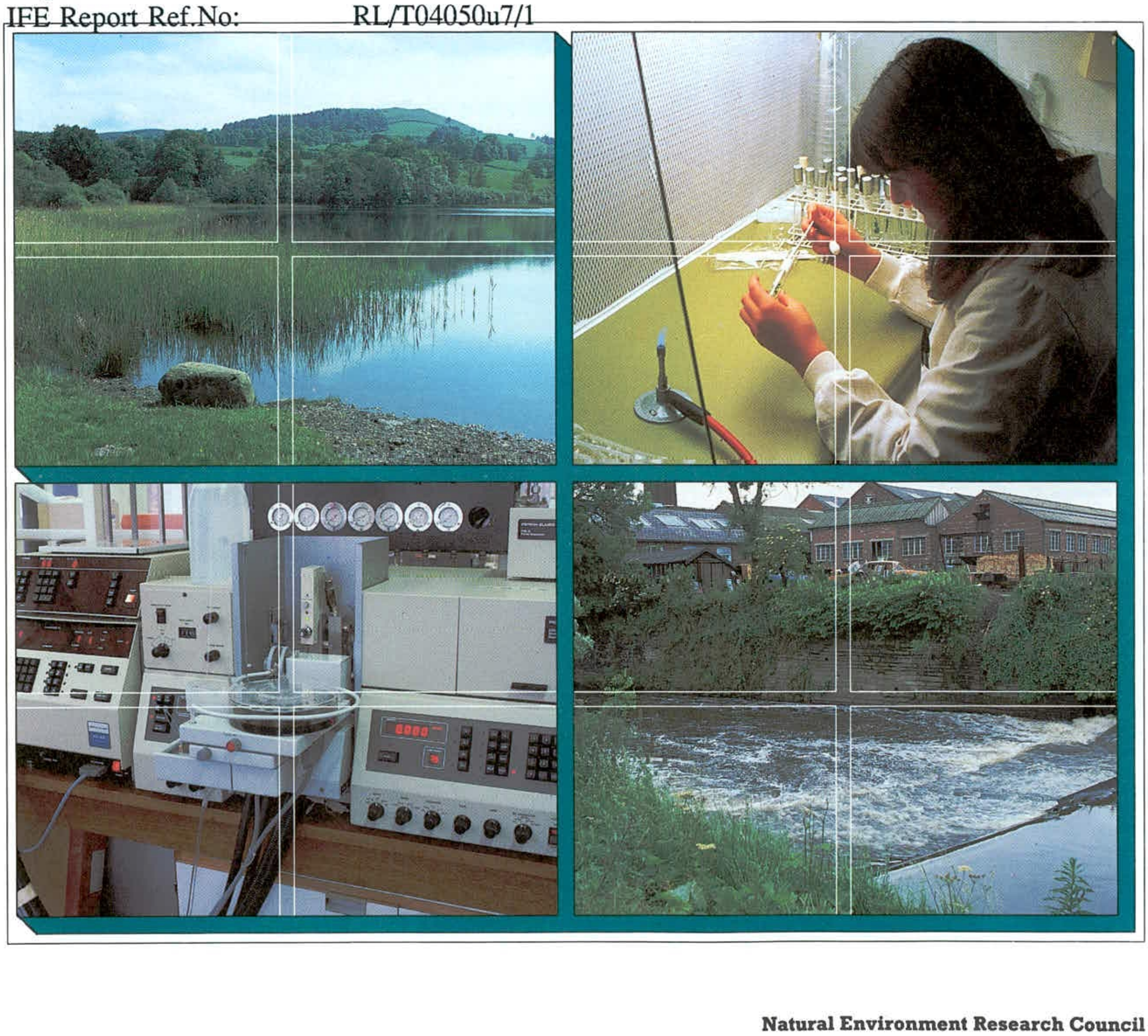
Institute of Freshwater Ecology

THERMAL STABILITY AND WATER QUALITY OF THE PROPOSED MIDLANDS RESERVOIR, MAURITIUS.
RECALCULATION OF MODEL PREDICTIONS AND RESPONSE TO CLIENT'S COMMENTS.

J Hilton

Report To: Gibb Environmental
Project No: T04050u7
IFE Report Ref.No: RL/T04050u7/1



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THERMAL STABILITY AND WATER QUALITY OF THE PROPOSED MIDLANDS RESERVOIR, MAURITIUS. RECALCULATION OF MODEL PREDICTIONS AND RESPONSE TO CLIENT'S COMMENTS.

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Report Date:	May 1995
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This report makes its recommendations from a state of the art understanding of the way in which aquatic systems work and is considered to represent the best advice available at the present time. However it should be borne in mind that changes in the physical and chemical properties of water are driven by a complex interaction of biological, chemical and physical processes which are still not entirely predictable and the Institute cannot guarantee that changes will occur exactly as predicted.

Comments on the client's comments on the Gibb report.

4.3.1 We agree that the water quality should be much higher, given the information about the catchment, but one has to believe the analytical results. I have removed the words "sewage effluent from the text, although it is still relevant, as it is a fairly provocative term. However, I have retained the feeling of a poor quality water.

5.1 paras.1 and 3 have been rewritten.

5.1.1 The new data supplied by the Mauritius Meteorological service show wind speeds much higher than in the data supplied to me earlier. As a result, the stratification status of the reservoir has reduced to polymictic, i.e. it will stratify for short periods on a number of occasions each year during the summer. This is a major change to the likely water quality, since the bottom water will not have all summer to deoxygenate. However, the high temperatures will mean that de-oxygenation occurs rapidly when the system temporarily statatifies, although it is likely that the stratification will be too short for sulphide, iron or manganese to attain high concentrations.

5.1.2 Water quality section has been rewritten.

5.1.3 The proposal for more detailed water quality sampling still holds given the poor water quality.

5.1.5 still stands but the water quality will not be quite as bad as predicted earlier. However, there is still a high BOD and high algal growth which will put a high oxygen demand on the system. The falls in the LNFC will help to get oxygen into the system.

<u>Changes to Gibb report resulting from recalculation of the stratification behaviour using new wind data and reassessment of the water quality using an extended data set.</u>

Replace the section from p.33 para 4. to p. 34 para 1 (inclusive) with:

Table 4-2 (A new table 4-2 is provided.) shows the water quality results for surface water samples taken from GRSE at the dam site between October 1994 and April 1995. This period covers both low and high flow periods.
(insert new paragraph)

Immediately it is clear that these results are not in agreement with the published data for the GSRE system at La Pipe (table 4-1). Both phosphate and nitrate levels measured in 1994/5 at the dam are about a factor of 3 higher than the reported 1990/91 data. Either the water quality in GRSE has changed over that time period or there was a significant input of other water between the dan site and La Pipe. Data for many of the determinands measured in 1994/5 are very variable. Only pH, DO, temp iron and conductivity have relative standard deviations less than 50%. A number of determinands show very large variability with RSD greater than 100%, i.e. suspended solids, nitrate, chlorophyll a, b and c. This suggests that the feed water quality is very variable.

The water is essentially circum-neutral. The conductivity is relatively low (100 uS/cm) as expected in run-off from highly leached soil exposed to such high rainfall. Dissolved oxygen values average about 77% saturation (saturation concentration = 8.58 mg/l at 23°C). However, the variability is high. Typically saturation is between 60 and 70% The higher average is due to one value with a saturation greater than 100% on the occasion of a high algal crop (during daylight hours high algal crops would be expected to produce over-saturated conditions. Conversely at night oxygen levels could drop to very low levels due to plant respiration). The regular occurrence of DO levels significantly lower than saturation is consistent with the high measured BOD and ammonia levels.

The BOD is very variable, ranging from <8 to 118 mg O/l. Typically BOD levels appear to be about 50 mg/l. There is a high correlation between the COD values and the BOD. The typical BOD/COD ratio of 70% indicates that much of the COD is easily biodegradable. The percentage of the dissolved nitrogen (nitrate + ammonia) in the form of ammonia is generally quite high (mean approximately 50%) and there is an obvious inverse relationship with DO. When considered together the data for DO, BOD, COD, ammonia and nitrate suggest that the feed water is of relatively low quality with a significant oxygen demand (see later for further discussion).

p.73 para 1. (beginning Future trends ...) Delete the last sentence and continue on after the previous sentence with no full stop:
, with high oxygen demand and high nutrient content. *(i.e. delete the offensive section about sewage effluent. However, we should not disguise the fact that it is a poor quality water.)*

p.73 para 2. delete full paragraph and add to the end of para 1:
The data presented in table 4-2 cover both high and low flow periods. Hence the poor

quality water cannot be attributed to low flows.

p.74, para 2 (beginning: By rearranging...)
line 3.. insert after 11-12 knots "(5.6-6.2 m/s)"
line 3.. insert after 12-13 knots "(6.2-6.7 m/s)"
Delete Sentence Since normal wind speeds ....permanently.
delete para 2 beginning This is consistent with estimates....
Replace with:
Table 5-1 gives data from the Mauritius Meteorological Service for the proportion of time each month that the wind speed exceeds 6.1 m/s. Total percentages range from 17 - 32%. Hence if a calm period occurs stratification will set in but it will be destroyed within a period of a few days by the next wind greater than approximately 6 m/s. As a result the proposed reservoir is likely to stratify for short periods of time over the period October to April and not at all from May to September. This is consistent with calculations of the Wedderburn depth made for wind speeds which are exceeded less than 3% of the time (i.e. less than 1 day month). Under these circumstances the Wedderburn depth hovers around the mean depth for January to March and is greater than the mean depth for the rest of the year. This is indicative of the ability to stratify regularly and be de-stratified regularly.

It should be remembered that at the high water temperatures which occur in this region, bacterial activity is very rapid. Given that the water has a high oxygen demand, it is probable that the bottom water will rapidly de-oxygenate after stratification, probably within a few days. This is comparable with the time scale of the likely lifetime of a single stratification event. Hence when stratification is destroyed the water quality in the whole reservoir will be very poor with low dissolved oxygen, high ammonia, and possibly high iron, manganese and sulphide concentrations. The low oxygen levels in the stratified bottom waters will also tend to draw nutrients out of the sediments and increase algal concentrations for several weeks after overturn.

p.74 section 5.1.2 para 2.
li.2 replace 0.28 and 0.49 with 0.33 and 0.51 respectively.
li.4 replace 0.38 with 0.49.

p.75 para.1
li.3. replace 35 with 40.
li.3 inset after reservoir: (phases 1 and 2)
li.4. replace 170 with 188.
li.8. replace 18 with 19.
para 2 delete and replace with:
Stratification periods are likely to be short but frequent. Hence algae will be unlikely to be able to take advantage of the higher nutrient loadings in the stratified system. Conversely, after each mixing event following stratification, more nutrients will be added to the system from the sediment. Hence, algal concentrations could reach at least those levels predicted by the nutrient limited stratification models.

para 4, 5, 6 and 7 delete. Replace with:

During the short periods of stratification blue green algae are likely to dominate. Blue green algae usually have a mechanism to make them float, hence, highly concentrated scums of blue green algae will develop at the down wind end of a reservoir if a gentle breeze blows during one of these periods. If livestock drink from these scums they can take in toxins associated with blue green algae and there are numerous recorded examples of this causing death. If humans bathe in the water they can suffer from skin rashes and stomach upsets. As a precaution, some consideration should be given to locating the draw off tower so as to minimise the abstraction of water from areas in the reservoir likely to develop blue green algal scums.

p. 78, section 5.1.3, para 1 is now redundant.
p.78, section 5.1.4, para 1. Last sentence
delete: if it is allowed to stratify.
replace with: on the occasions when it stratifies.

p.78, section 5.1.4, para 2. replace first sentence.
However, since wood decays slowly, the oxygen demand from the wood is likely to be small compared to the oxygen demand of the high algal growths in the reservoir.

Table 4-2. Water chemistry of the Grand River S.E. at the dam site.
parameter.

	13/10	27/10	24/11	09/01	01/02	11/04	mean± SD
pH	6.62	6.76	7.01	6.47	6.81	6.21	6.65± 0.28
Conductivity (mS/m)	10.2	9	7	6.6	8.7++	6.3	8.0 ±1.5
Total susp. solids (mg/l)	7.6	nil	5.2	20.4	2.4	24.8	10.1± 10.7
Dissolved oxygen (mg/l)**	6.0	5.2	9.4	-	5.7	-	6.5 ±1.9
Temperature (°C)**	23	23.5	25	23	26	24	24 ±1.2
Nitrate as N(mg/l)	0.12	0.134	0.85	0.414	0.037	0.147	0.284± 0.305
Ammonium as NH_4^+ (mg/l)	0.47	0.496	0.11	0.242	0.298	0.122	0.290 ±0.166
Ammonium as N (mg/l)	0.37	0.39	0.09	0.188	0.231	0.095	0.227± 0.130
Phosphate as P (mg/l)	0.28	0.44	0.15	0.37	0.098	0.628	0.328± 0.196
Total phosphorus (mg/l)	0.38	N/D	0.46	0.55	0.205	0.85	0.489± 0.238
COD (mg/l)	65	147	8	ND	50	81	70± 51
BOD (mg/l)	40	118	<8	ND	34	62	52± 41
Iron as Fe^{2+} (mg/l)	1.06	0.78	0.7	0.58	0.55	0.29	0.66± 0.26
Manganese as Mn^{2+} (mg/l)	0.06	<0.02	<0.02	0.026	<0.02	<0.02	<0.02
Chlorophyll a (mg/m³)	6.94	0.54	877	0.004	0.012	342	204 ±356
Chlorophyll b (mg/m³)	53	353	N/D	ND	0.006	ND	135± 190
Chlorophyll c (mg/m³)	0.05	N/D	N/D	0.003	0.004	500	125± 250

** in situ measurement at time of sampling. + concentration in mg/l as N. ++ reported as 87

5-1 Percentage of time wind speeds are greater than given speeds. (Wind speeds from Plaisance, for which days wind run are given have been increased by 10% for conditions at Midlands as recommended by the Mauritius Meteorological services.)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Number days	31	28	31	30	31	30	31	31	30	31	30	31
Speed m/s			Number of days within wind speed range									
6.1-8.8	7.55	6.11	6.13	5.3	5.31	8.84	9.925	9.53	7.175	5.4	5.12	5.54
9.4-11.6	0.88	0.81	0.735	0.22	0.34	0.96	0.86	0.85	0.515	0.255	0.085	0.18
12.1-14.9	0.12	0.45	0.078	0	0	0.03	0	0.095	0.015	0	0.03	0.015
15.4-18.2	0.06	0.195	0.055	0	0	0	0	0	0	0	0.015	0.03
18.7-22	0.03	0.06	0	0	0	0	0	0	0	0	0	0.015
>22.5	0.02	0.06	0	0	0	0	0	0	0	0	0	0
Total	8.66	7.685	6.998	5.52	5.65	9.83	10.79	10.48	7.705	5.655	5.25	5.78
Speed m/s				Percentage of time within wind speed range								
6.1-8.8	24.35	19.71	19.77	17.10	17.13	28.52	32.02	30.74	23.15	17.42	16.52	17.87
9.4-11.6	2.84	2.61	2.37	0.71	1.10	3.10	2.77	2.74	1.66	0.82	0.27	0.58
12.1-14.9	0.39	1.45	0.25	0.00	0.00	0.10	0.00	0.31	0.05	0.00	0.10	0.05
15.4-18.2	0.19	0.63	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.10
18.7-22	0.10	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
>22.5	0.06	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	27.94	24.79	22.57	17.81	18.23	31.71	34.79	33.79	24.85	18.24	16.94	18.65

Table 5-2 Calculated nutrient and chlorophyll concentrations in Midlands 1 assuming different limitations to growth.

	Nitrogen	Phosphorus	
areal loading ($g/m^2/a$)	7.31	4.73	
in-lake concentration (mg/m^3)	510	330	
Chlorophyll a concs under nutrient limitation			
mean annual (µg/l)[1]		43	mixed
mean annual (µg/l)[1]		123	annual stratify
mean annual (µg/l)[1]		52	permanent stratify
mean summer (µg/l)	19[2]	327[3]	
max summer (µg/l)[4]		188	

Chlorophyll a (µg/l) assuming limitation	light limitation			P
	June/July	equinox	Dec/Jan	OECD[1]
Fully mixed	70	86	102	43
mean stratified depth (3)	234	281	325	123(52)
mean stratified depth (1m)	741	884	1014	

(1). OECD; 1982; (2). Sakamoto, 1966;
(3). Dillon and Rigler, 1974; (4). Reynolds, 1991

Table 5-3 Calculated nutrient and chlorophyll concentrations in Midlands 2 assuming different limitations to growth.

	Nitrogen	Phosphorus	
areal loading ($g/m^2/a$)	5.71	3.70	
in-lake concentration (mg/m^3)	510	330	
Chlorophyll a concs under nutrient limitation			
mean annual (µg/l)[1]		38	mixed
mean annual (µg/l)[1]		136	annual stratify
mean annual (µg/l)[1]		50	permanent stratify
mean summer (µg/l)	19[2]	327[3]	
max summer (µg/l)[4]		171	

Chlorophyll a (µg/l) assuming		light limitation		P limitation
	June/July	equinox	Dec/Jan	OECD[1]
Fully mixed	50	63	75	38
mean stratified depth (3m)	234	281	325	136(50)
mean stratified depth (1m)	741	884	1014	

(1). OECD; 1982; (2). Sakamoto, 1966;
(3). Dillon and Rigler, 1974; (4). Reynolds, 1991.

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