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Independent review of the Environmental Impacts Assessment Report (EIAR) 2005 on the future Ilisu Dam (Turkey)

Prepared for

Erklärung von Bern - Berne Declaration

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1. Introduction

At the planning stage of dam construction on major rivers, a full consideration of the environmental impacts is generally required. The construction companies are therefore, required to prepare or contract an environmental impact assessment report (EIAR) in accordance with specific guidelines, generally addressing three major topics:

Social issues **-** consequence of people resettlement from the future flooded area;
Archeological issues **-** resulting from destruction or submerging important archeological sites;
Environmental issues - effect of large scale hydrological alteration of the natural river system with major impacts on the environment and water quality.

Such is the case of the Ilisu Dam Project on the Tigris River in southeastern Turkey, for which a new EIAR was completed in 2005 by the Ilisu Environment Group[1] (IEG), improving upon old EAIR (2001) prepared by the IEG[2].

In January 2006, Eawag was contracted by the Berne Declaration (Erklärung von Bern) to provide an independent review of the EIAR (2005), appraising whether the anticipated impacts were satisfactorily described and their extent adequately estimated by the new EIAR. For the social and archeological issues, we did not have the competence to make any remarks or recommendations. Focusing on the environmental issues only and relying on the sparse database presented by the EIAR (2005), this review (i) crosschecked and reevaluated the degree of some physical aspects for which the predictions were vague, confusing or appeared to be incorrect (i.e. sedimentation, reservoir lifetime, evaporation, greenhouse gas emissions and impounding period); and (ii) quantified the extent of several parameters with crucial roles on the environment and water quality (i.e. primary production, eutrophication, nutrient cycle, oxygen depletion or thermal stratification), which were recognized by the EIAR 2005 as possible consequence of the Ilisu project completion but left without any computation. Our findings are listed in tables at the end

of each subchapter and the main conclusions regarding the EIAR (2005) are summarized at the end of the report.

IEG[1] composed of Hydro Concept Engineering (Switzerland), Hydro-Québec International Inc. (Canada) and The Faculté Universitaire des Sciences Agronomiques of Gembloux (Belgium).
IEG[2] composed of Hydro Concept Engineering (Switzerland), Hydro-Québec International (Canada), Colenco (Switzerland), and Dolsar (Turkey.

2. Project description

2.1. Tigris River in Turkey

- Length – 385 km
- Drainage area: 41’000 km^2 + 15’000 km^2 beyond the Turkish border in Iraq
- Average discharge at Ilisu: Q = 502 $m^3 s^{-1}$ (15’842 Mm yr^{-1} = 15.84 $km^3 yr^{-1}$)
- Half of discharge occur between March and May (rainy season) and the maximum runoff spread from November through May. From May to June the high flow is supported by the snow melt.
- Highest discharge - April at Cizre: Q = 1’400 $m^3 s^{-1}$
- Driest month - Sept. at Cizre: Q = 115 $m^3 s^{-1}$
- Max. flow in 1966: Q = 8600 $m^3 s^{-1}$
- Main tributaries: Batman, Garzan and Botan
  - Tigris at Diyarbakir (6’078 km^2): mean annual flow of 2.2 $km^3 yr^{-1}$.
  - Batman River (4’871 km^2): mean annual flow of 4.4 $km^3 yr^{-1}$.
  - Garzan River (2’759 km^2): mean annual flow of 1.6 $km^3 yr^{-1}$; mean annual suspended load of 1.5-2.5 $Mm^3 yr^{-1}$.
  - Botan River (10’654 km^2): mean annual flow of 4.5 $km^3 yr^{-1}$; mean annual sediment load of 5-10 $Mm^3 yr^{-1}$.
  - Tigris at Rezuk (34’623 km^2) – downstream the confluence with Botan; mean annual flow of 15 $km^3 yr^{-1}$; mean annual sediment load: 15 - 30 $Mm^3 yr^{-1}$.
  - Tigris at Ilisu (35’517 km^2): mean annual flow of 15.524 $km^3 yr^{-1}$.
  - Tigris at Cizre (38’295 km^2): mean annual flow of 16.6 $km^3 yr^{-1}$.
- Present irrigation needs: 1’050x10^6 $m^3 yr^{-1}$ (1.05 $km^3 yr^{-1}$) accounting as 6.6% of the inflow of 15.8 $km^3 yr^{-1}$ if consider a 15% water return
- The future needs: 1’910x10^6 $m^3 yr^{-1}$ (1.9 $km^3 yr^{-1}$) as 12.1% of the inflow.
- Present irrigated land: 1’400 km^2
- Total future irrigated land: 2’650 km^2

2.2. Ilisu Dam

- 45 km upstream Cizre and about 80 km upstream the border with Syria.
- 135 m high,
- 1820 m crest length
- Volume: 43.8 Mm^3
- Install capacity: 1'200 MW, 6 Frencis turbine units of 200 MW
- Energy production: 3'833 GWh
- Spillway design for a maximum discharge of 18'000 m^3 s^{-1} at Maximum Water Level. The sill of the spillway at 15 m below the Normal Water Level

2.3. Ilisu Reservoir

- Area at Maximum Water Level of 526.8 m (a.s.l.): 313 km^2
- Area at Normal Water Level of 525 m (a.s.l.): 300 km^2
- Area at Minimum Operating Level of 485 m (a.s.l.): 100 km^2
- Volume (storage capacity)
  - Inactive (Dead Storage): 2'959 Mm^3 (2.95 km^3)
  - Active (Live Storage): 7'460 Mm^3 (7.46 km^3)
  - Total Storage: 10'410 Mm^3 (10.41 km^3)
- Average annual inflow: 15'450 Mm^3 yr^{-1} (15.45 km^3 yr^{-1})
- Reservoir length: 135 km
- Average discharge: 490 m^3 s^{-1}
- Early drawdown: 8-10 m
- Minimum Operation Level (485 m): 40 m below the Normal Water Level (525 m)
- Reservoir catchment area: 35'517 km^2
- Air temperature: -9 to 48 °C
- Average precipitation: 814 mm (0.814 m)
- Average evaporation: 1'695 mm (1.695 m)
- Water release during reservoir impounding
  - From April through October: $Q_{min} = 60\ m^3\ s^{-1} + 0.5x(Q_{inflow} - 60)\ m^3\ s^{-1}$

- From November through March: $Q_{min} = 100\ m^3\ s^{-1}$

2.4. Definitions of the reservoir storage capacity according to EIAR (2005)

“Normal Water Level: highest reservoir level normally permitted which can be exceeded only up to the Maximum Water Level in the case of large flood occurrence”.

“Minimum Operating Level (Drawdown Level): the lowest level at which the powerplant can still operate without risk of damages. Not to be confused with the “early drawdown” representing the minimum water levels reached each year”.

“Inactive Storage (Dead Storage): the volume of the reservoir below the Minimum Operating Level filled at the very beginning of the reservoir impounding period. This volume cannot be considered for the powerplant operation or for the water releases downstream”.

“Active Storage: the reservoir volume between the Minimum Operating Level and the Normal Water Level, represents the volume of water available for energy production including the minimum water flow needed for the release downstream in case these release would not be controlled by the powerplant alone”.

“Total Storage: sum of the inactive and active storages”.

3. Environmental impacts

3.1. Reservoir-induced seismicity

Even there are still many discussions concerning the processes that triggered seismic activities in the man-made reservoirs, there are two basic mechanisms, to which most of the scientists agree: (i) the additional stress on the underlying formations caused by filling up of the reservoir - related to the volume of the water in the reservoir; and (ii) increased pore water pressure along faults - depending upon the water levels in the reservoir above pre-reservoir groundwater levels (Abu Zeid 1995).

It is generally accepted that water weight or pressure cannot cause earthquakes in areas not subjected to previous seismic activity. In all reported cases of reservoir-induced seismicity, there were existing historic active faults in the area of the reservoir but only three documented cases have recorded a seismicity greater than a 6 on Richter scale: in China (at Xinfengjiang 1962), Central Africa (at Kariba in 1963) and the largest known reservoir-induced earthquake in India at Konya in 1967 with a magnitude of 6.5 on Richter Scale causing more than 200 deaths (Adams 1983).

From the experience of other chases, reservoir-induced seismicity may occur at the Ilisu reservoir within the first few years after the reservoir impounding (filling up). Even so, it is unlikely that the magnitude of possible earthquakes to go beyond 6 on the Richter scale, which is the maximum credible earthquake design for the Ilisu Dam. Therefore, possible to occur with a lower magnitude than 6 on Richter scale, reservoir-induced seismicity appear not to represent an issue for the Ilisu Project.

Seismicity	
1.	Reservoir induced seismicity is expected to appear after few years following impounding.
2.	For magnitude within 6 on Richter scale, an induced seismic activity may not represent an issue for the project.

3.2. Sedimentation

One of the main environmental issues resulting from impounding a river system characterized by large catchment area and rapid waters is represented by the great volume of sediment annually trapped behind the dam. Besides influencing biogeochemical processes within the reservoir, this will reduce considerable, in relative short period, the reservoir storage capacity and increase the downstream erosion.

Assessing the sediment balance for the Ilisu Reservoir, at page 3-11, the EIAR (2005) used an empirical formula ($Q_S = 13.959*A^{1.213}$, where A is the drainage area in km^2) to calculate a sediment volume up to 4’619’000 m^3 yr^{-1} being annually collected from the catchment area of 35’517 km^2. Part of this sediment is correctly assumed to be trapped in the upstream existing dams but no estimation of the retention capacity for Ilisu is done. Moreover, even correctly assumed by that the contribution of the bed load of the Tigris River to the total sediment load is negligible (in general, for large rivers, the overall contribution of the bed load to the total sediment load is only few %), the EIAR (2005) characterized and calculate the bed load in more details than the suspended load. However, two scenarios were assumed by the EIAR (2005) to have a major impact on sediment capture:

- ***Category 1***: 5 upstream projects in operation, construction or at the final stage with a total area of 7’181 km^2. Considering this, the report predicted that: *“the volume of sediments produced and transported would be in the order of 3'285'000 m^3/year and correspond to a sedimentation rate of 122 m^3/year km^2 in the Ilisu reservoir”*.

<u>Our calculation</u>: from 5 additional upstream projects, the sediment yield will be reduced by only 30%? This reduction seems to be too low. However, if subtracting the area of 7’181 km^2 from the Ilisu catchment (35’517 - 7’181 = 28’336) and using the above empirical formula, the sediment volume would reach about 3’512’000 m^3 yr^{-1} and not 3’285’000 m^3 yr^{-1} as reported by the EIAR (2005). Further, dividing by

the area of 28’336 km^2, the sedimentation rate would be 124 m^3 km^{-2} yr^{-1} and not 122 m^3 km^{-2} yr^{-1} as predicted by the EIAR (2005).

- ***Category 2***: another 5 projects in planning or reconnaissance with an additional area of 5’052 km^2 out of which only 30% will become implemented in the near future. With all those 10 projects considered, the sedimentation was predicted to decrease down to 119 m^3 km^{-2} yr^{-1}.

  Our calculation: 30% of the 5’052 km^2 represents 1515 km^2. Subtracting from the above calculated area of 28’336 km^2 and using the empirical formula, the annual sediment volume would reach indeed 3’285’000 m^3 yr^{-1} or a sedimentation rate of 122 m^3 km^{-2} yr^{-1} as calculated by EIAR (2005) but for the Category 1.

However, those are only small error as the difference between the two expected sediment volumes at the Ilisu up to 227’000 km^{-3} yr^{-1} is only 5% of the initial load of 4’619’000 m^3 yr^{-1}. The real concern is related to sediment estimates which seem to be incorrect and inconstant with the latter data. Few points below may explain our concern:

(1) In general, the weight of Total Suspended Solids (TSS) in water varies between 1.77 and 1.86 metric tons per m^3 (of g cm^{-3}) and the weight of dry TSS samples varies between 2.57 and 2.83 t m^{-3}. The bulk density of freshly deposited sediment based on a composition of 30% sand, 40% silt and 30% clay as described by the EIAR (2005) is about 1.4 g cm^{-3} but a compaction factor is needed. This problem is solved using an average sediment density of 1.56 g cm^{-3} which includes the correction for compaction (dry weight density of 2.6 g cm^{-3} and a porosity of 40%). Therefore, the volume of 3’285’000 m^3 yr^{-1} accumulating annually in the reservoir would correspond to a mass of 5’125’000 t yr^{-1} sediment. Dividing this load to the average annual inflow of 15’450x10^6 m^3 y^{-1}, the TSS concentration reaches 162 g m^{-3} and seems reasonable. This sediment mass of 5’125’000 t yr^{-1} ascribed to be deposited in the Ilisu Reservoir is practically factor of 2 higher that the later simulated inflow sediment load of 2’540’000 t yr^{-1} (Enclosures 2, page 23). A reservoir can not practically retain more

sediment than it is brought in by the inflow.. Why not use an average TSS concentration (in g m^{-3}) which together with the water flow (in m^3 yr^{-1}) would give as the annual sediment load at the reservoir inflow. Further, the sediment retention capacity can be predicted as function of the reservoir residence time (see below at point 3). Practically no TSS concentrations are available in the entire report and the only few data reported are for the upper stretch of the river.

(2) We tried to calculate the inflow load gathering data on the TSS inflows from a list of main annual suspended loads at different location along the Tigris River (page 3-14 and 3-15). The mean sediment load of the Tigris River downstream the confluence with Botan River is described by the EIAR 2005 (page 3-15) to vary between 15 and 30 Mm^3 yr^{-1}. As "Mm^3" represents "million cubic meters", (10^6 m^3), the suspended load is therefore varying between $15x10^6$ m^3 yr^{-1} and $30x10^6$ m^3 yr^{-1}. Please note that the sediment load "*produced and transported*" to the Ilisu given earlier by the EIAR (2005) was $4.6x10^6$ m^3 yr^{-1}. However, using a sediment density of 2.6 g cm^{-3} (assuming that is given as dry weight), the average volume of $22.5x10^6$ m^3 yr^{-1} (mean value between 15 and 30 $x10^6$ m^3 yr^{-1}) converts into a mass of $58x10^6$ t yr^{-1}. This is one order of magnitude higher that the previous simulated load of $2.5x10^6$ t yr^{-1}. Even using the density of fresh sediment of 1.8 g cm^{-3}, the sediment load will reach $40x10^6$ t yr^{-1}. Why this discrepancy and which one is the correct value? If compare to the annual sediment load of the Nile River at Aswan Reservoir inflow of $142x10^6$ t yr^{-1}, the sediment load of $58x10^6$ t yr^{-1} for Ilisu, even a factor of 2 to 4 lower is in the same order of magnitude and therefore, seems to be right. Only that the Nile River has an average water inflow of $84x10^9$ m^3 yr^{-1} with gives an average TSS concentration of 1700 g m^{-3}, considered already being a high value. For the Tigris River, with an annual water flow of $15.45x10^9$ m^3 yr^{-1}, the TSS concentration for the dry mass would correspond to 3700 mg l^{-1} or 2600 mg l^{-1} for the wet sample density. Even not impossible, those high concentrations are unlikely for such a river system. This conclusion is supported by the maximum reported TSS concentration for the Batman River of 240 mg l^{-1} (Table 3-2, Page 3/3). With this concentration and a mean annual flow of 4.4 km^3 yr^{-1}, the TSS load for the Batman River reaches 10^6 t yr^{-1}.

Unfortunately, no data on TSS load is given in the EIAR (2005) for this tributary and therefore, the correctitude of this value can't be verified

(3) At the bottom page 4-33, it is mention that *"as observed in other large reservoirs in Turkey, the suspended load will almost completely settle in the reservoir"*. We do fully agree with this sentence. A sediment retention capacity of a reservoir can be easily estimated from the slowdown of the water reaching the impoundment. To calculate the average water velocity in the Ilisu Reservoir, we use the relation between the volume (V) and the discharge (Q) which allow estimating the residence time (τ) or the time required by the inflow water to reach the outflow:

$$\tau \text{ (yr)} = V\ (km^3)/Q(km^3\ yr^{-1}) = 10.41/15.45 = 0.67 \text{ yr} = 8 \text{ months} = 246 \text{ days}$$

Knowing that the reservoir length at Normal Level will be 135 km, the average water velocity in the Ilisu Reservoir will decrease to about 0.635 cm s^{-1}. A residence time of 4.5 days and a main stream velocity of 34 cm s^{-1} resulted in the case of Iron Gate I Reservoir (Danube River) in a TSS retention up to 56 % of the incoming load (Teodoru and Wehrli 2005). For a residence time of 2.7 yr which correspond to a water velocity of 0.016 cm s^{-1}, the TSS retention in Lake Brienz (Switzerland) was calculated as 97 % of incoming load (Finger et al. submitted). Water velocities of about 0.8 cm s^{-1} for Aswan High Dam Reservoir (Egypt) were responsible for sediment retention of between 96 and 98 % (Shalash 1982). A linear correlation between the above mention cases was used for the Merowe Reservoir to estimate a retention capacity up to 92 % of the incoming sediment load resulting in a drop of water velocity from 40 - 80 cm s^{-1} down to 4.3 cm s^{-1} at the time of the dam completion (Teodoru et al. 2006). In the case of Ilisu, a water velocity of 0.6 cm s^{-1} would result in retaining up to 96 % of the sediment inflow load (see Figure 1).

Therefore, 96 % of the incoming sediment load will be trapped in the new forming Ilisu reservoir. This is in a good agreement with the EIAR 2005 assumption of almost completely settling down of the suspended load.

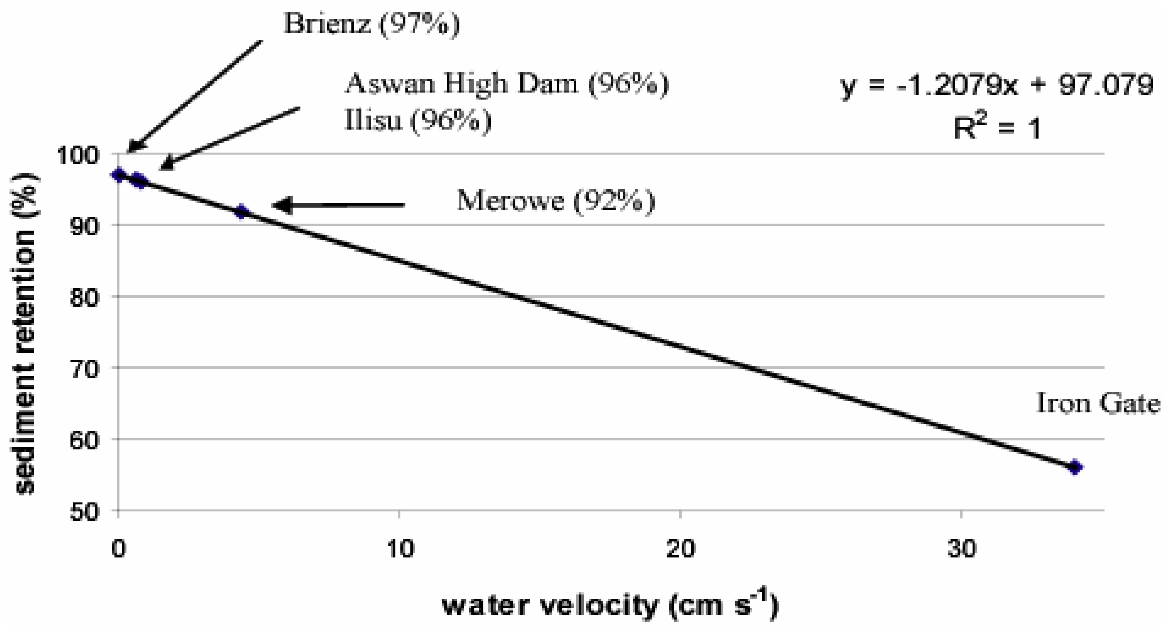

Figure 1

However, the missing parameter to calculate the total amount of sediment annually trapped in the Ilisu Reservoir is the TSS inflow load.

(4) For a TSS inflow load of $58x10^6$ t yr^{-1} (dry weight) or $40x10^6$ t yr^{-1} (fresh sediment) and a retention capacity of 96 %, the total sediment annually trapped in the reservoir would reach $56x10^6$ t yr^{-1} or $38x10^6$ t yr^{-1}, respectively, whereas using their simulated inflow load of $2.54x10^6$ t yr^{-1}, the mass of sediment annually retained would be $2.4x10^6$ t yr^{-1}. Therefore, with an average sediment inflow of $22.5x10^6$ m^3 yr^{-1} and a retention capacity of 96 %, annually, up to $21x10^6$ m^3 yr^{-1} will be accumulated in the Ilisu Reservoir, or only $1.5x10^6$ m^3 yr^{-1} if using the EIAR (2005) predicted inflow load, respectively.

(5) The life time of the reservoirs represent the time period until the reservoir will be filled up with sediment, loosing its storage capacity. This can be calculated by dividing the reservoir storage volume to the accumulation rate. If $3.3x10^6$ m^3 yr^{-1} sediment (as in EIAR 2005) is considered to be annually trapped behind the Ilisu

dam, the Dead Storage capacity of the reservoir of 2'959x10^6 m^3 will be lost in about 890 yr and would take another 2200 yr until the Total Storage capacity will be completely lost. Usually, the lifetime of relatively small reservoirs reaches few hundred years but not thousands. For instance, the lifetime of the Dead Storage capacity of the huge Aswan Reservoir is about 360 yr and will take up to 1000 yr till the Aswan will lose its active capacity. The lifetime of the Ilisu calculated based on the annual accumulation of 3.3x10^6 m^3 yr^{-1} may be too high and therefore, the sediment annually trapped behind the dam must be much higher. If considering an annual sediment accumulation of 21x10^6 m^3 yr^{-1}, the reservoir will lose its Dead Storage capacity in 140 yr and an additional period of 355 yr will be required to be completely filled up with sediment. For a sediment volume of 1.5x10^6 m^3 yr^{-1}, (corresponding to a mass of 2.5 x10^6 t yr^{-1}) the time requirement is in order of thousands years: 1970 and 4970 yr respectively.

Therefore, regarding the sedimentation issue it is still not clear which one of the three values find in the EIAR (2005) represents the real situation. Must probably, the closer value to the real situation is somewhere between 3.3x10^6 m^3 yr^{-1} and 15-30x10^6 m^3 yr^{-1}.

Sedimentation	
1.	A sediment yield of 3.3x10^6 m^3 yr^{-1} was calculated by the EIAR (2005) from the catchment area based on empirical formula.
2.	An inflow sediment load of 2.5x10^6 m^3 yr^{-1} was also predicted bythe EIAR (2005) predicted based on model simulation. This inflow load is actually lower than the total reservoir accumulation.
3.	A load of between 15 and 30x10^6 t m^3 yr^{-1}, one order of magnitude higher that previous values was latter reported by the EIAR (2005) to represent the sediment load of the river at the dam site. This load is also described in the old EIAR (2001).
4.	No dataset on suspended solids concentration is available to estimate which value should be considered closer to the real situation.
5.	Based on residence time we were able to predict a retention capacity up to 96 % of the incoming load. Using an average sediment load of 22.5x10^6 m^3 yr^{-1}, annually, up to 21x106 m3 yr-1 can be accumulate in the Ilisu Reservoir.
6.	No assessment of the impacts derived from such sedimentations was done by the EIAR (2005) for the reservoir itself or for the river downstream.
7.	No prediction for an important physical parameter - reservoir lifetime - was done by the EIAR (2005). According to our calculations, the reservoir lifetime will vary between 100 and 400 yr.

3.3. Water quality

3.3.1. Thermal stratification

A common effect of water storage due to river impoundment in arid or semi-arid areas is the onset of thermal stratification of the reservoir water column. Thermal stratification in natural lakes depend on external driving forces as hydro-meteorological conditions, location, wind induced surface forces, etc and internal properties such as lake morphometry (surface, shape depth), light absorption and the theoretical water residence time, function of reservoir volume and flow. The variations in the water level are important for the mixing of the lake water column and the distribution throughout the reservoir of the water during the seasonal flood. The extent of the flood and the penetration-depth distribution will determine the general pattern of thermal stratification.

The onset of thermal water column stratification is expected in the Ilisu Reservoir. Thermal stratification was also mentioned in the EIAR (2005) but no estimations were done. An empirical dependence of reservoir stratification on residence time (τ) to the maximum temperature difference between the surface and hypolimnion was found by Straskraba and Mauersberg (1988) for several reservoirs in Czech Republic. This is approximated by the equation:

$$\Delta T_{0\text{-}30} = 20\ (1\text{-}\exp\ (-0.0126 * \tau))$$

According to this formula, with a residence time (τ) of about 246 days, the temperature difference between surface and hypolimnion down to 30 m for Ilisu Reservoir will correspond to a maximum of about 19 °C. This value is exposed to large uncertainty and represents an upper estimate.

Consequently, during the summer period, the reservoir water column will become stratified probably over the entire reservoir length. During the flood period, the thermal

stratification may be destructed, especially on the upper stretch of the reservoir. The extent of the vertical convection throughout the reservoir and the pattern of disturbing the thermal stratification will depend upon the initial water level in the reservoir and the hydrological conditions of the flood. With a maximum reservoir length of 135 km and a water depth over 100 m in front of the dam, it is less probable that the entire volume of the Ilisu Reservoir to be a subject of totally mixing during the flood period. However, the changes in climatic conditions during the winter period will result in the overturn and mixing between epilimnion and hypolimnion allowing dissolved oxygen to penetrate the deep waters of the reservoir down to the bottom.

Thermal stratification	
1.	The onset of thermal stratification is mention in the EIAR (2005) but no estimation of the extent of this parameter was done.
2.	Using an empirical formula based on the water residence time, we were able to predict, with large uncertainty, an upper limit temperature difference of 19°C between the surface and 30 m depth during the summer period.
3.	It seems probably that the stratification will be destructed during the annual flood, but a minimum stratification will be maintained for the reservoir area in front of the dam. During the winter, a mixing process between surface and deep water is expected due to the overturn, supplying oxygen to the hypolimnion and increasing the surface nutrient pool.

3.3.2. Nutrients

The N and P concentration in the surface water are described at page 3-17 as:

- Inorganic nitrogen ($N\text{-}NO_3$+$N\text{-}NO_2$+$N\text{-}NH_4$): average 3.5 mg l^{-1} with a maximum value of $N\text{-}NO_2$ up to 13 mg l^{-1}.
- Inorganic phosphorus: PO_4: 0-0.53 mg l^{-1}, average 0.24 mg l^{-1} – not clear if is PO_4 or PO_4-P

Latter on, at page 4-38, nutrient concentrations are given for several station along the Tigris River. The nitrogen concentrations increase from 2 mg l^{-1} upstream the city of Diyarbakir to about 5.5 mg l^{-1} below the confluence with the Batman River and

progressively decrease to about 2.4 mg l^{-1} at a site around 20 km upstream the dam, whereas at Cizre the concentration increase again to 2 mg l^{-1}. Phosphorus show also local variations with an increase from 0.3 mg l^{-1} upstream Diyarbakir up to 1100 mg l^{-1} below Bismil, low concentration of about 0.2 mg l^{-1} below the confluence with Batman River, an increase downstream up to 0.6 mg l^{-1} followed by a decrease down to 0.03 mg l^{-1} close to the dam and more than 0.1 mg l^{-1} at Cizre (see Figure2). This large local variation in nutrient concentrations along the Tigris River, is believed to represent the cumulative effect of domestic waste water discharge from major cities, irrigation and industry. Few questions may arouse here: (1) Giving those high concentrations in the upper reach of the river, why are the concentrations so low at the reservoir site? Transported by the river downstream the concentrations should increase accordingly; (2) Is this a dilution effect or the river self purification capacity is so high? It would be good to see those data plotted together with the water discharges.

However, average concentrations calculated over the last four stations of 2.7 mg l^{-1} N and 0.22 mg l^{-1} P are even lower that the previous concentrations listed at page 3-17. It is also not clear if phosphorus values from Figure 2 are given as PO_4, PO_4-P or total P.

The EIAR (2005) is aware of high nutrient concentrations along the entire stretch and places the Tigris River up in the high eutrophic level (>30 µg P l^{-1} and 650 µg N l^{-1}) but no effort is spend on quantifying the impact of nutrient loading on water quality issue in the new forming reservoir estimating the range of primary production, the extent of oxygen depletion, nutrient cycle, greenhouse gas emissions or subsequent downstream-related impacts.

The major source of high nutrient input from the catchment is considered the upstream agriculture (irrigation), domestic waste water discharge from major cities as Diyarbakir, Bismil, Batman and Siirt (which release a cumulative rate of domestic waste water of about 3.7 m^3 s^{-1}) and industrial waste water. A short water residence time of 0.67 yr as in the case of Ilisu may result in a slow increase in nutrient concentration up to 5 % at the beginning of the reservoir impounding. However, the changes in nutrient concentration

within the reservoir will largely depend on the input and to a lesser extend on the internal processes.

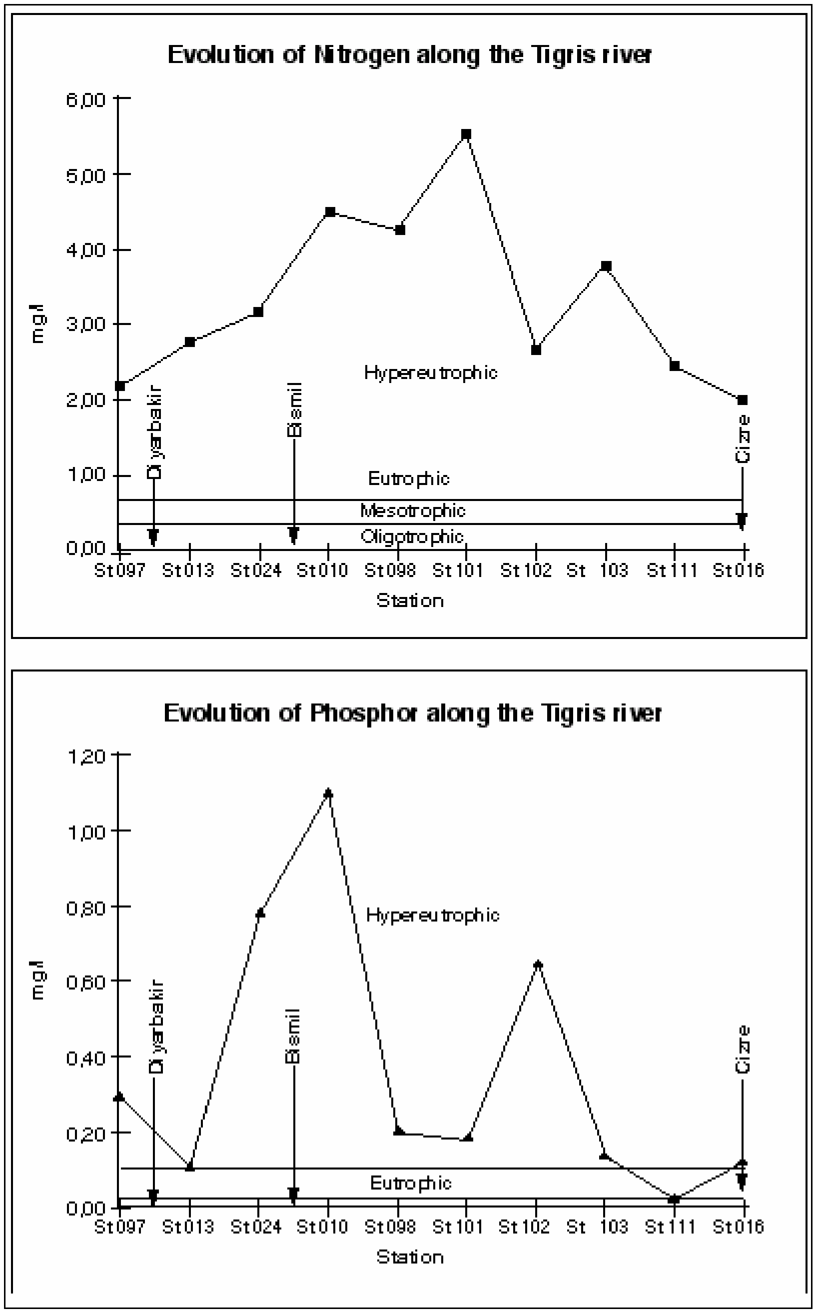

Figure 2

With the present average concentrations of 3.5 mg N l^{-1} and 0.24 mg P l^{-1} and an annual water discharge of 15.45 km^3 yr^{-1}, the inflow loads would reach about 54'000 t N yr^{-1} and 3'700 t P yr^{-1} respectively. The expected increase of 5% resulting from the internal processes will contribute annually with an additional 2'700 t N yr^{-1} and 200 t P yr^{-1}, respectively. Also, a large amount of organic matter is expected to be annually brought in by the river inflow. If assuming a Redfield molar ratio of 106C:16N:1P, the inflow organic carbon load would range between 150'000 and 300'000 t yr^{-1}.

Depending on the dam operation scheme, lower water release especially during the impounding phase will contribute to increase the nutrient content in the reservoir.

Nutrient	
1.	High nutrient concentration in the entire river stretch and at the dam site are reported by the EIAR (2005) but no quantification of the impact of high nutrient loading on water quality and internal biogeochemical processes such as primary production, oxygen depletion, nutrient cycle, greenhouse gas emissions or subsequent downstream-related impacts has been done.
2.	Using the EIAR (2005) stated concentrations of 3.5 mg N l^{-1} and 0.24 mg P l^{-1}, we were able to calculate an annual nutrient load of 54'000 t N yr^{-1} and 3'700 t P yr^{-1} respectively. We also predicted an annual incoming load between 150'000 and 300'000 t yr^{-1} organic carbon.
3.	From a residence time of 0.7 yr, we predict an annually increase in reservoir nutrient concentration up to 5 %. This implies that the availability of nutrient in the reservoir will be mainly dependent on the incoming loads and to a lesser extend to the internal processes. However, predicted by the EIAR (2005) to decrease during the coming period due to implementation of waste treatment plants, the nutrient loads will be still high up into the eutrophic level.

3.3.3. Limiting factors for primary production

Before estimating the extent of primary production, a good exercise may be identifying the limiting factor for primary production. Phosphorus concentration is a good indicator of primary production. Considering the values given as PO_4-P:

$$360\ \mu g\ PO_4\ l^{-1} \leftrightarrow 117\ \mu g\ P\ l^{-1} \leftrightarrow 3.7\ \mu mole\ P\ l^{-1}$$

According to the Redfield molar ration of 106 C: 16 N : 1 P, during photosynthesis for every atom of phosphorus assimilated, 16 atoms of N are also assimilated and 106 atoms of carbon fixed into organic matter. If all phosphorus would be consumed during primary production, a concentration of about 60 µmole N l^{-1} will be required or 840 µg N l^{-1}. As the nitrogen concentration of 5'200 µg N l^{-1} is actually six times higher, P may be the limiting factor in the reservoir productivity. Evan if the phosphorus values are given as PO_4-P (360 µg P l^{-1} ↔ 11.5 µmole P l^{-1}), the nitrogen required during primary production up to 2590 µg N l^{-1} is still a factor of two lower than the present concentration. Therefore, phosphorus may be considered the limiting factor for the reservoir productivity.

3.3.4. Primary production

The equivalent carbon fixation due to the total P assimilation as calculated above, may result in a primary production rates between 240 g C m^{-2} yr^{-1} (if 360 µg l^{-1} is given as PO_4) and 720 g C m^{-2} yr^{-1} (if 360 µg l^{-1} is given as P). The same range of primary production rates can be expected from the figure below which show the relation between P concentration and primary production measured is several lakes in Switzerland (Figure 3). For a reservoir area of 300 km^2 at the Normal Water Level, the carbon fixation in the Ilisu Reservoir will range between 72'000 t yr^{-1} and 216'000 t C yr^{-1} corresponding to a total organic matter production of between 180'000 t yr^{-1} and 450'000 t yr^{-1}. These values represent the *in-situ* carbon produced within the reservoir without considering the large amount of organic carbon predicted before to be transported annually from upstream areas by the river inflow.

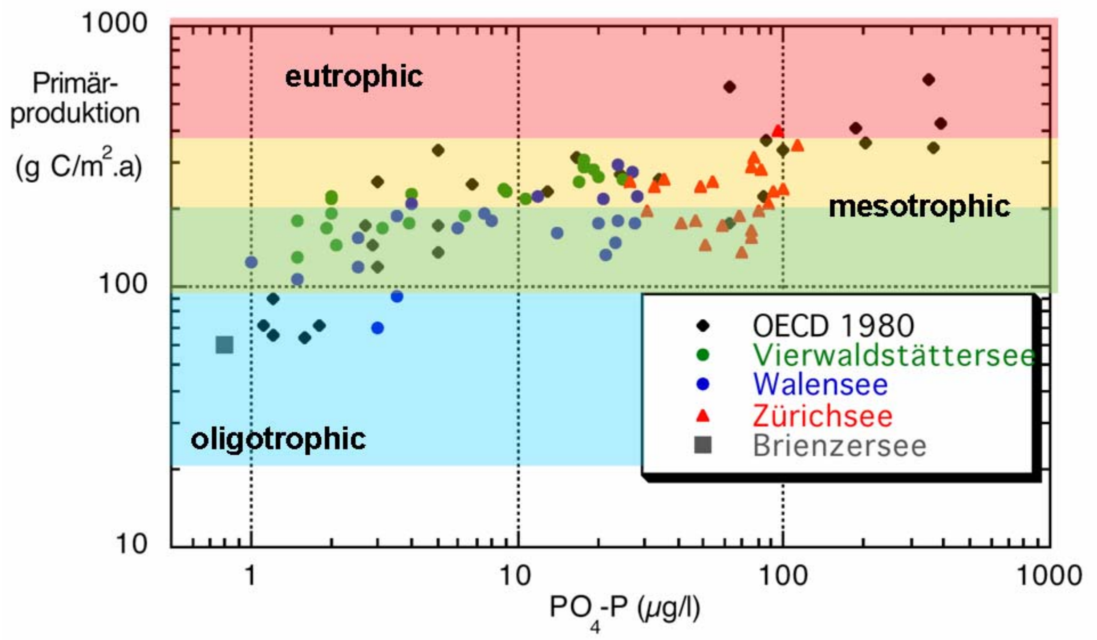

Figure 3

Nutrient limiting factor and primary production	
1.	Relying on the nutrient concentration presented by the EIAR (2005), we estimate that phosphorus may be the limiting factor for reservoir's productivity.
2.	However, the present phosphorus concentrations are high enough to support high productivity level in the range of between 250 and 700 g C m^{-2} yr^{-1}.
3.	Using the reservoir surface area of 300 km^2, we estimate an annul carbon fixation of between 72'000 t yr^{-1} and 216'000 t C yr^{-1}.
4.	During organic matter decomposition within the water column or sediment high oxygen consumption rates are expected, leading to total oxygen depletion of the deep waters. Therefore, anoxic conditions are anticipated few meters below the surface down to the lake floor which can mobilize heavy metals contained in the sediment.
5.	Oxygen depleted waters are not suitable for fishes or other organisms. Fishes as well as their eggs will not be able to survive in the deep, stratified water of the reservoir. The absence of oxygen in the deep waters together with high sedimentation rates, this may result in total extinction of benthic organisms in the reservoir area.
6.	The released from the dam of the colder, anoxic water, possible enriched in heavy metals, may have negative impacts on downstream ecology as well as water use for domestic activities or irrigation.

3.3.5. Greenhouse gas emissions

Concerning greenhouse gas emissions from the Ilisu Reservoir, in the EIAR 2005 at page 4-62, the following affirmation is made:

"The flooding of trees and vegetation will contribute to a biomass input in the reservoir. This organic biomass will eventually decompose generating greenhouse gas emission. Because the amount of kg/ha of organic material to be flooded is relatively small in semi-arid areas like Ilisu, CO_2 and CH_4 emissions by the reservoir itself should be small through the life cycle of the Project compared to reservoirs of the same size in tropical areas".

This assumption is not totally correct. Besides flooding of trees and already existent vegetation, the reservoir will support high primary production and therefore a large mass of degradable organic mater will be annual *in-situ* produced. Part of the organic matter will be flushed out of the system and decomposed within the water column, whereas another part will be accumulated in the sediment of the reservoir. The onset of water column stratification, at least during the summer period, with anoxic condition characterizing the deep waters was also predicted above. Therefore, organic matter decomposition in the water column may produce both CO_2 as well as CH_4. Even in the absence of anoxic deep-water, high sedimentation rates will result in prevalence of anoxic condition below the sediment-water interface and therefore, methane will be produced in the sediment. The methane may be exported either by ebullition or by diffusion. Ebullition results in direct flux of methane from the sediment to the atmosphere with limited impact of CH_4 oxidation in the water column (conversion of CH_4 to CO_2). The ebullition flux is generally related to the net CH_4 production rate in the sediment and the hydrostatic pressure, function of water level fluctuations. As the diffusive transport is much slower than ebullition, a large proportion of the diffusive CH_4 flux exported from anoxic sediment will be oxidized by methane-oxidizing bacteria when the CH_4 reaches the oxic sediment or water column. In the case of stratified water column, CH_4 will be

stored in the anoxic layer and emitted rapidly by diffusion during the turnover periods of winters. The diffusive flux component will depend on the difference in methane concentration between the water and the atmosphere, and on the physical rate of exchange between the water and the air.

High organic matter inflow is expected to correspond to large N and P loads characterizing the Tigris River. Unfortunately, no data on the organic matter is given by the EIAR (2005) and therefore, the estimation of the incoming load from the river upstream or the fraction of organic matter accumulating into the sediment of the reservoir has failed to be done. However, as the upstream organic matter load is expected to be high, its contribution to the total greenhouse gas flux is likely to be large, in the same order of magnitude with gas flux resulting from *in-situ* production. Assuming that only 10 % of the estimated incoming load of between 150'000 and 300'000 t yr^{-1} organic carbon will be decomposed within the water column and the sediment, between 15'000 and 30'000 t yr^{-1} organic carbon will be additionally available for CH_4 and CO_2 production.

Primary production in the Ilisu Reservoir was previously predicted to range between 240 g C m^{-2} yr^{-1} and 720 g C m^{-2} yr^{-1}. For a surface area of 300 km^2 at the Normal Water Level, the reservoir will be responsible for producing annually between 72'000 t yr^{-1} and 216'000 t C yr^{-1}. Considering that 20 % of this will be removed by sedimentation and the rest of 80 % may be washed out or decomposed within the water column, the organic carbon annually reaching the sediment of the reservoir would range between 14'000 and 43'000 t C yr^{-1}. Further, it can be assumed than half of the sedimentary organic carbon will be retained in the sediment and the other half will be converted by anaerobic microbial activity into CH_4 or oxidized and released as CO_2. As the percentage CO_2 to CH_4 produced during decomposition of organic matter depends upon many unknown parameters (the oxidation rates, the time and the extent of oxygen-free condition in the water column and below the sediment water interface or the diffusive fluxes from the sediment) our evaluation is limited only to an amount of total organic carbon ready to be annually converted into CH_4 and CO_2. This value varies between 7'000 t C yr^{-1} and

22’000 t C yr^{-1}. If all this organic carbon will be converted into CO_2 only, with a 1:1 ration, the annual emission will range between 7’000 and 22’000 t CO_2 yr^{-1}. Please note that this estimate represents a lower limit as no carbon resulting from decomposition of organic matter in the water column, no upstream load or the existing biomass flooded by the reservoir was considered. This simple scenario demonstrate that productivity in the Ilisu Reservoir may be responsible for large annually production of readily degradable biomass.

The EIAR (2005) estimated a total emission of CO_2 equivalent gasses in the order of 22 t/ TWh (1TWh = 10^3 GWh) for the first 10 years after the reservoir impoundment and decreasing down to 5 t/TWh after the first 10 years. With an energy production of 3’833 GWh (page 2-3), the predicted emission would reach:

$$(3833 \text{ GWh} \times 22 \text{ t } CO_2)/10^3 \text{ GWh} = 84 \text{ t } CO_2 \text{ yr}^{-1}$$

Compared to our estimates, the greenhouse gas emissions predicted by the EIAR (2005) is about three orders of magnitude lower.

Nutrient limiting factor and primary production	
1.	Relying on the nutrient concentration presented by the EIAR (2005), we estimate that phosphorus may be the limiting factor for reservoir’s productivity.
2.	However, the present phosphorus concentrations are high enough to support high productivity level in the range of between 250 and 700 g C m^{-2} yr^{-1}.
3.	Using the reservoir surface area of 300 km^2, we estimate an annul *in-situ* carbon fixation of between 70’000 t yr^{-1} and 200’000 t C yr^{-1}.
4.	The organic carbon available for CO_2 and CH_4 production in the sediment of the Ilisu Reservoir may range between 7’000 and 22’000 t C yr^{-1}. These values represent a lower estimate and do not include the additional carbon transported into the reservoir from the river upstream.
5.	Compared to the EIAR (2005) prediction of the CO_2 emmision, the greenhouse gas *in-situ* produced in the Ilisu Reservoir may be three orders of magnitude higher.

3.4. Water balance

3.4.1. Precipitation

The following data are presented by the EIAR (2005):

- Average annual precipitation in the area of the reservoir: 814 mm (814 mm mm^{-2} yr^{-1})
- Reservoir area: 100 ÷ 313x10^6 m^2
- Subcatchment area within the reservoir: catchment area at Ilisu (35’517 km^2) minus catchment area at Rezuk (34’623 km^2) equal 894x10^6 m^2

The annual volume gain due to precipitation only on the reservoir surface can be calculated as:

$$(100 \div 313)x10^6\ m^2\ x\ 0.814\ m\ yr^{-1} = 81 \div 255\ m^3\ yr^{-1}$$

The annual volume gain due to precipitation from the subcatchment within the reservoir can be estimated as:

$$894x10^6\ m^2\ x\ 0.814\ m\ yr^{-1} = 728x10^6\ m^3\ yr^{-1}$$

Subtracting from this volume the water directly gained on the surface area, the calculations lead to 646.3 and 472.9x10^6 m^3 yr^{-1}. Considering that only 15% of this actually reaches the reservoir (as assumed be EIAR 2005 for the water used in irrigation scheme), the real contribution of precipitation from the subcatchment within the reservoir may be only between 97 and 71x10^6 m^3 yr^{-1}.

According to this, the total annual precipitation will range between 178 x10^6 m^3 yr^{-1} (calculated as 81+97=178) and 326x10^6 m^3 yr^{-1} (calculated as 255+71).

Therefore, influenced by the reservoir area, the volume of water gained due to precipitation will vary between a minimum of 0.18 km^3 yr^{-1} and an upper limit of 0.33 km^3 yr^{-1}. This represents between 1.7 and 3.2% of the reservoir volume of 10.41 km^3 or with 1 to 2% of the river inflow of 15.45 km^3 yr^{-1}.

3.4.2. Evaporation

- Average annual evaporation rate was described as high 1695 mm (mm mm^2 yr^{-1})
- Reservoir area will fluctuate between 100 and $313x10^6$ m^2

Therefore, the water annually lost due to evaporation can be calculated as:

$$(100 \div 313)x10^6\ m^2\ x\ 1.695\ m\ yr^{-1} = (169.5 \div 530.5)x10^6\ m^3\ yr^{-1}$$

According to my calculations, the annual volume lost throughout evaporation will very between 0.17 km^3 yr^{-1} and 0.53 km^3 yr^{-1}. This represents a loss of 1.6 to 5 % of the reservoir volume or between 1 and 3.5% of the river inflow.

In Enclosures, at page 20, the EIAR (2005) reported a total volume lost annually due to evaporation of between 0.35 and 0.4 km^3 yr^{-1} representing 2.2 and 2.5% of the annual flow of 15'849x10^6 m^3 yr^{-1}. However, their predicted evaporation is in the same range with our rough estimation and therefore, it seems to be ok.

The volume annually lost throughout evaporation of 0.17÷0.53 km^3 yr^{-1} is more or less compensated by the volume of water gain from precipitation of 0.18÷0.33 km^3 yr^{-1} and therefore, the influence on the overall water balance will be minor.

Precipitation and evaporation	
1.	Using the precipitation value of 814 mm and evaporation of 1695 mm, and a reservoir surface area fluctuation between 100 and 313 km^2, the volume annually gain through precipitation will vary between 0.18 and 0.33 km^3 yr^{-1} whereas between 0.17 and 0.53 km^3 yr^{-1} will be lost annually through evaporation.
2.	The volume of water lost annually through evaporation up to 3% of the river inflow is compensated by the annual precipitation, and therefore, the influence on the total water balance can be considered negligible.
3.	Comparable precipitation and evaporation volumes were calculated by the EIAR (2005), and therefore, their estimates seem to the right.

3.4.3. Irrigation

Although the impact of evaporation/precipitation to the reservoir water balance can be consider negligible, the water abstraction due to the irrigation demand may play an important role in the total balance.

In the EIAR (2005), the water demand for irrigation projects is quite well done (Enclosures, page 18). The total water require for agriculture from April and October, with two categories of project (in operation, construction, or future planning) was considered by the EIAR (2005) to annually amount a total of 2.2 $km^3\ yr^{-1}$: 1.2 $km^3\ yr^{-1}$ for the Category 1 projects and an additional 1 $km^3\ yr^{-1}$ if considered the Category 2 projects. With the assumption that 15 % of this water will return back to the river, the net water abstraction for irrigation will reach only 1.9 km^3. The values seems to be right corresponding to a present demand of about 6.5 % of the inflow (1 $km^3\ yr^{-1}$) and reaching in future up to 12 %.

Irrigation	
1.	No re-evaluation or additional calculation of water abstraction for irrigation purpose beside the reported value has been performed.
2.	With a present requirement of 1.2 $km^3\ yr^{-1}$, the irrigation scheme will use more than 6 % of the river inflow increasing in future up to 12 %.
3.	This will lead to increased N and P loads from fertilizers and pesticides. As part of the water used for the irrigation scheme is anticipated by the EIAR (2005) to return to the reservoir, an increase in reservoir salt content is therefore expected. Evaporation may also contribute, in the lesser extent, to increased reservoir salt content.

3.4.4. Filling up of the reservoir

The hydrology of the reservoir is complex and generally well described at different chapters in the EIAR (2005). We focus here only on the discharge flow and the time span for filling up the reservoir.

In order to secure a minim outflow during impounding, the EIAR (2005) proposes the following monthly discharge rules:

- From April through October: Q_{min}=60 m^3 s^{-1} +0.5x(Q_{inflow}-60)m^3 s^{-1}
- From November through March: Q_{min}=100 m^3 s^{-1}

Critical question regarding the hydrological regime and are related to:

(i) how often do very dry years occur and what are their discharge characteristics?

(ii) what is the probability that the reservoir cannot provide the minimum downstream flow?

(iii) how irrigation needs affects the water balance?

(iv) what is the time required to fill up the reservoir, considering the above downstream water release rules,?

In Enclosures at page 26, Table 14 lists the monthly inflows for dry, average and wet conditions. We use this table (considering that the data presented are in m^3 s^{-1} as in previous Table 13 at page 25 and not in Mm^3 which will imply an overall 60% lower values) to calculate the monthly outflow (Q_{out}) according to the above formulas for three possible situations: dry, average and wet years (see Table 1). Converted to km^3 per month, the difference between the inflow (Q_{in}) and the outflow (Q_{out}) represents the water volume available monthly for storage (Table 2). In the EIAR (2005), at page 18 (Enclosures), Table 7 shows the monthly irrigation demand between April and October considering again two project categories. We consider only the Category 1 as the Ilisu Dam construction and the reservoir impounding will not take that long till the Category 2 projects (in reconnaissance, planning or in program) will be implemented.

Table 2 shows the present irrigation demand without considering the return of 15 % of the water used for irrigation as this period required may be larger that the impounding period. Therefore, securing a minimum downstream flow between 5 and 7 km^3 yr^{-1}, a water volume of 6 km^3 yr^{-1} up to 11 km^3 yr^{-1} can be annually stored without considering

the irrigation demand. With the annually irrigation demand up to 1.2 km^3 yr^{-1}, the annually storage may range between 5 and 10 km^3 yr^{-1} (Table 3).

$Q_{out\_April-October}$=60m^3/s-0.5*(Qin-60m^3/s)

$Q_{out\_Nov.-March}$=60m^3/s-0.5*(Qin-60m^3/s)

	Q_{in} (m^3/s)			Q_{out} (m^3/s)				
Months	**Dry**	**Aver.**	**Wet**	**Dry**	**Aver.**	**Wet**	**days**	**sec**
April	1002.88	1337.17	1604.61	531.44	698.59	832.31	30	2592000
May	797.69	1063.58	1276.30	428.85	561.79	668.15	31	2678400
June	341.93	455.91	547.09	200.97	257.96	303.55	30	2592000
July	141.94	189.26	227.11	100.97	124.63	143.56	31	2678400
August	85.27	113.70	136.44	72.64	86.85	98.22	31	2678400
September	75.87	101.17	121.40	67.94	80.59	90.70	30	2592000
October	103.87	138.49	166.19	81.94	99.25	113.10	31	2678400
November	171.95	229.27	275.13	100	100	100	30	2592000
December	272.15	362.87	435.44	100	100	100	31	2678400
January	260.01	346.68	416.02	100	100	100	31	2678400
February	397.11	529.48	635.38	100	100	100	28	2419200
March	677.25	903.00	1083.60	100	100	100	31	2678400

Table 1

	Q_{in} (km^3/month)			Q_{out} (km^3/month)			Q_{in}-Q_{out} (km^3/month)			**Irrigation**
Months	**Dry**	**Aver.**	**Wet**	**Dry**	**Aver.**	**Wet**	**Dry**	**Aver.**	**Wet**	**km^3/month**
April	2.599	3.466	4.159	1.377	1.811	2.157	1.222	1.655	2.002	0.000
May	2.137	2.849	3.418	1.149	1.505	1.790	0.988	1.344	1.629	0.083
June	0.886	1.182	1.418	0.521	0.669	0.787	0.365	0.513	0.631	0.277
July	0.380	0.507	0.608	0.270	0.334	0.384	0.110	0.173	0.224	0.324
August	0.228	0.305	0.365	0.195	0.233	0.263	0.034	0.072	0.102	0.283
September	0.197	0.262	0.315	0.176	0.209	0.235	0.021	0.053	0.080	0.175
October	0.278	0.371	0.445	0.219	0.266	0.303	0.059	0.105	0.142	0.040
November	0.446	0.594	0.713	0.259	0.259	0.259	0.186	0.335	0.454	0.000
December	0.729	0.972	1.166	0.268	0.268	0.268	0.461	0.704	0.898	0.000
January	0.696	0.929	1.114	0.268	0.268	0.268	0.429	0.661	0.846	0.000
February	0.961	1.281	1.537	0.242	0.242	0.242	0.719	1.039	1.295	0.000
March	1.814	2.419	2.902	0.268	0.268	0.268	1.546	2.151	2.634	0.000
Sum: (km^3 yr^{-1})	11.351	15.135	18.162	5.212	6.330	7.224	**6.139**	**8.805**	**10.938**	1.182

Table 2

	Dry	Average	Wet
Annual volume stored without irrigation (km^3/yr)	**6.139**	**8.805**	**10.938**
Annual volume stored with irrigation (km^3/yr)	**4.957**	**7.623**	**9.756**

	Time period (months) to fill up the reservoir volume of 10.41 km^3	
	without irrigation	**with irrigation**
Dry	20	25
Average	14	16
Wet	11	13

Table 3

According to our calculations, without considering the water abstraction for irrigation, the time required to fill up the reservoir may vary between 20 and 11 months for dry and wet years, respectively. Including the water abstraction for irrigation, the period may be extended to 25 and 13 months, respectively (Table 3).

It is known that the dam operation policy is to diminish the impounding phase as much as possible in order to produce electric power as soon as possible. For this, the EIAR (2005) simulated the reservoir impoundment choosing to 4 arbitrary starting dates: 1st of March, 1st of June, 1st of September and 1st of December. We summarized their results concerning the time required to fill up the reservoir storage capacity in Table 4. According to EIAR (2005), starting at 1st of March and considering a wet year, the minimum necessary time to reach the Normal Water Level of 525 m (a.s.l.) corresponding to a storage volume of 10.41 km^3 was only 2 months (Enclosures, page 27, Table 4). This is obvious wrong but before explaining why, it should be stressed the confusion between the terminology and data presented here. For example, in Enclosures at page 23, Table 11 gives the relation between surface, volume and elevation. The total storage volume of 10.41 km^3 corresponds to a surface area of 313 km^2 at Normal Water Level of 525 m a.s.l. (Table 10, page 22). Page 2-29 describe the reservoir surface area of 300 km^2 at Normal Water Level (525) and 313 km^2 at Maximum Water Level of 526.8 m. The same page 2-29 relates the Normal Water Level to the “live storage” capacity of

7’460 km^3. Nevertheless, even representing minor errors, a consistence between data and terminology throughout the report may be a positive aspect.

Returning to the impounding time and starting at 1st of March, even for a wet year when March and April may have the highest flow, they discharge represent together a volume of only 7.06 km^3 or 68% of the total reservoir. With an outflow calculated as 2.4 km^3, the water stored in the reservoir during March and April would reach a maximum of 4.6 km3 or about 45% of the storage capacity. Therefore, the reservoir can not be filled up in only 2 months.

Starting date		Dry	Average	Wet
		[months]		
1st March	No irrigation	24	10	2
	Irrigation	25	11	2
1st June	No irrigation	23	10	9
	Irrigation	33	10	9
1st September	No irrigation	20	7	6
	Irrigation	20	7	6
1st December	No irrigation	16	4	4
	Irrigation	27	4	4

Table 4. EIAR (2005) predictions on the impounding time (months)

We run a similar simulation using the same arbitrary starting dates. The results are summarized in Table 5 and listed in details in the Appendix (Table 6 to Table 13). The comparison between the EIAR (2005) estimates and our calculated impounding period show a relatively good agreement for a dry year. In general, a factor of two lower values were calculated by EIAR (2005) for an average flow year and more than a factor of three for a wet year could be found between the EIAR (2005) values compared to our simulated data.

Starting date		Dry	Average	Wet
		[months]		
1^{st} March	No irrigation	18	13	12
	Irrigation	24	13	12
1^{st} June	No irrigation	23	19	12
	Irrigation	33	22	19
1^{st} September	No irrigation	20	17	10
	Irrigation	28	18	15
1^{st} December	No irrigation	17	14	11
	Irrigation	25	15	13

Table 5. Our simple calculations of the impounding time (months)

Impounding time	
1.	For average flow years and wet years, the simulation of the impounding period performed by the EIAR (2005) seems to be generally factor of 2 (for average discharge years) and three (for wet years), respectively, lower than our estimated periods.
2.	As the impounding time is an important parameter for the hydroelectric company controlling the starting of power production, regulating the downstream discharge and influencing the reservoir water quality, a better address of this parameter may be essential.

4. Summery

4.1. Reservoir-induced seismicity

In all reported cases of reservoir-induced seismicity, there were existing historic active faults in the area of the reservoir but only three documented cases have recorded seismicity greater than a 6 on Richter scale: at Xinfengjiang in China (1962), at Kariba in Central Africa (1963) and at Konya in India (1967). A number of faults with E-W direction cross the Ilisu Reservoir area and earthquakes with a magnitude of 6 are anticipated by the EIAR (2005) in the vicinity of the dam site. Therefore, possible to occur, reservoir-induced seismicity with magnitude below 6 are not considered representing an issue for the Ilisu project. However, even the creation of the reservoir is not believed to potential become a hazard, the assessment of catastrophic consequences of hypothetical dam failure due to higher seismic activity or accidents on large downstream population appears nevertheless advisable.

4.2. Sedimentation

Large uncertainties exist in the EIAR (2005) concerning the estimation of reservoir sediment retention.

The values on sediment capture or riverine sediment loads presented by the report vary within one order of magnitude. Unsuccessful in re-evaluating this issue due to a lack of data, we estimated a sediment retention capacity of the Ilisu Reservoir up to 95 % of the incoming load.

For broad scale variations on sediment loads presented by the EIAR (2005), the corresponding lifetime of the active storage capacity of the reservoir can vary between

500 and 3’000 yr. Our calculation indicates a lower limit ranging between 100 and 400 yr.

The volume of sediment annually retained in the reservoir is expected to be substantial. As the water reaches the inflow, the coarse sediment will be deposited at the upper part of the reservoir where a delta can form in relatively short period. One suitable solution can be considered mechanical removal of the accumulating sediment but apparently costly, financing an appropriate maintenance of the reservoir may be difficult.

High sedimentation rate in the reservoir are expected to smother the benthic organisms by enormous quantities of silt deposited in the lake.

Large seasonal fluctuations in water level would expose extensive areas of the river bed and side banks of the reservoir to erosion increasing sedimentation.

Low sediment load passing throughout the dam will result downstream in dominating erosion. Scouring of the river bad as a result of low sediment loading and high water velocities (narrow river channel) can result in significant alterations of adjacent water table.

4.3. Water quality

High riverine nutrient loads reaching the Ilisu Reservoir will trigger the onset of eutrophication. Even implementing the proposed projects on waste water treatment plants and reducing the nutrient loads, internal processes within the reservoir will keep the concentrations up in the eutrophic level.

Decreased turbidity towards dam due to preferentially settling of the particles in the upper part of the reservoir will increase light penetration.

High nutrient availability together with a stable summer thermal stratification will increase the algal productivity in the reservoir.

A residence time of more than half a year will allow large parts of the biomass to be degraded within the water column reducing the oxygen level down to a total depletion and increasing the greenhouse gas emissions.

In the absence of the oxygen, sedimentary organic matter mineralization will lead to methane production, releasing into the water column large amount of nutrients.

Stored in the hypoliminion as a result of summer stratification, during late autumn and winter, mixing processes between hypolimnion and epilimnion will increase the nutrient pool favoring high rates of primary production up to 700 g C m^{-2} yr^{-1} able to fix annually between 70'000 and 200'000 t C yr^{-1}. Out of this, annually, up to 7'000 and 22'000 t C yr^{-1} will be available in the sediment of the Ilisu Reservoir for CO_2 and CH_4 production.

Stratified and oxygen depleted waters are not suitable for fishes or other organisms. Fishes as well as their eggs will not be able to survive in the deep water of the reservoir. Together with high sedimentation rates, this may result in total extinction of benthic organisms in the reservoir area.

4.4. Hydrology and water balance

Significant alterations on the hydrological regime of the Tigris River will occur with the construction of the Ilisu Dam. Eliminating the downstream annual flooding which flushed and cleanse the river once a year, the Ilisu dam will store the seasonal runoff into 10.4 km^3 reservoir for hydropower production and irrigation.

Based on inexistent water agreement between Turkey, Syria and Iraq, a minimum flow release during impounding takes in consideration only the downstream agricultural need and water supply requirement of Turkey. No transbordery impacts are considered.

The simulation of the impounding period performed by the EIAR (2005) for average flow years and wet years, seems to be generally factor of two (for average discharge years) and three (for wet years), respectively, lower than our estimates.

After the impounding phase, dam operation scheme will focus on power production which will ensure a discharge close to the present annual flow.

With a present requirement of 1.2 km^3 yr^{-1}, the irrigation scheme will use more than 6 % of the river inflow and increasing in future up to 12 %. As 15 % of this water is predicted to return to the reservoir, increased N and P, and a rise in reservoir salt content is therefore expected.

Additional hydrological alteration will appear in the near future with the new dam construction at Cizre.

The water annually lost throughout evaporation from the reservoir area up to 5 % of the reservoir volume will be compensated by the annual input via precipitation and therefore, for the overall balance can be considered negligible. Evaporation will increase the reservoir salt content.

4.5. General remarks

Considering the dam location close to the Syrian-Iraqi border, the impacts of the Ilisu Dam construction on downstream hydrology, water quality and sedimentation should not be considered only of local importance as it will also directly affect the riparian country.

Therefore, in the assessment of environmental impacts, transboundary impact analyses should be performed.

The present independent evaluation of the environmental impacts of the future Ilisu Project suffers from a lack of data and information. The minimum information that was provided was often vague, incomplete or contradictory. Without a solid base, the accuracy of this independent evaluation suffers with a large degree of uncertainty. However, we performed the present assessment with the information provided to the best of our ability, and within this limitation.

Many of the key environmental issues such as reservoir water quality, sedimentation and downstream effects were briefly discussed by the EIAR (2005) at a theoretical level, but no reliable assessment of their impacts has been performed. Without knowing the degree of impacts, finding appropriate solutions for minimizing the effects may be a difficult task.

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Appendix

Simulation without irrigation considered:

1st March		Q_{in} (km³/month)			Q_{out} (km³/month)			Vol. without irrigation		
		Dry	Aver.	Wet	Dry	Aver.	Wet	Dry	Aver.	Wet
1	March	1.814	2.419	2.902	0.268	0.268	0.268	1.546	2.151	2.634
2	April	2.599	3.466	4.159	1.377	1.811	2.157	2.768	3.806	4.636
3	May	2.137	2.849	3.418	1.149	1.505	1.790	3.756	5.150	6.265
4	June	0.886	1.182	1.418	0.521	0.669	0.787	4.121	5.663	6.896
5	July	0.380	0.507	0.608	0.270	0.334	0.384	4.231	5.836	7.120
6	August	0.228	0.305	0.365	0.195	0.233	0.263	4.265	5.908	7.223
7	September	0.197	0.262	0.315	0.176	0.209	0.235	4.286	5.961	7.302
8	October	0.278	0.371	0.445	0.219	0.266	0.303	4.344	6.067	7.444
9	November	0.446	0.594	0.713	0.259	0.259	0.259	4.531	6.402	7.898
10	December	0.729	0.972	1.166	0.268	0.268	0.268	4.992	7.106	8.797
11	January	0.696	0.929	1.114	0.268	0.268	0.268	5.420	7.766	9.643
12	February	0.961	1.281	1.537	0.242	0.242	0.242	6.139	8.805	10.938
13	March	1.814	2.419	2.902	0.268	0.268	0.268	7.685	10.956	13.573
14	April	2.599	3.466	4.159	1.377	1.811	2.157	8.907	12.611	15.575
15	May	2.137	2.849	3.418	1.149	1.505	1.790	9.895	13.955	17.204
16	June	0.886	1.182	1.418	0.521	0.669	0.787	10.261	14.468	17.835
17	July	0.380	0.507	0.608	0.270	0.334	0.384	10.370	14.642	18.059
18	August	0.228	0.305	0.365	0.195	0.233	0.263	10.404	14.713	18.161
19	September	0.197	0.262	0.315	0.176	0.209	0.235	10.425	14.767	18.241
20	October	0.278	0.371	0.445	0.219	0.266	0.303	10.483	14.872	18.383

Table 6

	1st June	Q_{in} (km^3/month)			Q_{out} (km^3/month)			Vol. gain without irrigation		
		Dry	Aver.	Wet	Dry	Aver.	Wet	Dry	Aver.	Wet
1	June	0.886	1.182	1.418	0.521	0.669	0.787	0.365	0.513	0.631
2	July	0.380	0.507	0.608	0.270	0.334	0.384	0.475	0.686	0.855
3	August	0.228	0.305	0.365	0.195	0.233	0.263	0.509	0.758	0.957
4	September	0.197	0.262	0.315	0.176	0.209	0.235	0.530	0.811	1.037
5	October	0.278	0.371	0.445	0.219	0.266	0.303	0.588	0.917	1.179
6	November	0.446	0.594	0.713	0.259	0.259	0.259	0.775	1.252	1.633
7	December	0.729	0.972	1.166	0.268	0.268	0.268	1.236	1.956	2.532
8	January	0.696	0.929	1.114	0.268	0.268	0.268	1.664	2.616	3.378
9	February	0.961	1.281	1.537	0.242	0.242	0.242	2.383	3.655	4.673
10	March	1.814	2.419	2.902	0.268	0.268	0.268	3.929	5.806	7.308
11	April	2.599	3.466	4.159	1.377	1.811	2.157	5.151	7.461	9.310
12	May	2.137	2.849	3.418	1.149	1.505	1.790	6.139	8.805	10.938
13	June	0.886	1.182	1.418	0.521	0.669	0.787	6.505	9.318	11.570
14	July	0.380	0.507	0.608	0.270	0.334	0.384	6.614	9.492	11.793
15	August	0.228	0.305	0.365	0.195	0.233	0.263	6.648	9.564	11.896
16	September	0.197	0.262	0.315	0.176	0.209	0.235	6.669	9.617	11.975
17	October	0.278	0.371	0.445	0.219	0.266	0.303	6.727	9.722	12.118
18	October	0.278	0.371	0.445	0.219	0.266	0.303	6.786	9.827	12.260
19	November	0.446	0.594	0.713	0.259	0.259	0.259	6.973	10.162	12.714
20	December	0.729	0.972	1.166	0.268	0.268	0.268	7.434	10.866	13.612
21	January	0.696	0.929	1.114	0.268	0.268	0.268	7.862	11.527	14.459
22	February	0.961	1.281	1.537	0.242	0.242	0.242	8.581	12.566	15.754
23	March	1.814	2.419	2.902	0.268	0.268	0.268	10.127	14.717	18.388
24	April	2.599	3.466	4.159	1.377	1.811	2.157	11.349	16.372	20.390

Table 7

	1st September	Q_{in} (km^3/month)			Q_{out} (km^3/month)			Vol. gain without irrigation		
		Dry	Aver.	Wet	Dry	Aver.	Wet	Dry	Aver.	Wet
1	September	0.197	0.262	0.315	0.176	0.209	0.235	0.021	0.053	0.080
2	October	0.278	0.371	0.445	0.219	0.266	0.303	0.079	0.158	0.222
3	November	0.446	0.594	0.713	0.259	0.259	0.259	0.266	0.494	0.676
4	December	0.729	0.972	1.166	0.268	0.268	0.268	0.727	1.198	1.574
5	January	0.696	0.929	1.114	0.268	0.268	0.268	1.155	1.858	2.421
6	February	0.961	1.281	1.537	0.242	0.242	0.242	1.874	2.897	3.716
7	March	1.814	2.419	2.902	0.268	0.268	0.268	3.420	5.048	6.350
8	April	2.599	3.466	4.159	1.377	1.811	2.157	4.642	6.703	8.352
9	May	2.137	2.849	3.418	1.149	1.505	1.790	5.630	8.047	9.981
10	June	0.886	1.182	1.418	0.521	0.669	0.787	5.996	8.560	10.612
11	July	0.380	0.507	0.608	0.270	0.334	0.384	6.105	8.733	10.836
12	August	0.228	0.305	0.365	0.195	0.233	0.263	6.139	8.805	10.938
13	September	0.197	0.262	0.315	0.176	0.209	0.235	6.160	8.859	11.018
14	October	0.278	0.371	0.445	0.219	0.266	0.303	6.219	8.964	11.160
15	November	0.446	0.594	0.713	0.259	0.259	0.259	6.405	9.299	11.614
16	December	0.729	0.972	1.166	0.268	0.268	0.268	6.866	10.003	12.513
17	January	0.696	0.929	1.114	0.268	0.268	0.268	7.295	10.664	13.359
18	February	0.961	1.281	1.537	0.242	0.242	0.242	8.013	11.703	14.654
19	March	1.814	2.419	2.902	0.268	0.268	0.268	9.560	13.853	17.289
20	April	2.599	3.466	4.159	1.377	1.811	2.157	10.782	15.509	19.290

Table 8

	1st December	Q_{in} (km³/month)			Q_{out} (km³/month)			Vol. gain without irrigation		
		Dry	Aver.	Wet	Dry	Aver.	Wet	Dry	Aver.	Wet
1	December	0.729	0.972	1.166	0.268	0.268	0.268	0.461	0.704	0.898
2	January	0.696	0.929	1.114	0.268	0.268	0.268	0.890	1.365	1.745
3	February	0.961	1.281	1.537	0.242	0.242	0.242	1.608	2.404	3.040
4	March	1.814	2.419	2.902	0.268	0.268	0.268	3.155	4.555	5.675
5	April	2.599	3.466	4.159	1.377	1.811	2.157	4.377	6.210	7.676
6	May	2.137	2.849	3.418	1.149	1.505	1.790	5.364	7.554	9.305
7	June	0.886	1.182	1.418	0.521	0.669	0.787	5.730	8.067	9.936
8	July	0.380	0.507	0.608	0.270	0.334	0.384	5.840	8.240	10.160
9	August	0.228	0.305	0.365	0.195	0.233	0.263	5.873	8.312	10.263
10	September	0.197	0.262	0.315	0.176	0.209	0.235	5.894	8.365	10.342
11	October	0.278	0.371	0.445	0.219	0.266	0.303	5.953	8.470	10.484
12	November	0.446	0.594	0.713	0.259	0.259	0.259	6.139	8.805	10.938
13	December	0.729	0.972	1.166	0.268	0.268	0.268	6.600	9.509	11.837
14	January	0.696	0.929	1.114	0.268	0.268	0.268	7.029	10.170	12.683
15	February	0.961	1.281	1.537	0.242	0.242	0.242	7.748	11.209	13.978
16	March	1.814	2.419	2.902	0.268	0.268	0.268	9.294	13.360	16.613
17	April	2.599	3.466	4.159	1.377	1.811	2.157	10.516	15.015	18.615
18	May	2.137	2.849	3.418	1.149	1.505	1.790	11.504	16.359	20.244

Table 9

Simulation including the irrigation:

	1st March	Q_{in} (km³/month)			Q_{out} (km³/month)			Vol. gain with irrigation			Irrigation
		Dry	Aver.	Wet	Dry	Aver.	Wet	Dry	Aver.	Wet	km³/month
1	March	1.814	2.419	2.902	0.268	0.268	0.268	1.546	2.151	2.634	0.000
2	April	2.599	3.466	4.159	1.377	1.811	2.157	2.768	3.806	4.636	0.000
3	May	2.137	2.849	3.418	1.149	1.505	1.790	3.673	5.067	6.182	0.083
4	June	0.886	1.182	1.418	0.521	0.669	0.787	3.761	5.303	6.536	0.277
5	July	0.380	0.507	0.608	0.270	0.334	0.384	3.547	5.152	6.436	0.324
6	August	0.228	0.305	0.365	0.195	0.233	0.263	3.298	4.941	6.256	0.283
7	September	0.197	0.262	0.315	0.176	0.209	0.235	3.144	4.819	6.160	0.175
8	October	0.278	0.371	0.445	0.219	0.266	0.303	3.162	4.885	6.262	0.040
9	November	0.446	0.594	0.713	0.259	0.259	0.259	3.349	5.220	6.716	0.000
10	December	0.729	0.972	1.166	0.268	0.268	0.268	3.810	5.924	7.615	0.000
11	January	0.696	0.929	1.114	0.268	0.268	0.268	4.238	6.584	8.461	0.000
12	February	0.961	1.281	1.537	0.242	0.242	0.242	4.957	7.623	9.756	0.000
13	March	1.814	2.419	2.902	0.268	0.268	0.268	6.503	9.774	12.391	0.000
14	April	2.599	3.466	4.159	1.377	1.811	2.157	7.725	11.429	14.393	0.000
15	May	2.137	2.849	3.418	1.149	1.505	1.790	8.630	12.690	15.939	0.083
16	June	0.886	1.182	1.418	0.521	0.669	0.787	8.719	12.926	16.293	0.277
17	July	0.380	0.507	0.608	0.270	0.334	0.384	8.504	12.776	16.193	0.324
18	August	0.228	0.305	0.365	0.195	0.233	0.263	8.255	12.564	16.012	0.283
19	September	0.197	0.262	0.315	0.176	0.209	0.235	8.101	12.443	15.917	0.175
20	October	0.278	0.371	0.445	0.219	0.266	0.303	8.119	12.508	16.019	0.040
21	November	0.446	0.594	0.713	0.259	0.259	0.259	8.306	12.843	16.473	0.000
22	December	0.729	0.972	1.166	0.268	0.268	0.268	8.767	13.547	17.371	0.000
23	January	0.696	0.929	1.114	0.268	0.268	0.268	9.196	14.208	18.218	0.000
24	February	0.961	1.281	1.537	0.242	0.242	0.242	9.914	15.247	19.513	0.000
25	March	1.814	2.419	2.902	0.268	0.268	0.268	11.460	17.398	22.147	0.000

Table 10

	1st June	Q_{in} (km^3/month)			Q_{out} (km^3/month)			Vol. gain with irrigation			Irrigation
		Dry	Aver.	Wet	Dry	Aver.	Wet	Dry	Aver.	Wet	km^3/month
1	June	0.886	1.182	1.418	0.521	0.669	0.787	0.088	0.236	0.354	0.277
2	July	0.380	0.507	0.608	0.270	0.334	0.384	-0.126	0.085	0.254	0.324
3	August	0.228	0.305	0.365	0.195	0.233	0.263	-0.375	-0.126	0.073	0.283
4	September	0.197	0.262	0.315	0.176	0.209	0.235	-0.529	-0.248	-0.022	0.175
5	October	0.278	0.371	0.445	0.219	0.266	0.303	-0.511	-0.182	0.080	0.040
6	November	0.446	0.594	0.713	0.259	0.259	0.259	-0.324	0.153	0.534	0.000
7	December	0.729	0.972	1.166	0.268	0.268	0.268	0.137	0.857	1.433	0.000
8	January	0.696	0.929	1.114	0.268	0.268	0.268	0.565	1.517	2.279	0.000
9	February	0.961	1.281	1.537	0.242	0.242	0.242	1.284	2.556	3.574	0.000
10	March	1.814	2.419	2.902	0.268	0.268	0.268	2.830	4.707	6.209	0.000
11	April	2.599	3.466	4.159	1.377	1.811	2.157	4.052	6.362	8.211	0.000
12	May	2.137	2.849	3.418	1.149	1.505	1.790	4.957	7.623	9.756	0.083
13	June	0.886	1.182	1.418	0.521	0.669	0.787	5.046	7.859	10.111	0.277
14	July	0.380	0.507	0.608	0.270	0.334	0.384	4.831	7.709	10.010	0.324
15	August	0.228	0.305	0.365	0.195	0.233	0.263	4.582	7.498	9.830	0.283
16	September	0.197	0.262	0.315	0.176	0.209	0.235	4.428	7.376	9.734	0.175
17	October	0.278	0.371	0.445	0.219	0.266	0.303	4.446	7.441	9.837	0.040
19	November	0.446	0.594	0.713	0.259	0.259	0.259	4.633	7.776	10.291	0.000
20	December	0.729	0.972	1.166	0.268	0.268	0.268	5.094	8.480	11.189	0.000
21	January	0.696	0.929	1.114	0.268	0.268	0.268	5.523	9.141	12.035	0.000
22	February	0.961	1.281	1.537	0.242	0.242	0.242	6.241	10.180	13.331	0.000
23	March	1.814	2.419	2.902	0.268	0.268	0.268	7.787	12.331	15.965	0.000
24	April	2.599	3.466	4.159	1.377	1.811	2.157	9.009	13.986	17.967	0.000
25	May	2.137	2.849	3.418	1.149	1.505	1.790	9.914	15.247	19.513	0.083
26	June	0.886	1.182	1.418	0.521	0.669	0.787	10.003	15.483	19.867	0.277
27	July	0.380	0.507	0.608	0.270	0.334	0.384	9.788	15.332	19.767	0.324
28	August	0.228	0.305	0.365	0.195	0.233	0.263	9.539	15.121	19.586	0.283
29	September	0.197	0.262	0.315	0.176	0.209	0.235	9.385	14.999	19.491	0.175
30	October	0.278	0.371	0.445	0.219	0.266	0.303	9.404	15.064	19.593	0.040
31	November	0.446	0.594	0.713	0.259	0.259	0.259	9.590	15.399	20.047	0.000
32	December	0.729	0.972	1.166	0.268	0.268	0.268	10.051	16.104	20.945	0.000
33	January	0.696	0.929	1.114	0.268	0.268	0.268	10.480	16.764	21.792	0.000
34	February	0.961	1.281	1.537	0.242	0.242	0.242	11.199	17.803	23.087	0.000

Table 11

1st September		Q_{in} (km³/month)			Q_{out} (km³/month)			Vol. gain with irrigation			Irrigation
		Dry	Aver.	Wet	Dry	Aver.	Wet	Dry	Aver.	Wet	km³/month
1	September	0.197	0.262	0.315	0.176	0.209	0.235	-0.154	-0.122	-0.095	0.175
2	October	0.278	0.371	0.445	0.219	0.266	0.303	-0.136	-0.057	0.007	0.040
3	November	0.446	0.594	0.713	0.259	0.259	0.259	0.051	0.279	0.461	0.000
4	December	0.729	0.972	1.166	0.268	0.268	0.268	0.512	0.983	1.359	0.000
5	January	0.696	0.929	1.114	0.268	0.268	0.268	0.940	1.643	2.206	0.000
6	February	0.961	1.281	1.537	0.242	0.242	0.242	1.659	2.682	3.501	0.000
7	March	1.814	2.419	2.902	0.268	0.268	0.268	3.205	4.833	6.135	0.000
8	April	2.599	3.466	4.159	1.377	1.811	2.157	4.427	6.488	8.137	0.000
9	May	2.137	2.849	3.418	1.149	1.505	1.790	5.332	7.749	9.683	0.083
10	June	0.886	1.182	1.418	0.521	0.669	0.787	5.421	7.985	10.037	0.277
11	July	0.380	0.507	0.608	0.270	0.334	0.384	5.206	7.834	9.937	0.324
12	August	0.228	0.305	0.365	0.195	0.233	0.263	4.957	7.623	9.756	0.283
13	September	0.197	0.262	0.315	0.176	0.209	0.235	4.803	7.502	9.661	0.175
14	October	0.278	0.371	0.445	0.219	0.266	0.303	4.822	7.567	9.763	0.040
15	November	0.446	0.594	0.713	0.259	0.259	0.259	5.008	7.902	10.217	0.000
16	December	0.729	0.972	1.166	0.268	0.268	0.268	5.469	8.606	11.116	0.000
17	January	0.696	0.929	1.114	0.268	0.268	0.268	5.898	9.267	11.962	0.000
18	February	0.961	1.281	1.537	0.242	0.242	0.242	6.616	10.306	13.257	0.000
19	March	1.814	2.419	2.902	0.268	0.268	0.268	8.163	12.456	15.892	0.000
20	April	2.599	3.466	4.159	1.377	1.811	2.157	9.385	14.112	17.893	0.000
21	May	2.137	2.849	3.418	1.149	1.505	1.790	10.289	15.373	19.439	0.083
22	June	0.886	1.182	1.418	0.521	0.669	0.787	10.378	15.609	19.794	0.277
23	July	0.380	0.507	0.608	0.270	0.334	0.384	10.164	15.458	19.693	0.324
24	August	0.228	0.305	0.365	0.195	0.233	0.263	9.914	15.247	19.513	0.283
25	September	0.197	0.262	0.315	0.176	0.209	0.235	9.760	15.125	19.417	0.175
26	October	0.278	0.371	0.445	0.219	0.266	0.303	9.779	15.190	19.520	0.040
27	November	0.446	0.594	0.713	0.259	0.259	0.259	9.965	15.525	19.973	0.000
28	December	0.729	0.972	1.166	0.268	0.268	0.268	10.426	16.229	20.872	0.000
29	January	0.696	0.929	1.114	0.268	0.268	0.268	10.855	16.890	21.718	0.000

Table 12

	1st December	Q_{in} (km^3/month)			Q_{out} (km^3/month)			Vol. gain with irrigation			Irrigation
		Dry	Aver.	Wet	Dry	Aver.	Wet	Dry	Aver.	Wet	km^3/month
1	December	0.729	0.972	1.166	0.268	0.268	0.268	0.461	0.704	0.898	0.000
2	January	0.696	0.929	1.114	0.268	0.268	0.268	0.890	1.365	1.745	0.000
3	February	0.961	1.281	1.537	0.242	0.242	0.242	1.608	2.404	3.040	0.000
4	March	1.814	2.419	2.902	0.268	0.268	0.268	3.155	4.555	5.675	0.000
5	April	2.599	3.466	4.159	1.377	1.811	2.157	4.377	6.210	7.676	0.000
6	May	2.137	2.849	3.418	1.149	1.505	1.790	5.281	7.471	9.222	0.083
7	June	0.886	1.182	1.418	0.521	0.669	0.787	5.370	7.707	9.576	0.277
8	July	0.380	0.507	0.608	0.270	0.334	0.384	5.156	7.556	9.476	0.324
9	August	0.228	0.305	0.365	0.195	0.233	0.263	4.906	7.345	9.296	0.283
10	September	0.197	0.262	0.315	0.176	0.209	0.235	4.752	7.223	9.200	0.175
11	October	0.278	0.371	0.445	0.219	0.266	0.303	4.771	7.288	9.302	0.040
12	November	0.446	0.594	0.713	0.259	0.259	0.259	4.957	7.623	9.756	0.000
13	December	0.729	0.972	1.166	0.268	0.268	0.268	5.418	8.327	10.655	0.000
14	January	0.696	0.929	1.114	0.268	0.268	0.268	5.847	8.988	11.501	0.000
15	February	0.961	1.281	1.537	0.242	0.242	0.242	6.566	10.027	12.796	0.000
16	March	1.814	2.419	2.902	0.268	0.268	0.268	8.112	12.178	15.431	0.000
17	April	2.599	3.466	4.159	1.377	1.811	2.157	9.334	13.833	17.433	0.000
18	May	2.137	2.849	3.418	1.149	1.505	1.790	10.239	15.094	18.979	0.083
19	June	0.886	1.182	1.418	0.521	0.669	0.787	10.327	15.330	19.333	0.277
20	July	0.380	0.507	0.608	0.270	0.334	0.384	10.113	15.179	19.233	0.324
21	August	0.228	0.305	0.365	0.195	0.233	0.263	9.864	14.968	19.052	0.283
22	September	0.197	0.262	0.315	0.176	0.209	0.235	9.709	14.847	18.957	0.175
23	October	0.278	0.371	0.445	0.219	0.266	0.303	9.728	14.912	19.059	0.040
24	November	0.446	0.594	0.713	0.259	0.259	0.259	9.914	15.247	19.513	0.000
25	December	0.729	0.972	1.166	0.268	0.268	0.268	10.375	15.951	20.411	0.000
26	January	0.696	0.929	1.114	0.268	0.268	0.268	10.804	16.612	21.258	0.000

Table 13