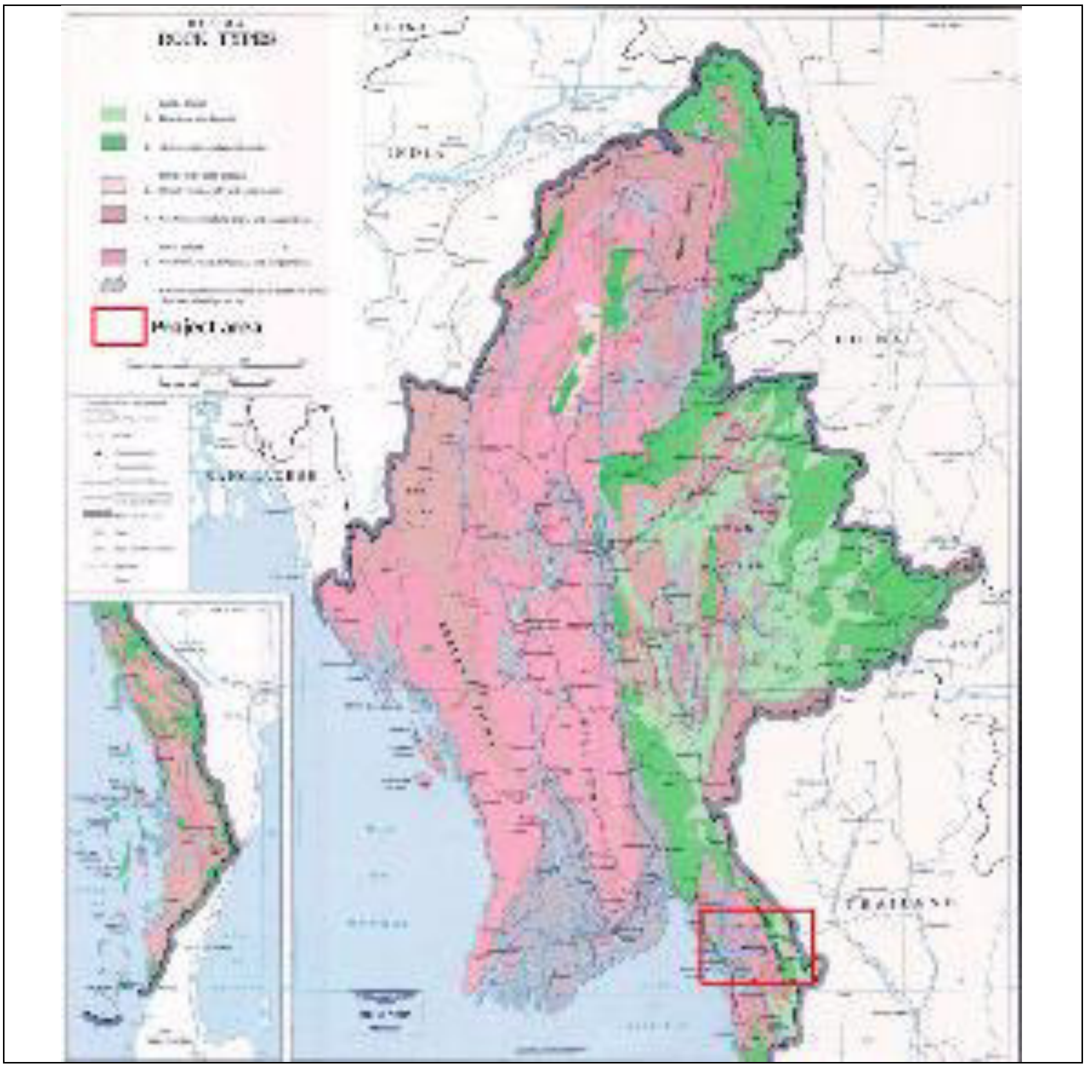
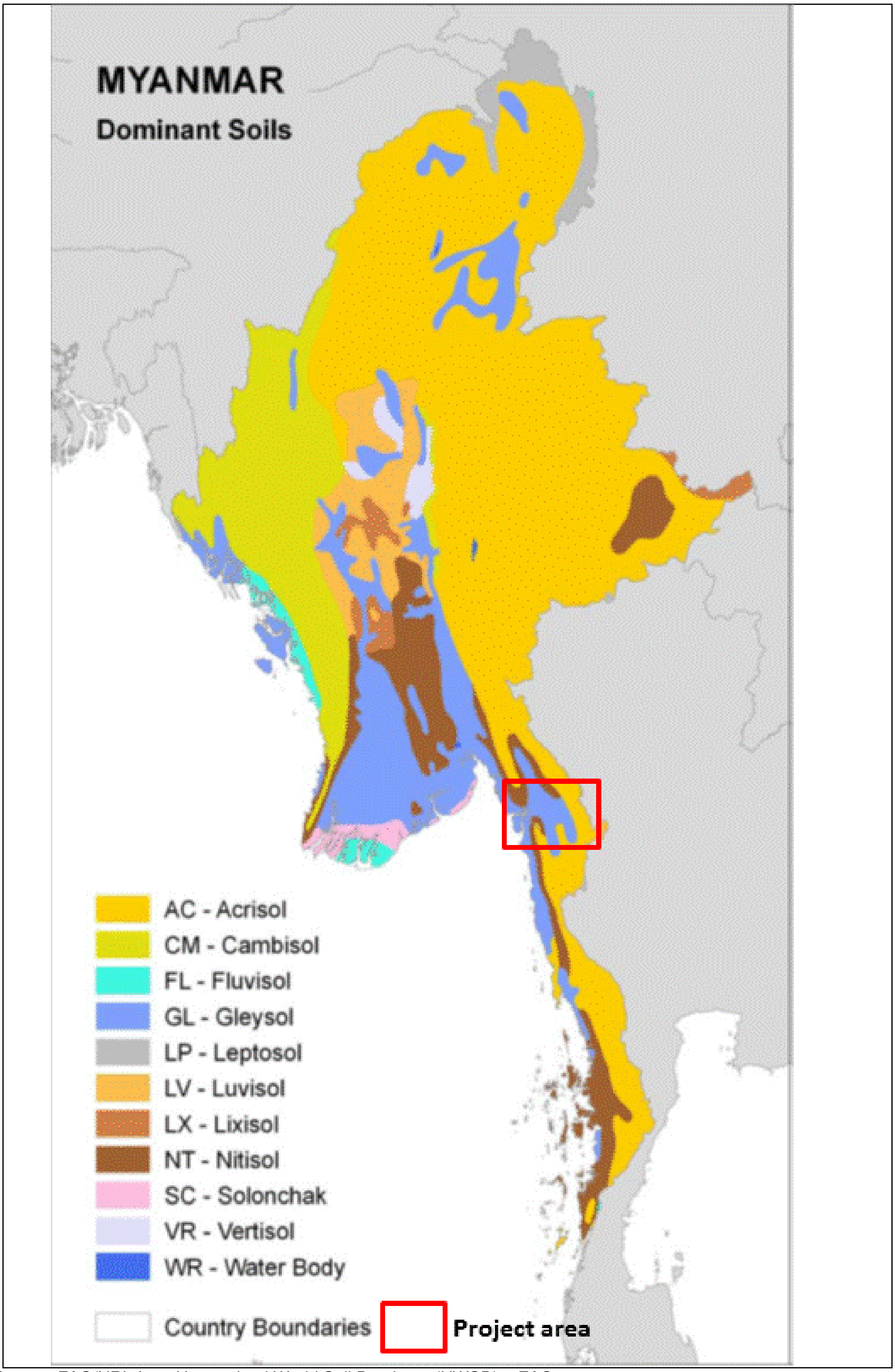


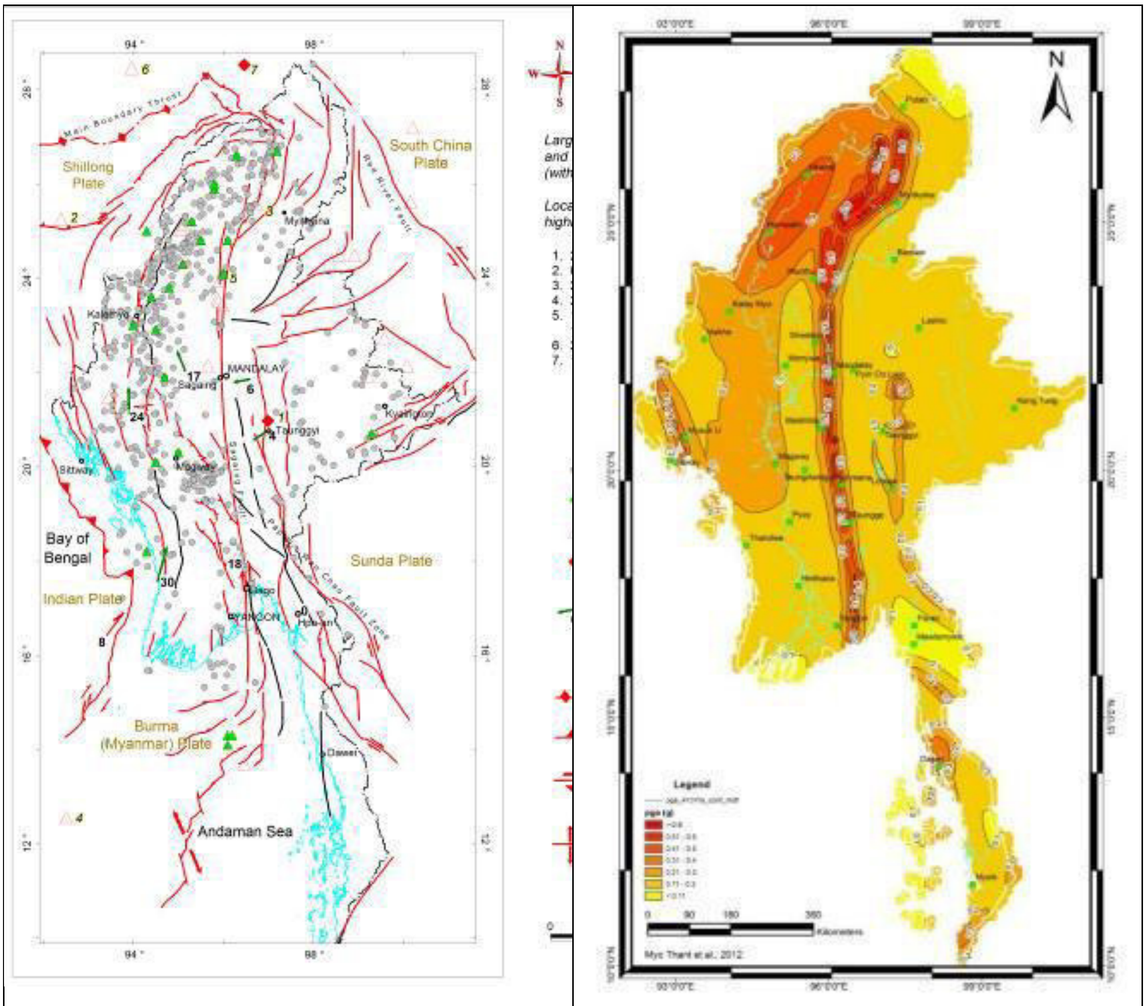
Figure 4-2: Distributions of 10 Dominant Soil Types in Myanmar



Source: FAO/NRL from Harmonized World Soil Database (HWSD) – FAO

According to the seismic zone map of Myanmar (**Figure 4-3**), Mawlamyine falls in the **low zone** with less than 0.11 PGA (Peak Ground Acceleration).

Figure 4-3: Seismic Zone Map of Myanmar



SEISMOTECTONIC MAP OF MYANMAR AND SURROUNDING REGIONS | *PROBABILISTIC SEISMIC HAZARD MAP OF MYANMAR (MYO THANT ET AL., 2012)*

Source: (Hazard Profile of Myanmar 2009)

This means that the risk related to earthquake is considered as moderate and has been fully integrated into the design standards applicable to the proposed facilities.

4.2 Climate

In the Andaman Sea, four seasons are distinguished:

- The North-east Monsoon, from December to March, which brings fine cool weather and very little rainfall to the area.
- The Pre-monsoon transition period, from April to May, characterized by relatively weak and variable winds (prevailing land and sea breezes) and hot temperatures (37°C on the coast).

- The South-west Monsoon, from June to September, characterized by dense nebulosity, nearly daily drizzle interspersed with squalls, thunderstorms and heavy torrential rains along the East coast of the Andaman Sea.
- The Post-Monsoon Transition, from October to November, which is relatively similar to the Pre-monsoon transition with cooler temperatures.

Mawlamyine climatic conditions reflect these general characteristics.

4.2.1 RAINFALL

As presented on **Figure 4-4**, Mawlamyine is located within the wettest part of Myanmar, receiving in average more than 4,800 mm of rain every year.

Annual rainfall average over the period 1965-2014 (50 years) is provided in **Figure 4-5**. Average annual rainfall over the 50 years period is 4864 mm. 82% of the annual rainfall falls from June to September, the 4 wettest month of the South-west monsoon.

4.2.2 TEMPERATURE

Temperature in Mawlamyine remains high all along the year as presented in **Figure 4-6**. January is the most contrasted month with about 15°C amplitude between maximum and minimum temperature while August presents almost no difference. Average minimum monthly temperature never drops below 15°C.

Figure 4-4: General Distribution of Rainfall in Myanmar

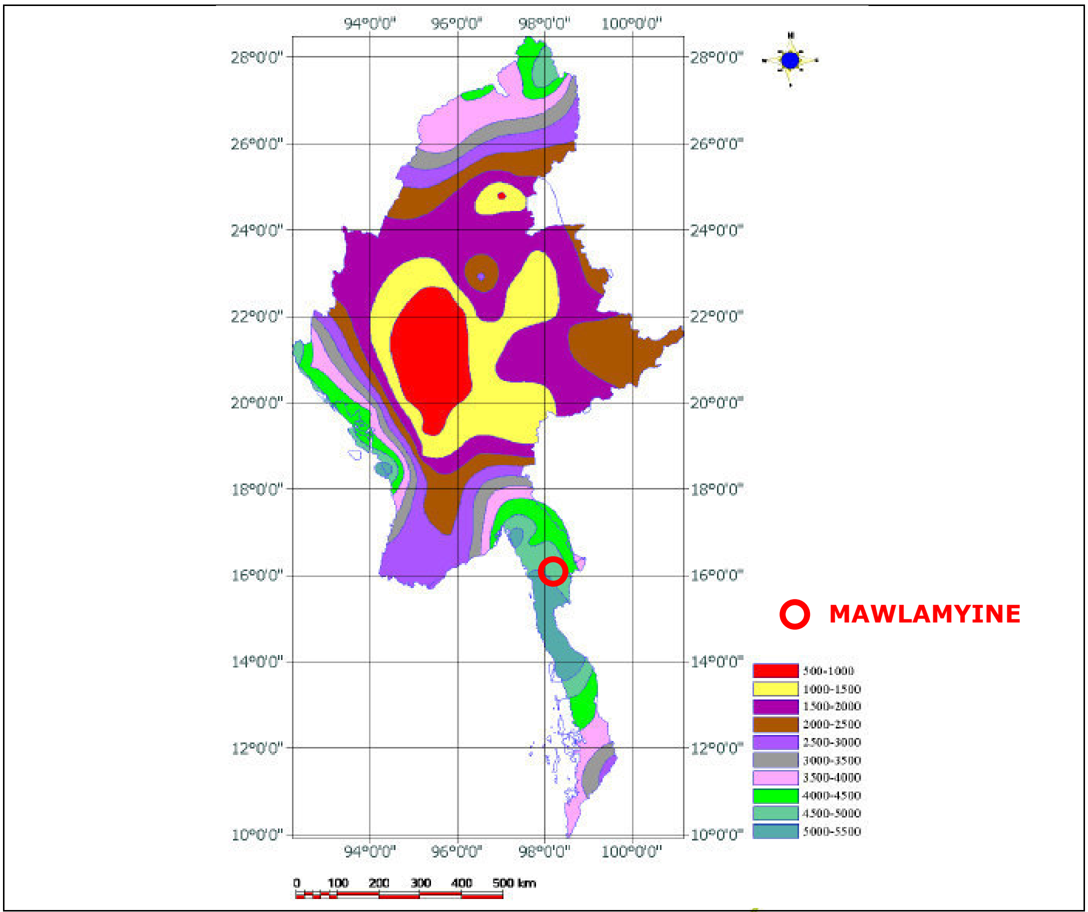


Figure 4-5: Average Annual Rainfall in Mawlamyine (Period 1965-2014)

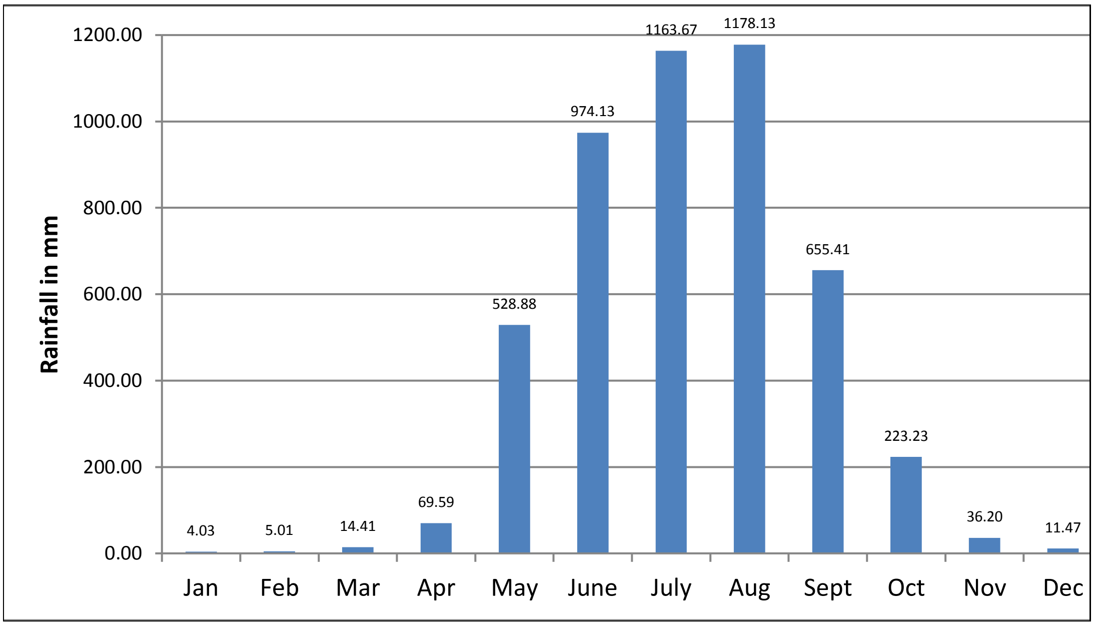
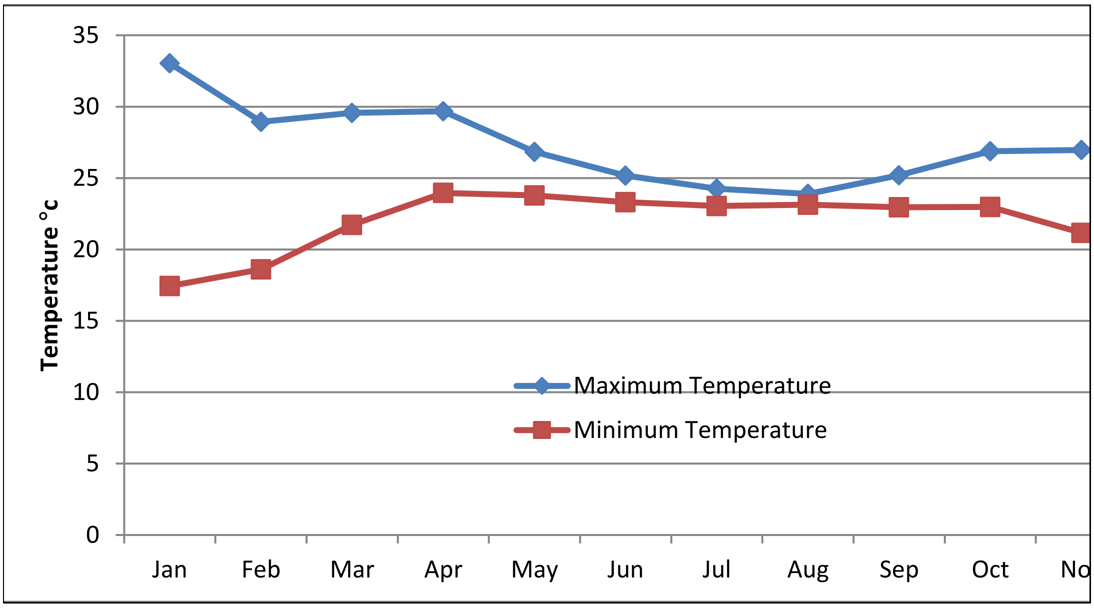


Figure 4-6: Average Annual Max. and Min. Temperature in Mawlamyine (Period 1967-2014)



4.2.3 WIND

In the morning, wind is predominantly from NE during the dry months and from SW during the wet season. In late afternoon, the wind is almost always from SW except in November and December when it stays from NE as shown in **Table 4-1**. The average monthly wind speed is moderate and doesn't exceed a maximum of 2.8 mph (or 1.25 m/s morning time in December).

Table 4-1: Average Wind Speed and Direction in Mawlamyine (2011-2015)

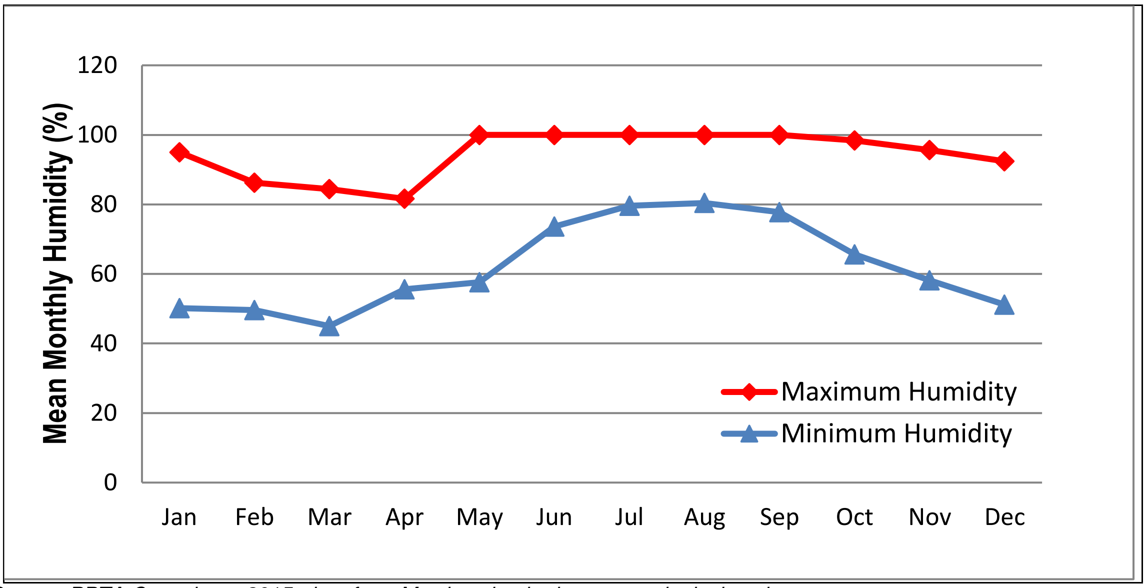
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Speed (mph) at 09:30	2.1	1.9	2.2	1.8	1.6	1.8	1.4	1.7	1.4	2.0	2.3	2.8
Direction at 9:30	NE	NE	NE	SW	SW	SW	SW	SW	SW	NE	NE	NE
Speed (mph) at 18:30	1.1	1.2	1.8	2	2.1	2.3	1.9	1.8	1.2	0.9	1.3	1.6
Direction at 18:30	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	NE	NE

Source: PPTA Consultant, 2015, data from Mawlamyine hydro-meteorological station

4.2.4 HUMIDITY

Mawlamyine has quite high humidity throughout the year by observing the 5 years data from 2010 to 2014 as shown in **Figure 4-7**. It was observed that the minimum average humidity was 45% in March and the maximum humidity reaches 100% during the wet season influence, from May to September.

Figure 4-7: Monthly Mean Humidity (2010-2014)



Source: PPTA Consultant, 2015, data from Mawlamyine hydro-meteorological station

4.3 Climate Change in Myanmar

Myanmar signed the UNFCC Convention on 11/06/1992 and ratified the convention on 25/11/1994. The country also ratified the Kyoto Protocol in 2003. Myanmar has recently submitted its Initial National Communication (INC) to UNFCCC. National Adaptation Programs of Actions (NAPA) have been prepared with the financial support of GEF/UNEP and are expected to be finalized in 2014.

4.3.1 THE NATIONAL TRENDS

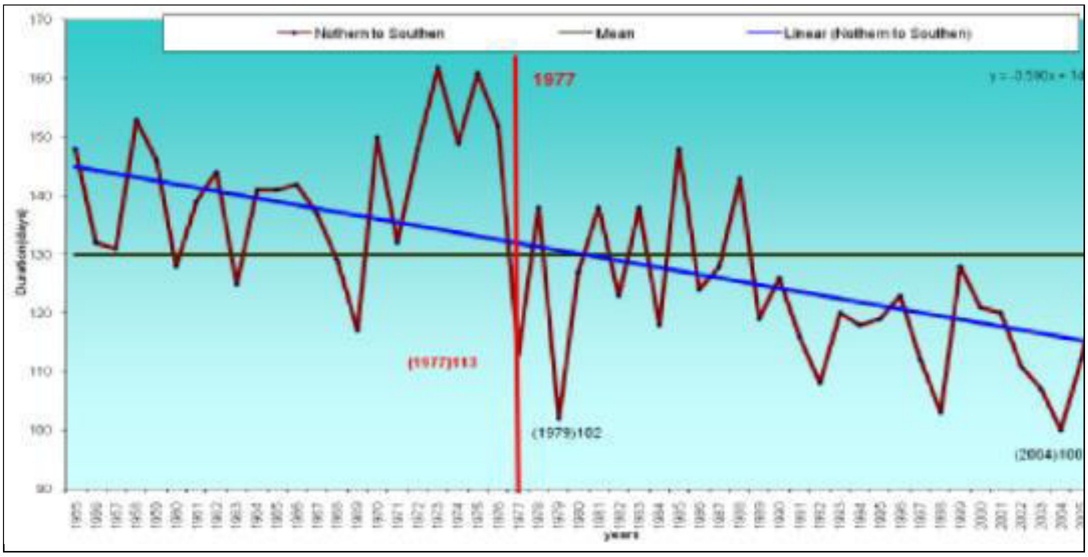
Due to its location in SE Asia and the length of its coastline, Climate Change (CC) is certainly a major concern for Myanmar. On the basis of the latest Climate Risk Index (period 1993-2012) ranking system (Global Climate Risk Index 2014, Germanwatch), Myanmar is reported as one of the most threatened country by climate change. The PPTA Consultant considers this pessimistic ranking must be interpreted carefully as it is mainly based on the losses in assets and lives during major extreme events related to climate change (typhoons and floods). The high index attributed to Myanmar results in fact, for 95% of its value, from only one event: Typhoon Nargis which killed almost 150,000 peoples in 2008. If we except this exceptional event, Myanmar appear, for 2014, not more threaten than other South Asian and South-east Asian neighbouring countries by CC.

However, Myanmar is facing progressive climate changes which threat particularly water resources and food security: Change in rainfall distribution and quantity and raise in temperature.

Figure 4-8 depicts the observed change in southwest monsoon duration: From the onset of the monsoon in Northern Myanmar until its withdrawal from the South, the monsoon duration over the last 50 years shows a significant reduction from 140-150 days in the mid-fifties to less than 120 days in 2008. Late arrival of the rain and early ending where particularly evident since the year 1977, when the duration of the rainy season dropped below 130 days, a critical limit for most cropping cycles.

According to regional information, the southwest monsoon duration has been shortened by about three weeks in northern Myanmar and one week in other parts of the country when compared to the situation observed in the fifties.

Figure 4-8: Monsoon duration (days) from onset in North till withdrawal from South (1955-2008)



Source: Some observed Climate Change Impacts in Myanmar, Dr Thin Nai Tham, Department of Meteorology and Hydrology, 2010.

Available information on climate change forecasts in Myanmar for period 2001 to 2020 anticipated:

- Slight warming of +0.5°c from June to November (rainy season) is anticipated in the whole country. During the dry season, warming will be more significant (+ 0.7 to +1.2°c) over the country, except in the delta area where temperature increase should not exceed +0.6°c.
- Only 5% increase of precipitation is forecasted for the period March-November in the whole country. During the dry season, which contributes to only 5-10% to the annual rainfall, the deficit may reach 45%, except in the delta region where dry season rain should remain normal.

4.3.2 THE SUB-NATIONAL TRENDS

Limited information has been collected so far by the PPTA Consultant at a local level. Observed temperature changes have affected some (though not all) regions to a significant degree thus far. Compared to the WMO's 1961–1990 average data, nine of the 17 state regions have observed an increase in annual temperature, two have seen decreases, and six have observed no appreciable change. Observed changes in **Kayin** and **Mon** States are provided in the **Table 4-2** presenting an analysis of records for the period 1951 to 2007 which identifies a more significant increase of temperature in Kayin State (+0.32 °C per decade) than in Mon state (+0.14°C per decade). Similarly, changes in rainfall over the same period show a decrease of 23.6 mm per decade for Kayin State while rainfall in Mon State increased by 71.57 mm per decade.

These figures have to be put into perspective with observations made in the other states of the country. Temperature increase rate in Kayin State is the highest observed in Myanmar, just followed by Lower Sagaing (0.30°c increase per decade) and Mandalay region (0.20°c increase per decade). For rainfall changes, the rainfall increase observed in Mon State is second after Upper Sagaing Region (+215.2 mm per decade) and just before Kachin State (+64.71 mm per decade). Like Kayin State, two other places observed rainfall decrease over the observation period: Bago Region (-81.08 mm decrease per decade) and Lower Sagaing Region (-17.4 mm per decade).

Table 4-2: Temperature and Rainfall Changes in Kayin and Mon States

State	Station	Mean Annual Temperature (°C)	Temp. Increase per Decade (°C)	Mean Annual Rainfall (mm)	Rainfall Change per Decade (mm)
Kayin	Hpa An	27.2	0.32	4 346	-23.6
Mon	Mawlamyine	27.1	0.14	4 816	+71.57

MOECAF, 2012, Myanmar Initial National Communication to UNFCCC

4.3.3 OBSERVED TRENDS IN MAWLAMYINE

Rainfall Historical Trend

In addition to the general assessment of CC from GCM, the PPTA Consultant carried out an analysis of Mawlamyine hydro-meteorological station monthly data, available for the period 1965-2014 (50 years), in order (i) to confirm or infirm the general trends from the GCM and (ii) provide more specific conclusions for the Mawlamyine area where the project is located. The trend over the 50 years period is identified based on the evolution of the 10 years mobile average: each point on the graph represents the average of the 10 precedent years; this approach provides a better clarity of the general trend through eliminating individual fluctuating values of each year, which reflects better the long term tendency.

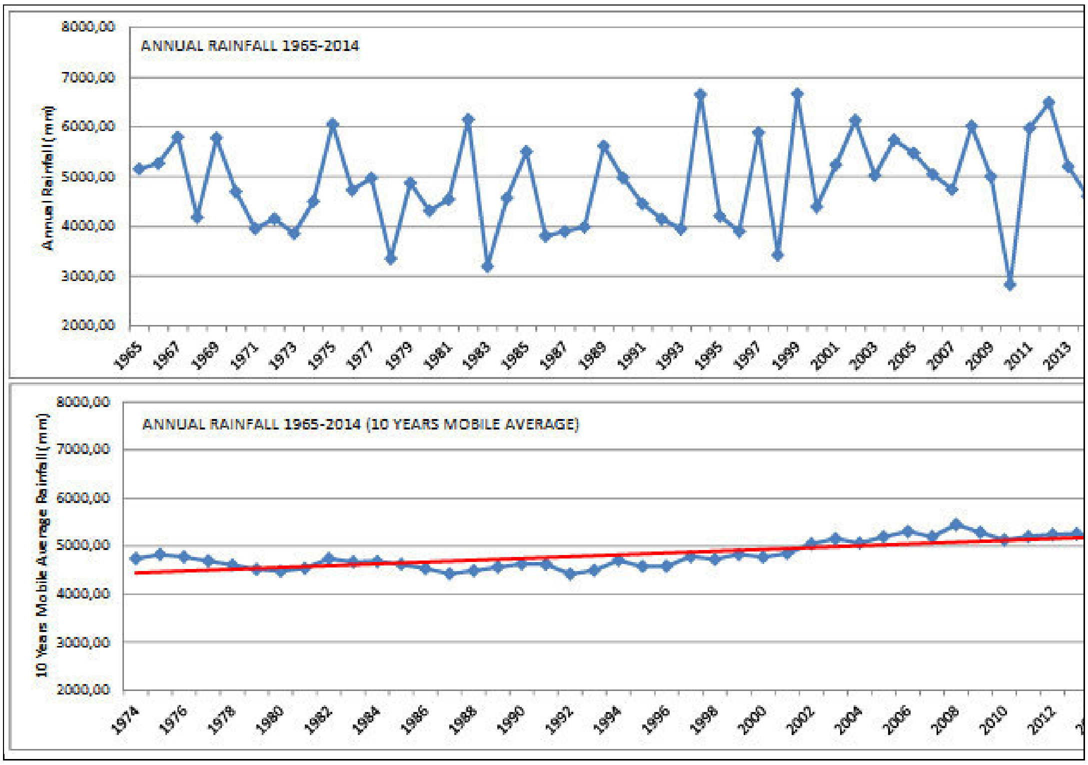
Figure 4-9 presents annual rainfall along the 50 years observation period (upper) and the same analysis but based on 10 years mobile average (lower). The 10 years mobile average clearly highlights a raising linear trend (red line) in the annual rainfall during the past 50 years, with an increase of about 500 mm/year between 1965 and 2014, or in average about 100 mm/decade.

This is in line with MOECAF estimate (UNFCCC, 2012) of an annual rainfall increase of 71.57 mm per decade for Mon State.

Figure 4-10 presents a more detailed analysis for the 6 raining months (May to October) over the observation period and based on the 10 years mobile average. In red, the resulting linear trend curve. The results lead to the following observations:

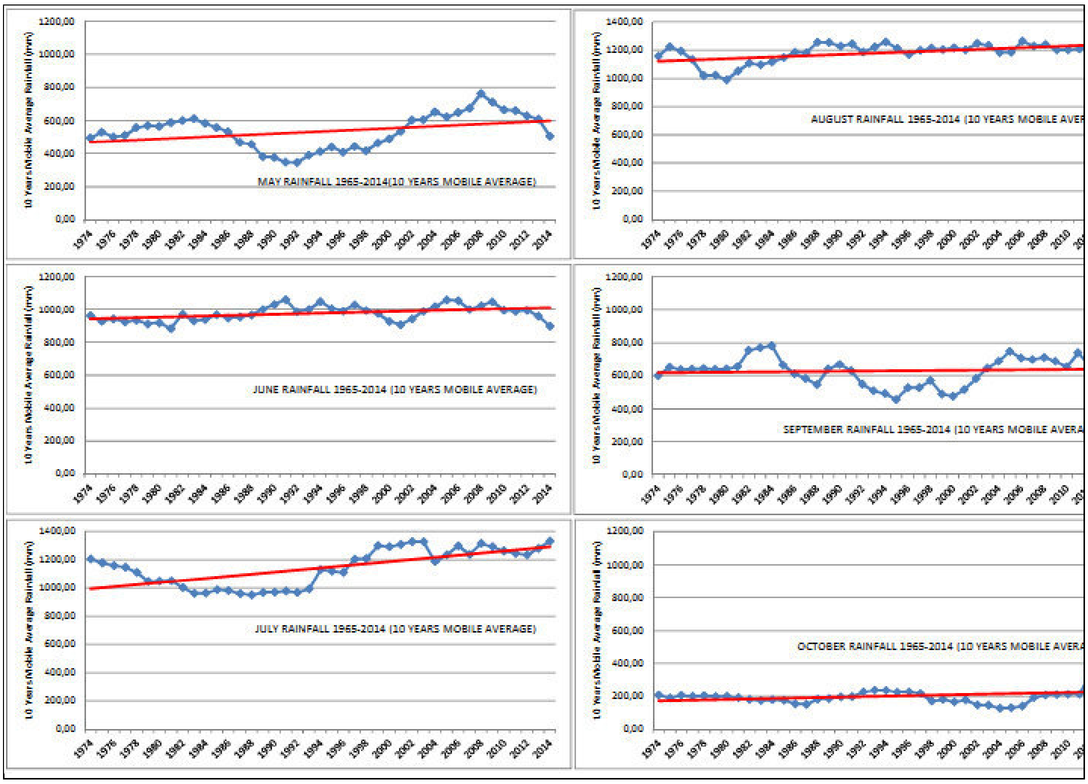
- June, September and October are rather stable with only insignificant increase over the 50 years period (increase of 50 mm in June, less for the other two months).
- The most significant increase over the 50 years in monthly rainfall is observed in May (about 120 mm) and mainly in July (almost 300 mm over the period), reflecting the general strengthening of the rainy season in the region.

Figure 4-9: Annual Rainfall Trends in Mawlamyine (Period 1965-2014)



Source: PPTA Consultant, 2015.

Figure 4-10: Monthly Rainfall Trends in Mawlamyine (Period 1965-2014)



Source: PPTA Consultant, 2015.

Temperature Trends

Data on minimum and maximum monthly temperature observed in Mawlamyine meteorological station were collected for the period 1967-2014 (48 years). Analysis performed on maximum monthly temperature is depicted in **Figure 4-11**, showing the monthly maximum temperature distribution over the period and the linear trend curve (in red).

- All the months of the year show increasing maximum temperature trends;
- July and November show the highest increase with almost 2°C;
- April and May are more stable with an increase in maximum temperature of about 0,5°C;
- The remaining months trends increase by about 1°C over the period.

The same analysis performed on the maximum annual average temperature shows an increase of about 1.1°C over the 48 years or about 0.23°C increase per decade. This value is significantly higher than the value of 0.14°C of increase by decade presented by MONREC as an average for the Mon State.

Sea Level Trends

A rise in global sea levels has been observed in recent decades, and with continued global warming temperatures, the IPCC predicts this trend to continue throughout the century. There are two primary factors affecting sea level rise relating to global warming:

- First is thermal expansion: It is estimated that approximately 60 % of the global heat energy increases are stored in the upper ocean and 30 % in ocean waters at greater depths, resulting in total oceanic absorption of 90 % of heat energy increases. As ocean waters absorb heat energy, they naturally expand, contributing to rising ocean levels.

- The second primary factor is melting ice sheets and glaciers: As the Antarctic and Greenland ice sheets melt, runoff from melting glaciers empties into the world's oceans, resulting in sea level rise.

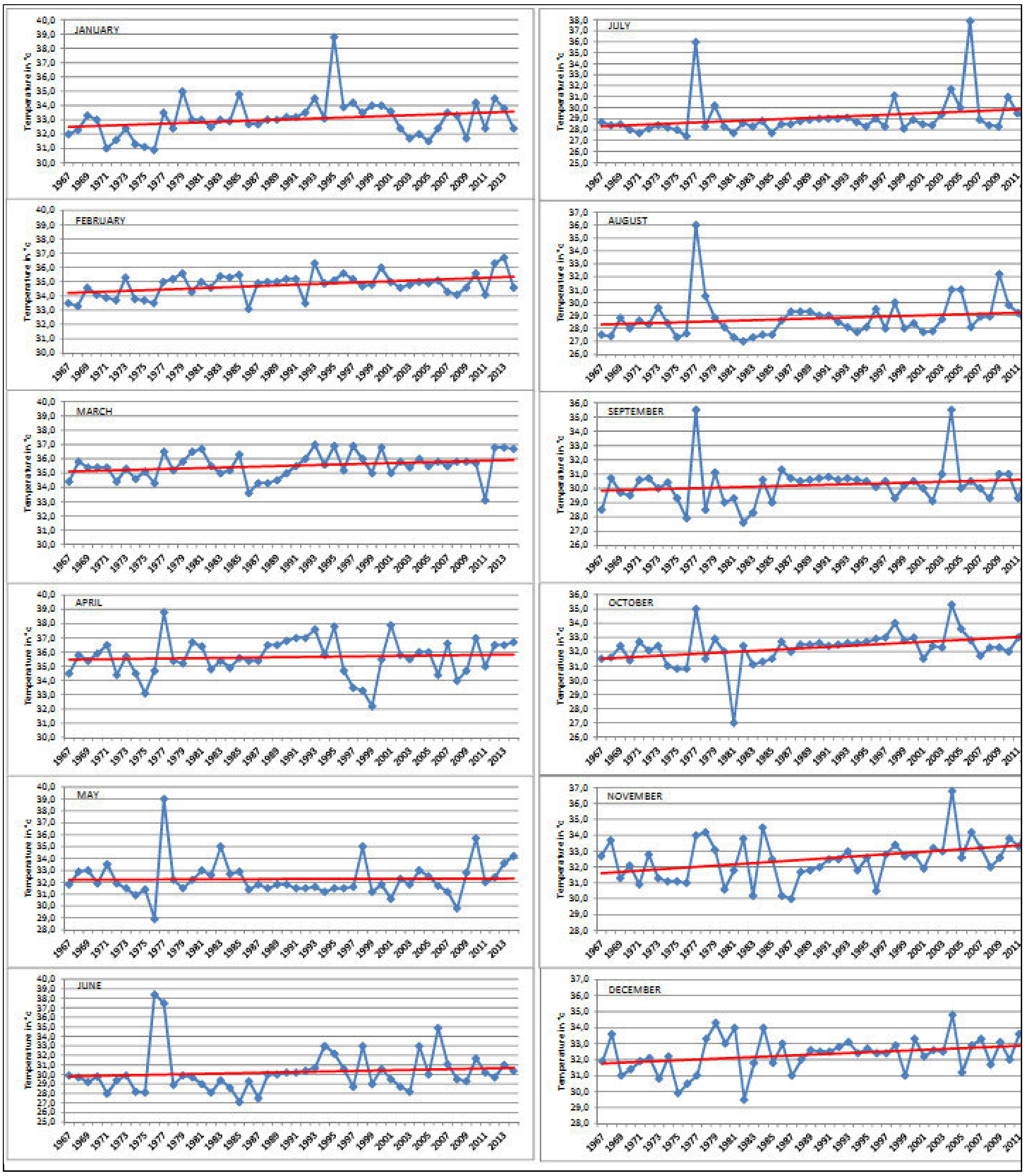
Table 4-3: IPCC Projections for Future Temperature and Sea Level Changes

		2046–2065		2081–2100	
	Scenario	Mean	*Likely* range[c]	Mean	*Likely* range[c]
Global Mean Surface Temperature Change (°C)[a]	RCP2.6	1.0	0.4 to 1.6	1.0	0.3 to 1.7
	RCP4.5	1.4	0.9 to 2.0	1.8	1.1 to 2.6
	RCP6.0	1.3	0.8 to 1.8	2.2	1.4 to 3.1
	RCP8.5	2.0	1.4 to 2.6	3.7	2.6 to 4.8
	Scenario	Mean	*Likely* range[d]	Mean	*Likely* range[d]
Global Mean Sea Level Rise (m)[b]	RCP2.6	0.24	0.17 to 0.32	0.40	0.26 to 0.55
	RCP4.5	0.26	0.19 to 0.33	0.47	0.32 to 0.63
	RCP6.0	0.25	0.18 to 0.32	0.48	0.33 to 0.63
	RCP8.5	0.30	0.22 to 0.38	0.63	0.45 to 0.82

IPCC, Climate Change 2013: The Physical Science Basis, 25.

The latest IPCC report also provides an assessment that it is very likely that mean sea levels rose worldwide by approximately 1.7 mm per year since 1901 (through 2010). Furthermore, the rate of rise has increased in recent decades, with an average of 2.0 mm per year since 1971 and 3.2 mm per year since 1993.

Figure 4-11: Monthly Temperature Trends in Mawlamyine (1967-2014)



Source: PPTA Consultant, 2015.

IPCC Projections for future temperatures and sea level rise are provided in **Table 4-3** according to various scenarios of CC. In order to be on the safe side, it is considered that a level rise of 0.5 m by 2065 and 1.0 m by 2100 is reasonable for planning projects in the coastal zone of Myanmar, including Mawlamyine. This value does not integrate surge raise created by low pressure tropical storms (typhoons) which already occur but are anticipated to become more frequent in the future. However, Mawlamyine is not facing directly the sea, being well protected from such phenomenon by a large island.

Conclusions

Both temperature and rainfall show increasing trends in Mawlamyine along the last 50 years of observations, in line with MONREC trend analysis for Mon State.

Annual rainfall increased by 500 mm over a 50 years period, or a raise of about 100 mm/decade. The month of July shows the highest raise during the 50 years period, about 300 mm, followed by May with 120 mm. Other months are almost stable or show only slight increase.

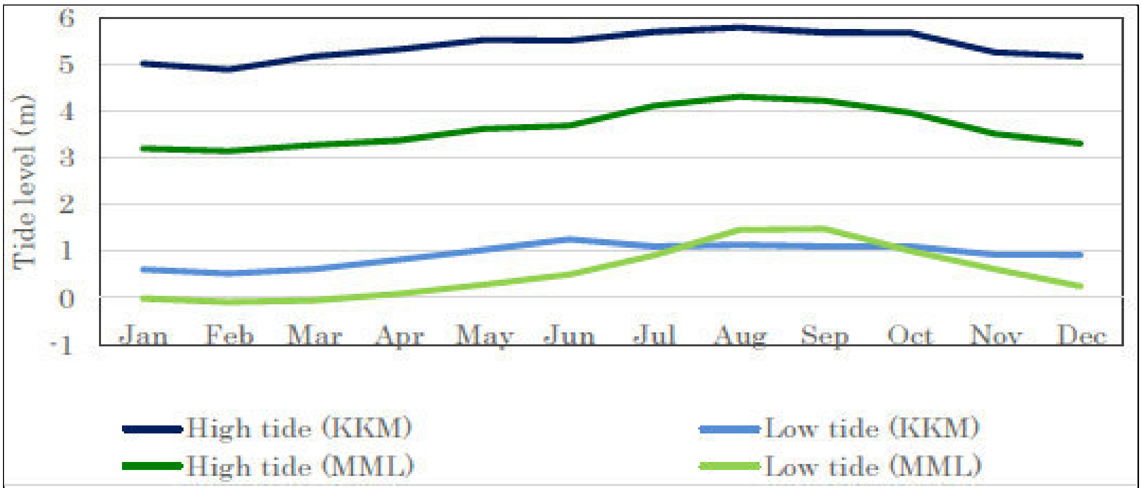
Temperature also increased over the same period. The average annual maximum temperature rose by 1.1°C over the last 48 years, or an increase of about 0.23°C per decade, a value significantly higher than what is considered in the Mon State (0.14°C increase per decade). July and November are the months showing the highest raise over the period, about 2°C. According to IPCC, sea level rise could reach 0.82 m by the end of the century. The present project considers a safety over-elevation of 1 meter as a design criteria for concerned project components, to avoid long term flooding risk. All these results are consistent with the trends generally presented by MOECAF for Mon State.

4.4 Surface Water

4.4.1 OCEANOGRAPHY

Due to the location of Mawlamyine in the estuary of the Thanlwin River, the surface water levels in the lower river system are under the influence of the sea tide. In Mawlamyine area, tide stations are located in Kyaikkami and Mawlamyine town. Average annual tide amplitude (difference between high and low tide) is approximately 4.5 m in Kyaikkami and decreases to about 3 m in Mawlamyine. Monthly tidal information for both stations in 2010 is provided in **Figure 4-12**.

Figure 4-12: Average Monthly Tide Level at Kyaikkami (KKM) and Mawlamyine (MML)



Source : Mawlamyine Port Authority

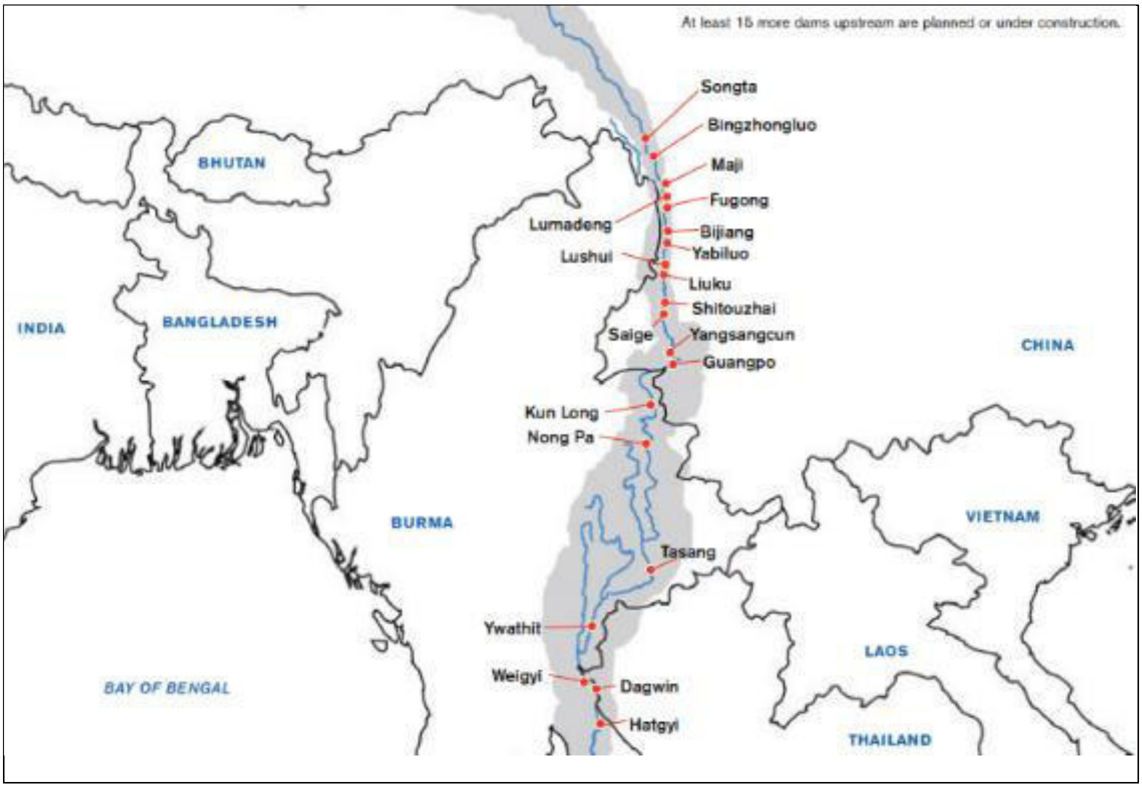
4.4.2 HYDROLOGY AND FLOODS

The Salween River is about 2,815 km long which flows from the Tibetan Plateau into the Andaman Sea in Southeast Asia. In its lower reach in Myanmar, the river is named Thanlwin River. It drains a narrow and mountainous watershed of 324,000 km² (125,000 sq mi) that extends into the countries of China, Burma and Thailand. Steep canyon walls line the swift, powerful and undammed Salween, one of the longest free-flowing rivers in the world. Its extensive drainage basin supports a biodiversity comparable with the Mekong and is home to about 7 million people. In 2003, key parts of the mid-region watershed of the river were included within the "Three Parallel Rivers of Yunnan Protected Areas", a UNESCO World Heritage Site.

Mawlamyine is located along the estuary of the Thanlwin River. *Thanlwin discharge is estimated as 157 billion m^3/year, which translates close to 5,000 m^3/s in average. Near the head of the Delta, a mean low flow of 2 300 m3/s and a flood discharge of 32,600 m3/s are reported. However, several hydroelectric projects are already identified all along the course of the river, both in China and in Myanmar, which may have drastic impact in the long term on the river hydrology.* **Figure 4-13** *presents the location of sites where potential hydropower development is identified.*

Attran River is a river of Burma (most of its course) and Thailand (its uppermost part). In Thailand, it is usually known as the Kasat River. It merges into the larger Gyaing River and Salween River near Mawlamyine. A main tributary of the Attran River is the Zami River. The Attran and its tributaries begin near the Thai-Burmese border and flow in a general north-north-west direction. The Attran River is presently used for the water supply of some areas of Mawlamyine.

Figure 4-13: ***Proposed Dams in the Salween River***



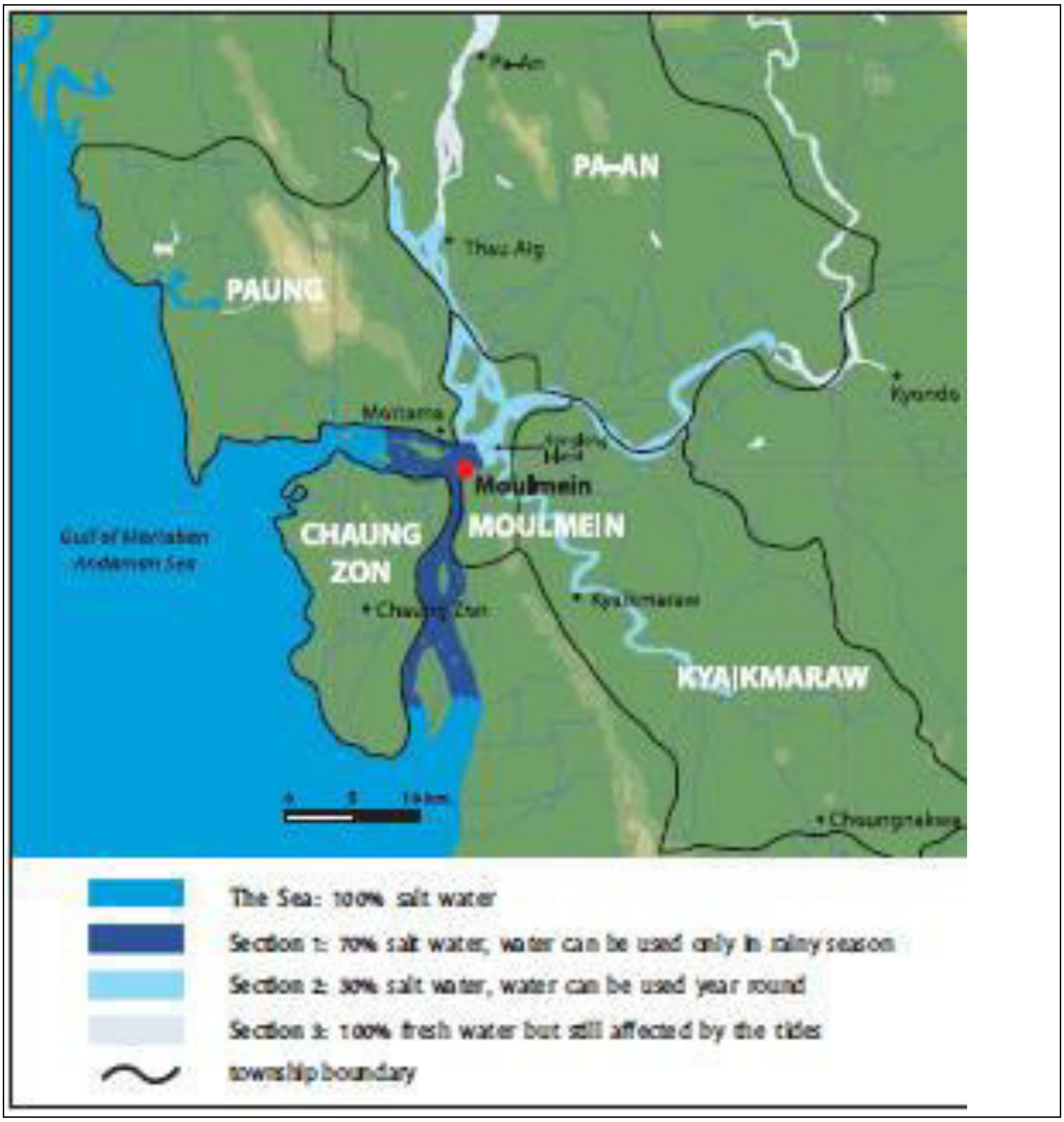
Source: Salween Watch, 13 March 2013

As described above with rising sea levels and the impact of upstream reservoirs, there is a significant risk that the saline wedge can encroach further upstream.

This has been particularly observed with respect to the estuaries of other Asian Rivers, notably the Mekong and the Brahmaputra-Ganges. At present there have been limited reporting (see **Figure 4-14**) and no attempt to simulate future saline conditions of the lower Thanlwin under different future scenarios, however, by analogy with nearby rivers the future risks can be appreciated.

For example, on the Mekong recent research generally shows that the saline wedge is expected to encroach 10 km further upstream by 2030 and 20 km by 2090 from a late 1990's baseline. While this could be used as an indication of potential future changes on the Thanlwin taking into account climate change and sea level rise, it can be appreciated that the Thanlwin is a very different river morphologically when compared to the Mekong. In addition, even in the baseline conditions, the saline wedge had already encroached significantly up certain branches of the Mekong Delta.

Figure 4-14: Existing salinity conditions (isohalines) of surface waters in the Lower Thanlwin



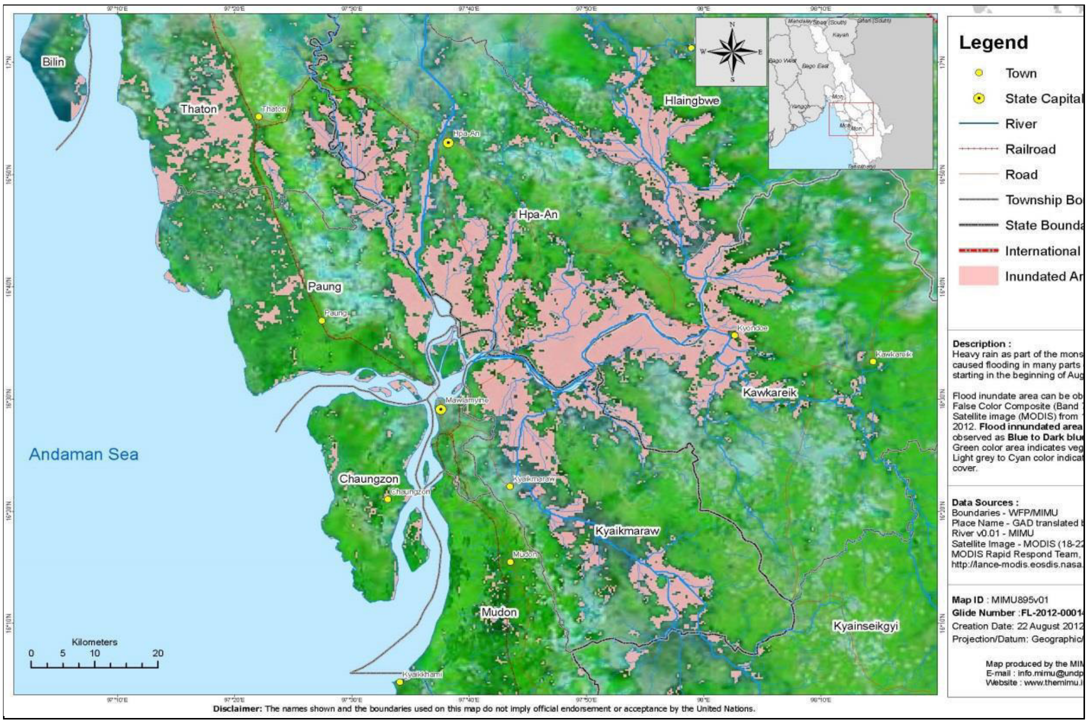
Source: Salween Watch, 13 March 2013

The floods in Southeast Myanmar could be generally classified into two types, namely: "widespread flood" and the "flash flood". Most of them occur around the middle of the southwest monsoon from June to October.

The widespread flood mainly hits the lower and middle reaches of the large rivers such as Thanlwin, Attran and Gyaing Rivers, having a catchment area larger than few thousands of square kilometres. The water levels of the downstream/middle streams of these rivers tend to gradually rise. Because of such gradual rise of river water levels, the residents have time for evacuation from the flooded zones and therefore the human damages including the death seldom occur. However, once the river water levels exceed the river bank levels, extensive and prolonged flood inundation occur. As most major urban centres are located along the downstream reach of the large rivers and are inundated over a long period, economic damages from flood tend to be huge. For this reason, most recorded major flood damages in the Southeast Myanmar result from the wide spread flood.

In contrast to the widespread flood, flash-floods tend to occur along small rivers and creeks where the peak water level rises very rapidly immediately after the heavy rainfall event. Due to such features, flash flood results into potential risk of serious human damages including fatalities. However, since flash flood is limited to limited areas and residents being well aware of the risks, the flood damages are far smaller than those of the wide-spread flood described above (Ministry of Border Affairs & JICA, 2013). See **Figure 4-15** for details of 2012 flooding.

Figure 4-15: Inundated Areas of 18-22 August 2012 Flood around Mawlamyine and Hpa-An



Source: Department of Meteorology and Hydrology, 2015

Thanlwin River tends to be the main cause of serious flood damages in Mawlamyine area. The critical level in Hpa-An (where the only control station is located) above which flood occurs is 7.50 m (staff gauge reading by the

Department of Meteorology and Hydrology). According to the records of DMH, the river water levels in the Thanlwin River exceeded the critical level seven years out of ten (period 2003-2012) and water levels above the critical level lasted for 5 to 46 days.

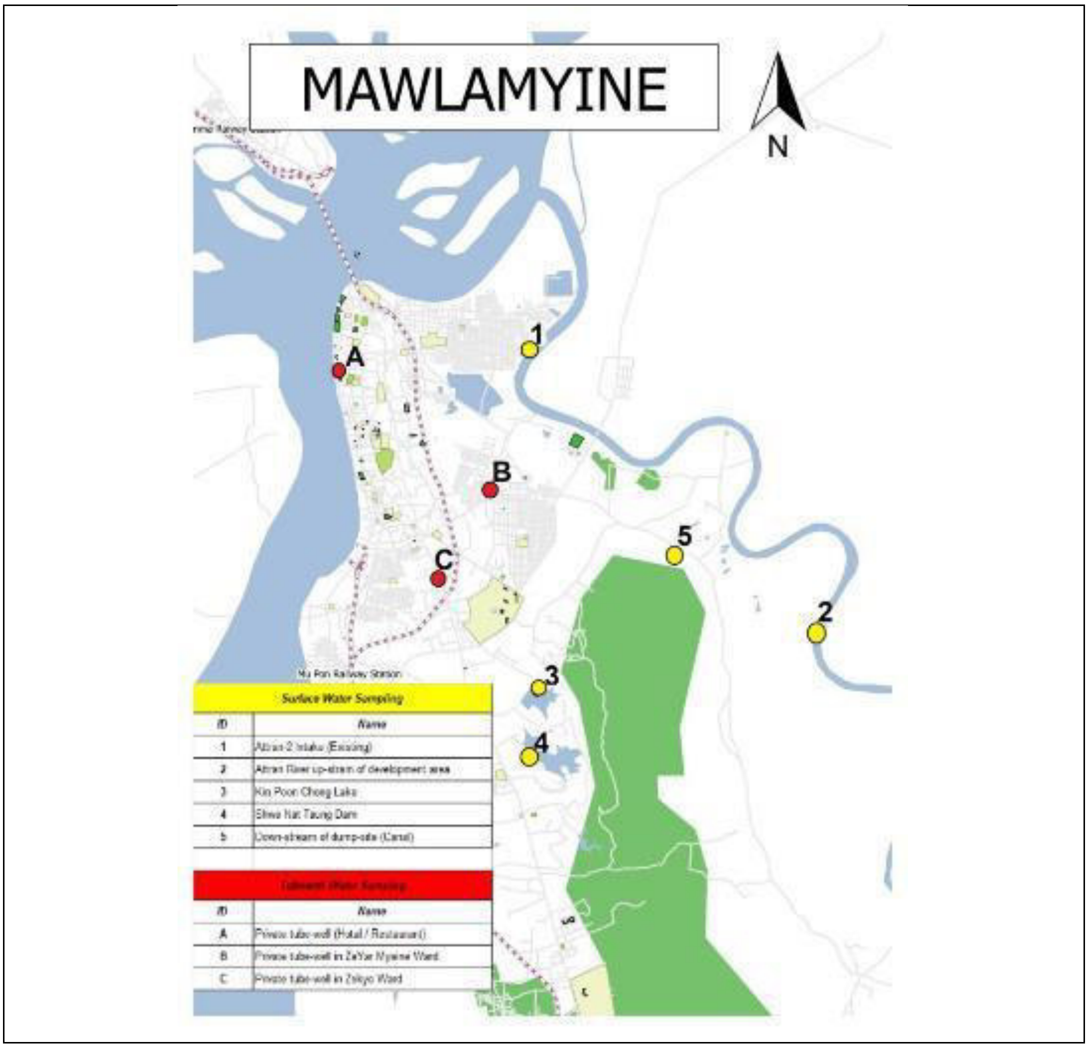
However, flood is not a major issue in Mawlamyine urban area due to the hilly topography of the city. Flooding from the Thanlwin hardly affects more than the strand road (5 m elevation) along the river bank, and not concerned by project activities. Project components are all located at an elevation >15 m.

4.5 Hydrogeology

In Mon State, groundwater is abstracted from three kinds of wells: (i) hand-dug wells (10 to 12 m), shallow-wells (25 to 50 m) and tube wells (more than 60 m) (Ministry of Border Affairs & JICA, 2013).

There is not much information about groundwater in Mawlamyine. According to the final report on Myanmar Three Cities Water Supply Management Improvement Project (Ministry of Health, Labour and Welfare of Japan, 2003), it was concluded that underground water levels in Mawlamyine tend to be low in the dry season and even depleted sometimes. Underground water abstracted from shallow wells close to the river is brackish and is hardly used for drinking purpose (ref. following section).

Figure 4-16: Sampling Locations for WQ Survey in Mawlamyine



4.6 Air Quality

There is no available information on air quality in Mawlamyine. The main issue is related to the regular burning of dry tree leaves and waste dumped in the natural drains and along streets, which releases smoke. However, due to the present limited industrial activity in the area, limited road traffic and the permanent wind blowing dominantly from the Andaman Sea, the city doesn't face presently significant problem regarding air quality.

4.7 Water Quality

The PPTA Consultant appointed a Yangon laboratory (E-Guard) to undertake a water quality survey. Sampling was carried out in September 2015. Location of water quality samplings in Mawlamyine are presented in **Figure 4-16**.

4.7.1 SURFACE WATER QUALITY

For surface water, 4 samples of surface water (samples 1 to 4) including 2 river samples (No.1 and 2), 2 lake samples (No. 3 and 4) and 1 sample of leachate from the dumpsite (No. 5) have been analysed. Results of analysis are provided in **Table 4-4**.

Table 4-4: Surface Water Quality Analysis in Mawlamyine

No.	Parameter	Unit	01	02	03	04	05
1	Temperature	°C	28.3	28.9	28.5	28.7	29.5
2	EC	µS	87.3	85.1	22.5	36.9	2210
3	DO	mg/l	6.21	6.47	6.57	7.58	1.52
4	pH		7.10	7.29	6.24	6.99	7.41
5	Turbidity	NTU	25	28	4	6	108
6	BOD	mg/l	11	< 1	6	8	154
7	COD	mg/l	< 10	< 10	< 10	< 10	737
8	TSS	mg/l	72.67	72	62.67	81	-
9	T phosphorus	mg/l	0.01	0.01	< 0.01	< 0.01	0.73
10	Phosphate	mg/l	Nil	Nil	Nil	Nil	4.26
11	Total Nitrogen	mg/l	< 0.6	< 0.6	< 0.6	< 0.6	65.24
12	Nitrate	mg/l	0.05	0.07	0.11	0.15	0.86
13	Ammonia	mg/l	Nil	Nil	Nil	Nil	45.14
14	Ammonium	mg/l	Nil	Nil	Nil	Nil	47.73
15	Total Coliforms	Cfu /100 ml	43	50	26	28	Numerous
16	Sulphate	ppm	22.87	69.35	98.6	94.81	120.27
17	Chloride	mg/l	< 1.4	< 1.4	1.07	1.42	-
18	Calcium	mg/l	14.24	15.13	3.12	6.23	-
19	Magnesium	mg/l	5.40	5.94	1.35	2.70	-
20	Sodium	mg/l	1.57	1.28	1.28	1.67	-
21	Potassium	mg/l	0.59	0.59	0.5	0.5	-
22	Alkalinity	mg/l	37	37.5	11.5	16.5	-

KhinPonChong water presents a very low mineralisation (EC=22.5 µS), which is in line with the water origin: only rain water with a limited run-off due to the small size of the catchment, so with limited opportunity to be enriched with soil minerals.

Total suspended solids value is 62.7 mg/l, which looks a bit high when compared with the low turbidity value of 4 NTU. Discrepancy between the two values may be due to the presence of few larger particles in the sample with limited effect on turbidity but with more impact on the suspended solid mass.

Organic pollution is low, in relation to the small size of the catchment still devoid of any industrial activity or of any settlement.

All parameters of KhinPonChong reservoir are compatible for its use as drinking water after treatment.

4.7.2 UNDERGROUND WATER QUALITY

For underground water, 3 samples from tubewells have been sampled and analysed as shown in **Table 4-5**.

Table 4-5: Results of the tube well water samplings in Mawlamyine

No.	Parameter	Unit	A	B	C
1	Temperature	°C	28.6	29	28.4
2	Electric conductivity	µS	1349	407	250
3	Dissolved Oxygen	mg/l	7.56	7.67	7.36
4	pH		7.13	7.49	5.87
5	Turbidity	NTU	54	22	3
6	BOD	mg/l	10	10	7
7	COD	mg/l	<10	<10	<10
8	Total Suspended Solids	mg/l	227.33	70	40
9	Total phosphorus	mg/l	0.13	0.12	<0.01
10	Phosphate	mg/l	0.31	0.21	Nil
11	Total Nitrogen	mg/l	0.84	<0.6	2.52
12	Nitrate	mg/l	0.15	0.22	1.86
13	Ammonia	mg/l	1.18	0.22	2.55
14	Ammonium	mg/l	1.25	0.23	2.69
15	Total Coliforms	Cfu /100 ml	30	28	35
16	Sulphate	ppm	200.89	124.51	91.2
17	Chloride	mg/l	302.04	6.03	40.06
18	Calcium	mg/l	148.59	64.95	17.80
19	Magnesium	mg/l	18.90	14.58	1.08
20	Sodium	mg/l	149.52	0.98	29.52
21	Potassium	mg/l	4.62	2.26	3.54
22	Alkalinity	mg/l	239.5	214	40

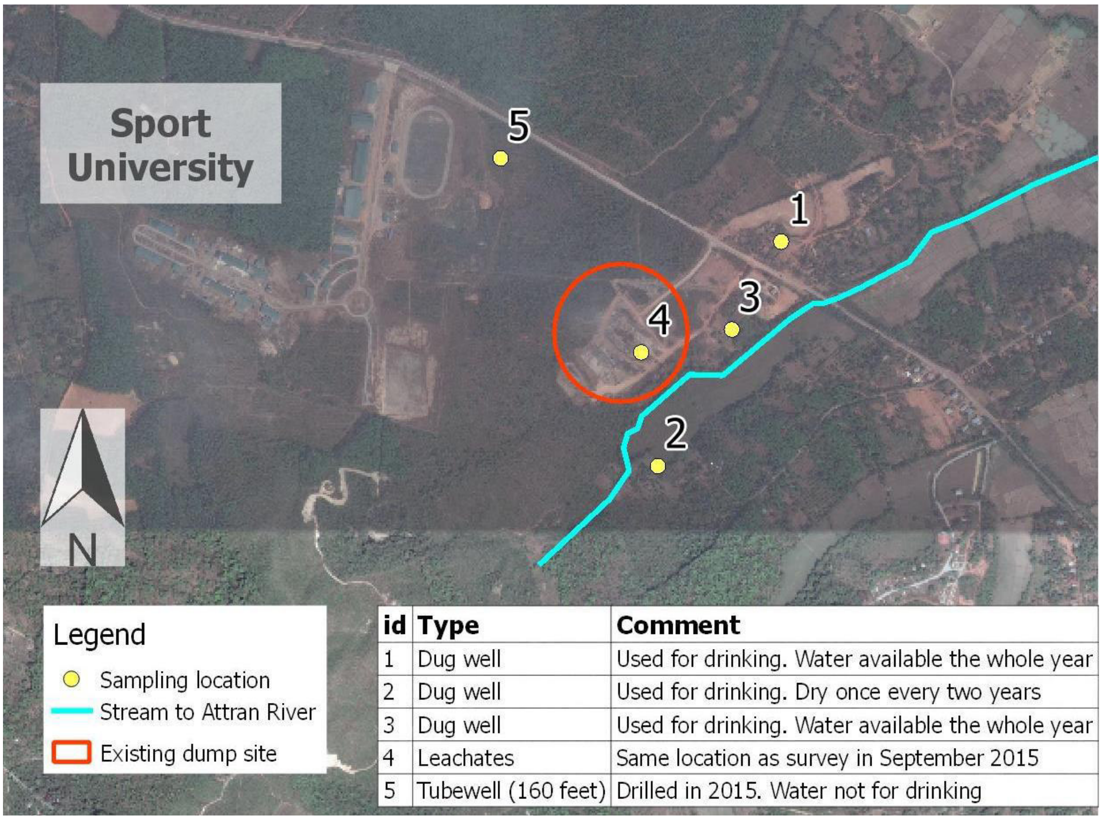
The high salinity of tube well N°1 located along the Thanlwin river bank reflects the influence of the sea and the salinity of the water in the estuary. Turbidity and TSS values are high for underground resources, probably reflecting the inappropriate design of the tube wells or the fine sediment at the level of the pumping. All wells are contaminated, as a result of the several septic tanks as the unique sanitation system of Mawlamyine.

In addition to this general baseline analysis, the PPTA Consultant has undertaken a water quality survey in July 2016 specifically in relation to potential contamination from the existing dumpsite on groundwater immediately downstream of the site. The location of water quality samplings in Mawlamyine are presented in Figure 4-17.

The aquifer flow direction is estimated from South toward North-East where Attran River flows. Then two dug wells have been selected downstream the dump site, near the main road (Sampling # 1 and 3 on the map). One dug well (Sampling #2) and one tubewell (Sampling #4) have been selected upstream the dump site.

Results of analysis are provided in **Table 4-4**.

Figure 4-17: Water quality sampling at Mawlamyine dump site surrounding wells



id	Type	Comment
1	Dug well	Used for drinking. Water available the whole year
2	Dug well	Used for drinking. Dry once every two years
3	Dug well	Used for drinking. Water available the whole year
4	Leachates	Same location as survey in September 2015
5	Tubewell (160 feet)	Drilled in 2015. Water not for drinking

With regard to these analyses the following interpretations have been made:

- For sample N°4 (landfill leachate) most of the parameters are higher than the national standards for municipal landfill leachates with high BOD (and COD although strangely this latter value is not included in the standard), TSS and other parameters; there is however no sign of heavy metal contamination in the leachate as per the previous results reported above.
- The tubewell near government houses (Sample #5) is not in regular use as the housing are not yet inhabited. It would be appropriate in the future to connect these areas to the proposed water supply project given the risk from existing and future contamination.
- **Coliforms (total and faecal):** Total coliform detected in all the samples and faecal coliforms detected in all except in Sample 2 (Upstream)
- **pH** is very low in sampling 1, 2 and 3 (pH < 6)
- **Turbidity** is higher than WHO standards in S 2, S3, S4 and S5. It is very high in S4 because sediment concentration is important in the leachates.
- **Iron** is higher than WHO standards in all the samplings. The concentration is more important upstream (S2 has 1.22 mg/l and S5 has 3.5 mg/l) than downstream (around 0.4 mg/l in S1 and S3)
- **The BOD and COD level** are quite low (except the leachates). The COD/BOD ratio is not usable as it seems the level of detection for COD measurement is 32 mg/l. At the leachate pond, COD reaches 900 mg/l while BOD is around 400 mg/l (in rainy season).
- **Fluoride** is quite high (0.5 to 1 mg/l) but still lower than WHO standards

In general, there is no specific correlation between pollution in samples downstream and upstream of the dump site although the tubewell (N° 5) exhibits water quality exceeding WHO standards for both physical and microbiological parameters

Table 4-6: Underground water quality analysis near Mawlamyine dump site

No.	Parameter	Unit	01	02	03	04	05	WHO guidelines
1	pH		5.9	5.6	5.3	7.3	7.1	6.5 – 8.5
2	Colour	TCU	Nil	10	Nil	180	30	15 TCU
3	Turbidity	NTU	4	24	6	626	52	5 NTU
4	Conductivity	microS/cm	47	22	28	9250	282	
5	Total Hardness	mg/l as CaCO3	2	4	4	840	114	500 mg/l as CaCO3
6	Calcium Hardness	mg/l as CaCO3	1	2	2	558	78	
7	Magnesium hardness	mg/l as CaCO3	1	2	2	282	36	
8	Total Alkalinity	mg/l as CaCO3	4	8	4	1210	152	
9	Phenolphthalein Alkalinity	mg/l as CaCO3	Nil	Nil	Nil	Nil	Nil	
10	Carbonate	mg/l as CaCO3	Nil	Nil	Nil	Nil	Nil	
11	Bicarbonate	mg/l as CaCO3	4	8	4	1210	152	
12	Iron	mg/l	0.33	1.22	0.42	4.86	3.54	0.3 mg/l
13	Chloride	mg/l	6	3	4	2300	3	250 mg/l
14	Sodium Chloride (as NaCl)	mg/l	10	5	7	3795	5	
15	Sulphate (as SO4)	mg/l	Nil	Nil	Nil	320	28	200 mg/l
16	Total Solids	mg/l	30	43	26	5850	219	1500 mg/l
17	Suspended Solids	mg/l	7	32	12	1230	78	
18	Dissolved solids	mg/l	23	11	14	4620	141	1000 mg/l
19	Manganese	mg/l	Nil	Nil	Nil	0.2	Nil	0.05 mg/l
20	Phosphate	mg/l	Nil	Nil	Nil	1.95	Nil	
21	Salinity	ppt	< 0.1	< 0.1	< 0.1	5.2	< 0.1	
22	Temperature	°C	25.1	25	25.1	25	25	
23	Fluoride	mg/l	0.8	1.1	0.9	0.3	0.5	1.5 mg/l
24	Lead (as Pb)	mg/l	Nil	Nil	Nil	Nil	Nil	0.01 mg/l
25	Arsenic (As)	mg/l	Nil	Nil	Nil	Nil	Nil	0.01 mg/l
26	Nitrate	mg/l	0.2	0.3	0.2	3.5	0.4	50 mg/l
27	Ammonia	mg/l	Nil	Nil	Nil	10.00	Nil	
28	Ammonium	mg/l	Nil	Nil	Nil	10.57	Nil	
29	DO	mg/l	3.8	3.4	5.2	Nil	7.2	
30	COD	mg/l	< 32	< 32	< 32	896	< 32	

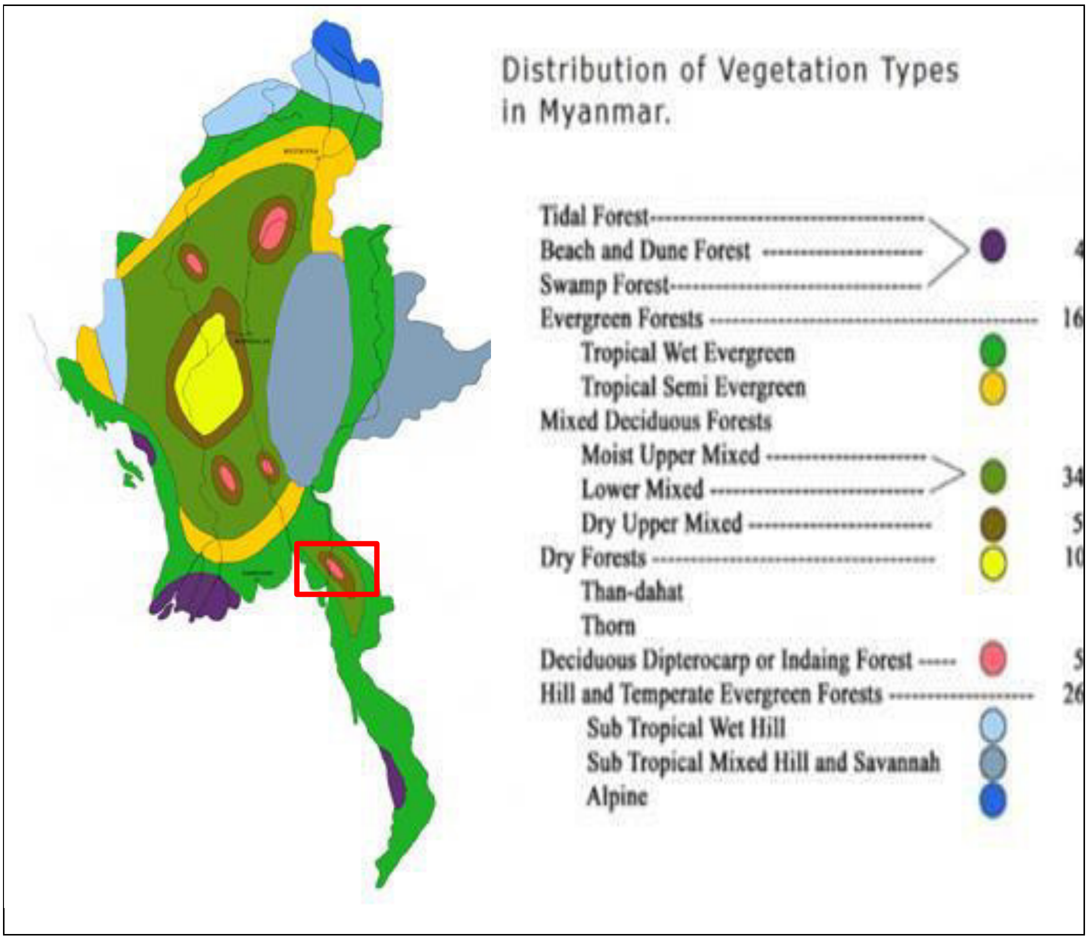
No.	Parameter	Unit	01	02	03	04	05	WHO guidelines
31	BOD	mg/l	7	9	5	390	8	
32	Cyanide	mg/l	Nil	Nil	Nil	Nil	Nil	0.07 mg/l
33	Zinc	mg/l	Nil	Nil	Nil	Nil	Nil	3 mg/l
34	Copper	mg/l	Nil	Nil	Nil	Nil	Nil	2 mg/l
35	Total Coliform Count	CFU /100 ml	4	3	3	18	8	Not detected
36	Thermotolerant (faecal) Coliform Count	CFU /100 ml	1	ND	1	7	2	Not detected

4.8 Terrestrial & Aquatic Ecology

4.8.1 NATURAL AND URBAN VEGETATION

As shown on **Figure 4-18**, there are various vegetative types ranging from Tropical Wet Evergreen, Moist Upper Mixed Deciduous forest, Lower Mixed Deciduous forest, Dry Upper Mixed Deciduous Forest, and Deciduous Dipterocarp or Indaing Forest.

Figure 4-18: Distribution of Vegetation Types in Myanmar



Source: A Checklist of the Trees, Shrub, Herbs, and Climbers of Myanmar. Contributions from the United States National Herbarium. Volume 45: 1-59

As Mon is located in the tropical climate zone with intense rains, evergreen forests (Tropical wet evergreen) and mixed deciduous forests thrive in the region of the state. Marshes grow along some coastal plains and valleys of rivers and creeks and trees such as *Dipterocarpus tuberculatus* grow on laterite-like land in areas east of Mawlamyine.

Mangroves are observed in the mouths of tidal rivers as the Thanlwin River in Mon State. According to the National Report of Myanmar on Sustainable Management of the Bay of Bengal Large Marine Ecosystem (2003), as many as 24 species of mangrove trees have been recorded along the Myanmar coastline. Genus most frequently observed include Rhizophora, Sonneratia, Avicennia, Bruguiera and Xylocarpus spp (Department of Fisheries Myanmar, 2003). In Mawlamyine area, only few mangrove trees are scattered along the banks of the Thanlwin and the Attran rivers. But these areas represent almost the upstream distribution limit of mangrove, as the salinity of the water reduces. No mangrove vegetation is observed within or close to the project component areas.

SOME MANGROVE TREES ALONG THE THANLWIN RIVER MIXED WITH DUMPED WASTE

MANGROVE TREES ALONG THE ATTRAN RIVER

The following trees and shrubs species presented in **Table 4-7** are the most common ones observed in Mawlamyine region. Most of these trees are widely distributed in SE Asia and also widely used for plantation in urban areas. None is registered as a protected species either at international (IUCN) or national levels.

Table 4-7: Species of Trees and Shrubs found in Mawlamyine region

VERNACULAR NAME (BURMESE)	SCIENTIFIC NAME
Htan pin	*Borassus flabellifer* (Arecaceae)
Da hat pin	*Tectona hamiltoniana* (Verbenaceae)
Yin Mar pin	*Chukrassia tabularis* (Meliaceae)
Shaw phyu	*Sterculia versicolor* (Sterculiaceae)
In Gyin pin	*Shorea siamensis* (Dipterocarpaceae)
Ngu pin	*Cassia fistula* (Caesalpiniaceae)
Pa Dauk	*Pterocarpus macrocarpus* (Fabaceae)
Ta Mar	*Azadirachta indica* (Meliaceae)
Bawzagaing	*Leucaena leucocephala* (Mimosaceae)
Seinban	*Delonix regia* (Caesalpiniaceae)
Tayok-saga	*Plumeria rubra (Apocynaceae)*
Magyi	*Tamarindus indica* (Caesalpiniaceae)
Kokko	*Albizia lebbek* (Mimosaceae)
Nyaung pin	*Ficus religrasa* (Moraceae)
Banda	*Terminalia catappa* (Combretaceae)
Arthaw-ka	*Polyalthia longifolia* (Annonaceae)
Swedaw	*Bauhinia monandra* (Caesalpiniaceae)
Eu-ca-lit	*Eucalyptus ovata* (Myrtaceae)
Thayat	*Mangifera indica (Anacardiaceae)*
Thiho (Cashew nut)	*Anacardium occidentale* (Anacardiaceae)
Kyun (Teak)	*Tectona grandis* (Verbenaceae)
Khayay	*Mimusops elengi* (Sapotaceae)

Vernacular Name (Burmese)	Scientific Name
Maniawga	*Carallia brachiata* (Rhizophoraceae)
Mahogany	*Swietenia macrophylla* (Meliaceae)

4.8.2 AQUATIC FAUNA

Very limited information is available on the fish population in the project region. Only one study on fish composition in the downstream section of Thanlwin River was carried out from May to October 2014 by the Department of Zoology, University of Mawlamyine (Than, Tun, & Htay, 2014). According to the study, 22 species were observed in the Mottama area, close to Mawlamyine. The species observed are listed in **Table 4-8**. None of these species is registered as protected either at international or national levels.

Table 4-8: Main Fish Species in Mawlamyine Region Water Bodies

Vernacular Name (Burmese)	Scientific Name
Nga hpe	*Notopterus notopterus* (Notopteridae)
Nga tha lauk	*Tenualosa ilisha* (Clupeidae)
Mee tan thwe	*Colia dussumieri* (Engraulididae)
Nga phan ma	*Osteobrama belangeri* (Cyprinidae)
Nga khone ma	*Puntius sophora* (Bagridae)
Nga zin yine	*Mystus vittatus* (Bagridae)
Nga nu than	*Ompok bimaculatus* (Siluridae)
Ka ka loung	*Eutropiichthys vacha* (Schilbeidae)
Nga yant gaung to	*Channa orientalis* (Channidae)
Nga yant	*Channa striatus* (Channidae)
Nga mway doh kyar	*Macrognathus zebrinus* (Mastacembelidae)
Nga mway don pyaung	*Macrognathus aral* (Mastacembelidae)
Moe nga yaung	*Arius caelatus* (Ariidae)
Pin lei nga khue	*Plotosus canius* (Plotosidae)
Nga khoo	*Clarias batrachus* (Centropomidae)
Nga si ooe	*Gerres filamentosus* (Gerrreidae)
Nga pyat khone	*Johnius coitor* (Sciaenidae)
Nga poke thin	*Otolithoides pama* (Sciaenidae)
Kabu lu	*Rhinomugil corsula* (Mugilidae)
Nga pon na	*Polynemus paradiseus* (Polynemidae)
Ka tha boe	*Glossogobius giuris* (Gobiidae)
Nga bee	*Scatophagus argus* (Scatophagidae)

No information is available on the fish population of Kin Pong Chong reservoir. According to the water supply department, no fishing activities happen on the lake where boats are not allowed. Also, very few fishes are reported because the very low level of mineralisation and nutrients of the water. Indeed, the lake is also free of aquatic vegetation and algae.