Journal of Chemical, Biological and Physical Sciences

An International Peer Review E-3 Journal of Sciences

*Available online at*www.jcbsc.org

Section D: Environmental Sciences

CODEN (USA): JCBPAT Research Article

The prediction of impact on Eighteen mile Swamp and Brown Lake due to ground water extraction and sand mining in North Stradebroke Island, Australia

M. Mazbah Uddin *[1, 2, 3]

[1]Tropical Biodiversity and Ecosystems (TROPIMUNDO)

[2]University Libre De Bruxelles & Virje Universiteit Brussel, Brussels, Belgium

[3]Department of Zoology, University of Chittagong, Chittagong- 4331, Bangladesh

Received: 16 February 2017**; Revised:** 28 February 2017; **Accepted:** 06 March 2017

Abstract: The freshwater ecosystems are vulnerable due to human induced environmental changes such as sand mining, groundwater extraction and land conversion. Changes of water quality; hydrology and macro invertebrates can offer a greater understanding of the aquatic systems. The Brown Lake is a perched aquifer and no connection to the regional aquifer as a result lake water level mostly depends on rainfall and runoff. Eighteen Mile Swamp is semi perched and connected to the regional groundwater aquifer and gaining water from groundwater. The water quality data demonstrated that the Brown Lake has higher dissolved oxygen, low pH and lower turbidity than the Eighteen mile Swamp and both lakes have the low amount of nutrients show oligotrophic. The macro invertebrates diversity lower in the Eighteen Mile Swamp than Brown Lake and absence of sensitive species show bad water quality for macro invertebrates. The potential impacts on the Brown Lake due to groundwater extractions would be very low risk because of perched aquifer. Eighteen Mile Swamp is dependent on the groundwater discharge to lake but the potential impacts due to groundwater extractions would be low because of high rainfall and groundwater recharge rate. The potential impacts owing to sand mining would be high in Brown Lake because of no outflow from the lake as a result change water quality very quickly, but in the Eighteen Mile Swamp also has an impact but it would reduce through stream flow from the lake.

Keywords: Water quality, hydrology, macro invertebrates, groundwater extraction, sand mining, north Stradebroke Island and Australia

INTRODUCTION

The global fresh water ecosystems are accommodate about 6% of described species in the world and enrich of valuable natural resources [1]. At the same time, fresh water biodiversity has higher decline rate than terrestrial ecosystems[1]. Fresh water sources such as lakes; ground water is primary source of water for the least developed countries[2, 3]. Due to high demographic increase in the world and enhance water demand creates high environmental pressure on groundwater ecosystems as well as surface water[2].Most of the least developed countries, deplete of ground water is owing to agricultural activities and use as public drinking source [2]. Besides, sand mining, urbanization, industrial activities and coastal tourism are also responsible for enhancing depletion pressure on lakes and ground water ecosystems [2, 3]. In addition; divide of fresh water to several stakeholders have severe impact on fresh water ecosystems[2]. In Australia, the allocation and reallocation of water, agricultural and irrigation activities along Murray River basin has significant impact on their flow and water balance as well as ecosystems[4]. Furthermore, North Stradebroke is an Island in Australia, which is very upscale for its tourism, sand mining and ground water supply for local people but due to their connected and perched disconnected ground water systems make this island as unique ecosystem[5]. The island has been, for many years, subject to groundwater extraction for municipal purpose and support mineral sand mining operations in this island. These operations have much impact of the plants, water quality, hydrology, fishes, invertebrates of the swamp and lakes[5, 6, 7]. The aim of the present study is to investigate the water quality, hydrology and macroinvertebrate of the Brown Lake and Eighteen Mile Swamp to assess the future potential impact of groundwater extraction and sand mining operation.

2. MATERIALS AND METHODS

2**.1 Study Area:** The present study was conducted in the North Stradebroke Island at the Eastern boundary of the Southern Moreton Bay at Brisbane in Australia (Figure 1).Geologically, the island is composed of fine Aeolian sand mostly Cainozoic age, which has undergone weathering to deposition of ferricate layers and carbonaceous indurate layers[6]. In addition, the land forms of this island are mainly older and higher sand dunes and fringing low lands as well as the hydrology influenced by this land forms[6].The hydrology of the island is the coastal wetlands that surrounded by island and there are two groundwater system on the island; the regional interconnected system and disconnected perched systems[8].This island has a number of permanent and ephemeral surface water features and over 100 lakes or wetlands. These lakes are divided into either perched lakes or water table lakes. Brown Lake is a perched lake and located northern side of the island and it is naturally acidic and oligotrophic and the water quality of the lake mostly influenced by the terrain, atmosphere and surrounding littoral and sublitoral vegetations[9]. The inputs of particulate organic matter and dissolved organic matter from the surrounding catchment sources contributing the water quality of the lake.

The Eighteen Mile Swamp is located in the eastern side of North Stradbroke Island, between the main Pleistocene and Holocene dune system of the island, with topologically and biologically complex water body[10].Swamp is relatively young and evolved about 420 years ago from estuarine system to fresh water wetland[11].The Swamp is consist of lagoons and vegetated hummocks, dominated by sedges with fresh water Creek. The Swamp has 4 - 8m layer peat, above the marine mud and form water table window water holes to provide habitat for fish, invertebrates and aquatic macrophytes[10].The hydrology of the Eighteen Mile Swamp is influenced by rainfall, runoff and groundwater discharge, owing to lower permeability of the marine mud and peats act as a local semi confining layer to the regional aquifer[12].

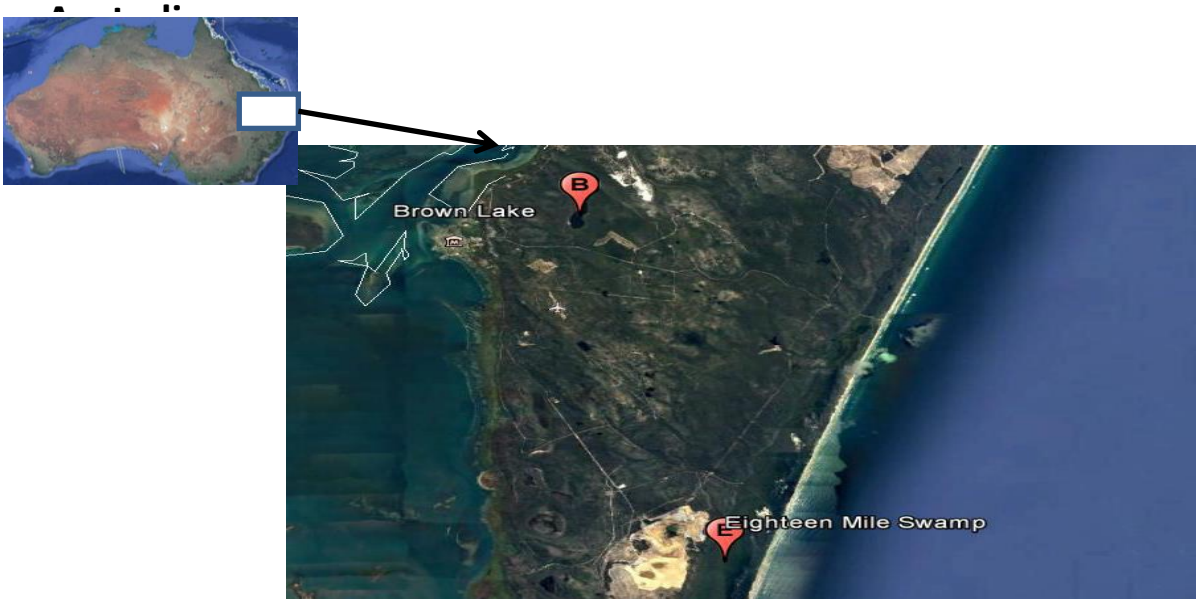

Figure 1: Study area showing the North strakebroke Island, eastern boundary of the Moreton Bay, Australia. The red marking indicates the sampling sites,(B:Brown lake 27°29'24.38"S,153°25'56.56"E),(E: Eighteen Mile Swamp,27°36'3.17"S,153°27'56.01"E) (source : Google Earth.com)

2.2 Sample Collection and Analysis: In the present study, water sample from surface water as well as groundwater was collected from Brown lake and Eighteen Mile Swamp during the month May 2014. Turbidity, p^H and dissolved oxygen was measured during the field sampling with Multi parameter quantify device (HI 9829). Macro invertebrates were collected through mesh net with sediment and carried to lab for identification. Macroinvertebrates were identified up to the order level with the help of Microscope and taxonomy books. Paired t –test was conducted in between the water quality facts to see the difference between two lakes. Minitab 14 was used for the statistical analysis.

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3. RESULTS AND DISCUSSION

3.1 Hydrology of Brown Lake and Eighteen Mile Swamp: From the historical data of the Brown Lake and Eighteen Mile Swamp shows that surface water and groundwater table fluctuated according to the changes in rainfall (Figure 2 and 3). Historical hydrological data of Brown Lake show that the natural variability of water levels less than 1m over the six-year period and fluctuated with the rainfall and lake is losing water to perch aquifer (Figure 2). The hydrological data of the North of Eighteen Mile Swamp shows that the variability of surface water and groundwater levels greater than 1 m and weakly fluctuated with rainfall and lake is gaining water from the groundwater (Figure 3). The Brown Lake is a perched aquifer as the elevation of the surface water and groundwater table very close and

there is no connection to the regional aquifer. As a result, the inputs of the water in the lake mostly depend on the rainfall, runoff and any materials enter into the lake will accumulate in the sediment and stay in the water column[13].

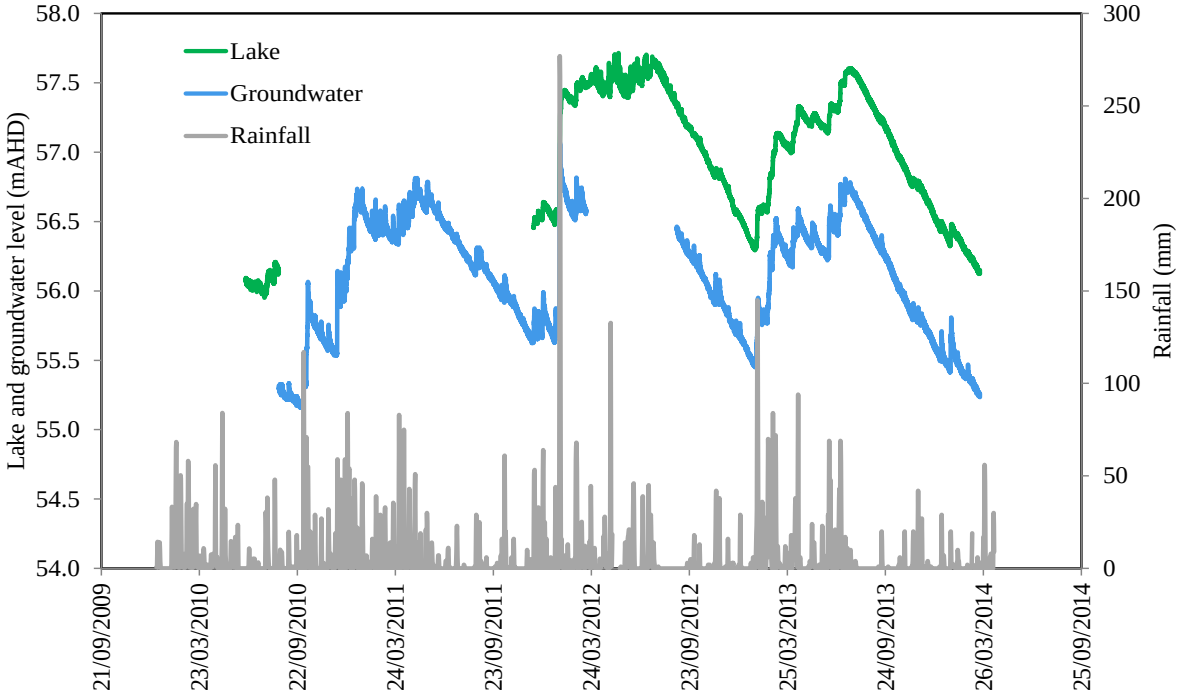

Figure 2: Lake Water and ground water table in relation with rainfall in the Brown Lake

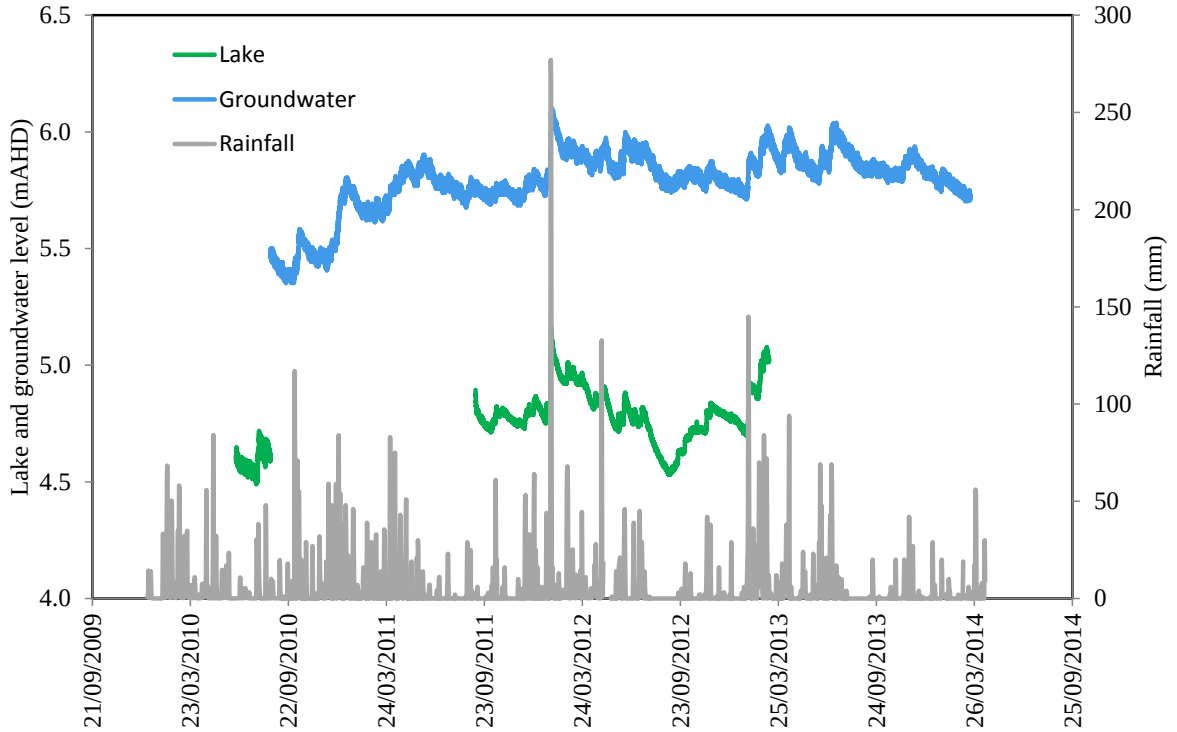

Figure 3: Lake Water and ground table relation with rainfall in the 18 Mile Swamp North

3.2 Water quality of Brown Lake and Eighteen Mile Swamp: There was a significant difference (P= 0.019) was found of turbidity between Brown lake and Eighteen Mile Swamp (Figure 4). The turbidity was increased by about 26 NTU in the Eighteen Mile Swamp than Brown Lake. The turbidity was significantly higher (P < 0.05) in the Eighteen Mile Swamp than Brown Lake (Figure 4). The mean turbidity of the Eighteen Mile Swamp had 1.6 ± 0.1 NTU and Brown Lake had 27.88 ± 7.83 NTU (Figure 4). The surface water pH of Eighteen Mile Swamp was higher than the Brown Lake (Figure 5).

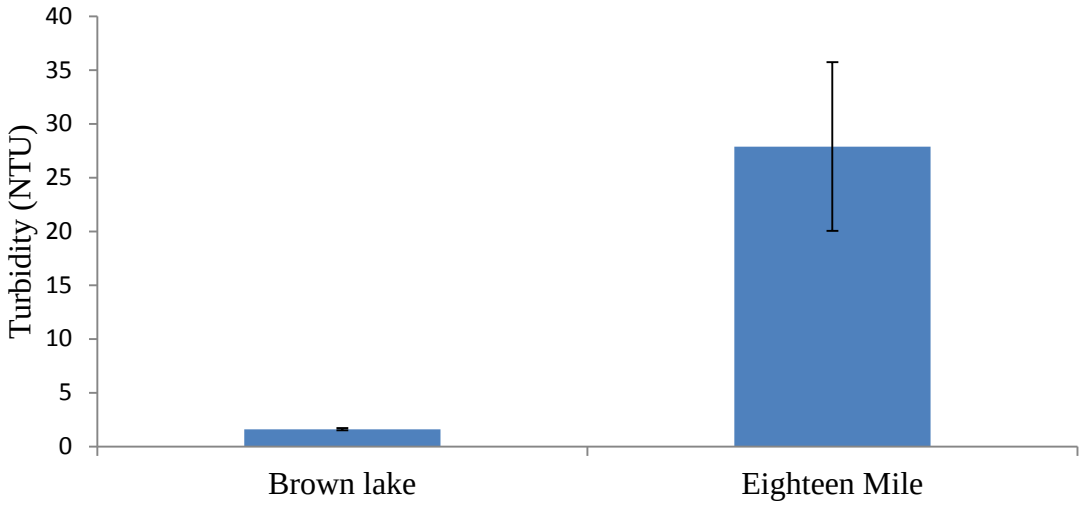

Figure 4: The mean ± SE turbidity of water in brown lake and Eighteen Mile Swamp.

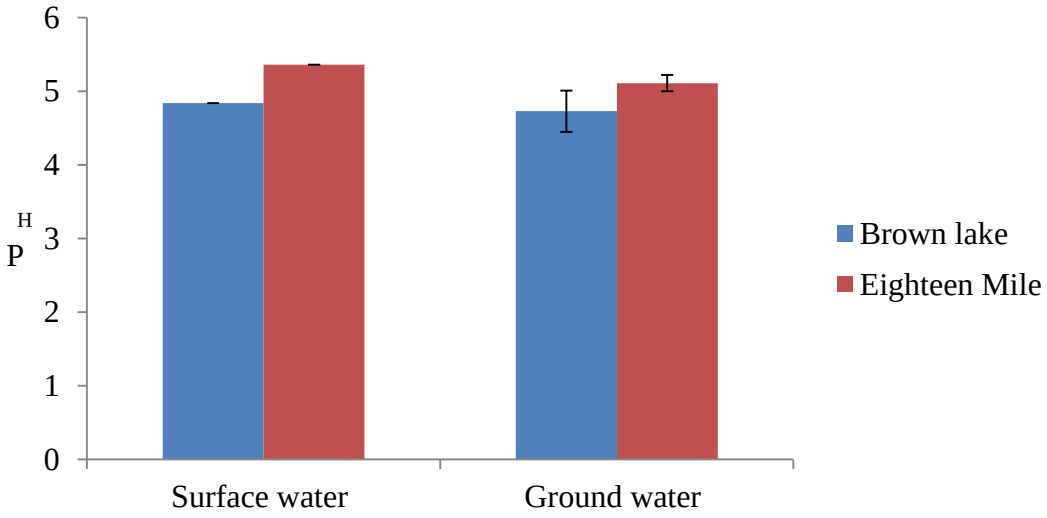

Figure 5: The pH of surface and ground water in Brown Lake and Eighteen Mile Swamp.

The pH of Brown Lake had 4.48± 0 and 5.36± 0 for Eighteen Mile Swamp (Figure 5). There was no significant difference (P= 0.334) was found the ground water pH in between Eighteen Mile Swamp to Brown lake But higher pH is in the Eighteen Mile Swamp ground water than Brown lake. The mean

pH in the ground water is 5.11± 0.11 for Eighteen Mile Swamp and 4.73± 0.28 for Brown Lake (Figure 5). The groundwater quality of the regional aquifer is fresh and slightly acidic, but shallow ground water pH ranges from neutral to strongly acidic and salinity is highly variable due to permanent and ephemeral lakes, lagoons in this island[5, 7].Therefore, rainfall and runoff transport humic, fluvic and tannic acids that increase the pH of the Brown Lake surface water as well ground water due to the perched layers are connected to the lake water system[5].The historical data on water quality of the Brown Lake show that the turbidity and pH of the lake closely related and fluctuate positively (Figure 7). This indicates that when runoff and rainfall transport nutrients to the lake and increase turbidity and pH resulting decrease turbidity and pH of the lake. In addition, there was significant difference was found in the concentration of dissolved oxygen in between the Eighteen Mile Swamp and Brown Lake surface water. The concentration was significantly ($P< 0.05$) higher in the Brown Lake than Eighteen Mile Swamp (Figure 6). The mean dissolved oxygen in Brown Lake is 10.76 ± .06 mg/l and Eighteen Mile Swamp is 6.27 ± 1.62 mg/l **(Figure 6).**

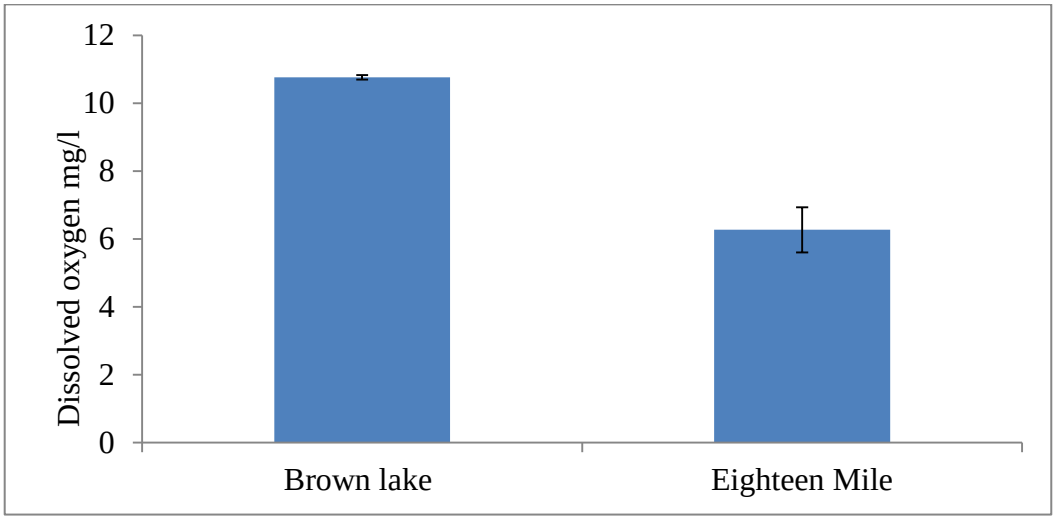

Figure 6: The mean ± SE of dissolved oxygen of Brown Lake and Eighteen Mile Swmap

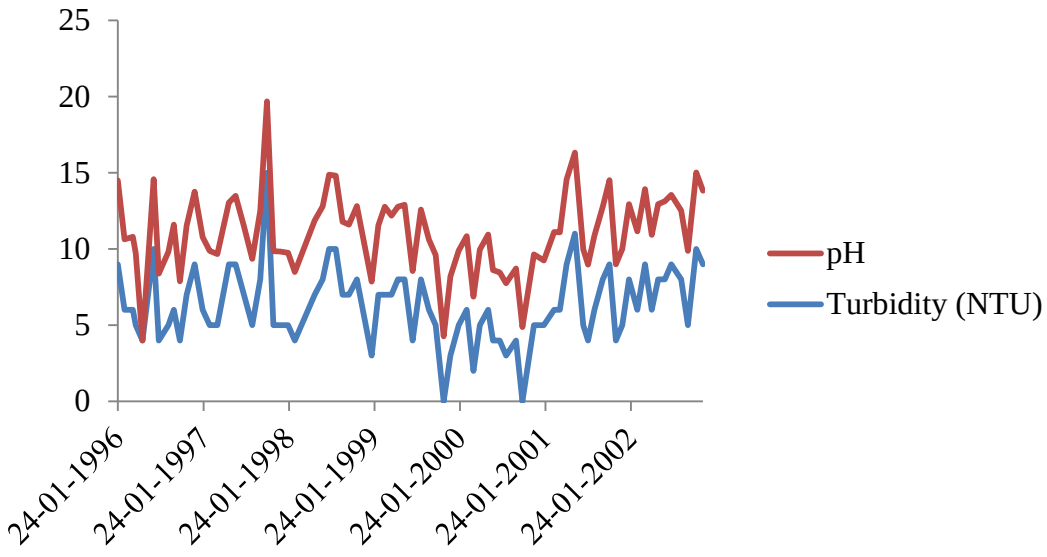

Figure 7: Historical data fluctuation of turbidity and pH of Brown Lake

This is due to high aquatic and steep vegetation in the lake as well as high peat content in their sediment[5]. In addition, high dissolve oxygen in the Brown Lake is owing to natural flow into the lake and seepage through lakebed[5].The Eighteen Mile Swamp is a semi perched aquifer, composed of peat layers and the Swamp contain sedge land plants, dead plants, and litter from the plants which increase the turbidity of the water and decrease dissolved oxygen[5].In addition, low water contact with the atmosphere as well as some surface streams are feeding into swamp , reducing dissolved oxygen[10].The dissolved oxygen of the Eighteen Mile Swamp surface water ranges from 10.45-10.90mg/l and for groundwater this is very low (1.60 mg/l). The dissolved oxygen of water mostly depends on the temperature and both seasonal and daily cycles. The electrical conductivity of Eighteen Mile Swamp is higher than the Brown Lake. The Eighteen Mile Swamp is connected to the regional aquifer and slow surface flow from north to south to the Swan Bay and dissolved organic matter such as leaves, tannins increase the pH, SO4 ions of the groundwater[10].

3.3 Macroinvertebrates of Brown Lake and Eighteen Mile Swamp: Macroinvertebrates are bio-assessment indicator to decide the water quality of the aquatic ecosystems[14, 15].Water quality is very important for the physiology of macroinvertebrates in the aquatic systems[16].The macroinvertebrates data on both lakes show that, Brown Lake has identified 8 orders and Eighteen Mile Swamp has 6 orders of macroinvertebrates during the study period (Figure 8). The orders Ephemeroptera and Tricoptera are not present in the swamps as these two orders are very sensitive to the environmental pollution. Figure 8 indicates that higher abundance of macroinvertebrates is the Diptera (family Chironomidae) and Odonata (family Corduliidae) in Eighteen Mile Swamp that is the indicator of poor water quality than that in the Brown Lake. Previous study noted that 16 families of macro invertebrates were in the Brown Lake and 13 families in Eighteen Mile Swamp but they did not find family Corduliidae in the Eighteen Mile Swamp[7].

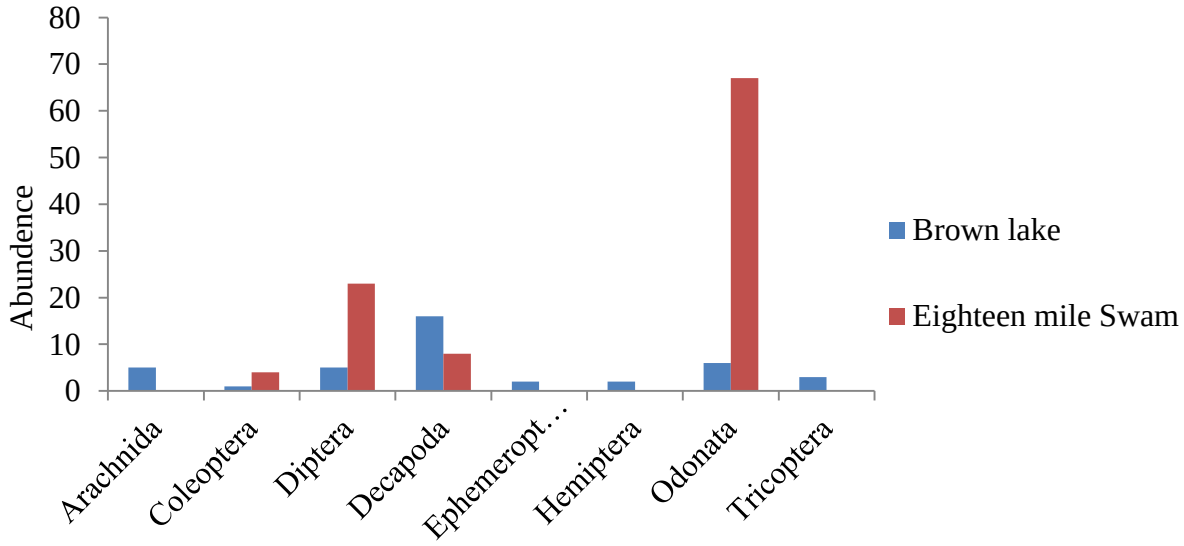

Figure 8: Macroinvertebrates abundances in Brown Lake and Eighteen Mile Swamp.

3.4 Potential impacts of groundwater extraction: There are some potential impacts of the hydrology and water quality due to groundwater extraction in Lake Geneva, reduce inflow and

outflow by 65% during the dry period[14]. Therefore, in the western Australia Bankasia Woodland coastal Swamp plain, the under story species decreased between 20 and 80% and over story species decreased 64 % due to groundwater extraction[17]. Therefore, resource overlapping may increase conflict with other animals[18]. Eighteen Mile Swamp is influenced by the direct rainfall, runoff and groundwater discharge. Due to groundwater extraction from the regional aquifer, difference of groundwater and surface water levels will increase and cut the groundwater drainage to the lake. As a result, the water logging capacity of the lake will reduce, which is very important for the aquatic macroinvertebrates.In addition, lower groundwater discharge will reduce the organic sediments to the lake resulting in an increase in the organic matter in the lake[6]. The pre-development scenario of the Eighteen Mile Swamp shows that the fluctuation of the regional groundwater water table has significant contributions to the surface water and their perennial status[7].

All development scenarios of Eighteen Mile Swamp shows that lowering the groundwater table less than 0.30m will have a lower risk of dependent ecosystem[7]. Besides, the surface water level of the Eighteen Mile Swamp is depends on the ground water discharge and rainfall these are also important for mixing of nutrients into lakes but all development scenario shows less risk to plants for ground water extraction from the lake[6, 7].The Brown Lake is underlined by perching aquifer and this lake has no connection to the regional groundwater table. That's why the potential impacts on this lake will be minimal. But pumping activities can be breached the perched aquifer and decrease the flow to the lake[17].

3.5 Potential impacts of mining: Sand mining has great impact on the hydrology and water quality. One of the most dramatic impacts was on the Lake Kounpee due to sand mining that breached the confining aquifer layer and the perched aquifers no longer flow to the lake[5]. The seepage rate of these ponds was much higher than the predicted model, resulting the lake rising from 3 m and downing the riparian vegetation[5]. In the Eighteen Mile Swamp, due to sand mining, sand dunes exposed and low permeability layer (cement, sand and iron oxides) of the dunes eroded. As a result, the seepage of the dunes increased and increases the Swamp water, but lower permeability is important for the peat depositions. Draining from the dredge pond to swamp includes lots of nutrients and minerals that change the water quality of the Swamp affecting the macroinvertebrates community by increasing turbidity and decreasing dissolved oxygen. Reclamation of land can change the vegetation pattern. Heavy rainfall erosion of the mining area brings large amount of cement, sand and iron oxides to the lake that increases the bloom of phytoplankton and pH of the lake. The sand mining in the edge of the Brown Lake can breach the confining aquifer layers and change the perched aquifer flow from lake to regional aquifer, As a result, lake lose water, but due to exposure of the lower permeable layers, the lake also gains a considerable amount of water. Drainage from the sand mining may increase nutrients, turbidity, and lower dissolved oxygen and changes macroinvertebrates species.

4. Conclusion and recommendations: From the results and discussion, it is clearly show that sand mining and ground water extraction has impact on this island water quality, macroinvertebrate as well as hydrology. Sand mining impact on Brown Lake is higher than the Eighteen Mile Swamp due to no outflow from the lake but in the Eighteen Mile Swamp has stream flow from the lake. But Ground water extraction has higher impact on Eighteen Mile Swamp than Brown Lake, owing to depend on the regional aquifer. For better understanding of the surface water and groundwater interaction and potential impacts of groundwater extraction and sand mining to the dependent ecosystems, we need to further monitoring productivity of lakes, evaporation, vegetation communities, root depth of the vegetation, soil types and their parameters, and stream flow. The groundwater extraction impact prediction is very difficult to assess and to get better prediction; we need to check vegetations rooting depth, wetland bathymetry, surface water and groundwater interactions, perched aquifer role,

evapotranspiration, and soil properties. Integrated ecological and groundwater monitoring program to measure the ecosystem conditions and palaeoclimatic studies for understanding the hydrological variability across long time scales to predict the groundwater variability.

5. ACKNOWLEDGMENT

Author is greatly acknowledged to the University of Queensland for field research help. Author is also thankful to TROPIMUNDO for financial support during field trip.

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Corresponding author: M. Mazbah Uddin;
Department of Zoology, University of Chittagong, Chittagong- 4331, Bangladesh
On line publication Date: 6.03.2017