Annex to Chapter 14

A-14. ANNEX TO CHAPTER 14

Figure A14-1 Regional Location Plan of the Upper Tana Catchment

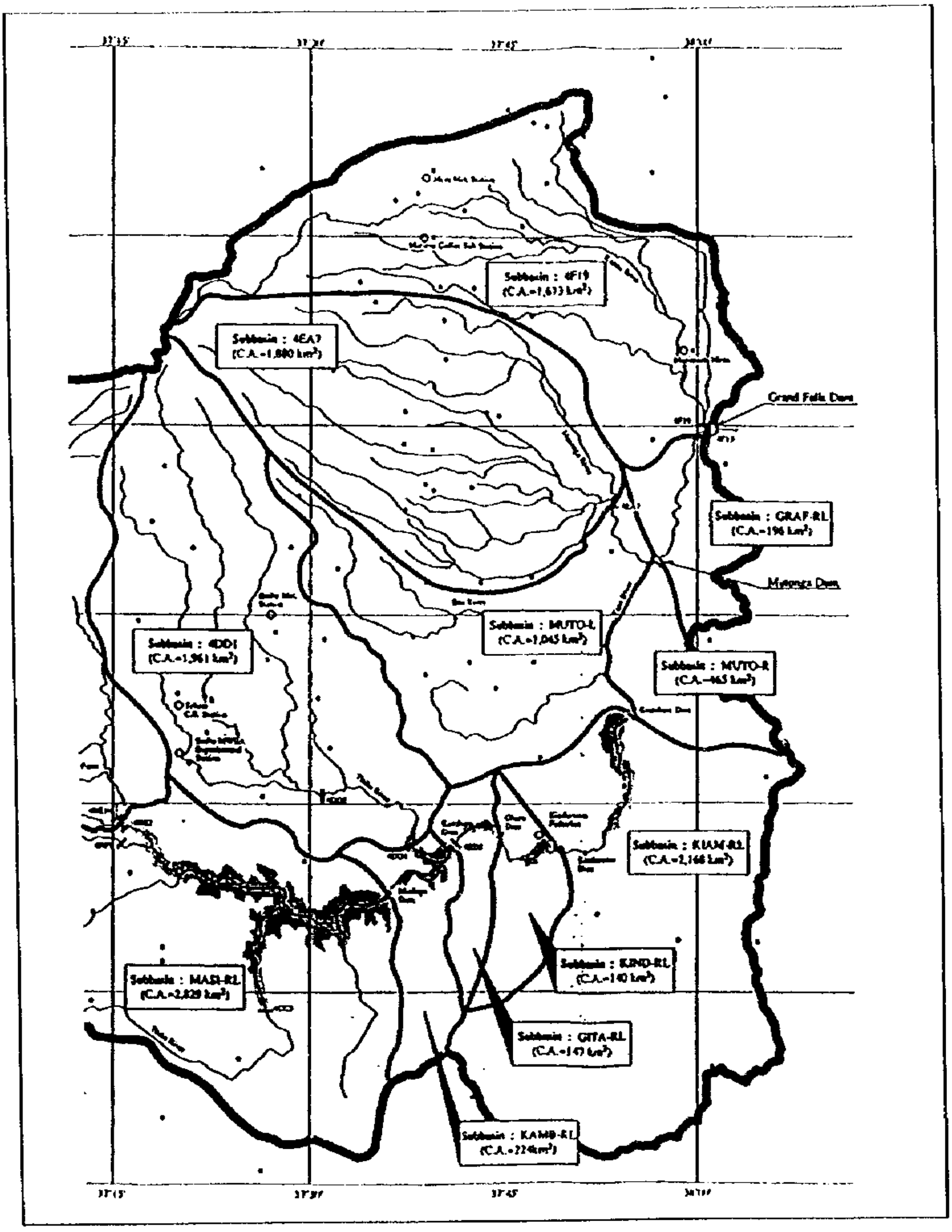


Figure A14-2 Mutonga Reservoir: Location Plan

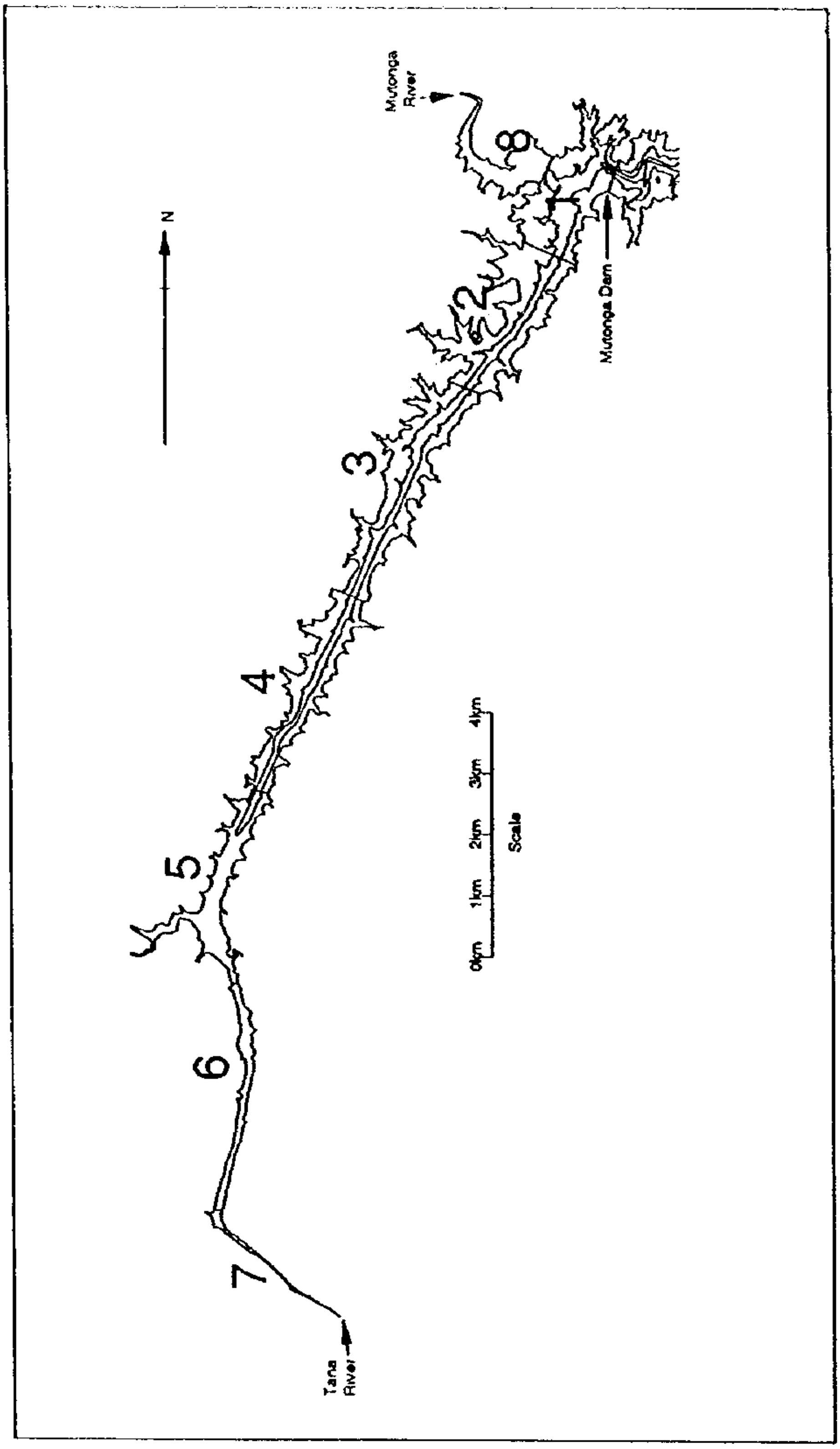


Figure A14-3 Mutonga Reservoir: Schematic Section

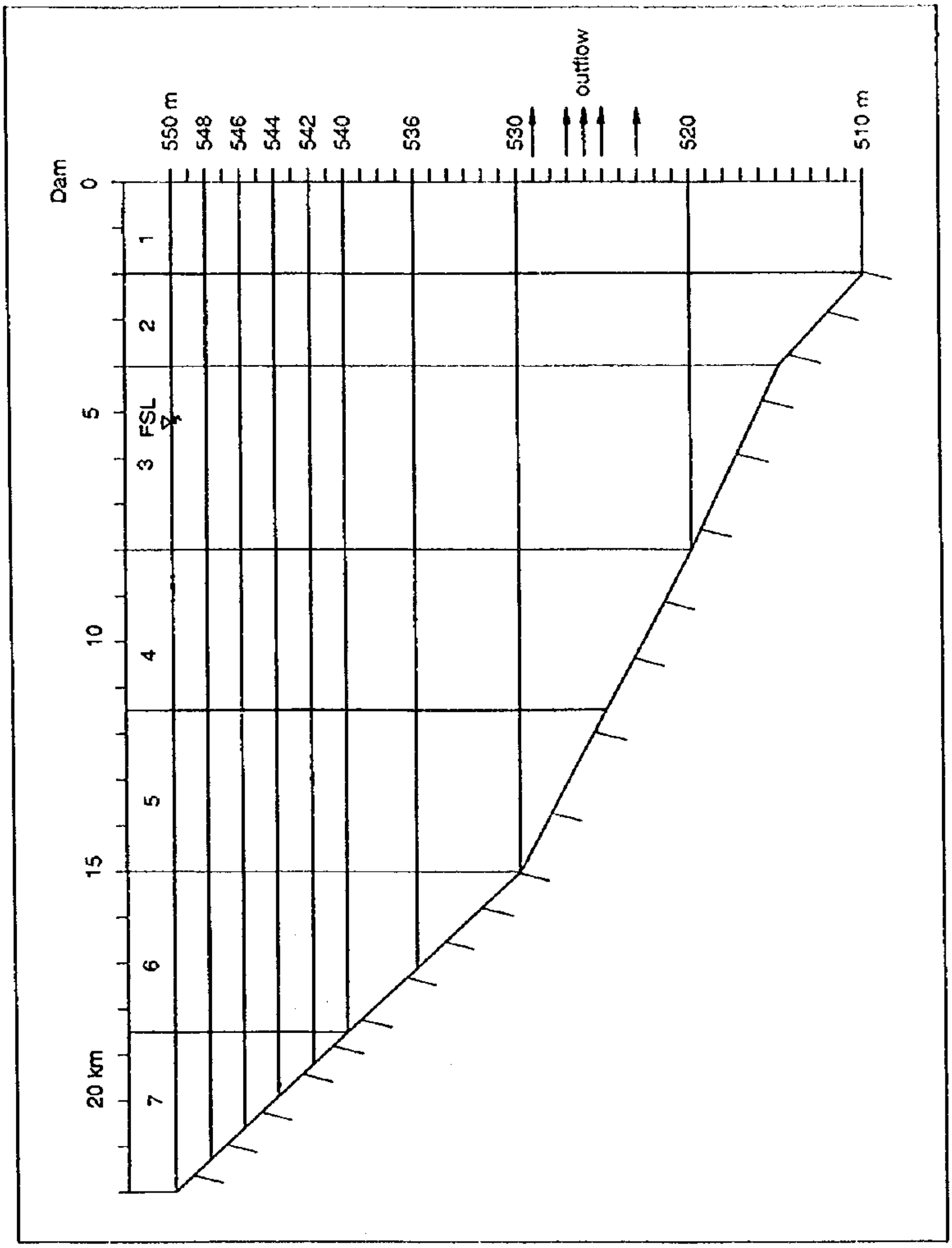
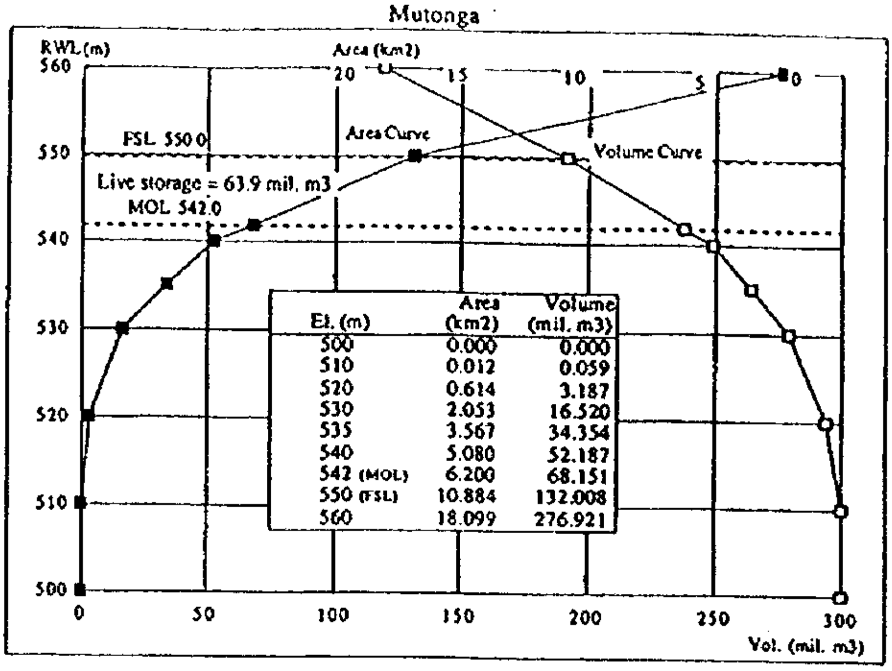


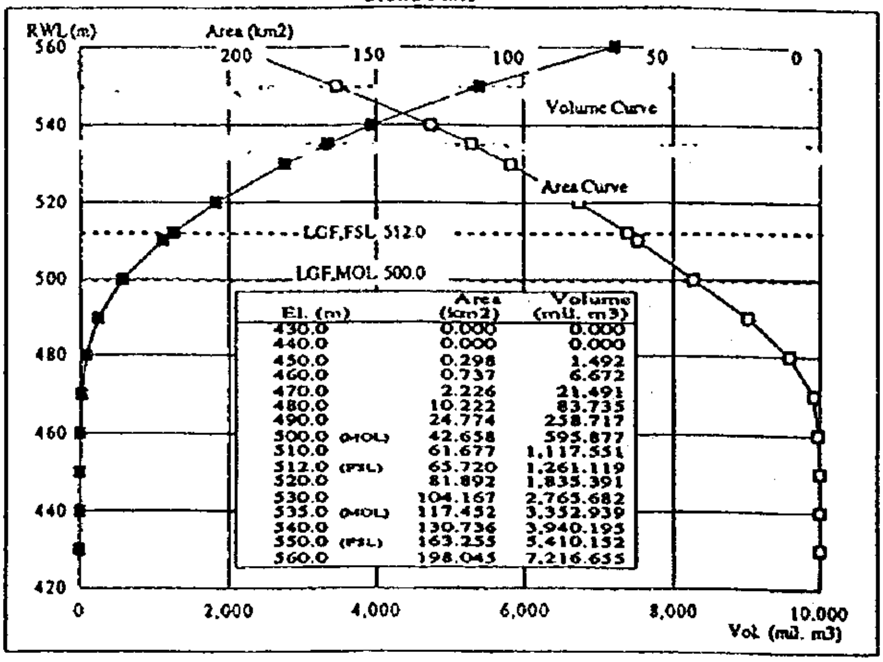
Figure A14-4 Reservoir Geometry Characteristics

Mutonga



El. (m)	Area (km2)	Volume (mil. m3)
500	0.000	0.000
510	0.012	0.059
520	0.614	3.187
530	2.053	16.520
535	3.567	34.354
540	5.080	52.187
542 (MOL)	6.200	68.151
550 (FSL)	10.884	132.008
560	18.099	276.921

Grand Falls



El. (m)	Area (km2)	Volume (mil. m3)
430.0	0.000	0.000
440.0	0.000	0.000
450.0	0.298	1.492
460.0	0.737	6.672
470.0	2.226	21.491
480.0	10.222	83.735
490.0	24.774	258.717
500.0 (MOL)	42.658	595.877
510.0	61.677	1,117.551
512.0 (FSL)	65.720	1,261.119
520.0	81.892	1,835.391
530.0	104.167	2,765.682
535.0 (MOL)	117.452	3,352.939
540.0	130.736	3,940.195
550.0 (FSL)	163.255	5,410.152
560.0	198.045	7,216.655

Figure A14-5 Low Grand Falls Reservoir: Location Plan

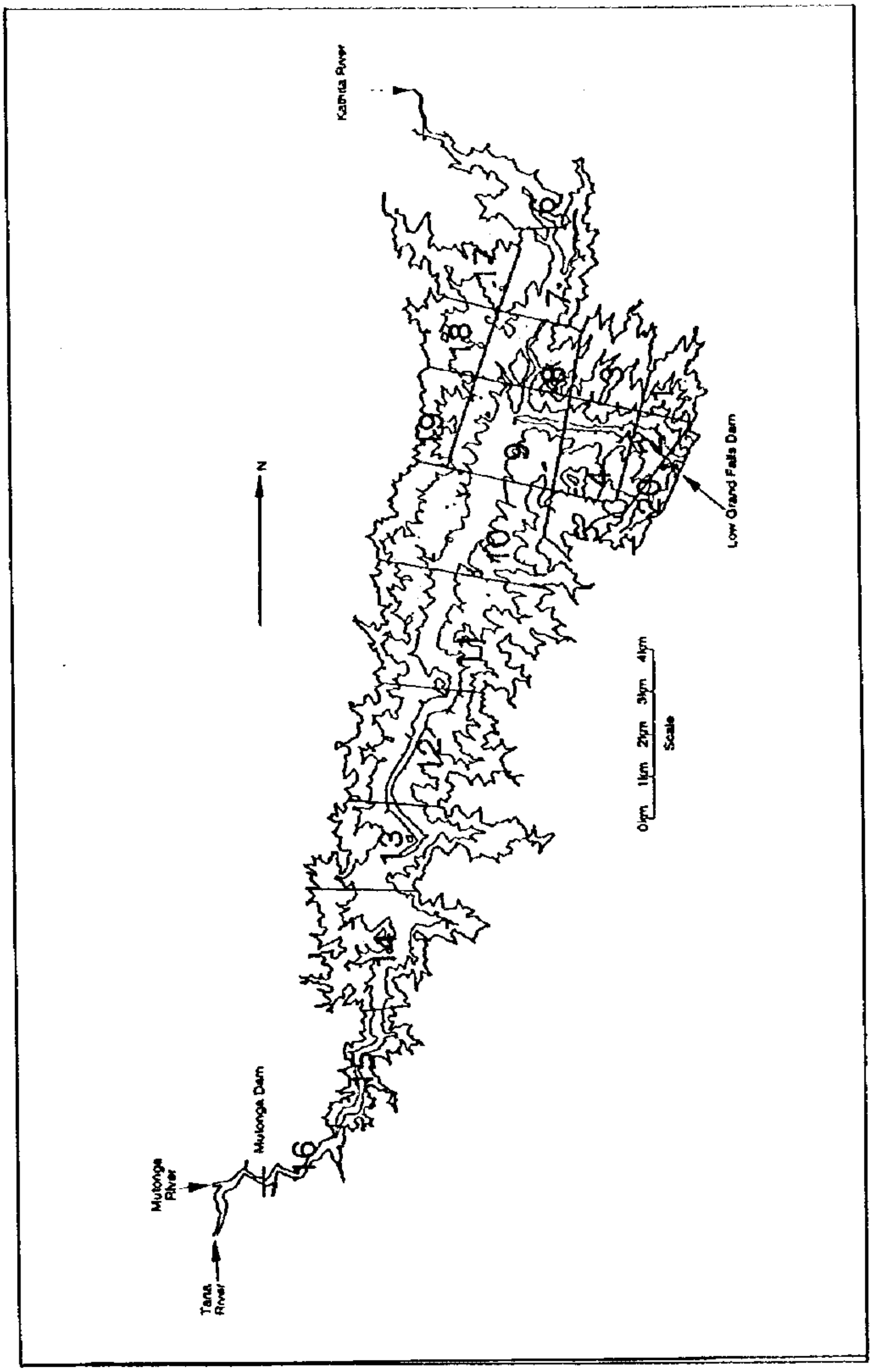


Figure A14-6 Low Grand Falls Reservoir: Schematic Section

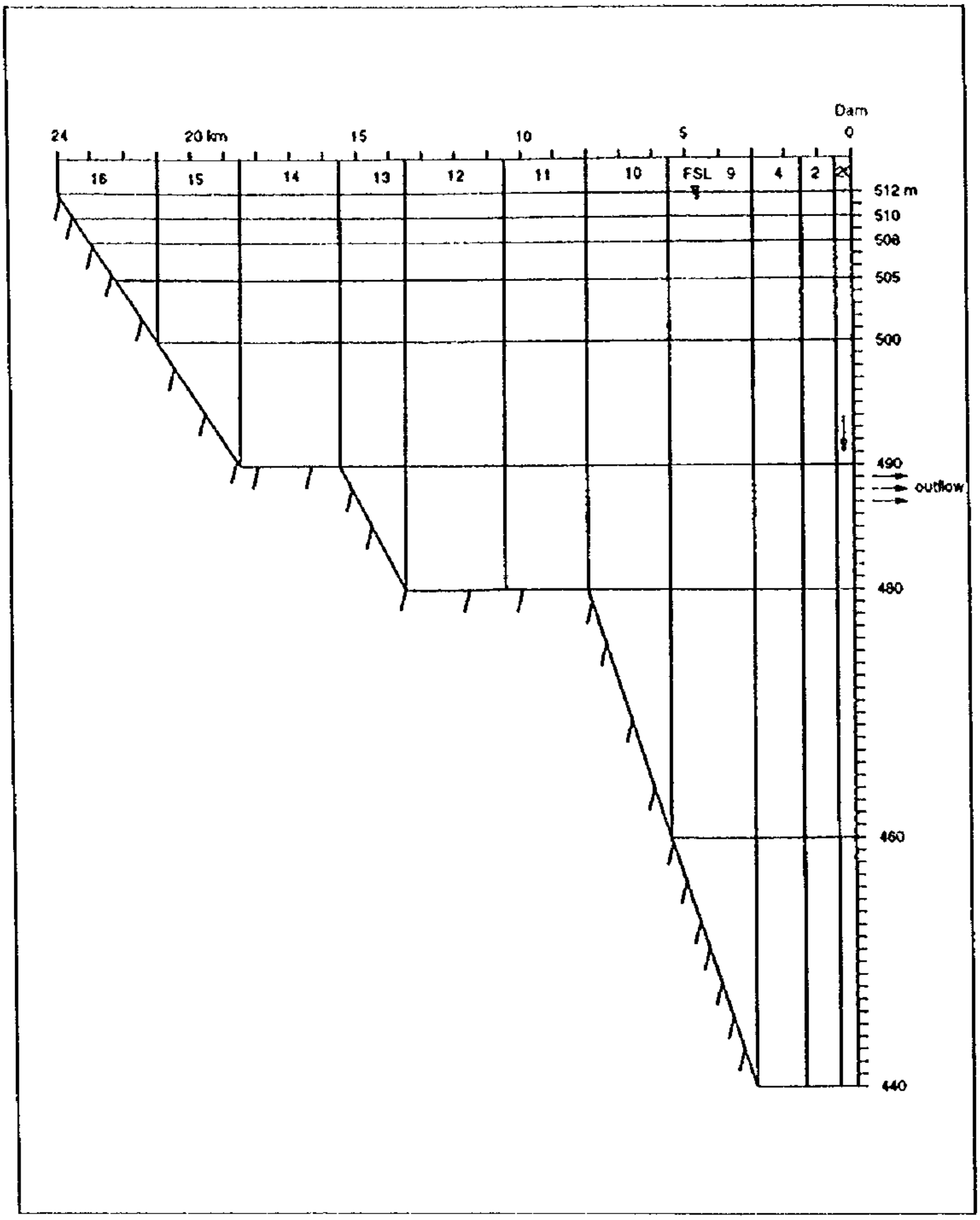
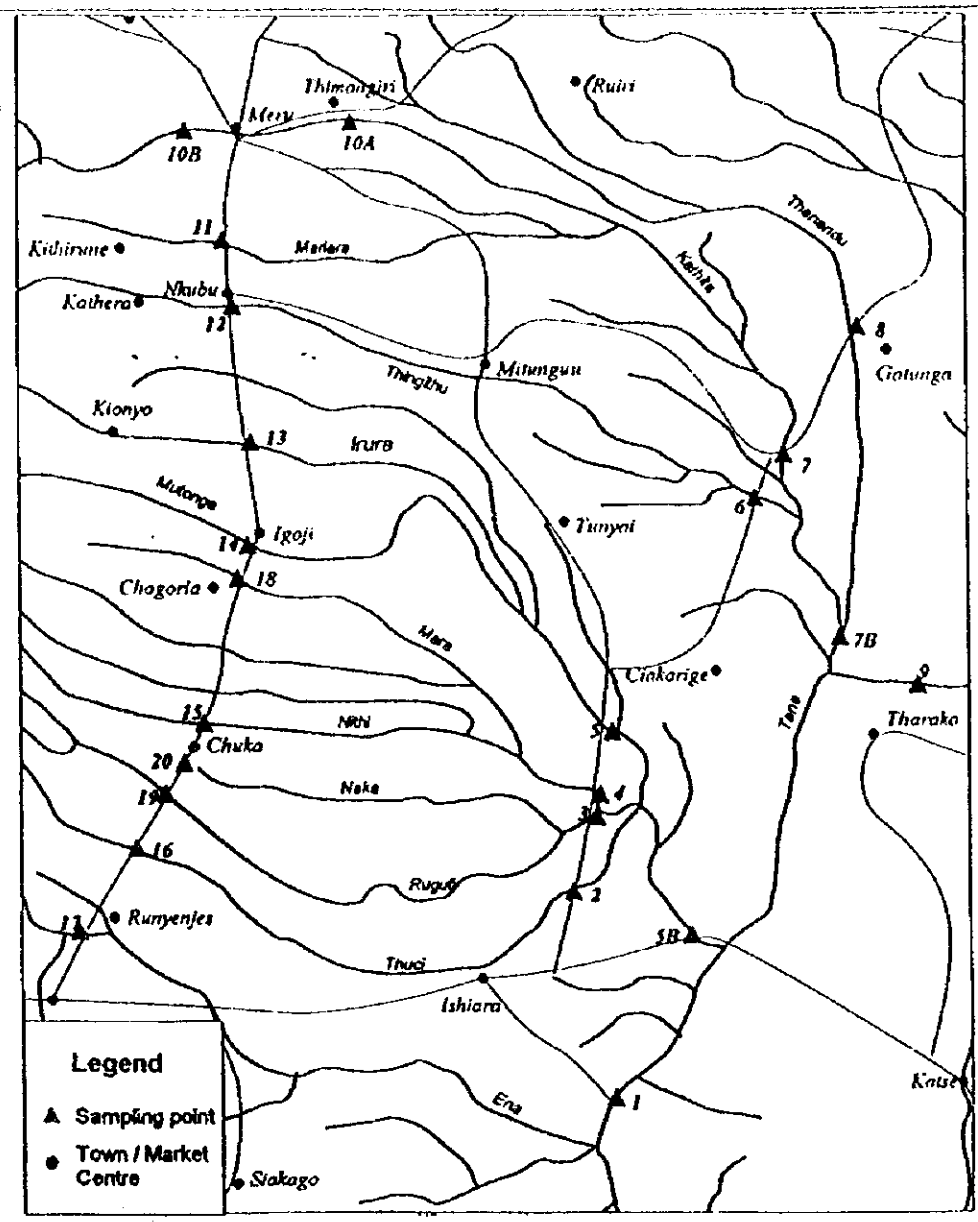


Figure A14-7 River Sampling Sites



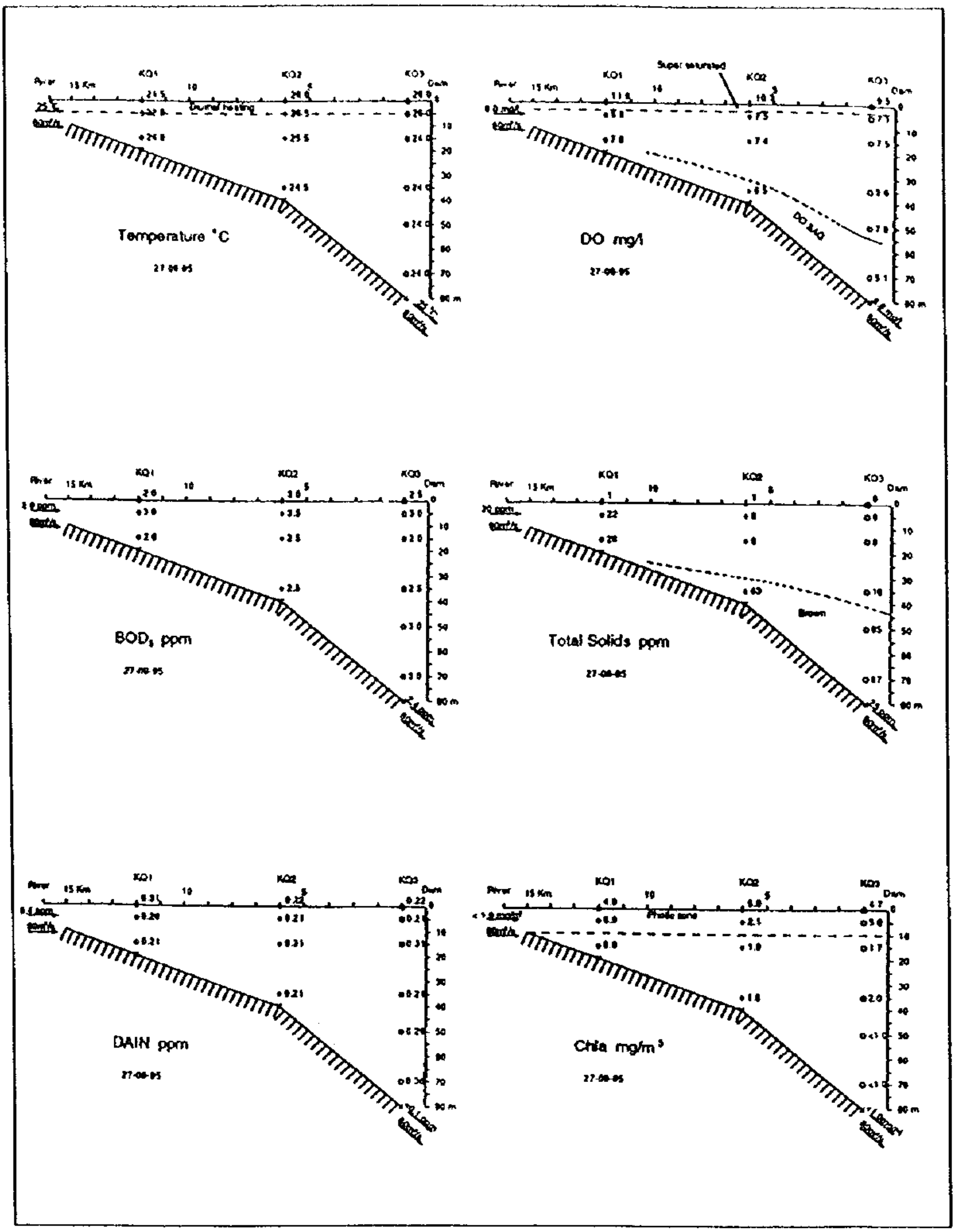
Lower Catchment Basins

1. Irira bridge
2. Thuci river
3. Ruguti river
4. Mara river
5. Mutonga
6. Thingithu river
7. Kathita river
8. Thanandu river
9. Grand Falls (Tana)

Upper Catchment Stations

10. Kathita river
11. Mariara river
12. Thingithu river
13. Irura river
14. Mutonga river
15. Nithi river
16. Thuci river
17. Ena river
18. Mara river
19. Ruguti river
20. Naka river

Figure A14-8 Kiambere Reservoir: Late Dry Season Survey, 27 September 1995



Water Quality theory used in 3DSL

Mathematical model theory

In order to model the water quality of a reservoir many inter-dependent processes need to be simulated. These may be conveniently separated into three main groups; transport and mixing processes, biochemical interaction of water quality variables and the utilisation and re-cycling of nutrients by living matter.

In order to minimise computation the calculation of flows, salt transpott and gravitational circulation is performed in the flow model and the results used to drive the water quality and algal growth model. In this way the effects of several different pollution control measures can be predicted by running the flow model for one prescribed yearly cycle and then using the results to crive several runs of the water quality model simulating the effect of a different measure.

Equations of transport

The model applies mass balance equations for each of the substances under consideration in each of a series of inter-connected elements.

In each element the mass balance equation for an arbitrary substance can be written as:

$$\frac{\partial C}{\partial t} + \frac{\partial}{\partial x}(uC) + \frac{\partial}{\partial y}(vC) + \frac{\partial}{\partial z}(wC) =$$

$$K_x \frac{\partial^2 C}{\partial x^2} + K_y \frac{\partial^2 C}{\partial y^2} + K_z \frac{\partial^2 C}{\partial z^2} + \omega C + \Sigma S \qquad (1)$$

where

C is the concentration of substance
u,v,w are the components of velocity
K_x,K_y,K_z are the components of the coefficient of eddy diffusivity
ω is the settling velocity for particulate substances
Σ is the net effect of all the source and sink terms simulated in the water quality and ecosystem interactions for the substance.

The numerical solution of this equation for the many water quality variables is described in Appendix A.

Water Quality

3DSL models the interactions between the following 12 water quality parameters:

Slow dissolved carbonaceous biochemical oxygen demand (CSB)
Fast dissolved carbonaceous biochemical oxygen demand (CFB)
Slow organic nitrogen (CSN)
Fast organic nitrogen (CFN)
Ammoniacal nitrogen (CAM)

Nitrate nitrogen (CON)
Dissolved oxygen (CDO)
Salinity (CS)
Temperature (TM)
Suspended solids (inert particulate) (CMUD)
Fast particulate biochemical oxygen demand (CFBMUD)
Slow particulate biochemical oxygen demand (CSBMUD)

The temperature is not modelled directly but is passed from the flow model.

The temperature in each element is used to determine the rates of reactions, and temperature and salinity to determine the saturation concentration of dissolved oxygen using Fox's equation. The suspended solids concentration is used to predict light extinction in the ecosystem part of the model.

The interactions between the water quality variables are as follows. Organic nitrogen hydrolyses to ammoniacal nitrogen. If there is an oxygen concentration of at least 5% of saturation ammoniacal nitrogen is oxidised to nitrate. Carbonaceous material (BOD) is oxidised using dissolved oxygen, however if the dissolved oxygen concentration is less than 5% of saturation then nitrate is utilised to provide the necessary oxygen. If there is no nitrate (or insufficient to satisfy all the demand) oxygen is obtained by the reduction of sulphates producing the malodorous gas hydrogen sulphide (the model keeps a log of oxygen obtained in this way as an indicator of anaerobic conditions). The particulate organic matter on the bed continues to oxidise exerting an oxygen demand on the water in the element above.

The use of two components of organic nitrogen and carbon is based on studies which have shown that the rate of oxidation of organic matter, in fresh and saline water, is best represented by a composite exponential. It is assumed that the organic matter being oxidised consists of several components which are oxidised independently at different rates. Studies by the Water Research Centre (WRc) have shown that the oxidation of a wide range of organic wastes can be adequately represented by the use of two rate constants, one being one fifth the value of the other, so that:

$$y = E_c\,[1 - ((1 - \rho)e^{-kt} + \rho e^{-kt/5})] \qquad (2)$$

where

- y is the uptake of oxygen in time t
- k is the standard (fast) rate constant
- ρ is the proportion of organic material considered to be oxidised at the slower rate
- E_c is the ultimate oxygen uptake, that is the amount of oxygen consumed during the total oxidation of the substance.

The usual BOD determination is over a period of five days so that the value obtained needs to be adjusted to give the ultimate demand. If B is the 5 day BOD at 20°C then E_c is defined as

$$E_c = \lambda B \qquad (3)$$

where

λ is a constant

The fast rate constant for carbonaceous material at 20°C is usually taken to be 0.23 per day.

Substituting y = B, t = 5 and k = 0.23 d^{-1} in equation (2) gives

$$\lambda = \frac{1}{0.69 - 0.48\rho} \qquad (4)$$

In the case of untreated settled sewage $\rho = 0$ so that the appropriate value of λ is 1.45. The rate constants for the reactions in the water quality part of the model are functions of water temperature and are prescribed by equations of the form

$$K_t = K_{20}\left(1 + \frac{\alpha}{100}\right)^{T-20} \qquad (5)$$

where

K_t	is the value of the constant at T°C
K_{20}	is the value of the constant at 20°C
α	is the temperature coefficient

The source-sink term associated with each reaction is of the form K.V.C.

where

K	is the first order decay rate (s^{-1})
V	is the element volume
C	is the concentration of substance

The reaction coefficients used in the study are given in Table 2. Nitrification of ammonia can only occur when the dissolved oxygen concentration is greater than 5% of the saturated value so the source-sink term has the form

$$\Sigma S = K_{FN} \cdot V \cdot C_{FN} + K_{SN} \cdot V \cdot C_{SN} - H_1(DO) \cdot K_{AM} \cdot V \cdot C_{AM} \qquad (6)$$

where

$H_1(DO) = 1$ if $DO \geq 5\%$
$H_1(DO) = 0$ if $DO \leq 5\%$

If there is insufficient dissolved oxygen to satisfy the carbonaceous oxygen demand then sufficient nitrate is reduced to satisfy the demand. The source-sink term for nitrate is of the form

$$\Sigma S = H_1(DO) \cdot K_{AM} \cdot V \cdot C_{AM} - D_H \tag{7}$$

where

D_H is the reduction of nitrates needed to satisfy the oxygen demand when dissolved oxygen levels are less than 5% saturation.

Dissolved oxygen is used in the oxidation of carbonaceous material and in the nitrification of ammonia and is added to the system through reaeration at the water surface.

The reaeration rate is

$$K_A = f\,\frac{A}{V}(1.016)^{T-20} \tag{8}$$

where

A is the plan area of the surface of the element
V is the element volume
f is the exchange coefficient for oxygen which has a value of the order of 0.05m/hr although this does vary with the wind speed.

A value of f is prescribed for each segment so that sheltered and exposed segments can be differentiated.

The source-sink term for dissolved oxygen is of the form

$$\Sigma S = K_A \cdot V \cdot DOD - H_2(DO) \cdot V \cdot (K_{FB} \cdot C_{FB} + K_{SB} \cdot C_{SB} + BD) - 4.57 \cdot H_1(DO) \cdot V \cdot K_{AM} \cdot C_{AM} \tag{9}$$

where

$H_2(DO)$ controls the consumption of dissolved oxygen in the oxidation of carbonaceous material.
BD is the benthal demand calculated as described in section 2.4
4.57 is the mass of oxygen consumed in the oxidation of a unit mass of ammonia
DOD is the deficit of dissolved oxygen, the amount of oxygen needed to fully saturate a unit mass of water

DOD = DOS - DO

DOS is the saturation concentration of oxygen (kg/m^3) as calculated from Fox's equation.

$$DOS = 0.00143\,[(10.291 - 0.2809T + 0.006009\,T^2 - 0.0000632T^3) - 0.607\,(0.1161 - 0.003922T + 0.0000631T^2)\,S] \qquad (10)$$

where

T	is the water temperature in °C
S	is the salinity (kg/m^3)

Ecosystem

A simple algal growth model is used which includes the effect of 7 substances, these are:

Algal carbon (AC)
Detrital carbon (DC)
Slow organic nitrogen (CSN)
Nitrate (CON)
Orthophosphate (CPH)
Silica (CSI)
Dissolved oxygen (CDO)

Nitrate, organic nitrogen and dissolved oxygen are the 'link substances' between the water quality and algal growth parts of the model. Concentrations of these substances (C^*) are calculated from water quality considerations and amended according to the algal growth to give C^+.

Primary production

Productivity is calculated from the temperature dependant maximum productivity for the species of phytoplankton considered. The maximum productivity is then modified to take account of the limiting effects of nutrient concentrations using Michaelis-Menten relationships.

$$PROD = P_{MAX}(T) \cdot \mu_1 \cdot \min(\mu_2, \mu_3, \mu_4) \qquad (11)$$

where

$P_{MAX}(T)$ is maximum productivity for species

$$P_{MAX}(T) = \exp\,(2.30259mT + c) \qquad (12)$$

(where m and c are constants)

μ_1 is limitation due to light intensity (I)

$$\mu_1 = \frac{e}{k_3(b_2 - b_1)}\left[\exp\left(-\frac{I}{I_m}e^{-k_3 b_2}\right) - \exp\left(-\frac{I}{I_m}e^{k_3 b_1}\right)\right] \qquad (13)$$

b_2 is the depth of bottom face of element from water surface (m)
b_1 is depth of top face of element from the water surface (m)
I_m is light intensity required for maximum productivity
k_3 is an equivalent extinction coefficient which takes account of turbidity in the overlying water
μ_2 is limitation due to nitrate concentration

$$\mu_2 = \frac{CON}{CON + MON} \tag{14}$$

μ_3 is limitation due to phosphate concentration

$$\mu_3 = \frac{CPH}{CPH + MPH} \tag{15}$$

μ_4 is limitation due to silica concentration

$$\mu_4 = \frac{CSI}{CSI + MSI} \tag{16}$$

MON, MPH, MSI are the nutrient concentrations which would permit 50% of maximum productivity.

Respiration

Losses due to respiration are calculated as a function of temperature as

$$RESP = RP_{10} \cdot Q_{10}^{\frac{T-10}{10}} \times AC \tag{17}$$

RP_{10} is the respiration rate at 10°C
Q_{10} is the rate of increase of respiration for a 10°C rise in temperature.

1. Mortality of algae

In the algal growth model mortality includes the losses due to grazing by zooplankton which is modelled explicitly by

$$INAK = Mp \bullet AC \tag{18}$$

Mp is the mortality of algae (day^{-1})

Decomposition

Detritus is considered to decay in a similar manner to BOD

$$DECC = KR \bullet DC \tag{19}$$

where

$$KR = K_{DC} \bullet (1 + \alpha_{DC})^{(T-20)} \tag{20}$$

K_{DC} and α_{DC} are constants

Settling of algae and detritus
As algae and detritus are particulate the model allows for settlement in the settling procedure. Particles either settle into a lower element and are then incorporated into the equations for that element or are deposited on the bed where a log is kept of the masses deposited. This calculation is performed before the ecosystem reactions are calculated.

Effect of ecosystem on water quality

From the processes described above, the resultant concentrations of algal growth parameters are:

$$AC_k^+ = AC_k^* + (PROD - INAK - RESP) \times VOLRAT \quad (21)$$

$$DC_k^+ = DC_k^* + (INAK - DECC) \times VOLRAT \quad (22)$$

$$CON_k^+ = CON_k^* + JNPN \bullet PROD \bullet VOLRAT \quad (23)$$

$$CSN_k^+ = CSN_k^* + JNPN \bullet DECC \bullet VOLRAT \quad (24)$$

$$CPH_k^+ = CPH_k^* + JNPP\,(DECC - PROD) \times VOLRAT \quad (25)$$

$$CSI_k^+ = CSI_k^* + JNPS\,(DECC - PROD) \times VOLRAT \quad (26)$$

$$CDO_k^+ = CDO_k^* + 2.67\,(PRODD\text{-}DECC\text{-}RESP) \times VOLRAT \quad (27)$$

where JNPN, JNPP, JNPS are the nutrient to carbon ratios in the algae for the relevant nutrient and 2.67 is the carbon to oxygen conversion factor.

$$VOLRAT = \frac{V_k^-}{V_k^+}$$

Coliforms

It is possible to include an indication of coliform distribution in the system. A more accurate assessment is impossible because the elements are large, the advective and dispersive discharges relatively small and the mortality rate of coliforms high. As with other substances the concentration of coliforms due to advection/dispersion is calculated and this concentration CF* amended to allow for mortality.

$$CF_k^+ = CF_k^* - MORT \times VOLRAT \quad (28)$$

$$MORT = M_{CF} \times CF_k^-$$

M_{CF} is mortality of coliforms (day^{-1})

Benthal demand

Both particulate BOD and detrital material settling onto the bed exhibit an oxygen demand. The rate of decay of material on the bed is taken to be similar to its rate in suspension, thus the total benthal demand is:

$$BD = 2.67 \bullet KR \bullet (SETDC+SETAC) + K_{FB}\,SETFBOD + K_{SB}\,SETSBOD \quad (29)$$

where

SETDC, SETAC, SETFBOD, SETSBOD are the total amounts of settled detrital carbon, algal carbon, fast BOD and slow BOD respectively.

The amount of material on the bed is then decayed so:

$$SETDC^{+} = (1 - KR)\,SETDC \qquad (30)$$
$$SETAC^{+} = (1 - KR)\,SETAC \qquad (31)$$
$$SETFBOD^{+} = (1 - K_{FB})\,SETFBOD \qquad (32)$$
$$SETSBOD^{+} = (1 - K_{SB})\,SETSBOD \qquad (33)$$

Light penetration

The calculated concentrations of particulate are used to calculate the penetration of light into the water column. This is done by calculating the extinction coefficient, k_3, within each element of the model as a function of the concentrations of suspended mud and algae.

$$k_3 = 1.7\,(0.025(CMUD + CFBMUD + CSBMUD) + 0.04) + 0.85\,(AC + DC) \qquad (33)$$

where CMUD, CFBMUD, CSBMUD are the concentrations of mud, fast particulate BOD and slow particulate BOD (mg/l).

AC, DC are the concentrations of algal and detrital carbon (mg/l).

The constant of proportionality relating the light extinction coefficient to the suspended solids was based on empirical relationships derived by IMER for the Bristol Channel.

Effluent loadings

In addition to the transport processes modelled by the transport equations it is necessary to take account of the initial vertical mixing. In stratified conditions, where vertical mixing is inhibited, an effluent loading discharging near the bed will tend to remain in the lower layers. The level at which an outfall loading is exerted is determined using a simple model of the initial spreading of a buoyant plume. This is described in Appendix B.

Solution procedure

The equations described above are solved using the following procedure.

(i) Solve transport equations taking account of loading of dissolved substances
(ii) Calculate the settling of particulate substances and the resultant benthal demand
(iii) Amend concentrations to take account of particulate loadings
(iv) Calculate the reactions and amend concentrations.

The above steps are repeated for each model timestep.

TABLE A14-1

TYPICAL WET SEASON CONDITIONS: MUTONGA RESERVOIR

TYPICAL WET SEASON CONDITIONS IN MUTONGA RESERVOIR

SETTLED MUD (T) Typical wet season conditions

7	6	5	4	3	2	1
0.	0.	0.	0.1729E-04	0.3118E-05	0.2174E-03	254.5
0.	0.	0.	0.4952E-05	0.1124E-05	0.1304E-03	339.4
0.	0.	0.	0.1039E-05	0.1106E-05	0.6649E-04	71.58
0.	0.	0.	0.1463E-06	0.1170E-05	0.3293E-04	42.32
0.	0.	0.	0.	545.1	0.1439E-04	0.1762
0.	0.	0.	0.	701.4	565.5	624.6
0.	0.	0.	0.1432E-06	1087.	968.9	1077.
0.	0.	0.	0.	0.	2.238	851.9
0.	0.	0.	0.	0.	0.	893.4

BEDLOAD G/M2/DAY Typical wet season conditions

7	6	5	4	3	2	1
0.1631E-01	0.3696E-01	0.2804	0.6541	0.9955	1.152	1.005
0.2779E-01	0.6070E-01	0.2941	0.5324	0.8101	1.204	1.112
0.4195E-01	0.8465E-01	0.3016	0.5639	0.8016	1.243	1.215
0.6059E-01	0.1076	0.3060	0.5511	0.7769	1.241	1.256
0.1008	0.1350	0.3525	0.5607	0.7979	1.248	1.317
0.	0.	0.3522	0.5789	0.7982	1.270	1.320
0.	0.	0.4674	0.5826	0.8400	1.274	1.404
0.	0.	0.	0.	1.114	1.437	1.405
0.	0.	0.	0.	0.	0.	1.413

BED DETRITUS MGS Typical wet season conditions

7	6	5	4	3	2	1
0.3480E+06	0.9778E+07	0.2524E+09	0.6516E+09	0.1146E+10	0.1690E+10	0.9909E+09
0.1189E+07	0.1796E+08	0.2928E+09	0.6108E+09	0.1112E+10	0.1944E+10	0.1197E+10
0.2246E+07	0.2629E+08	0.3051E+09	0.6356E+09	0.1100E+10	0.2045E+10	0.1319E+10
0.3607E+07	0.3439E+08	0.3093E+09	0.6270E+09	0.1075E+10	0.2038E+10	0.1355E+10
0.5354E+08	0.2315E+09	0.3608E+09	0.6400E+09	0.1118E+10	0.2088E+10	0.1453E+10
0.	0.	0.3202E+09	0.5391E+09	0.1379E+10	0.2073E+10	0.2364E+10
0.	0.	0.8907E+09	0.2163E+10	0.2190E+10	0.3120E+10	0.3816E+10
0.	0.	0.	0.	0.4347E+10	0.3511E+10	0.3017E+10
0.	0.	0.	0.	0.	0.	0.3184E+10

FAST DIS.BOD PPM Typical wet season conditions

7	6	5	4	3	2	1
1.242	1.187	0.9205	0.6336	0.4783	0.4423	0.5116
1.236	1.166	0.9391	0.6115	0.4440	0.4116	0.4571
1.213	1.145	0.8708	0.5554	0.3829	0.3678	0.4104
1.208	1.117	0.9794	0.5503	0.3355	0.3332	0.3811
1.127	1.051	0.7774	0.4030	0.2367	0.2715	0.3609
0.	0.	0.7769	0.4117	0.2368	0.2723	0.3620
0.	0.	0.4864	0.4051	0.2290	0.2731	0.4880
0.	0.	0.	0.	0.1776	0.3101	0.4884
0.	0.	0.	0.	0.	0.	0.4864

SLOW DIS.BOD PPM Typical wet season conditions

7	6	5	4	3	2	1
1.248	1.239	1.168	1.065	0.9959	1.036	1.097
1.247	1.234	1.177	1.050	0.9712	1.007	1.052
1.242	1.231	1.153	1.018	0.9310	0.9767	1.016
1.242	1.222	1.193	1.010	0.8929	0.9402	0.9855
1.224	1.210	1.127	0.9454	0.8421	0.8987	0.9762
0.	0.	1.127	0.9478	0.8422	0.9021	0.9771
0.	0.	0.9907	0.9448	0.8410	0.9029	1.082
0.	0.	0.	0.	0.8362	0.9541	1.083
0.	0.	0.	0.	0.	0.	1.082

TYPICAL WET SEASON CONDITIONS IN MUTONGA RESERVOIR

AMMONIA PPM Typical wet season conditions

7	6	5	4	3	2	1
0.4182E-07	-.8221E-06	0.5904E-05	0.3583E-04	0.5921E-04	0.1272E-03	0.1398E-03
-.1232E-06	-.5508E-06	0.2525E-05	0.5034E-04	0.7985E-04	0.1308E-03	0.1503E-03
0.1331E-06	-.1945E-05	0.9795E-05	0.7691E-04	0.1219E-03	0.1708E-03	0.1826E-03
-.1282E-06	0.8064E-06	-.4013E-05	0.9583E-04	0.1756E-03	0.1631E-03	0.1592E-03
0.3425E-06	-.2578E-05	0.1424E-04	0.1362E-03	0.2629E-03	0.2678E-03	0.2558E-03
0.	0.	0.1428E-04	0.1397E-03	0.2629E-03	0.2879E-03	0.2562E-03
0.	0.	0.9682E-04	0.1419E-03	0.2942E-03	0.2886E-03	0.2273E-03
0.	0.	0.	0.	0.4933E-03	0.3429E-03	0.2272E-03
0.	0.	0.	0.	0.	0.	0.2278E-03

NITRATE PPM Typical wet season conditions

7	6	5	4	3	2	1
0.2501	0.2530	0.2163	0.1568	0.7398E-01	0.2111	0.3672
0.2500	0.2511	0.2440	0.2762	0.2680	0.3594	0.4698
0.2500	0.2500	0.2495	0.2644	0.2656	0.3948	0.4682
0.2497	0.2504	0.2468	0.2917	0.3154	0.3539	0.4075
0.2498	0.2493	0.2529	0.3050	0.3858	0.4584	0.5382
0.	0.	0.2530	0.3105	0.3858	0.4918	0.5399
0.	0.	0.2868	0.3117	0.4223	0.4938	0.6324
0.	0.	0.	0.	0.6600	0.6220	0.6328
0.	0.	0.	0.	0.	0.	0.6328

DIS.OXYGEN %SAT Typical wet season conditions

7	6	5	4	3	2	1
97.22	96.38	99.42	103.6	110.3	115.4	108.9
97.16	96.01	93.98	82.88	78.64	87.30	85.39
96.81	95.88	91.72	85.49	81.47	83.72	84.27
96.84	95.46	93.85	82.47	76.44	80.76	82.47
95.54	94.20	89.63	79.96	73.85	75.62	78.58
0.	0.	89.62	79.66	73.85	75.05	78.59
0.	0.	82.06	79.45	72.76	75.03	82.13
0.	0.	0.	0.	66.94	74.49	82.14
0.	0.	0.	0.	0.	0.	82.00

DO CONC PPM Typical wet season conditions

7	6	5	4	3	2	1
8.392	8.320	8.582	8.943	9.510	10.06	9.559
8.387	8.288	8.113	7.158	6.787	7.603	7.476
8.357	8.276	7.919	7.390	7.043	7.301	7.380
8.359	8.240	8.101	7.135	6.623	7.020	7.192
8.247	8.131	7.739	6.927	6.428	6.612	6.903
0.	0.	7.738	6.902	6.428	6.574	6.905
0.	0.	7.100	6.884	6.347	6.574	7.255
0.	0.	0.	0.	5.923	6.576	7.257
0.	0.	0.	0.	0.	0.	7.244

TEMPERATURE DEGC Typical wet season conditions

7	6	5	4	3	2	1
25.00	25.00	25.00	25.00	25.06	24.35	23.98
25.00	25.00	25.00	24.97	25.01	24.47	24.14
25.00	25.00	24.99	24.91	24.91	24.38	24.13
25.00	25.00	25.01	24.86	24.78	24.58	24.38
25.00	25.00	24.99	24.79	24.50	24.22	23.94
0.	0.	24.99	24.77	24.49	24.11	23.93
0.	0.	24.86	24.77	24.36	24.10	23.60
0.	0.	0.	0.	23.50	23.64	23.60
0.	0.	0.	0.	0.	0.	23.60

TYPICAL WET SEASON CONDITIONS IN MUTONGA RESERVOIR

INERT S.SOL. PPM Typical wet season conditions

7	6	5	4	3	2	1
64.28	58.01	47.20	40.61	32.99	32.81	41.96
59.39	60.24	56.14	61.84	57.88	49.99	56.48
60.11	60.67	61.45	68.34	68.90	59.72	63.15
59.00	59.82	58.25	69.94	73.76	64.97	65.64
62.10	68.12	65.80	76.02	77.00	73.57	73.52
0.	0.	65.80	75.76	77.01	74.98	73.57
0.	0.	73.95	76.09	79.09	75.05	74.57
0.	0.	0.	0.	95.19	82.72	74.57
0.	0.	0.	0.	0.	0.	74.57

CHLOROPHYLL PPB Typical wet season conditions

7	6	5	4	3	2	1
0.9868	0.7582	3.543	7.465	11.07	12.81	10.17
0.9785	0.8516	1.187	-.3389	0.1151E-02	3.198	2.258
0.9681	0.8793	0.7955	0.6612	0.3953	1.665	1.660
0.9814	0.8741	0.8055	0.3080	0.1704	0.9457	1.192
0.9021	0.8083	0.5855	0.3341	0.2478	0.6540	1.070
0.	0.	0.5851	0.3107	0.2479	0.6514	1.074
0.	0.	0.3527	0.3055	0.2719	0.6557	1.598
0.	0.	0.	0.	0.4666	0.8949	1.600
0.	0.	0.	0.	0.	0.	1.589

ALGAL CARBON PPB Typical wet season conditions

7	6	5	4	3	2	1
49.34	37.91	177.2	373.3	553.3	640.3	508.5
48.92	42.58	59.34	-16.95	0.5753E-01	159.9	112.9
48.40	43.97	39.78	33.06	19.76	83.23	83.02
49.07	43.71	40.27	15.40	8.519	47.28	59.62
45.11	40.42	29.28	16.71	12.39	32.70	53.48
0.	0.	29.25	15.54	12.40	32.57	53.71
0.	0.	17.63	15.28	13.60	32.78	79.88
0.	0.	0.	0.	23.33	44.74	79.98
0.	0.	0.	0.	0.	0.	79.44

DETRITAL CAR PPB Typical wet season conditions

7	6	5	4	3	2	1
0.2602	1.276	11.77	27.34	40.95	46.76	41.00
0.7425	2.363	12.98	24.43	36.70	52.67	48.48
1.373	3.403	12.95	24.30	34.85	53.83	52.40
2.219	4.400	12.85	23.65	33.50	53.51	54.10
4.029	5.577	14.94	24.17	34.67	54.06	57.13
0.	0.	14.98	25.13	34.70	55.34	57.33
0.	0.	20.21	25.31	36.65	55.54	60.92
0.	0.	0.	0.	48.69	62.71	60.96
0.	0.	0.	0.	0.	0.	61.31

PHOSPHATE PPM Typical wet season conditions

7	6	5	4	3	2	1
0.5001E-01	0.5045E-01	0.4496E-01	0.3627E-01	0.2736E-01	0.7691E-02	0.9882E-02
0.5001E-01	0.5015E-01	0.4918E-01	0.5223E-01	0.5358E-01	0.3644E-01	0.3452E-01
0.4999E-01	0.5006E-01	0.4960E-01	0.4740E-01	0.4720E-01	0.3687E-01	0.3361E-01
0.4997E-01	0.4998E-01	0.4995E-01	0.4864E-01	0.4752E-01	0.4179E-01	0.3888E-01
0.4996E-01	0.5003E-01	0.4972E-01	0.4624E-01	0.4200E-01	0.3742E-01	0.3315E-01
0.	0.	0.4972E-01	0.4641E-01	0.4199E-01	0.3587E-01	0.3306E-01
0.	0.	0.4779E-01	0.4634E-01	0.4009E-01	0.3577E-01	0.2815E-01
0.	0.	0.	0.	0.2698E-01	0.2889E-01	0.2813E-01
0.	0.	0.	0.	0.	0.	0.2814E-01

TYPICAL WET SEASON CONDITIONS IN MUTONGA RESERVOIR

U-VELOCITY east-west (m/s)

8
-.2882E-01
-.2405E-01
-.1559E-01
-.1070E-01
0.5740E-02
0.1954E-01
0.6242E-01
0.8139E-01
0.

7	6	5	4	3	2	1
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.1667
0.	0.	0.	0.	0.	0.	0.

V-VELOCITY north-south (m/s)

8
0.
0.
0.
0.
0.
0.
0.
0.
0.

7	6	5	4	3	2	1
0.	0.1561	0.2029	0.5100E-01	0.4899E-01	0.7051E-01	0.9456E-03
0.	0.1687	0.1926	0.5204E-01	0.4242E-01	0.6635E-01	0.9277E-02
0.	0.1765	0.1775	0.5092E-01	0.3641E-01	0.4825E-01	0.2103E-01
0.	0.1626	0.1661	0.4910E-01	0.2708E-01	0.4439E-01	0.2271E-01
0.	0.1334	0.1418	0.4528E-01	0.1856E-01	0.2517E-01	0.2549E-01
0.	0.	0.	0.4491E-01	0.1572E-01	0.1926E-01	0.1864E-01
0.	0.	0.	0.2107E-01	0.3539E-02	0.6559E-02	0.2320E-02
0.	0.	0.	0.	0.	-.2079E-01	-.1276E-01
0.	0.	0.	0.	0.	0.	0.

VERTICAL VELOCITY down: -ve (m/s)

8
-.1415E-03
-.2042E-03
-.2822E-03
-.4030E-03
-.6159E-03
-.7914E-03
-.1302E-02
0.
0.

7	6	5	4	3	2	1
-.7207E-03	-.1029E-04	-.1084E-04	0.1060E-04	0.1788E-06	-.1489E-04	0.7663E-05
-.5252E-03	-.9609E-05	-.2417E-04	0.1979E-04	0.2553E-05	-.2818E-04	0.9950E-05
-.3386E-03	-.9723E-05	-.3947E-04	0.2809E-04	0.3009E-05	-.2681E-04	-.2477E-05
-.1578E-03	-.7691E-05	-.6019E-04	0.3317E-04	0.6782E-05	-.2414E-04	-.1864E-04
0.	0.	-.9229E-04	0.3622E-04	0.9060E-05	-.1304E-04	-.4338E-04
0.	0.	-.6485E-04	0.2839E-04	0.1242E-04	0.5956E-06	-.9157E-04
0.	0.	0.	0.	0.2263E-04	-.3115E-05	-.2271E-03
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.

TYPICAL WET SEASON CONDITIONS IN MUTONGA RESERVOIR

X-DISCHARGES east-west (cumec)

8
-24.64
-18.33
-10.51
-6.281
2.669
13.29
48.69
65.12
0.

7	6	5	4	3	2	1
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	200.0
0.	0.	0.	0.	0.	0.	0.

Y-DISCHARGES north-south (cumec)

8
0.
0.
0.
0.
0.
0.
0.
0.
0.

7	6	5	4	3	2	1
0.	39.84	35.24	23.51	38.53	38.90	9.590
0.	30.37	31.20	20.66	30.20	34.57	15.46
0.	25.07	25.55	17.82	23.19	23.40	32.48
0.	20.32	21.43	15.37	14.95	19.71	29.68
0.	14.40	16.59	12.22	8.576	9.915	26.68
0.	0.	0.	21.29	11.63	12.48	25.50
0.	0.	0.	19.12	2.920	3.818	2.276
0.	0.	0.	0.	0.	-12.79	-11.67
0.	0.	0.	0.	0.	0.	0.

Z-DISCHARGES down: -ve (cumec)

8
-94.64
-113.0
-123.5
-129.8
-127.1
-113.8
-65.12
0.
0.

7	6	5	4	3	2	1
-90.16	-4.603	-11.72	15.01	0.3696	-29.31	15.05
-59.79	-3.776	-22.26	24.56	4.737	-48.41	17.92
-34.72	-3.292	-29.99	29.92	4.943	-39.33	-4.055
-14.40	-2.186	-36.05	29.50	9.704	-29.36	-27.46
0.	0.	-40.41	25.86	11.04	-12.59	-56.81
0.	0.	-19.12	16.20	11.89	0.4300	-95.60
0.	0.	0.	0.	12.79	-1.112	-146.6
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.

TYPICAL WET SEASON CONDITIONS IN MUTONGA RESERVOIR

VOLUMES m3

8
0.1453E+07
0.1222E+07
0.9908E+06
0.7595E+06
0.5283E+06
0.7003E+06
0.5814E+06
0.3000E+06
0.

7	6	5	4	3	2	1
0.2621E+06	0.9506E+06	0.2327E+07	0.3011E+07	0.4340E+07	0.4189E+07	0.4092E+07
0.2390E+06	0.8404E+06	0.2003E+07	0.2657E+07	0.3922E+07	0.3686E+07	0.3765E+07
0.2164E+06	0.7316E+06	0.1681E+07	0.2306E+07	0.3498E+07	0.3185E+07	0.3438E+07
0.1938E+06	0.6229E+06	0.1359E+07	0.1955E+07	0.3074E+07	0.2683E+07	0.3110E+07
0.1713E+06	0.5141E+06	0.1037E+07	0.1603E+07	0.2650E+07	0.2181E+07	0.2783E+07
0.	0.	0.1465E+07	0.2569E+07	0.4352E+07	0.3375E+07	0.4707E+07
0.	0.	0.2064E+07	0.3190E+07	0.4567E+07	0.3237E+07	0.5068E+07
0.	0.	0.	0.	0.5043E+07	0.3333E+07	0.4879E+07
0.	0.	0.	0.	0.	0.	0.8883E+06

X-1D-DISCHARGES (cumec)

8
70.00

7	6	5	4	3	2	1
0.	0.	0.	0.	0.	0.	200.0

Y-1D-DISCHARGES (cumec)

8
0.

7	6	5	4	3	2	1
0.	130.0	130.0	130.0	130.0	130.0	130.0

LATERAL INFLOWS (cumec)

8
70.00

7	6	5	4	3	2	1
130.0	0.	0.	0.	0.	0.	0.

Table A14-2

Typicval Wet Season Conditions:
Low Grand Falls Reservoir

TYPICAL WET SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 100

SETTLED MUD (T)

19	18	17
21.57	34.54	122.9
106.0	84.47	108.0
250.9	190.6	231.6
622.1	473.3	1040.
743.1	1243.	0.
117.0	239.3	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
0.	0.	0.1169E-02	304.0	186.1	129.4	65.34	0.	8.676	117.6	442.5
0.	0.	0.6361E-03	407.3	349.7	273.4	187.9	27.98	55.48	226.2	179.4
0.	0.	0.1921E-03	754.7	704.4	622.0	454.0	66.72	124.5	420.1	246.5
0.	0.	0.9969E-04	1139.	1206.	1284.	1032.	165.0	310.4	976.9	579.9
0.	0.	201.2	2117.	2481.	2763.	2458.	1011.	1480.	1250.	0.
0.	0.	0.	0.	3466.	4684.	2596.	2030.	1301.	253.3	0.
0.	0.	0.	0.	0.	0.	0.	2611.	282.0	0.	0.
0.	0.	0.	0.	0.	0.	0.	175.9	0.	0.	0.

5	4	3
0.	2.352	51.48
0.	37.08	103.0
0.	90.79	244.1
0.	243.1	639.9
0.	916.4	890.9
0.	1082.	388.5
0.	1377.	0.
0.	296.4	0.

2	1	20
8.087	27.97	0.
15.12	48.49	0.
37.49	119.6	0.
106.2	329.7	0.
310.0	400.2	0.
416.0	224.5	0.
678.2	89.48	676.2
183.4	0.	183.3

TYPICAL WET SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 100

BEDLOAD G/M2/DAY

19	18	17
0.8559E-01	0.7664E-01	0.7118E-01
0.2076	0.1875	0.1750
0.2514	0.2291	0.2182
0.2774	0.2556	0.2526
0.2845	0.2678	0.
0.2884	0.2737	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
0.3522E-01	0.2285	0.4100	0.3803	0.2946	0.1790	0.1293	0.	0.7788E-01	0.7373E-01	0.9231E-01
0.5687E-01	0.2736	0.4574	0.4550	0.4116	0.3314	0.2793	0.2186	0.1896	0.1653	0.1359
0.1003	0.3270	0.4765	0.4674	0.4265	0.3560	0.3144	0.2601	0.2341	0.2110	0.1745
0.1990	0.3837	0.4275	0.4084	0.3789	0.3361	0.3135	0.2794	0.2624	0.2486	0.2067
0.	0.3864	0.4185	0.4016	0.3730	0.3304	0.3130	0.2866	0.2730	0.2612	0.
0.	0.	0.	0.3938	0.3678	0.3241	0.3079	0.2899	0.2791	0.2672	0.
0.	0.	0.	0.	0.	0.	0.3023	0.2901	0.2799	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.2871	0.	0.	0.

5	4	3
0.8669E-01	0.7792E-01	0.7387E-01
0.2092	0.1955	0.1864
0.2587	0.2467	0.2368
0.2789	0.2721	0.2658
0.2856	0.2803	0.2776
0.	0.2835	0.2822
0.	0.2835	0.
0.	0.2816	0.

2	1	20
0.7065E-01	0.6821E-01	0.6419E-01
0.1832	0.1777	0.1710
0.2405	0.2340	0.2348
0.2688	0.2641	0.2662
0.2782	0.2759	0.2776
0.2814	0.2801	0.2786
0.2818	0.2808	0.2796
0.2792	0.	0.2787

TYPICAL WET SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 100

BED DETRITUS MGS

19	18	17
0.4113E+08	0.5137E+08	0.1401E+09
0.2706E+09	0.1890E+09	0.2136E+09
0.5202E+09	0.3665E+09	0.4227E+09
0.9689E+09	0.6907E+09	0.1503E+10
0.1182E+10	0.1886E+10	0.
0.1883E+09	0.3700E+09	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
0.6147E+07	0.2875E+09	0.1122E+10	0.8547E+09	0.6086E+09	0.4192E+09	0.1879E+09	0.	0.1291E+08	0.9710E+08	0.1771E+09
0.1408E+08	0.2218E+09	0.1329E+10	0.9131E+09	0.9337E+09	0.8500E+09	0.5875E+09	0.7567E+08	0.1250E+09	0.3481E+09	0.1277E+09
0.4488E+08	0.4057E+09	0.2118E+10	0.1444E+10	0.1504E+10	0.1441E+10	0.1048E+10	0.1428E+09	0.2444E+09	0.7004E+09	0.2511E+09
0.1870E+09	0.8186E+09	0.3193E+10	0.2117E+10	0.2242E+10	0.2288E+10	0.1762E+10	0.2589E+09	0.4636E+09	0.1398E+10	0.6993E+09
0.	0.1539E+10	0.7041E+10	0.3889E+10	0.4561E+10	0.4831E+10	0.4168E+10	0.1617E+10	0.2281E+10	0.1861E+10	0.
0.	0.	0.	0.4042E+10	0.6353E+10	0.8106E+10	0.4356E+10	0.3279E+10	0.2042E+10	0.3845E+09	0.
0.	0.	0.	0.	0.	0.	0.3927E+10	0.4224E+10	0.4450E+09	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.2838E+09	0.	0.	0.

5	4	3
0.6860E+08	0.4784E+07	0.8876E+08
0.9963E+08	0.1008E+09	0.2531E+09
0.1952E+09	0.2012E+09	0.5092E+09
0.3568E+09	0.3763E+09	0.9684E+09
0.4321E+08	0.1447E+10	0.1396E+10
0.	0.1725E+10	0.6173E+09
0.	0.2198E+10	0.
0.	0.4731E+09	0.

2	1	20
0.1619E+08	0.5140E+08	0.1467E+08
0.4163E+08	0.1250E+09	0.3870E+08
0.8627E+08	0.2604E+09	0.8385E+08
0.1639E+09	0.4987E+09	0.1622E+09
0.4879E+09	0.6256E+09	0.4867E+09
0.6603E+09	0.3553E+09	0.6538E+09
0.1079E+10	0.1421E+09	0.1070E+10
0.2915E+09	0.	0.2910E+09

TYPICAL WET SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 100

FAST DIS.BOD PPM

19	18	17
0.5099E-01	0.6486E-01	0.8497E-01
0.3431E-01	0.4242E-01	0.5130E-01
0.3067E-01	0.3539E-01	0.3850E-01
0.9723E-02	0.1109E-01	0.1127E-01
0.9704E-02	0.1052E-01	0.
0.8956E-02	0.9428E-02	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
0.4885	0.3669	0.1538	0.1074	0.7141E-01	0.4703E-01	0.4223E-01	0.4825E-01	0.6710E-01	0.1341	0.3995
0.4718	0.3525	0.1451	0.9729E-01	0.6342E-01	0.3916E-01	0.3288E-01	0.3383E-01	0.4606E-01	0.9219E-01	0.2700
0.4797	0.3599	0.1356	0.8968E-01	0.5945E-01	0.3828E-01	0.3274E-01	0.3102E-01	0.3803E-01	0.6436E-01	0.1785
0.3681	0.1444	0.4524E-01	0.2833E-01	0.1908E-01	0.1292E-01	0.1128E-01	0.9979E-02	0.1175E-01	0.1940E-01	0.1082
0.	0.1420	0.4357E-01	0.2817E-01	0.1890E-01	0.1256E-01	0.1105E-01	0.9788E-02	0.1067E-01	0.1401E-01	0.
0.	0.	0.	0.2290E-01	0.1779E-01	0.1148E-01	0.9897E-02	0.9003E-02	0.9416E-02	0.1146E-01	0.
0.	0.	0.	0.	0.	0.	0.9234E-02	0.8617E-02	0.8498E-02	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.7850E-02	0.	0.	0.

5	4	3
0.4285E-01	0.4383E-01	0.5135E-01
0.3105E-01	0.3080E-01	0.3500E-01
0.3001E-01	0.2927E-01	0.3081E-01
0.1009E-01	0.9526E-02	0.9499E-02
0.9552E-02	0.9242E-02	0.9201E-02
0.	0.8674E-02	0.8608E-02
0.	0.8399E-02	0.
0.	0.7487E-02	0.

2	1	20
0.4148E-01	0.4375E-01	0.4062E-01
0.2910E-01	0.3002E-01	0.2866E-01
0.2851E-01	0.2814E-01	0.2886E-01
0.9414E-02	0.9053E-02	0.9850E-02
0.9010E-02	0.8900E-02	0.8770E-02
0.8583E-02	0.8464E-02	0.8639E-02
0.8411E-02	0.8174E-02	0.8529E-02
0.7211E-02	0.	0.7150E-02

TYPICAL WET SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR

DAY 100

SLOW DIS.BOD PPM

19	18	17
0.3935	0.4012	0.4171
0.3344	0.3368	0.3437
0.3525	0.3496	0.3496
0.1637	0.1648	0.1649
0.1646	0.1648	0.
0.1625	0.1622	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
1.086	0.9766	0.6877	0.6060	0.5243	0.4461	0.4151	0.3960	0.4046	0.4593	0.6672
1.058	0.9373	0.6467	0.5582	0.4772	0.3967	0.3633	0.3380	0.3416	0.3840	0.5443
1.098	0.9989	0.6341	0.5419	0.4682	0.4052	0.3819	0.3573	0.3554	0.3734	0.4487
0.9117	0.4918	0.2651	0.2219	0.1957	0.1775	0.1721	0.1652	0.1677	0.1824	0.3355
0.	0.4866	0.2607	0.2213	0.1951	0.1755	0.1703	0.1652	0.1657	0.1719	0.
0.	0.	0.	0.2078	0.1921	0.1717	0.1662	0.1628	0.1627	0.1663	0.
0.	0.	0.	0.	0.	0.	0.1638	0.1616	0.1597	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.1586	0.	0.	0.

5	4	3
0.3946	0.3878	0.3895
0.3349	0.3272	0.3283
0.3638	0.3572	0.3515
0.1698	0.1662	0.1639
0.1653	0.1641	0.1637
0.	0.1621	0.1618
0.	0.1612	0.
0.	0.1574	0.

2	1	20
0.3837	0.3818	0.3844
0.3210	0.3204	0.3180
0.3590	0.3515	0.3659
0.1677	0.1643	0.1738
0.1638	0.1633	0.1636
0.1620	0.1616	0.1628
0.1615	0.1605	0.1623
0.1563	0.	0.1561

TYPICAL WET SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 100

AMMONIA PPM

19	18	17
0.1240E-03	0.1250E-03	0.1264E-03
0.2050E-03	0.2033E-03	0.2018E-03
0.2207E-03	0.2207E-03	0.2207E-03
0.3137E-03	0.3126E-03	0.3126E-03
0.3133E-03	0.3127E-03	0.
0.3141E-03	0.3138E-03	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
-.3289E-05	0.1458E-04	0.8039E-04	0.9701E-04	0.1106E-03	0.1173E-03	0.1191E-03	0.1219E-03	0.1234E-03	0.1281E-03	0.1466E-03
0.6325E-05	0.3672E-04	0.1320E-03	0.1596E-03	0.1820E-03	0.1965E-03	0.2002E-03	0.2028E-03	0.2006E-03	0.1931E-03	0.1747E-03
-.1037E-04	0.1366E-04	0.1404E-03	0.1716E-03	0.1948E-03	0.2102E-03	0.2143E-03	0.2185E-03	0.2181E-03	0.2134E-03	0.2027E-03
0.5219E-04	0.1989E-03	0.2811E-03	0.2963E-03	0.3050E-03	0.3102E-03	0.3115E-03	0.3130E-03	0.3115E-03	0.3053E-03	0.2456E-03
0.	0.2007E-03	0.2826E-03	0.2965E-03	0.3052E-03	0.3109E-03	0.3122E-03	0.3131E-03	0.3125E-03	0.3097E-03	0.
0.	0.	0.	0.3015E-03	0.3063E-03	0.3122E-03	0.3135E-03	0.3140E-03	0.3137E-03	0.3119E-03	0.
0.	0.	0.	0.	0.	0.	0.3142E-03	0.3144E-03	0.3147E-03	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.3152E-03	0.	0.	0.

5	4	3
0.1168E-03	0.1178E-03	0.1212E-03
0.1970E-03	0.1985E-03	0.2011E-03
0.2121E-03	0.2134E-03	0.2171E-03
0.3106E-03	0.3119E-03	0.3130E-03
0.3129E-03	0.3131E-03	0.3132E-03
0.	0.3139E-03	0.3140E-03
0.	0.3141E-03	0.
0.	0.3153E-03	0.

2	1	20
0.1152E-03	0.1181E-03	0.1108E-03
0.1957E-03	0.1987E-03	0.1902E-03
0.2093E-03	0.2142E-03	0.2022E-03
0.3108E-03	0.3124E-03	0.3073E-03
0.3130E-03	0.3131E-03	0.3129E-03
0.3137E-03	0.3139E-03	0.3132E-03
0.3139E-03	0.3142E-03	0.3135E-03
0.3155E-03	0.	0.3155E-03

TYPICAL WET SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 100

NITRATE PPM

19	18	17
0.5171	0.5245	0.5325
0.4820	0.4862	0.4912
0.5765	0.5750	0.5748
0.4907	0.4914	0.4914
0.4911	0.4914	0.
0.4906	0.4907	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
0.6312	0.5936	0.5056	0.4918	0.4888	0.4960	0.5035	0.5150	0.5251	0.5480	0.6190
0.6262	0.6050	0.5599	0.5391	0.5160	0.4874	0.4787	0.4795	0.4855	0.5080	0.5863
0.6342	0.6379	0.6135	0.6050	0.5962	0.5853	0.5806	0.5761	0.5743	0.5733	0.5704
0.6077	0.5456	0.5079	0.5006	0.4961	0.4935	0.4927	0.4913	0.4923	0.4970	0.5398
0.	0.5447	0.5072	0.5005	0.4961	0.4928	0.4920	0.4913	0.4917	0.4937	0.
0.	0.	0.	0.4982	0.4955	0.4920	0.4911	0.4907	0.4908	0.4921	0.
0.	0.	0.	0.	0.	0.	0.4907	0.4904	0.4901	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.4898	0.	0.	0.

5	4	3
0.5148	0.5180	0.5208
0.4712	0.4721	0.4781
0.5728	0.5726	0.5734
0.4933	0.4921	0.4912
0.4915	0.4913	0.4912
0.	0.4907	0.4907
0.	0.4905	0.
0.	0.4896	0.

2	1	20
0.5204	0.5203	0.5235
0.4677	0.4720	0.4614
0.5707	0.5713	0.5676
0.4929	0.4916	0.4953
0.4914	0.4912	0.4914
0.4908	0.4907	0.4912
0.4907	0.4904	0.4910
0.4894	0.	0.4893

TYPICAL WET SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 100

DIS.OXYGEN %SAT

							19	18	17	
							99.43	99.14	98.80	
							93.50	93.48	93.33	
							85.51	85.71	85.69	
							70.96	71.15	71.15	
							71.00	71.12	0.	
							70.87	70.91	0.	
							0.	0.	0.	
							0.	0.	0.	
16	15	14	13	12	11	10	9	8	7	6
84.54	91.57	100.8	101.8	101.5	100.8	100.3	99.65	99.21	98.07	93.23
83.97	83.86	84.38	86.07	88.56	92.28	93.54	93.79	93.78	93.20	90.63
84.70	84.39	81.81	81.98	82.68	84.43	85.29	85.85	86.19	86.69	86.93
81.46	74.79	71.42	70.98	70.82	70.94	71.02	71.07	71.33	72.22	80.65
0.	74.70	71.36	70.97	70.80	70.84	70.90	71.04	71.16	71.56	0.
0.	0.	0.	70.68	70.70	70.71	70.78	70.90	70.94	71.18	0.
0.	0.	0.	0.	0.	0.	70.74	70.82	70.76	0.	0.
0.	0.	0.	0.	0.	0.	0.	70.70	0.	0.	0.
						5	4	3		
						99.99	99.78	99.45		
						94.73	94.66	94.11		
						87.30	87.37	86.66		
						71.47	71.34	71.16		
						71.09	71.12	71.11		
						0.	70.99	70.97		
						0.	70.95	0.		
						0.	70.80	0.		
							2	1	20	
							99.83	99.63	100.0	
							95.11	94.65	95.88	
							88.40	87.49	89.97	
							71.57	71.29	72.19	
							71.17	71.15	71.21	
							71.04	71.03	71.15	
							71.00	70.94	71.10	
							70.85	0.	70.85	

TYPICAL WET SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 100

DO CONC PPM

19	18	17
8.605	8.582	8.554
8.086	8.087	8.075
7.396	7.415	7.414
6.133	6.149	6.149
6.137	6.146	0.
6.125	6.129	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
7.298	7.905	8.704	8.794	8.776	8.717	8.678	8.623	8.588	8.494	8.091
7.249	7.240	7.288	7.435	7.653	7.976	8.087	8.111	8.112	8.067	7.857
7.311	7.286	7.068	7.085	7.147	7.300	7.376	7.426	7.456	7.502	7.530
7.033	6.461	6.171	6.134	6.120	6.130	6.138	6.142	6.165	6.242	6.979
0.	6.453	6.166	6.132	6.119	6.122	6.128	6.139	6.150	6.185	0.
0.	0.	0.	6.108	6.109	6.111	6.117	6.127	6.131	6.152	0.
0.	0.	0.	0.	0.	0.	6.113	6.120	6.116	0.	0.
0.	0.	0.	0.	0.	0.	0.	6.110	0.	0.	0.

5	4	3
8.652	8.635	8.607
8.192	8.187	8.141
7.551	7.557	7.496
6.177	6.166	6.150
6.144	6.147	6.146
0.	6.135	6.134
0.	6.132	0.
0.	6.119	0.

2	1	20
8.640	8.623	8.657
8.226	8.187	8.293
7.647	7.569	7.783
6.186	6.161	6.239
6.151	6.150	6.155
6.140	6.138	6.150
6.136	6.131	6.145
6.123	0.	6.123

TYPICAL WET SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 100

TEMPERATURE DEGC

19	18	17
24.84	24.83	24.82
24.88	24.87	24.86
24.88	24.87	24.86
24.93	24.93	24.93
24.93	24.93	0.
24.93	24.93	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
25.00	24.99	24.96	24.94	24.92	24.89	24.88	24.85	24.83	24.79	24.68
25.00	24.99	24.97	24.95	24.94	24.92	24.91	24.89	24.87	24.84	24.74
25.00	24.99	24.94	24.93	24.91	24.90	24.89	24.88	24.87	24.85	24.79
24.99	24.96	24.94	24.94	24.93	24.93	24.93	24.93	24.93	24.92	24.85
0.	24.96	24.94	24.94	24.93	24.93	24.93	24.93	24.93	24.92	0.
0.	0.	0.	24.94	24.93	24.93	24.93	24.93	24.93	24.92	0.
0.	0.	0.	0.	0.	0.	24.93	24.93	24.93	0.	0.
0.	0.	0.	0.	0.	0.	0.	24.93	0.	0.	0.

5	4	3
24.85	24.85	24.84
24.89	24.88	24.88
24.88	24.87	24.87
24.93	24.93	24.93
24.93	24.93	24.93
0.	24.93	24.93
0.	24.93	0.
0.	24.93	0.

2	1	20
24.84	24.84	24.84
24.88	24.88	24.88
24.87	24.87	24.87
24.93	24.93	24.92
24.93	24.93	24.93
24.93	24.93	24.93
24.93	24.93	24.93
24.93	0.	24.93

TYPICAL WET SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR

DAY 100

INERT S.SOL. PPM

19	18	17
6.900	7.788	9.265
13.54	13.79	14.42
20.75	20.41	20.48
36.28	35.69	35.63
36.45	36.03	0.
36.66	36.27	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
77.30	57.68	27.39	19.93	13.73	8.597	6.990	6.699	7.877	13.07	34.37
73.33	65.21	41.71	33.37	25.76	17.84	14.90	13.41	13.77	17.14	30.02
74.64	68.00	46.97	39.69	33.08	25.78	22.91	20.64	20.23	21.33	28.62
70.00	54.65	44.74	41.84	39.77	37.69	36.97	36.21	35.72	35.03	31.23
0.	54.47	44.49	41.84	39.78	37.89	37.29	36.50	36.12	35.65	0.
0.	0.	0.	41.63	39.72	37.84	37.32	36.70	36.40	35.97	0.
0.	0.	0.	0.	0.	0.	37.40	36.78	36.48	0.	0.
0.	0.	0.	0.	0.	0.	0.	36.65	0.	0.	0.

5	4	3
5.974	5.844	6.512
12.20	11.87	12.53
19.08	18.53	19.17
35.81	35.74	35.80
36.41	36.24	36.18
0.	36.43	36.39
0.	36.44	0.
0.	36.42	0.

2	1	20
5.378	5.660	4.962
11.06	11.46	10.12
17.21	17.99	15.48
35.42	35.58	34.71
36.13	36.08	36.08
36.33	36.29	36.16
36.35	36.33	36.22
36.33	0.	36.32

TYPICAL WET SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR   DAY 100

CHLOROPHYLL PPB

19	18	17
0.8297	0.7594	0.7362
1.357	1.245	1.179
0.3651	0.3635	0.3578
0.3526E-01	0.3856E-01	0.3879E-01
0.3581E-01	0.3723E-01	0.
0.3250E-01	0.3308E-01	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
1.613	2.946	4.520	4.066	3.019	1.776	1.262	0.8825	0.7631	0.7384	0.7193
1.569	1.492	1.216	1.361	1.598	1.831	1.732	1.414	1.255	1.070	0.6702
1.622	1.238	0.4933	0.3822	0.3391	0.3844	0.4058	0.3922	0.3950	0.4135	0.5035
1.239	0.4699	0.1410	0.8764E-01	0.6002E-01	0.4544E-01	0.4229E-01	0.3776E-01	0.4270E-01	0.6558E-01	0.3045
0.	0.4613	0.1353	0.8687E-01	0.5914E-01	0.4207E-01	0.3856E-01	0.3641E-01	0.3830E-01	0.4813E-01	0.
0.	0.	0.	0.6960E-01	0.5520E-01	0.3783E-01	0.3389E-01	0.3278E-01	0.3344E-01	0.3923E-01	0.
0.	0.	0.	0.	0.	0.	0.3167E-01	0.3145E-01	0.2964E-01	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.2865E-01	0.	0.	0.

5	4	3
0.8676	0.7561	0.7238
1.426	1.317	1.247
0.4848	0.4691	0.4239
0.4920E-01	0.4384E-01	0.3900E-01
0.3778E-01	0.3729E-01	0.3688E-01
0.	0.3369E-01	0.3343E-01
0.	0.3296E-01	0.
0.	0.2855E-01	0.

2	1	20
0.6844	0.6713	0.6343
1.250	1.214	1.233
0.5166	0.4712	0.5952
0.5005E-01	0.4222E-01	0.6780E-01
0.3819E-01	0.3753E-01	0.3897E-01
0.3456E-01	0.3404E-01	0.3732E-01
0.3392E-01	0.3260E-01	0.3605E-01
0.2788E-01	0.	0.2773E-01

TYPICAL WET SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR

DAY 100

ALGAL CARBON PPB

19	18	17
41.49	37.97	36.81
67.83	62.25	58.97
18.25	18.18	17.89
1.763	1.928	1.939
1.790	1.862	0.
1.625	1.654	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
80.65	147.3	226.0	203.3	151.0	88.81	63.11	44.12	38.15	36.92	35.97
78.45	74.60	60.82	68.03	79.88	91.54	86.59	70.71	62.73	53.52	33.51
81.09	61.88	24.67	19.11	16.95	19.22	20.29	19.61	19.75	20.68	25.17
61.93	23.49	7.049	4.382	3.001	2.272	2.114	1.888	2.135	3.279	15.22
0.	23.06	6.764	4.343	2.957	2.103	1.928	1.820	1.915	2.406	0.
0.	0.	0.	3.480	2.760	1.891	1.695	1.639	1.672	1.961	0.
0.	0.	0.	0.	0.	0.	1.583	1.573	1.482	0.	0.
0.	0.	0.	0.	0.	0.	0.	1.432	0.	0.	0.

5	4	3
43.38	37.80	36.19
71.31	65.83	62.35
24.24	23.45	21.19
2.460	2.192	1.950
1.889	1.864	1.844
0.	1.684	1.672
0.	1.648	0.
0.	1.427	0.

2	1	20
34.22	33.57	31.72
62.52	60.71	61.64
25.83	23.56	29.76
2.502	2.111	3.390
1.910	1.877	1.948
1.728	1.702	1.866
1.696	1.630	1.802
1.394	0.	1.386

TYPICAL WET SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 100

DETRITAL CAR PPB

							19	18	17	
							3.461	3.104	2.879	
							8.927	8.061	7.515	
							11.17	10.17	9.683	
							12.38	11.40	11.27	
							12.66	11.94	0.	
							12.84	12.21	0.	
							0.	0.	0.	
							0.	0.	0.	
16	15	14	13	12	11	10	9	8	7	6
0.7747	9.212	16.86	15.56	11.98	7.224	5.203	3.691	3.146	3.001	3.815
1.736	11.63	20.01	19.82	17.81	14.28	12.01	9.397	8.145	7.101	5.865
3.652	13.73	20.66	20.38	18.71	15.75	13.94	11.55	10.38	9.327	7.654
8.227	16.56	18.71	17.91	16.69	14.90	13.93	12.45	11.70	11.08	9.136
0.	16.67	18.29	17.65	16.44	14.62	13.89	12.76	12.17	11.64	0.
0.	0.	0.	17.28	16.28	14.40	13.68	12.91	12.44	11.91	0.
0.	0.	0.	0.	0.	0.	13.50	12.93	12.48	0.	0.
0.	0.	0.	0.	0.	0.	0.	12.80	0.	0.	0.
						5	4	3		
						3.452	3.117	2.966		
						8.938	8.365	7.986		
						11.46	10.93	10.50		
						12.43	12.13	11.86		
						12.72	12.49	12.37		
						0.	12.64	12.58		
						0.	12.64	0.		
						0.	12.56	0.		
							2	1	20	
							2.814	2.723	2.545	
							7.825	7.596	7.295	
							10.64	10.37	10.37	
							11.99	11.78	11.87	
							12.40	12.30	12.38	
							12.55	12.49	12.43	
							12.57	12.53	12.47	
							12.46	0.	12.44	

TYPICAL WET SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR

DAY 100

PHOSPHATE PPM

19	18	17
0.1316E-02	0.1531E-02	0.1827E-02
0.3036E-02	0.2868E-02	0.2927E-02
0.1111E-01	0.1066E-01	0.1053E-01
0.1560E-01	0.1544E-01	0.1542E-01
0.1559E-01	0.1547E-01	0.
0.1561E-01	0.1551E-01	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
0.2802E-01	0.2171E-01	0.6693E-02	0.3788E-02	0.2107E-02	0.1199E-02	0.1058E-02	0.1234E-02	0.1530E-02	0.2487E-02	0.6074E-02
0.2767E-01	0.2492E-01	0.1772E-01	0.1441E-01	0.1063E-01	0.5819E-02	0.3963E-02	0.2956E-02	0.2728E-02	0.3339E-02	0.6759E-02
0.2817E-01	0.2637E-01	0.2027E-01	0.1818E-01	0.1609E-01	0.1339E-01	0.1217E-01	0.1100E-01	0.1041E-01	0.9696E-02	0.8621E-02
0.2585E-01	0.2044E-01	0.1743E-01	0.1678E-01	0.1635E-01	0.1593E-01	0.1577E-01	0.1558E-01	0.1540E-01	0.1498E-01	0.1127E-01
0.	0.2037E-01	0.1736E-01	0.1677E-01	0.1633E-01	0.1592E-01	0.1579E-01	0.1559E-01	0.1548E-01	0.1527E-01	0.
0.	0.	0.	0.1659E-01	0.1630E-01	0.1588E-01	0.1574E-01	0.1561E-01	0.1553E-01	0.1538E-01	0.
0.	0.	0.	0.	0.	0.	0.1571E-01	0.1561E-01	0.1554E-01	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.1557E-01	0.	0.	0.

5	4	3
0.1105E-02	0.1162E-02	0.1309E-02
0.2190E-02	0.2028E-02	0.2353E-02
0.1012E-01	0.9903E-02	0.1019E-01
0.1544E-01	0.1545E-01	0.1548E-01
0.1557E-01	0.1553E-01	0.1552E-01
0.	0.1555E-01	0.1554E-01
0.	0.1554E-01	0.
0.	0.1553E-01	0.

2	1	20
0.1152E-02	0.1195E-02	0.1149E-02
0.1540E-02	0.1840E-02	0.8588E-03
0.9203E-02	0.9646E-02	0.8200E-02
0.1534E-01	0.1543E-01	0.1509E-01
0.1549E-01	0.1549E-01	0.1546E-01
0.1552E-01	0.1552E-01	0.1548E-01
0.1552E-01	0.1552E-01	0.1549E-01
0.1550E-01	0.	0.1550E-01

TYPICAL WET SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 100

VOLUMES m3

19	18	17
0.3717E+07	0.4369E+07	0.3184E+07
0.3419E+07	0.4086E+07	0.2641E+07
0.4321E+07	0.5504E+07	0.3205E+07
0.5049E+07	0.7507E+07	0.5635E+07
0.4207E+07	0.7508E+07	0.
0.5031E+06	0.1046E+07	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
0.6542E+06	0.2807E+07	0.1030E+08	0.9751E+07	0.1311E+08	0.1682E+08	0.1619E+08	0.1059E+08	0.6438E+07	0.6336E+07	0.2132E+07
0.5383E+06	0.2445E+07	0.9357E+07	0.9035E+07	0.1238E+08	0.1599E+08	0.1559E+08	0.1053E+08	0.6300E+07	0.5762E+07	0.1660E+07
0.5956E+06	0.3168E+07	0.1230E+08	0.1235E+08	0.1720E+08	0.2242E+08	0.2208E+08	0.1558E+08	0.9041E+07	0.7342E+07	0.1922E+07
0.4278E+06	0.3946E+07	0.1589E+08	0.1739E+08	0.2502E+08	0.3317E+08	0.3333E+08	0.2540E+08	0.1398E+08	0.8767E+07	0.1688E+07
0.	0.3311E+07	0.1911E+08	0.2331E+08	0.3606E+08	0.4982E+08	0.5207E+08	0.4573E+08	0.2016E+08	0.7708E+07	0.
0.	0.	0.	0.9349E+07	0.1680E+08	0.2772E+08	0.3091E+08	0.3267E+08	0.8086E+07	0.1119E+07	0.
0.	0.	0.	0.	0.	0.	0.2176E+08	0.1274E+08	0.1724E+07	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.7847E+06	0.	0.	0.

5	4	3
0.9724E+06	0.7238E+07	0.4678E+07
0.7565E+06	0.7141E+07	0.4245E+07
0.8390E+06	0.1039E+08	0.5526E+07
0.6095E+06	0.1647E+08	0.6964E+07
0.1166E+06	0.2789E+08	0.7246E+07
0.	0.1922E+08	0.1775E+07
0.	0.8562E+07	0.
0.	0.1954E+07	0.

2	1	20
0.3181E+07	0.2541E+07	0.3181E+07
0.3103E+07	0.2294E+07	0.3103E+07
0.4514E+07	0.3004E+07	0.4514E+07
0.7147E+07	0.3842E+07	0.7147E+07
0.1247E+08	0.4481E+07	0.1247E+08
0.9314E+07	0.1757E+07	0.9314E+07
0.4557E+07	0.4085E+06	0.4557E+07
0.2110E+07	0.	0.3014E+07

TYPICAL WET SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR

DAY 100

U-VELOCITY east-west (m/s)

19	18	17
0.1073E-02	0.1904E-02	0.1751E-02
0.8879E-03	0.1507E-02	0.1234E-02
-.3935E-03	0.3425E-03	0.5390E-03
-.6740E-03	-.2232E-03	-.1044E-02
-.5089E-03	-.6273E-03	0.
-.2515E-03	-.2698E-03	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
0.	0.	0.	0.	0.	0.	0.4783E-02	0.6284E-02	0.2861E-04	0.	0.
0.	0.	0.	0.	0.	0.	0.4593E-02	0.6047E-02	0.1716E-03	0.	0.
0.	0.	0.	0.	0.	0.	0.2139E-02	0.4349E-02	0.6011E-03	0.	0.
0.	0.	0.	0.	0.	0.	0.1340E-02	0.3877E-02	0.6342E-03	0.	0.
0.	0.	0.	0.	0.	0.	0.1026E-02	0.2976E-02	0.5726E-03	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.1330E-02	0.6876E-03	0.	0.
0.	0.	0.	0.	0.	0.	0.	-.9581E-03	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	-.1593E-02	0.	0.	0.

5	4	3
0.	0.5549E-02	0.4134E-03
0.	0.5379E-02	0.4777E-03
0.	0.4253E-02	0.8958E-03
0.	0.3968E-02	0.9710E-03
0.	0.3429E-02	0.1217E-02
0.	0.2355E-02	0.7358E-03
0.	0.5959E-03	0.
0.	-.1998E-03	0.

2	1	20
0.9278E-02	0.	0.
0.8916E-02	0.	0.
0.5976E-02	0.	0.
0.5390E-02	0.	0.
0.4495E-02	0.	0.
0.4821E-02	0.	0.3359E-01
0.2817E-02	0.	0.
0.1682E-03	0.	0.

TYPICAL WET SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 100

V-VELOCITY north-south (m/s)

19	18	17
0.	0.1792E-02	0.3722E-03
0.	0.1448E-02	0.9146E-04
0.	0.6842E-03	-.1394E-03
0.	0.3274E-03	0.2150E-03
0.	0.4610E-04	0.
0.	0.	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
0.	0.1023	0.3621E-01	0.1225E-01	0.1157E-01	0.1033E-01	0.5426E-02	0.3630E-02	0.4662E-03	0.1233E-02	-.1813E-02
0.	0.1065	0.3497E-01	0.1191E-01	0.1098E-01	0.9789E-02	0.5181E-02	0.3369E-02	0.2227E-03	0.6818E-03	-.2495E-02
0.	0.1024	0.2895E-01	0.8335E-02	0.6478E-02	0.5358E-02	0.3258E-02	0.3006E-02	-.4136E-03	-.3378E-03	-.3247E-02
0.	0.8157E-01	0.2502E-01	0.7171E-02	0.5356E-02	0.4327E-02	0.2839E-02	0.2936E-02	-.6802E-03	-.1113E-02	-.3819E-02
0.	0.	0.2003E-01	0.5384E-02	0.4042E-02	0.2834E-02	0.1949E-02	0.3208E-02	-.9848E-03	-.2073E-02	0.
0.	0.	0.	0.	0.1448E-02	0.7181E-03	0.8058E-03	0.2390E-02	-.6186E-03	-.2690E-02	0.
0.	0.	0.	0.	0.	0.	0.	0.1732E-02	-.1268E-03	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

5	4	3
0.	0.7777E-04	-.1893E-02
0.	-.2029E-04	-.1743E-02
0.	0.1499E-02	-.2951E-03
0.	0.1333E-02	0.8886E-04
0.	0.2197E-02	0.7392E-03
0.	0.	0.9783E-03
0.	0.	0.
0.	0.	0.

2	1	20
0.	0.1913E-04	0.
0.	-.4297E-03	0.
0.	-.1236E-02	0.
0.	-.9478E-03	0.
0.	-.2961E-03	0.
0.	0.4344E-03	0.
0.	0.1256E-02	0.
0.	0.	0.

TYPICAL WET SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 100

VERTICAL VELOCITY down: -ve (m/s)

19	18	17
0.4416E-05	0.1888E-05	0.8075E-06
0.8881E-05	0.3514E-05	0.1605E-05
0.1018E-04	0.4022E-05	0.3077E-05
0.9244E-05	0.4988E-05	0.
0.6749E-05	0.3108E-05	0.
0.	0.	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
-.5043E-03	-.9651E-05	0.7859E-06	-.1527E-06	0.5267E-06	-.1094E-05	-.1381E-05	0.1304E-05	-.1410E-05	-.2852E-05	-.1878E-04
-.4355E-03	-.2058E-04	0.1563E-05	0.4160E-08	0.1036E-05	-.2122E-05	-.2960E-05	0.2739E-05	-.2571E-05	-.5718E-05	-.1757E-04
-.3225E-03	-.4222E-04	0.1020E-05	-.7838E-06	0.1150E-05	-.2518E-05	-.4167E-05	0.4469E-05	-.2332E-05	-.9373E-05	-.1386E-04
0.	-.7240E-04	-.2163E-06	-.1215E-05	0.1253E-05	-.2526E-05	-.6489E-05	0.7471E-05	-.1627E-05	-.1498E-04	0.
0.	0.	0.	-.4184E-05	0.7479E-06	-.1646E-05	-.7555E-05	0.9321E-05	0.1814E-06	-.2183E-04	0.
0.	0.	0.	0.	0.	0.	-.6862E-05	0.1038E-04	-.6604E-06	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.1569E-04	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

5	4	3
-.1478E-04	-.2888E-05	0.3036E-05
-.3382E-04	-.5659E-05	0.6314E-05
-.4472E-04	-.8335E-05	0.8230E-05
-.2874E-03	-.1125E-04	0.1169E-04
0.	-.1527E-04	0.1559E-04
0.	-.1267E-04	0.
0.	-.7610E-05	0.
0.	0.	0.

2	1	20
0.4671E-05	-.4547E-06	-.1971E-04
0.7865E-05	-.1195E-06	-.3872E-04
0.5439E-05	0.2878E-05	-.5829E-04
-.7934E-06	0.8788E-05	-.8818E-04
-.1810E-04	0.1843E-04	-.1496E-03
-.2242E-04	0.2900E-04	0.2933E-04
-.6402E-05	0.	0.3792E-05
0.	0.	0.

TYPICAL WET SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 100

X-DISCHARGES east-west (cumec)

19	18	17
4.701	6.514	1.970
3.836	5.049	0.9993
-2.461	1.632	0.4730
-6.622	-1.619	-1.174
-6.184	-5.787	0.
-.6792	-.6474	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
0.	0.	0.	0.	0.	0.	6.372	27.53	0.8034E-01	0.	0.
0.	0.	0.	0.	0.	0.	5.236	26.49	0.4433	0.	0.
0.	0.	0.	0.	0.	0.	3.176	28.57	1.929	0.	0.
0.	0.	0.	0.	0.	0.	2.513	42.45	2.270	0.	0.
0.	0.	0.	0.	0.	0.	1.539	62.64	1.503	0.	0.
0.	0.	0.	0.	0.	0.	0.	18.12	0.1031	0.	0.
0.	0.	0.	0.	0.	0.	0.	-8.575	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	-2.389	0.	0.	0.

5	4	3
0.	23.54	0.6177
0.	22.61	0.6535
0.	26.38	1.596
0.	39.94	2.185
0.	60.96	3.011
0.	30.56	0.4967
0.	7.867	0.
0.	-.4197	0.

2	1	20
30.95	0.	0.
28.40	0.	0.
26.71	0.	0.
35.84	0.	0.
44.50	0.	0.
31.58	0.	220.0
21.41	0.	0.
0.6098	0.	0.

TYPICAL WET SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR

DAY 100

Y-DISCHARGES north-south (cumec)

19	18	17
0.	3.323	0.8219
0.	2.366	0.1900
0.	1.251	-.3909
0.	0.4543	1.647
0.	0.1614E-01	0.
0.	0.	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
0.	50.05	37.61	41.46	40.75	44.11	35.13	17.76	1.833	3.748	-2.992
0.	45.05	33.71	36.80	37.54	40.40	32.85	16.06	0.8485	2.015	-3.758
0.	54.53	37.95	34.83	31.77	31.83	30.34	20.13	-2.224	-1.402	-5.947
0.	50.37	45.66	41.27	40.57	39.98	42.58	29.20	-5.484	-6.862	-7.304
0.	0.	45.07	45.63	42.75	39.04	48.12	55.45	-12.21	-14.93	0.
0.	0.	0.	0.	6.624	4.632	10.98	28.83	-3.681	-4.842	0.
0.	0.	0.	0.	0.	0.	0.	13.73	-.1617	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

5	4	3
0.	0.2000	-6.248
0.	-.4839E-01	-5.699
0.	4.773	-1.414
0.	5.672	0.6831
0.	8.240	9.258
0.	0.	5.650
0.	0.	0.
0.	0.	0.

2	1	20
0.	-.6974E-01	0.
0.	-1.071	0.
0.	-4.357	0.
0.	-5.028	0.
0.	-2.576	0.
0.	2.281	0.
0.	2.261	0.
0.	0.	0.

TYPICAL WET SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 100

Z-DISCHARGES down : -ve (cumec)

19	18	17
8.023	4.013	1.148
14.22	6.887	1.957
13.01	6.877	2.821
6.847	6.451	0.
0.6792	0.6474	0.
0.	0.	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
-150.0	-12.44	3.858	-.7143	3.357	-8.978	-11.00	6.904	-4.518	-8.710	-17.01
-104.9	-23.79	6.950	0.1813E-01	6.222	-16.53	-22.55	14.34	-7.958	-15.48	-13.25
-50.37	-40.36	3.829	-3.039	6.283	-18.02	-29.58	23.02	-6.839	-20.50	-7.304
0.	-45.07	-.5625	-3.741	5.697	-15.43	-40.45	37.41	-4.327	-19.77	0.
0.	0.	0.	-6.624	1.992	-6.347	-31.59	38.58	0.2489	-4.842	0.
0.	0.	0.	0.	0.	0.	-13.73	24.86	-.1617	0.	0.
0.	0.	0.	0.	0.	0.	0.	2.389	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

5	4	3
-6.172	-10.43	6.785
-11.46	-19.96	12.69
-9.861	-28.34	13.77
-6.701	-35.84	13.01
0.	-36.50	5.256
0.	-18.41	0.
0.	-1.969	0.
0.	0.	0.

2	1	20
7.336	-.5480	-30.95
12.06	-.1301	-59.35
8.030	2.630	-86.06
-1.097	5.474	-121.9
-20.13	5.038	-166.4
-16.83	2.261	22.02
-1.030	0.	0.6098
0.	0.	0.

TYPICAL WET SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR

DAY 100

X-1D-DISCHARGES (cumec)

							19	18	17	
							-7.410	5.142	2.268	
16	15	14	13	12	11	10	9	8	7	6
0.	0.	0.	0.	0.	0.	18.84	194.8	6.330	0.	0.
						5	4	3		
						0.	211.4	3.560		
							2	1	20	
							220.0	0.	220.0	

Y-1D-DISCHARGES (cumec)

							19	18	17	
							0.	7.410	2.268	
16	15	14	13	12	11	10	9	8	7	6
0.	200.0	200.0	200.0	200.0	200.0	200.0	181.2	-21.08	-22.27	-20.00
						5	4	3		
						0.	18.84	2.231		
							2	1	20	
							0.	-8.560	0.	

LATERAL INFLOWS (cumec)

							19	18	17	
							0.	0.	0.	
16	15	14	13	12	11	10	9	8	7	6
200.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	20.00
						5	4	3		
						0.	0.	0.		
							2	1	20	
							0.	0.	0.	

TYPICAL WET SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 100

FB stream conc.s (ppm)

							19	18	17	
							0.	0.	0.	
16	15	14	13	12	11	10	9	8	7	6
0.4900	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.000
						5	4	3		
						0.	0.	0.		
							2	1	20	
							0.	0.	0.	

SB stream conc.s (ppm)

							19	18	17	
							0.	0.	0.	
16	15	14	13	12	11	10	9	8	7	6
1.080	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.000
						5	4	3		
						0.	0.	0.		
							2	1	20	
							0.	0.	0.	

DO stream conc.s (ppm)

							19	18	17	
							0.	0.	0.	
16	15	14	13	12	11	10	9	8	7	6
7.250	0.	0.	0.	0.	0.	0.	0.	0.	0.	8.500
						5	4	3		
						0.	0.	0.		
							2	1	20	
							0.	0.	0.	

TYPICAL WET SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR

DAY 100

ON stream conc.s (ppm)

							19	18	17	
							0.	0.	0.	
16	15	14	13	12	11	10	9	8	7	6
0.6300	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.000
						5	4	3		
						0.	0.	0.		
							2	1	20	
							0.	0.	0.	

MUD stream conc. (ppm)

							19	18	17	
							0.	0.	0.	
16	15	14	13	12	11	10	9	8	7	6
74.50	0.	0.	0.	0.	0.	0.	0.	0.	0.	120.0
						5	4	3		
						0.	0.	0.		
							2	1	20	
							0.	0.	0.	

AC stream conc.s (ppm)

							19	18	17	
							0.	0.	0.	
16	15	14	13	12	11	10	9	8	7	6
0.8000E-01	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.5000E-01
						5	4	3		
						0.	0.	0.		
							2	1	20	
							0.	0.	0.	

TYPICAL WET SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR   DAY 100

PH stream conc.s (ppm)

							19	18	17	
							0.	0.	0.	
16	15	14	13	12	11	10	9	8	7	6
0.2800E-01	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.1000E-01
						5	4	3		
						0.	0.	0.		
							2	1	20	
							0.	0.	0.	

TP stream conc.s deg. C

							19	18	17	
							0.	0.	0.	
16	15	14	13	12	11	10	9	8	7	6
25.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	24.00
						5	4	3		
						0.	0.	0.		
							2	1	20	
							0.	0.	0.	

Table A14-3

Typical Dry Season Conditions:
Mutonga Reservoir

TYPICAL DRY SEASON CONDITIONS IN MUTONGA RESERVOIR

SETTLED MUD (T) Typical dry season conditions

7	6	5	4	3	2	1
0.	0.	0.	12.17	11.38	0.4868	71.23
0.	0.	0.	19.28	180.4	0.9026	104.6
0.	0.	0.	19.10	234.4	127.3	121.9
0.	0.	0.1598E-07	27.66	247.2	174.7	133.6
0.	0.	0.	234.9	231.5	219.4	134.5
0.	0.	0.	191.5	285.6	213.6	217.9
0.	0.	0.	743.5	421.3	319.5	315.8
0.	0.	0.	0.	0.	245.5	249.6
0.	0.	0.	0.	0.	0.	261.7

BEDLOAD G/M2/DAY Typical dry season conditions

7	6	5	4	3	2	1
0.3659E-01	0.1453	0.4721	0.4534	0.3666	0.2526	0.2521
0.7497E-01	0.1834	0.4810	0.4793	0.4719	0.4459	0.4377
0.1114	0.2204	0.4834	0.4809	0.4702	0.5005	0.4921
0.1633	0.2573	0.4902	0.4903	0.4768	0.5237	0.5238
0.2087	0.2778	0.4801	0.4854	0.4897	0.5435	0.5552
0.	0.	0.4802	0.4852	0.4904	0.5673	0.5821
0.	0.	0.4782	0.4839	0.5036	0.6003	0.6535
0.	0.	0.	0.	0.5515	0.6477	0.6544
0.	0.	0.	0.	0.	0.	0.6610

BED DETRITUS MGS Typical dry season conditions

7	6	5	4	3	2	1
0.1702E+07	0.4364E+08	0.4303E+09	0.4564E+09	0.4296E+09	0.3727E+09	0.2470E+09
0.4530E+07	0.6079E+08	0.4883E+09	0.5365E+09	0.6286E+09	0.6957E+09	0.4521E+09
0.7275E+07	0.7443E+08	0.4992E+09	0.5499E+09	0.6518E+09	0.8161E+09	0.5279E+09
0.1109E+08	0.8753E+08	0.5046E+09	0.5624E+09	0.6664E+09	0.8639E+09	0.5652E+09
0.1194E+09	0.5062E+09	0.5116E+09	0.5709E+09	0.6978E+09	0.9126E+09	0.6079E+09
0.	0.	0.4546E+09	0.4650E+09	0.8621E+09	0.9262E+09	0.1035E+10
0.	0.	0.9452E+09	0.1852E+10	0.1328E+10	0.1473E+10	0.1747E+10
0.	0.	0.	0.	0.2102E+10	0.1557E+10	0.1383E+10
0.	0.	0.	0.	0.	0.	0.1466E+10

FAST DIS.BOD PPM Typical dry season conditions

7	6	5	4	3	2	1
2.191	1.887	1.129	0.6272	0.4086	0.2470	0.2395
2.115	1.729	1.068	0.5448	0.3305	0.2142	0.2042
1.982	1.598	0.9309	0.4398	0.2404	0.1723	0.1730
1.922	1.543	0.9910	0.4104	0.1793	0.1449	0.1533
1.266	0.8240	0.2275	0.6795E-01	0.3855E-01	0.8329E-01	0.1132
0.	0.	0.2272	0.6951E-01	0.3877E-01	0.7989E-01	0.1164
0.	0.	0.4474E-01	0.4237E-01	0.3822E-01	0.7696E-01	0.1302
0.	0.	0.	0.	0.3915E-01	0.7616E-01	0.1301
0.	0.	0.	0.	0.	0.	0.1285

SLOW DIS.BOD PPM Typical dry season conditions

7	6	5	4	3	2	1
2.232	2.161	1.868	1.573	1.404	1.107	1.047
2.229	2.130	1.860	1.485	1.291	1.072	1.012
2.177	2.071	1.741	1.320	1.098	0.9742	0.9436
2.203	2.099	1.928	1.259	0.9339	0.9348	0.9263
1.914	1.623	0.8488	0.5583	0.5115	0.6764	0.7326
0.	0.	0.8484	0.5615	0.5122	0.6554	0.7308
0.	0.	0.5081	0.5075	0.5156	0.6431	0.7553
0.	0.	0.	0.	0.5406	0.6440	0.7552
0.	0.	0.	0.	0.	0.	0.7534

TYPICAL DRY SEASON CONDITIONS IN MUTONGA RESERVOIR

AMMONIA PPM Typical dry season conditions

7	6	5	4	3	2	1
0.1625E-05	0.2945E-05	0.4039E-04	0.9362E-04	0.1235E-03	0.1766E-03	0.1924E-03
-.2434E-05	0.1081E-05	0.4227E-04	0.1296E-03	0.1750E-03	0.2082E-03	0.2220E-03
0.4431E-05	0.9991E-05	0.7049E-04	0.1742E-03	0.2295E-03	0.2418E-03	0.2468E-03
-.7025E-05	-.3091E-05	0.1346E-04	0.1966E-03	0.2853E-03	0.2584E-03	0.2553E-03
0.3285E-04	0.9228E-04	0.3181E-03	0.4067E-03	0.4190E-03	0.3508E-03	0.3257E-03
0.	0.	0.3182E-03	0.4057E-03	0.4188E-03	0.3586E-03	0.3259E-03
0.	0.	0.4240E-03	0.4237E-03	0.4192E-03	0.3648E-03	0.3158E-03
0.	0.	0.	0.	0.4182E-03	0.3687E-03	0.3159E-03
0.	0.	0.	0.	0.	0.	0.3166E-03

NITRATE PPM Typical dry season conditions

7	6	5	4	3	2	1
0.3981	0.3873	0.3134	0.2838	0.2673	0.2275	0.2253
0.3982	0.3977	0.3897	0.3839	0.3595	0.2756	0.2642
0.3965	0.3967	0.3873	0.3631	0.3441	0.2859	0.2758
0.3994	0.3998	0.4061	0.3552	0.3250	0.3004	0.2890
0.3914	0.3771	0.3112	0.2773	0.2621	0.2610	0.2558
0.	0.	0.3111	0.2776	0.2622	0.2571	0.2531
0.	0.	0.2731	0.2708	0.2610	0.2532	0.2474
0.	0.	0.	0.	0.2490	0.2485	0.2474
0.	0.	0.	0.	0.	0.	0.2474

DIS.OXYGEN %SAT Typical dry season conditions

7	6	5	4	3	2	1
96.89	95.69	98.72	96.87	97.16	97.10	93.75
96.34	90.57	79.83	66.68	65.59	77.58	77.29
93.88	87.87	75.67	66.37	63.58	72.03	73.07
94.02	88.11	78.29	64.91	60.83	67.54	69.72
80.63	70.50	58.16	55.95	58.47	65.45	68.76
0.	0.	58.16	56.01	58.48	65.41	69.17
0.	0.	54.60	55.28	58.65	65.37	70.85
0.	0.	0.	0.	62.02	66.18	70.84
0.	0.	0.	0.	0.	0.	70.67

DO CONC PPM Typical dry season conditions

7	6	5	4	3	2	1
8.365	8.260	8.524	8.369	8.400	8.462	8.192
8.316	7.818	6.893	5.764	5.676	6.756	6.746
8.105	7.586	6.538	5.748	5.516	6.280	6.381
8.115	7.605	6.752	5.628	5.290	5.885	6.084
6.965	6.099	5.065	4.890	5.118	5.731	6.024
0.	0.	5.065	4.895	5.119	5.729	6.063
0.	0.	4.773	4.834	5.134	5.729	6.213
0.	0.	0.	0.	5.438	5.803	6.213
0.	0.	0.	0.	0.	0.	6.198

TEMPERATURE DEGC Typical dry season conditions

7	6	5	4	3	2	1
25.00	25.00	24.99	24.95	24.90	24.42	24.26
25.00	25.00	24.99	24.91	24.85	24.47	24.33
25.00	24.99	24.94	24.80	24.69	24.40	24.29
25.01	25.01	25.05	24.73	24.55	24.43	24.34
24.96	24.87	24.47	24.25	24.15	24.14	24.10
0.	0.	24.47	24.26	24.15	24.11	24.08
0.	0.	24.23	24.21	24.14	24.08	24.04
0.	0.	0.	0.	24.06	24.05	24.04
0.	0.	0.	0.	0.	0.	24.04

TYPICAL DRY SEASON CONDITIONS IN MUTONGA RESERVOIR

INERT S.SOL. PPM   Typical dry season conditions

7	6	5	4	3	2	1
40.41	35.35	23.79	16.80	12.36	10.76	12.86
38.15	38.59	34.22	30.75	24.94	18.30	19.08
40.22	40.89	40.06	38.59	32.78	22.41	22.15
36.66	38.38	40.41	40.78	35.58	25.67	24.37
51.44	60.99	48.73	41.57	35.20	27.56	25.72
0.	0.	48.73	41.55	35.20	27.97	25.72
0.	0.	43.08	40.44	34.98	28.03	24.87
0.	0.	0.	0.	33.55	27.73	24.87
0.	0.	0.	0.	0.	0.	24.87

CHLOROPHYLL PPB   Typical dry season conditions

7	6	5	4	3	2	1
1.108	1.936	5.412	4.790	3.698	2.630	2.427
1.146	0.9556	1.133	0.8827	1.596	2.534	2.202
1.107	0.8060	0.5028	0.1835	0.2149	1.057	0.9050
1.004	0.7458	0.4435	0.1878	0.1335	0.5019	0.5812
0.6138	0.3857	0.1129	0.5881E-01	0.8821E-01	0.2965	0.4484
0.	0.	0.1128	0.5939E-01	0.8842E-01	0.2845	0.4664
0.	0.	0.4227E-01	0.4915E-01	0.8924E-01	0.2726	0.5300
0.	0.	0.	0.	0.1187	0.2742	0.5295
0.	0.	0.	0.	0.	0.	0.5196

ALGAL CARBON PPB   Typical dry season conditions

7	6	5	4	3	2	1
55.38	96.80	270.6	239.5	184.9	131.5	121.3
57.31	47.78	56.63	44.14	79.82	126.7	110.1
55.36	40.30	25.14	9.175	10.74	52.87	45.25
50.18	37.29	22.17	9.392	6.676	25.09	29.06
30.69	19.29	5.647	2.941	4.411	14.82	22.42
0.	0.	5.639	2.969	4.421	14.22	23.32
0.	0.	2.113	2.457	4.462	13.63	26.50
0.	0.	0.	0.	5.935	13.71	26.48
0.	0.	0.	0.	0.	0.	25.98

DETRITAL CAR PPB   Typical dry season conditions

7	6	5	4	3	2	1
1.089	6.024	19.43	18.41	14.66	10.20	10.35
2.886	7.959	21.20	21.12	20.50	19.10	18.86
4.651	9.356	20.92	21.08	20.78	21.94	21.58
6.830	10.80	20.94	21.31	20.93	22.94	22.90
8.785	11.81	20.82	21.28	21.59	23.87	24.30
0.	0.	20.82	21.28	21.64	24.97	25.58
0.	0.	20.92	21.26	22.22	26.54	28.76
0.	0.	0.	0.	24.25	28.60	28.83
0.	0.	0.	0.	0.	0.	29.12

PHOSPHATE PPM   Typical dry season conditions

7	6	5	4	3	2	1
0.1975E-01	0.1813E-01	0.7265E-02	0.3366E-02	0.1540E-02	0.1934E-02	0.3713E-02
0.1968E-01	0.1963E-01	0.1869E-01	0.1901E-01	0.1619E-01	0.8580E-02	0.8746E-02
0.1955E-01	0.1962E-01	0.1901E-01	0.1747E-01	0.1613E-01	0.1117E-01	0.1100E-01
0.1976E-01	0.1981E-01	0.2022E-01	0.1727E-01	0.1533E-01	0.1298E-01	0.1236E-01
0.1933E-01	0.1851E-01	0.1465E-01	0.1259E-01	0.1157E-01	0.1119E-01	0.1081E-01
0.	0.	0.1464E-01	0.1260E-01	0.1157E-01	0.1101E-01	0.1067E-01
0.	0.	0.1236E-01	0.1219E-01	0.1150E-01	0.1081E-01	0.1032E-01
0.	0.	0.	0.	0.1067E-01	0.1052E-01	0.1032E-01
0.	0.	0.	0.	0.	0.	0.1032E-01

TYPICAL DRY SEASON CONDITIONS IN MUTONGA RESERVOIR

U-VELOCITY east-west (m/s)

8
-.1548E-01
-.1310E-01
-.7079E-02
-.4914E-02
0.2197E-02
0.1056E-01
0.2402E-01
0.2743E-01
0.

7	6	5	4	3	2	1
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.5417E-01
0.	0.	0.	0.	0.	0.	0.

V-VELOCITY north-south (m/s)

8
0.
0.
0.
0.
0.
0.
0.
0.
0.

7	6	5	4	3	2	1
0.	0.5471E-01	0.8280E-01	0.2759E-01	0.2404E-01	0.3500E-01	0.2700E-03
0.	0.5970E-01	0.7856E-01	0.2786E-01	0.1888E-01	0.3226E-01	0.3324E-02
0.	0.7316E-01	0.6258E-01	0.2474E-01	0.1439E-01	0.1821E-01	0.1142E-01
0.	0.6713E-01	0.5794E-01	0.2304E-01	0.7971E-02	0.1613E-01	0.1126E-01
0.	0.3332E-01	0.2946E-01	0.1387E-01	0.2663E-02	0.4594E-02	0.8725E-02
0.	0.	0.	0.1318E-01	0.1871E-02	0.2096E-02	0.4403E-02
0.	0.	0.	-.3092E-02	-.1820E-02	-.3322E-02	-.2023E-02
0.	0.	0.	0.	0.	-.1029E-01	-.6961E-02
0.	0.	0.	0.	0.	0.	0.

VERTICAL VELOCITY down: -ve (m/s)

8
-.4670E-04
-.7451E-04
-.1051E-03
-.1518E-03
-.2319E-03
-.2829E-03
-.4388E-03
0.
0.

7	6	5	4	3	2	1
-.2648E-03	0.1046E-05	-.1345E-05	0.4232E-05	0.1973E-06	-.8631E-05	0.5565E-05
-.1966E-03	0.6227E-05	-.3390E-05	0.6750E-05	0.2036E-05	-.1645E-04	0.8540E-05
-.1169E-03	0.3158E-05	-.4573E-05	0.8339E-05	0.2097E-05	-.1327E-04	0.1537E-05
-.3943E-04	0.5345E-06	-.6239E-05	0.6824E-05	0.4339E-05	-.9786E-05	-.6327E-05
0.	0.	-.7853E-05	0.4981E-05	0.5569E-05	-.4740E-05	-.1487E-04
0.	0.	0.9517E-05	-.2287E-05	0.7064E-05	0.1249E-06	-.3130E-04
0.	0.	0.	0.	0.1121E-04	0.1089E-06	-.7658E-04
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.

TYPICAL DRY SEASON CONDITIONS IN MUTONGA RESERVOIR

X-DISCHARGES east-west (cumec)

8
-13.23
-9.985
-4.771
-2.884
1.022
7.178
18.73
21.94
0.

7	6	5	4	3	2	1
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	65.00
0.	0.	0.	0.	0.	0.	0.

Y-DISCHARGES north-south (cumec)

8
0.
0.
0.
0.
0.
0.
0.
0.
0.

7	6	5	4	3	2	1
0.	13.87	14.34	12.89	18.88	19.29	2.301
0.	10.75	12.73	11.06	13.44	16.81	5.540
0.	10.39	9.011	8.658	9.164	8.834	17.63
0.	8.391	7.474	7.213	4.400	7.163	14.72
0.	3.599	3.447	3.744	1.230	1.810	9.135
0.	0.	0.	6.245	1.384	1.358	6.024
0.	0.	0.	-2.806	-1.501	-1.933	-1.985
0.	0.	0.	0.	0.	-6.330	-6.369
0.	0.	0.	0.	0.	0.	0.

Z-DISCHARGES down: -ve (cumec)

8
-31.23
-41.22
-45.99
-48.87
-47.85
-40.67
-21.94
0.
0.

7	6	5	4	3	2	1
-33.13	0.4679	-1.455	5.995	0.4078	-16.99	10.93
-22.38	2.447	-3.122	8.376	3.776	-28.26	15.38
-11.99	1.069	-3.475	8.883	3.446	-19.46	2.517
-3.599	0.1519	-3.736	6.070	6.209	-11.90	-9.321
0.	0.	-3.439	3.556	6.789	-4.575	-19.48
0.	0.	2.806	-1.305	6.762	0.9020E-01	-32.68
0.	0.	0.	0.	6.330	0.3888E-01	-49.43
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.

TYPICAL DRY SEASON CONDITIONS IN MUTONGA RESERVOIR

VOLUMES m3

8
0.1453E+07
0.1222E+07
0.9908E+06
0.7595E+06
0.5283E+06
0.7003E+06
0.5814E+06
0.3000E+06
0.

7	6	5	4	3	2	1
0.2621E+06	0.9506E+06	0.2327E+07	0.3011E+07	0.4340E+07	0.4189E+07	0.4092E+07
0.2390E+06	0.8404E+06	0.2003E+07	0.2657E+07	0.3922E+07	0.3686E+07	0.3765E+07
0.2164E+06	0.7316E+06	0.1681E+07	0.2306E+07	0.3498E+07	0.3185E+07	0.3438E+07
0.1938E+06	0.6229E+06	0.1359E+07	0.1955E+07	0.3074E+07	0.2683E+07	0.3110E+07
0.1713E+06	0.5141E+06	0.1037E+07	0.1603E+07	0.2650E+07	0.2181E+07	0.2783E+07
0.	0.	0.1465E+07	0.2569E+07	0.4352E+07	0.3375E+07	0.4707E+07
0.	0.	0.2064E+07	0.3190E+07	0.4567E+07	0.3237E+07	0.5068E+07
0.	0.	0.	0.	0.5043E+07	0.3333E+07	0.4879E+07
0.	0.	0.	0.	0.	0.	0.8883E+06

X-1D-DISCHARGES (cumec)

8
18.00

7	6	5	4	3	2	1
0.	0.	0.	0.	0.	0.	65.00

Y-1D-DISCHARGES (cumec)

8
0.

7	6	5	4	3	2	1
0.	47.00	47.00	47.00	47.00	47.00	47.00

LATERAL INFLOWS (cumec)

8
18.00

7	6	5	4	3	2	1
47.00	0.	0.	0.	0.	0.	0.

Figure A14-4

Typical Dry Season Conditions:
Low Grand Falls Reservoir

TYPICAL DRY SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR - DAY 230

SETTLED MUD (T) Typical dry season conditions

19	18	17
9.986	15.37	52.65
53.98	42.14	53.03
120.9	92.43	112.6
247.2	190.4	419.2
294.5	496.4	0.
46.38	95.43	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
0.	0.	105.1	155.0	94.92	64.64	31.62	0.	3.754	47.08	181.2
0.	0.	204.9	216.0	184.8	142.7	96.36	14.26	26.56	98.31	75.39
0.	0.	573.8	331.9	314.5	286.1	212.5	32.08	59.21	192.5	106.7
0.	139.1	622.4	407.2	446.6	494.3	402.9	65.59	124.2	392.7	243.8
0.	0.	1345.	747.5	914.9	1061.	957.1	400.0	589.4	499.8	0.
0.	0.	0.	0.	1287.	1810.	1016.	804.1	517.4	101.2	0.
0.	0.	0.	0.	0.	0.	0.	1037.	112.4	0.	0.
0.	0.	0.	0.	0.	0.	0.	70.15	0.	0.	0.

5	4	3
0.	1.060	22.23
0.	18.12	48.24
0.	43.87	115.2
0.	96.93	254.5
0.	364.6	354.6
0.	430.6	154.7
0.	549.3	0.
0.	118.7	0.

2	1	20
3.733	12.62	0.
7.663	24.05	0.
18.89	58.98	0.
42.70	132.3	0.
123.7	159.8	0.
165.9	89.60	0.
270.9	35.76	270.5
73.62	0.	73.60

TYPICAL DRY SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 230

BEDLOAD G/M2/DAY Typical dry season conditions

19	18	17
0.2495E-01	0.2349E-01	0.2244E-01
0.5097E-01	0.4790E-01	0.4610E-01
0.7569E-01	0.7231E-01	0.7046E-01
0.7995E-01	0.7671E-01	0.7617E-01
0.8169E-01	0.7863E-01	0.
0.8224E-01	0.7974E-01	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
0.2342E-01	0.8078E-01	0.8110E-01	0.7198E-01	0.5777E-01	0.4016E-01	0.3241E-01	0.	0.2365E-01	0.2378E-01	0.3779E-01
0.5864E-01	0.1259	0.1388	0.1273	0.1071	0.7882E-01	0.6532E-01	0.5288E-01	0.4784E-01	0.4540E-01	0.5180E-01
0.1020	0.1395	0.1435	0.1340	0.1192	0.9821E-01	0.8805E-01	0.7720E-01	0.7268E-01	0.6875E-01	0.5993E-01
0.1185	0.1292	0.1249	0.1154	0.1050	0.9282E-01	0.8749E-01	0.8053E-01	0.7781E-01	0.7588E-01	0.6960E-01
0.	0.1191	0.1137	0.1083	0.1013	0.9125E-01	0.8743E-01	0.8197E-01	0.7962E-01	0.7791E-01	0.
0.	0.	0.	0.1056	0.9908E-01	0.8956E-01	0.8622E-01	0.8250E-01	0.8065E-01	0.7901E-01	0.
0.	0.	0.	0.	0.	0.	0.8409E-01	0.8229E-01	0.8072E-01	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.8166E-01	0.	0.	0.

5	4	3
0.2454E-01	0.2337E-01	0.2234E-01
0.4964E-01	0.4769E-01	0.4578E-01
0.7492E-01	0.7332E-01	0.7145E-01
0.7993E-01	0.7856E-01	0.7742E-01
0.8167E-01	0.8061E-01	0.8005E-01
0.	0.8125E-01	0.8097E-01
0.	0.8120E-01	0.
0.	0.8068E-01	0.

2	1	20
0.2225E-01	0.2156E-01	0.2179E-01
0.4586E-01	0.4479E-01	0.4498E-01
0.7212E-01	0.7083E-01	0.7157E-01
0.7771E-01	0.7682E-01	0.7729E-01
0.8018E-01	0.7964E-01	0.7999E-01
0.8085E-01	0.8056E-01	0.8037E-01
0.8096E-01	0.8070E-01	0.8066E-01

TYPICAL DRY SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 230

BED DETRITUS MGS Typical dry season conditions

19	18	17
0.1216E+08	0.1600E+08	0.4498E+08
0.6803E+08	0.4956E+08	0.5781E+08
0.1580E+09	0.1168E+09	0.1379E+09
0.2848E+09	0.2114E+09	0.4623E+09
0.3461E+09	0.5646E+09	0.
0.5479E+08	0.1099E+09	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
0.6274E+07	0.1031E+09	0.2244E+09	0.1636E+09	0.1206E+09	0.9501E+08	0.4763E+08	0.	0.3979E+07	0.3192E+08	0.7483E+08
0.1856E+08	0.1023E+09	0.3942E+09	0.2511E+09	0.2412E+09	0.2040E+09	0.1397E+09	0.1871E+08	0.3229E+08	0.9774E+08	0.4987E+08
0.5348E+08	0.1799E+09	0.6504E+09	0.4210E+09	0.4264E+09	0.4017E+09	0.2966E+09	0.4276E+08	0.7656E+08	0.2300E+09	0.8740E+08
0.1214E+09	0.2848E+09	0.9551E+09	0.6113E+09	0.6345E+09	0.6447E+09	0.5017E+09	0.7611E+08	0.1402E+09	0.4346E+09	0.2392E+09
0.	0.4911E+09	0.1958E+10	0.1072E+10	0.1264E+10	0.1362E+10	0.1188E+10	0.4716E+09	0.6784E+09	0.5657E+09	0.
0.	0.	0.	0.1108E+10	0.1748E+10	0.2286E+10	0.1244E+10	0.9522E+09	0.6019E+09	0.1159E+09	0.
0.	0.	0.	0.	0.	0.	0.1114E+10	0.1222E+10	0.1309E+09	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.8235E+08	0.	0.	0.

5	4	3
0.1964E+08	0.1453E+07	0.2718E+08
0.2410E+08	0.2510E+08	0.6350E+08
0.5703E+08	0.6036E+08	0.1549E+09
0.1042E+09	0.1108E+09	0.2875E+09
0.1261E+08	0.4245E+09	0.4107E+09
0.	0.5042E+09	0.1807E+09
0.	0.6424E+09	0.
0.	0.1383E+09	0.

2	1	20
0.5164E+07	0.1646E+08	0.5058E+07
0.1065E+08	0.3221E+08	0.1044E+08
0.2616E+08	0.7958E+08	0.2593E+08
0.4833E+08	0.1480E+09	0.4806E+08
0.1434E+09	0.1842E+09	0.1431E+09
0.1936E+09	0.1042E+09	0.1924E+09
0.3162E+09	0.4165E+08	0.3150E+09
0.8540E+08	0.	0.8530E+08

TYPICAL DRY SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 230

FAST DIS.BOD PPM Typical dry season conditions

19	18	17
0.1414E-01	0.1882E-01	0.2540E-01
0.8761E-02	0.1152E-01	0.1434E-01
0.8775E-02	0.1178E-01	0.1352E-01
0.1617E-02	0.2570E-02	0.2680E-02
0.1569E-02	0.2356E-02	0.
0.1342E-02	0.1930E-02	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
0.1205	0.7375E-01	0.2698E-01	0.1863E-01	0.1275E-01	0.9565E-02	0.9793E-02	0.1307E-01	0.1954E-01	0.4172E-01	0.1394
0.1132	0.6550E-01	0.2281E-01	0.1480E-01	0.9811E-02	0.6920E-02	0.6696E-02	0.8419E-02	0.1274E-01	0.2815E-01	0.9488E-01
0.7056E-01	0.3198E-01	0.9959E-02	0.6803E-02	0.5430E-02	0.5442E-02	0.6191E-02	0.8541E-02	0.1287E-01	0.2574E-01	0.7692E-01
0.1047E-01	0.2578E-02	0.9998E-03	0.8663E-03	0.9201E-03	0.1110E-02	0.1255E-02	0.1679E-02	0.2861E-02	0.6842E-02	0.4724E-01
0.	0.9661E-03	0.8618E-03	0.8644E-03	0.9316E-03	0.1112E-02	0.1238E-02	0.1574E-02	0.2370E-02	0.4383E-02	0.
0.	0.	0.	0.8424E-03	0.8945E-03	0.1055E-02	0.1155E-02	0.1327E-02	0.1834E-02	0.3198E-02	0.
0.	0.	0.	0.	0.	0.	0.1088E-02	0.1209E-02	0.1571E-02	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.1122E-02	0.	0.	0.

5	4	3
0.1127E-01	0.1194E-01	0.1462E-01
0.7489E-02	0.7763E-02	0.9401E-02
0.7834E-02	0.8252E-02	0.9614E-02
0.1699E-02	0.1675E-02	0.1883E-02
0.1476E-02	0.1516E-02	0.1574E-02
0.	0.1327E-02	0.1339E-02
0.	0.1243E-02	0.
0.	0.1106E-02	0.

2	1	20
0.1127E-01	0.1219E-01	0.1088E-01
0.7307E-02	0.7792E-02	0.7037E-02
0.7982E-02	0.8322E-02	0.7815E-02
0.1635E-02	0.1629E-02	0.1619E-02
0.1473E-02	0.1481E-02	0.1416E-02
0.1325E-02	0.1321E-02	0.1345E-02
0.1256E-02	0.1236E-02	0.1284E-02
0.1072E-02	0.	0.1064E-02

TYPICAL DRY SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 230

SLOW DIS.BOD PPM Typical dry season conditions

19	18	17
0.1769	0.1760	0.1791
0.1464	0.1435	0.1435
0.1110	0.1130	0.1144
0.2376E-01	0.2564E-01	0.2570E-01
0.2420E-01	0.2611E-01	0.
0.2355E-01	0.2513E-01	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
0.7182	0.5704	0.3601	0.3101	0.2622	0.2160	0.1960	0.1800	0.1785	0.1931	0.2612
0.7247	0.5431	0.3211	0.2662	0.2232	0.1850	0.1677	0.1511	0.1490	0.1617	0.2119
0.5387	0.3187	0.1648	0.1367	0.1218	0.1157	0.1140	0.1135	0.1191	0.1385	0.1875
0.9740E-01	0.3606E-01	0.2305E-01	0.2136E-01	0.2161E-01	0.2291E-01	0.2339E-01	0.2447E-01	0.2768E-01	0.3874E-01	0.1273
0.	0.2298E-01	0.2179E-01	0.2152E-01	0.2176E-01	0.2267E-01	0.2316E-01	0.2433E-01	0.2643E-01	0.3211E-01	0.
0.	0.	0.	0.2140E-01	0.2162E-01	0.2240E-01	0.2283E-01	0.2353E-01	0.2494E-01	0.2893E-01	0.
0.	0.	0.	0.	0.	0.	0.2260E-01	0.2314E-01	0.2416E-01	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.2283E-01	0.	0.	0.

5	4	3
0.1810	0.1757	0.1747
0.1562	0.1503	0.1484
0.1207	0.1187	0.1190
0.2721E-01	0.2602E-01	0.2648E-01
0.2439E-01	0.2452E-01	0.2474E-01
0.	0.2371E-01	0.2378E-01
0.	0.2341E-01	0.
0.	0.2284E-01	0.

2	1	20
0.1728	0.1715	0.1716
0.1485	0.1464	0.1479
0.1196	0.1181	0.1204
0.2628E-01	0.2580E-01	0.2664E-01
0.2449E-01	0.2458E-01	0.2436E-01
0.2378E-01	0.2379E-01	0.2398E-01
0.2350E-01	0.2344E-01	0.2367E-01
0.2272E-01	0.	0.2269E-01

TYPICAL DRY SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 230

AMMONIA PPM Typical dry season conditions

19	18	17
0.4075E-04	0.4189E-04	0.4294E-04
0.6746E-04	0.6781E-04	0.6804E-04
0.8250E-04	0.8165E-04	0.8134E-04
0.1026E-03	0.1021E-03	0.1021E-03
0.1025E-03	0.1020E-03	0.
0.1027E-03	0.1022E-03	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
0.2918E-05	0.1395E-04	0.3084E-04	0.3440E-04	0.3675E-04	0.3764E-04	0.3827E-04	0.3968E-04	0.4070E-04	0.4330E-04	0.5611E-04
-.2853E-06	0.2484E-04	0.5732E-04	0.6419E-04	0.6744E-04	0.6690E-04	0.6636E-04	0.6610E-04	0.6530E-04	0.6299E-04	0.6302E-04
0.2714E-04	0.6098E-04	0.8436E-04	0.8752E-04	0.8779E-04	0.8538E-04	0.8394E-04	0.8190E-04	0.7990E-04	0.7513E-04	0.6751E-04
0.9402E-04	0.1032E-03	0.1046E-03	0.1045E-03	0.1040E-03	0.1033E-03	0.1030E-03	0.1025E-03	0.1016E-03	0.9911E-04	0.8010E-04
0.	0.1048E-03	0.1046E-03	0.1044E-03	0.1040E-03	0.1033E-03	0.1030E-03	0.1025E-03	0.1019E-03	0.1006E-03	0.
0.	0.	0.	0.1044E-03	0.1040E-03	0.1033E-03	0.1030E-03	0.1027E-03	0.1023E-03	0.1013E-03	0.
0.	0.	0.	0.	0.	0.	0.1029E-03	0.1027E-03	0.1024E-03	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.1027E-03	0.	0.	0.

5	4	3
0.3753E-04	0.3809E-04	0.3896E-04
0.6214E-04	0.6277E-04	0.6324E-04
0.7929E-04	0.7939E-04	0.7921E-04
0.1018E-03	0.1020E-03	0.1019E-03
0.1025E-03	0.1024E-03	0.1023E-03
0.	0.1026E-03	0.1025E-03
0.	0.1026E-03	0.
0.	0.1026E-03	0.

2	1	20
0.3767E-04	0.3833E-04	0.3741E-04
0.6192E-04	0.6267E-04	0.6143E-04
0.7874E-04	0.7911E-04	0.7831E-04
0.1019E-03	0.1020E-03	0.1018E-03
0.1024E-03	0.1023E-03	0.1024E-03
0.1025E-03	0.1025E-03	0.1025E-03
0.1026E-03	0.1026E-03	0.1025E-03
0.1026E-03	0.	0.1026E-03

TYPICAL DRY SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR

DAY 230

NITRATE PPM Typical dry season conditions

19	18	17
0.1672	0.1657	0.1644
0.1611	0.1599	0.1591
0.1632	0.1621	0.1616
0.1239	0.1240	0.1239
0.1242	0.1244	0.
0.1241	0.1243	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
0.2461	0.2228	0.1931	0.1867	0.1807	0.1748	0.1717	0.1682	0.1662	0.1629	0.1521
0.2449	0.2218	0.1891	0.1810	0.1745	0.1682	0.1651	0.1618	0.1601	0.1579	0.1522
0.2274	0.1988	0.1769	0.1720	0.1690	0.1670	0.1658	0.1641	0.1632	0.1619	0.1515
0.1384	0.1258	0.1234	0.1231	0.1233	0.1239	0.1240	0.1242	0.1248	0.1273	0.1418
0.	0.1234	0.1232	0.1232	0.1234	0.1238	0.1239	0.1242	0.1246	0.1259	0.
0.	0.	0.	0.1232	0.1234	0.1237	0.1238	0.1241	0.1243	0.1252	0.
0.	0.	0.	0.	0.	0.	0.1238	0.1240	0.1242	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.1239	0.	0.	0.

5	4	3
0.1692	0.1681	0.1671
0.1620	0.1611	0.1604
0.1663	0.1656	0.1649
0.1255	0.1250	0.1250
0.1243	0.1244	0.1244
0.	0.1242	0.1242
0.	0.1241	0.
0.	0.1239	0.

2	1	20
0.1679	0.1673	0.1679
0.1608	0.1605	0.1607
0.1661	0.1654	0.1665
0.1252	0.1249	0.1253
0.1244	0.1244	0.1244
0.1242	0.1242	0.1243
0.1241	0.1241	0.1242
0.1239	0.	0.1239

TYPICAL DRY SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 230

DIS.OXYGEN %SAT Typical dry season conditions

19	18	17
99.05	98.72	98.45
83.16	83.50	83.76
86.27	86.58	86.76
80.86	80.94	80.93
80.89	80.98	0.
80.84	80.91	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
75.68	87.21	96.39	97.73	98.73	99.64	99.78	99.47	99.27	98.52	92.61
74.66	75.48	77.91	78.76	79.87	81.60	82.45	83.32	84.10	85.87	90.06
77.34	80.49	83.35	84.07	84.67	85.34	85.70	86.22	86.60	87.29	89.00
79.78	80.23	80.48	80.56	80.65	80.78	80.83	80.91	81.07	81.64	86.02
0.	80.40	80.51	80.57	80.65	80.77	80.82	80.90	81.00	81.29	0.
0.	0.	0.	80.56	80.62	80.74	80.79	80.85	80.91	81.11	0.
0.	0.	0.	0.	0.	0.	80.78	80.81	80.86	0.	0.
0.	0.	0.	0.	0.	0.	0.	80.78	0.	0.	0.

5	4	3
100.5	100.3	99.96
84.17	84.19	84.31
86.25	86.38	86.47
81.07	81.01	81.03
80.91	80.92	80.93
0.	80.87	80.87
0.	80.84	0.
0.	80.80	0.

2	1	20
100.5	100.1	100.6
84.43	84.31	84.55
86.45	86.45	86.50
81.04	81.00	81.06
80.92	80.93	80.92
80.88	80.88	80.89
80.85	80.84	80.87
80.81	0.	80.82

TYPICAL DRY SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR

DAY 230

DO CONC PPM

Typical dry season conditions

19	18	17
8.618	8.595	8.576
7.228	7.261	7.286
7.518	7.547	7.564
7.039	7.045	7.045
7.041	7.049	0.
7.037	7.043	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
6.535	7.539	8.348	8.470	8.564	8.653	8.671	8.653	8.642	8.591	8.120
6.443	6.524	6.749	6.827	6.927	7.082	7.158	7.240	7.312	7.476	7.879
6.692	6.985	7.251	7.317	7.372	7.432	7.465	7.512	7.548	7.613	7.779
6.937	6.981	7.004	7.011	7.019	7.031	7.036	7.043	7.057	7.109	7.507
0.	6.998	7.007	7.012	7.020	7.030	7.034	7.042	7.051	7.077	0.
0.	0.	0.	7.011	7.017	7.027	7.032	7.037	7.043	7.061	0.
0.	0.	0.	0.	0.	0.	7.031	7.034	7.038	0.	0.
0.	0.	0.	0.	0.	0.	0.	7.031	0.	0.	0.

5	4	3
8.745	8.725	8.700
7.311	7.315	7.327
7.513	7.526	7.534
7.057	7.052	7.054
7.042	7.044	7.045
0.	7.039	7.039
0.	7.037	0.
0.	7.033	0.

2	1	20
8.741	8.714	8.751
7.335	7.326	7.345
7.532	7.532	7.536
7.054	7.051	7.056
7.044	7.044	7.043
7.040	7.040	7.041
7.037	7.036	7.039
7.034	0.	7.034

TYPICAL DRY SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 230

TEMPERATURE DEGC Typical dry season conditions

19	18	17
24.52	24.48	24.45
24.59	24.56	24.53
24.42	24.41	24.40
24.49	24.49	24.49
24.49	24.49	0.
24.50	24.49	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
24.98	24.91	24.80	24.76	24.71	24.64	24.59	24.53	24.48	24.38	24.05
25.01	24.92	24.79	24.75	24.72	24.68	24.65	24.60	24.56	24.48	24.19
24.86	24.67	24.53	24.50	24.48	24.46	24.45	24.43	24.41	24.38	24.24
24.56	24.51	24.50	24.50	24.50	24.50	24.50	24.49	24.49	24.47	24.33
0.	24.50	24.50	24.50	24.50	24.50	24.50	24.49	24.49	24.48	0.
0.	0.	0.	24.50	24.50	24.50	24.50	24.50	24.49	24.49	0.
0.	0.	0.	0.	0.	0.	24.50	24.50	24.49	0.	0.
0.	0.	0.	0.	0.	0.	0.	24.50	0.	0.	0.

5	4	3
24.54	24.52	24.50
24.62	24.61	24.59
24.45	24.44	24.43
24.49	24.49	24.49
24.49	24.49	24.49
0.	24.50	24.49
0.	24.50	0.
0.	24.50	0.

2	1	20
24.52	24.51	24.52
24.61	24.60	24.61
24.44	24.44	24.44
24.49	24.49	24.49
24.49	24.49	24.49
24.50	24.50	24.49
24.50	24.50	24.50
24.50	0.	24.50

TYPICAL DRY SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR

DAY 230

INERT S.SOL. PPM   Typical dry season conditions

19	18	17
1.326	1.447	1.658
2.831	2.847	2.931
4.243	4.195	4.210
5.611	5.579	5.577
5.625	5.590	0.
5.649	5.610	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
23.54	15.42	6.412	4.597	3.102	1.873	1.469	1.298	1.424	2.180	5.959
23.20	18.22	10.14	7.944	5.999	4.052	3.311	2.804	2.731	3.068	5.266
19.87	14.50	9.079	7.698	6.474	5.188	4.692	4.223	4.097	4.109	5.124
9.308	7.187	6.227	6.000	5.857	5.717	5.667	5.603	5.562	5.481	5.263
0.	6.343	6.053	5.961	5.847	5.726	5.685	5.627	5.593	5.540	0.
0.	0.	0.	5.988	5.843	5.726	5.697	5.653	5.620	5.572	0.
0.	0.	0.	0.	0.	0.	5.756	5.676	5.632	0.	0.
0.	0.	0.	0.	0.	0.	0.	5.667	0.	0.	0.

5	4	3
1.152	1.101	1.172
2.495	2.399	2.424
3.975	3.891	3.884
5.557	5.556	5.542
5.624	5.611	5.603
0.	5.637	5.632
0.	5.648	0.
0.	5.648	0.

2	1	20
1.016	1.046	0.9765
2.250	2.278	2.178
3.776	3.790	3.712
5.540	5.540	5.529
5.609	5.601	5.613
5.632	5.628	5.627
5.643	5.638	5.636
5.643	0.	5.642

TYPICAL DRY SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 230

CHLOROPHYLL PPB Typical dry season conditions

19	18	17
0.2396	0.2276	0.2249
0.2744	0.2569	0.2503
0.1851	0.1856	0.1858
0.1010E-01	0.1205E-01	0.1202E-01
0.1051E-01	0.1280E-01	0.
0.8907E-02	0.1085E-01	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
0.5737	0.9791	0.8609	0.7417	0.5790	0.3968	0.3167	0.2502	0.2297	0.2330	0.2799
0.7070	0.7006	0.7399	0.6733	0.5721	0.4330	0.3608	0.2878	0.2636	0.2581	0.2502
0.4536	0.2295	0.1505	0.1448	0.1580	0.1833	0.1886	0.1902	0.1963	0.2149	0.2285
0.6885E-01	0.1826E-01	0.8159E-02	0.6718E-02	0.7322E-02	0.9756E-02	0.1038E-01	0.1151E-01	0.1583E-01	0.3176E-01	0.1478
0.	0.6991E-02	0.6489E-02	0.6528E-02	0.7150E-02	0.8471E-02	0.9142E-02	0.1069E-01	0.1348E-01	0.2160E-01	0.
0.	0.	0.	0.6200E-02	0.6463E-02	0.7420E-02	0.7957E-02	0.8861E-02	0.1074E-01	0.1612E-01	0.
0.	0.	0.	0.	0.	0.	0.7140E-02	0.8033E-02	0.9112E-02	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.7329E-02	0.	0.	0.

5	4	3
0.2493	0.2294	0.2213
0.2928	0.2711	0.2609
0.2069	0.2033	0.2021
0.1763E-01	0.1496E-01	0.1563E-01
0.1104E-01	0.1116E-01	0.1155E-01
0.	0.9230E-02	0.9344E-02
0.	0.8546E-02	0.
0.	0.7324E-02	0.

2	1	20
0.2182	0.2136	0.2140
0.2608	0.2544	0.2568
0.2059	0.2027	0.2081
0.1570E-01	0.1477E-01	0.1654E-01
0.1112E-01	0.1135E-01	0.1081E-01
0.9386E-02	0.9398E-02	0.9872E-02
0.8741E-02	0.8555E-02	0.9132E-02
0.7091E-02	0.	0.7029E-02

TYPICAL DRY SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR

DAY 230

ALGAL CARBON PPB Typical dry season conditions

19	18	17
11.98	11.38	11.25
13.72	12.84	12.51
9.255	9.280	9.291
0.5050	0.6025	0.6009
0.5254	0.6400	0.
0.4453	0.5423	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
28.68	48.95	43.04	37.08	28.95	19.84	15.84	12.51	11.48	11.65	13.99
35.35	35.03	36.99	33.66	28.60	21.65	18.04	14.39	13.18	12.91	12.51
22.68	11.47	7.527	7.241	7.900	9.163	9.429	9.511	9.814	10.75	11.42
3.442	0.9132	0.4079	0.3359	0.3661	0.4878	0.5189	0.5753	0.7917	1.588	7.389
0.	0.3495	0.3244	0.3264	0.3575	0.4236	0.4571	0.5347	0.6739	1.080	0.
0.	0.	0.	0.3100	0.3231	0.3710	0.3979	0.4430	0.5369	0.8062	0.
0.	0.	0.	0.	0.	0.	0.3570	0.4016	0.4556	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.3664	0.	0.	0.

5	4	3
12.46	11.47	11.06
14.64	13.55	13.05
10.34	10.16	10.10
0.8815	0.7482	0.7813
0.5521	0.5580	0.5774
0.	0.4615	0.4672
0.	0.4273	0.
0.	0.3662	0.

2	1	20
10.91	10.68	10.70
13.04	12.72	12.84
10.30	10.14	10.40
0.7852	0.7386	0.8271
0.5559	0.5676	0.5404
0.4693	0.4699	0.4936
0.4371	0.4278	0.4566
0.3545	0.	0.3515

TYPICAL DRY SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 230

DETRITAL CAR PPB Typical dry season conditions

19	18	17
0.9916	0.9335	0.8885
2.120	1.993	1.916
3.223	3.077	2.996
3.475	3.320	3.297
3.540	3.415	0.
3.569	3.462	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
0.7498	3.304	3.274	2.888	2.305	1.596	1.287	1.033	0.9403	0.9473	1.528
2.375	5.356	5.883	5.378	4.499	3.288	2.719	2.199	1.990	1.893	2.176
4.299	5.945	6.227	5.810	5.150	4.212	3.764	3.288	3.091	2.921	2.545
5.070	5.536	5.388	4.967	4.536	4.030	3.798	3.495	3.373	3.286	2.989
0.	5.159	4.963	4.730	4.416	3.964	3.796	3.556	3.454	3.376	0.
0.	0.	0.	4.620	4.308	3.891	3.745	3.581	3.500	3.425	0.
0.	0.	0.	0.	0.	0.	3.653	3.573	3.504	0.	0.
0.	0.	0.	0.	0.	0.	0.	3.547	0.	0.	0.

5	4	3
0.9689	0.9276	0.8851
2.059	1.981	1.900
3.184	3.115	3.033
3.465	3.407	3.357
3.544	3.497	3.472
0.	3.527	3.514
0.	3.525	0.
0.	3.503	0.

2	1	20
0.8818	0.8528	0.8653
1.902	1.856	1.870
3.060	3.003	3.039
3.369	3.331	3.351
3.478	3.454	3.470
3.509	3.496	3.488
3.514	3.503	3.501
3.483	0.	3.478

TYPICAL DRY SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR

DAY 230

PHOSPHATE PPM Typical dry season conditions

19	18	17
0.2011E-02	0.2082E-02	0.2185E-02
0.1653E-02	0.1704E-02	0.1764E-02
0.2150E-02	0.2181E-02	0.2209E-02
0.2889E-02	0.2897E-02	0.2900E-02
0.2883E-02	0.2885E-02	0.
0.2884E-02	0.2884E-02	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
0.9516E-02	0.6682E-02	0.3395E-02	0.2791E-02	0.2348E-02	0.2062E-02	0.1994E-02	0.2006E-02	0.2102E-02	0.2441E-02	0.3755E-02
0.9358E-02	0.6959E-02	0.3571E-02	0.2823E-02	0.2264E-02	0.1820E-02	0.1687E-02	0.1643E-02	0.1707E-02	0.1995E-02	0.3223E-02
0.7545E-02	0.5323E-02	0.3477E-02	0.3058E-02	0.2700E-02	0.2337E-02	0.2215E-02	0.2129E-02	0.2142E-02	0.2261E-02	0.3056E-02
0.3632E-02	0.3076E-02	0.2937E-02	0.2915E-02	0.2903E-02	0.2890E-02	0.2886E-02	0.2883E-02	0.2882E-02	0.2870E-02	0.2977E-02
0.	0.2938E-02	0.2920E-02	0.2911E-02	0.2902E-02	0.2891E-02	0.2888E-02	0.2882E-02	0.2882E-02	0.2876E-02	0.
0.	0.	0.	0.2909E-02	0.2901E-02	0.2891E-02	0.2888E-02	0.2883E-02	0.2883E-02	0.2879E-02	0.
0.	0.	0.	0.	0.	0.	0.2886E-02	0.2883E-02	0.2884E-02	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.2883E-02	0.	0.	0.

5	4	3
0.2000E-02	0.1996E-02	0.2032E-02
0.1595E-02	0.1583E-02	0.1613E-02
0.2019E-02	0.2011E-02	0.2031E-02
0.2853E-02	0.2865E-02	0.2865E-02
0.2878E-02	0.2877E-02	0.2876E-02
0.	0.2881E-02	0.2880E-02
0.	0.2881E-02	0.
0.	0.2882E-02	0.

2	1	20
0.1984E-02	0.1991E-02	0.1978E-02
0.1556E-02	0.1565E-02	0.1542E-02
0.1970E-02	0.1987E-02	0.1945E-02
0.2860E-02	0.2865E-02	0.2855E-02
0.2876E-02	0.2875E-02	0.2876E-02
0.2880E-02	0.2879E-02	0.2878E-02
0.2880E-02	0.2880E-02	0.2879E-02
0.2882E-02	0.	0.2882E-02

TYPICAL DRY SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR

DAY 230

VOLUMES m3

19	18	17
0.3717E+07	0.4368E+07	0.3184E+07
0.3419E+07	0.4086E+07	0.2641E+07
0.4321E+07	0.5504E+07	0.3205E+07
0.5049E+07	0.7507E+07	0.5635E+07
0.4207E+07	0.7508E+07	0.
0.5031E+06	0.1046E+07	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
0.6537E+06	0.2807E+07	0.1030E+08	0.9749E+07	0.1311E+08	0.1682E+08	0.1618E+08	0.1059E+08	0.6437E+07	0.6335E+07	0.2131E+07
0.5383E+06	0.2445E+07	0.9357E+07	0.9035E+07	0.1238E+08	0.1599E+08	0.1559E+08	0.1053E+08	0.6300E+07	0.5762E+07	0.1660E+07
0.5956E+06	0.3168E+07	0.1230E+08	0.1235E+08	0.1720E+08	0.2242E+08	0.2208E+08	0.1558E+08	0.9041E+07	0.7342E+07	0.1922E+07
0.4278E+06	0.3946E+07	0.1589E+08	0.1739E+08	0.2502E+08	0.3317E+08	0.3333E+08	0.2540E+08	0.1398E+08	0.8767E+07	0.1688E+07
0.	0.3311E+07	0.1911E+08	0.2331E+08	0.3606E+08	0.4982E+08	0.5207E+08	0.4573E+08	0.2016E+08	0.7708E+07	0.
0.	0.	0.	0.9349E+07	0.1680E+08	0.2772E+08	0.3091E+08	0.3267E+08	0.8086E+07	0.1119E+07	0.
0.	0.	0.	0.	0.	0.	0.2176E+08	0.1274E+08	0.1724E+07	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.7847E+06	0.	0.	0.

5	4	3
0.9722E+06	0.7237E+07	0.4677E+07
0.7565E+06	0.7141E+07	0.4245E+07
0.8390E+06	0.1039E+08	0.5526E+07
0.6095E+06	0.1647E+08	0.6964E+07
0.1166E+06	0.2789E+08	0.7246E+07
0.	0.1922E+08	0.1775E+07
0.	0.8562E+07	0.
0.	0.1954E+07	0.

2	1	20
0.3181E+07	0.2540E+07	0.3181E+07
0.3103E+07	0.2294E+07	0.3103E+07
0.4514E+07	0.3004E+07	0.4514E+07
0.7147E+07	0.3842E+07	0.7147E+07
0.1247E+08	0.4481E+07	0.1247E+08
0.9314E+07	0.1757E+07	0.9314E+07
0.4557E+07	0.4085E+06	0.4557E+07
0.2110E+07	0.	0.3014E+07

TYPICAL DRY SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR

DAY 230

U-VELOCITY east-west (m/s)

19	18	17
0.8130E-03	0.6424E-02	0.4367E-02
0.9710E-03	0.5975E-02	0.3899E-02
-.5947E-03	-.1069E-02	-.1016E-02
-.6924E-03	-.1616E-02	-.2828E-02
-.7733E-03	-.1505E-02	0.
-.3811E-03	-.8697E-03	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
0.	0.	0.	0.	0.	0.	0.5157E-02	0.7315E-02	-.3411E-03	0.	0.
0.	0.	0.	0.	0.	0.	0.4839E-02	0.7069E-02	-.9863E-04	0.	0.
0.	0.	0.	0.	0.	0.	0.7059E-03	0.1649E-02	-.4622E-03	0.	0.
0.	0.	0.	0.	0.	0.	0.5857E-04	0.1216E-02	-.1904E-03	0.	0.
0.	0.	0.	0.	0.	0.	-.8390E-03	0.4314E-03	-.2052E-04	0.	0.
0.	0.	0.	0.	0.	0.	0.	-.6275E-03	0.2200E-03	0.	0.
0.	0.	0.	0.	0.	0.	0.	-.2282E-02	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	-.7622E-03	0.	0.	0.

5	4	3
0.	0.2273E-02	-.6230E-03
0.	0.2154E-02	-.4198E-03
0.	0.1595E-02	0.5136E-03
0.	0.1452E-02	0.6663E-03
0.	0.1283E-02	0.8319E-03
0.	0.6086E-03	0.5943E-03
0.	-.1477E-03	0.
0.	-.1536E-03	0.

2	1	20
0.1395E-02	0.	0.
0.1390E-02	0.	0.
0.1797E-02	0.	0.
0.1795E-02	0.	0.
0.1696E-02	0.	0.
0.2240E-02	0.	0.1145E-01
0.1583E-02	0.	0.
0.6775E-03	0.	0.

TYPICAL DRY SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 230

V-VELOCITY north-south (m/s)

19	18	17
0.	0.3360E-02	-.1288E-02
0.	0.2878E-02	-.1686E-02
0.	0.8973E-03	0.1417E-02
0.	0.4580E-03	0.8320E-03
0.	-.4918E-04	0.
0.	0.	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
0.	0.4509E-01	0.2478E-01	0.8505E-02	0.9810E-02	0.9272E-02	0.4869E-02	0.4160E-02	-.6446E-04	0.7244E-02	0.2857E-02
0.	0.4652E-01	0.2350E-01	0.8037E-02	0.9170E-02	0.8661E-02	0.4540E-02	0.3771E-02	-.4029E-03	0.6471E-02	0.1401E-02
0.	0.3311E-01	0.1147E-01	0.2010E-02	0.1361E-02	0.1066E-02	0.6729E-03	0.1094E-02	0.3036E-03	-.1060E-02	-.3494E-02
0.	0.9127E-02	0.3307E-02	0.9269E-03	0.4491E-03	0.2019E-03	0.3382E-03	0.7805E-03	-.1672E-03	-.2160E-02	-.5450E-02
0.	0.	-.1979E-02	-.2768E-03	-.5942E-03	-.8267E-03	-.3132E-04	0.3938E-03	-.1049E-02	-.3829E-02	0.
0.	0.	0.	0.	-.1029E-02	-.1105E-02	-.4307E-03	-.2989E-03	-.1639E-02	-.5467E-02	0.
0.	0.	0.	0.	0.	0.	0.	-.4916E-03	-.1823E-02	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

5	4	3
0.	-.8306E-03	0.1986E-02
0.	-.1085E-02	0.1704E-02
0.	0.1358E-02	0.3534E-04
0.	0.1040E-02	-.2484E-03
0.	0.2203E-02	-.3667E-03
0.	0.	0.1688E-03
0.	0.	0.
0.	0.	0.

2	1	20
0.	0.1508E-04	0.
0.	0.2634E-03	0.
0.	-.1830E-03	0.
0.	-.3096E-03	0.
0.	-.2979E-03	0.
0.	-.9613E-05	0.
0.	0.4506E-03	0.
0.	0.	0.

TYPICAL DRY SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR

DAY 230

VERTICAL VELOCITY down: -ve (m/s)

19	18	17
0.5388E-05	0.6066E-05	0.5456E-05
0.1167E-04	0.1261E-04	0.1182E-04
0.1299E-04	0.1284E-04	0.1042E-04
0.1410E-04	0.1234E-04	0.
0.1022E-04	0.1002E-04	0.
0.	0.	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
-.1444E-03	0.2848E-05	0.6225E-06	0.1234E-05	0.7864E-06	-.9817E-06	-.5395E-06	0.1489E-05	-.2064E-06	-.7273E-05	-.1625E-04
-.9658E-04	0.5748E-05	0.1176E-05	0.2824E-05	0.1564E-05	-.1927E-05	-.1259E-05	0.2889E-05	-.8913E-07	-.1565E-04	-.2231E-04
-.3609E-04	0.4240E-05	-.3745E-06	0.2728E-05	0.1658E-05	-.2106E-05	-.1055E-05	0.4658E-05	-.9213E-06	-.1988E-04	-.1978E-04
0.	0.7153E-05	-.8103E-06	0.2809E-05	0.1653E-05	-.1943E-05	-.7518E-06	0.6989E-05	-.1365E-05	-.2834E-04	0.
0.	0.	0.	0.2974E-05	0.9074E-06	-.3261E-06	0.3912E-06	0.8132E-05	-.3173E-05	-.4427E-04	0.
0.	0.	0.	0.	0.	0.	0.1948E-05	0.8345E-05	-.9490E-05	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.7508E-05	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

5	4	3
-.2156E-04	-.3793E-05	-.2921E-05
-.5050E-04	-.7782E-05	-.6177E-05
-.6275E-04	-.9573E-05	-.6088E-05
-.4083E-03	-.1179E-04	-.5484E-05
0.	-.1535E-04	0.1799E-05
0.	-.1327E-04	0.
0.	-.3172E-05	0.
0.	0.	0.

2	1	20
-.3118E-05	0.6958E-06	-.2963E-05
-.5783E-05	0.6945E-06	-.5925E-05
-.7700E-05	0.5317E-06	-.1159E-04
-.1135E-04	0.1010E-05	-.2102E-04
-.2184E-04	0.4249E-05	-.4122E-04
-.2341E-04	0.1041E-04	0.1930E-04
-.1728E-04	0.	0.1527E-04

TYPICAL DRY SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR

DAY 230

X-DISCHARGES east-west (cumec)

19	18	17
3.561	21.97	4.912
4.195	20.02	3.158
-3.720	-5.093	-.8913
-6.803	-11.73	-3.182
-9.396	-13.89	0.
-1.029	-2.087	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
0.	0.	0.	0.	0.	0.	6.869	32.04	-.9578	0.	0.
0.	0.	0.	0.	0.	0.	5.516	30.96	-.2548	0.	0.
0.	0.	0.	0.	0.	0.	1.048	10.83	-1.484	0.	0.
0.	0.	0.	0.	0.	0.	0.1098	13.32	-.6816	0.	0.
0.	0.	0.	0.	0.	0.	-1.258	9.080	-.5387E-01	0.	0.
0.	0.	0.	0.	0.	0.	0.	-8.550	0.3300E-01	0.	0.
0.	0.	0.	0.	0.	0.	0.	-20.42	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	-1.143	0.	0.	0.

5	4	3
0.	9.643	-.9309
0.	9.053	-.5742
0.	9.892	0.9153
0.	14.61	1.499
0.	22.80	2.059
0.	7.896	0.4011
0.	-1.950	0.
0.	-.3225	0.

2	1	20
4.654	0.	0.
4.429	0.	0.
8.032	0.	0.
11.94	0.	0.
16.79	0.	0.
14.67	0.	75.00
12.03	0.	0.
2.456	0.	0.

TYPICAL DRY SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 230

Y-DISCHARGES north-south (cumec)

19	18	17
0.	6.229	-2.844
0.	4.703	-3.503
0.	1.641	3.972
0.	0.6355	6.373
0.	-.1721E-01	0.
0.	0.	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
0.	22.06	25.73	28.78	34.56	39.57	31.51	20.34	-.2533	22.01	4.713
0.	19.68	22.65	24.83	31.36	35.74	28.79	17.98	-1.535	19.12	2.109
0.	17.63	15.04	8.400	6.674	6.335	6.268	7.324	1.633	-4.402	-6.399
0.	5.636	6.035	5.335	3.402	1.866	5.071	7.762	-1.348	-13.32	-10.42
0.	0.	-4.453	-2.346	-6.284	-11.39	-.7733	6.807	-13.01	-27.57	0.
0.	0.	0.	0.	-4.709	-7.126	-5.869	-3.606	-9.751	-9.840	0.
0.	0.	0.	0.	0.	0.	0.	-3.898	-2.324	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

5	4	3
0.	-2.136	6.555
0.	-2.588	5.571
0.	4.321	0.1694
0.	4.425	-1.910
0.	8.262	-4.593
0.	0.	0.9746
0.	0.	0.
0.	0.	0.

2	1	20
0.	0.9227E-01	0.
0.	0.6567	0.
0.	-.6452	0.
0.	-1.643	0.
0.	-2.591	0.
0.	-.5047E-01	0.
0.	0.8111	0.
0.	0.	0.

TYPICAL DRY SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR

DAY 230

Z-DISCHARGES   down : -ve   (cumec)

19	18	17
9.790	12.90	7.757
18.69	24.71	14.42
16.61	21.95	9.555
10.44	15.96	0.
1.029	2.087	0.
0.	0.	0.
0.	0.	0.
0.	0.	0.

16	15	14	13	12	11	10	9	8	7	6
-42.94	3.672	3.056	5.771	5.012	-8.057	-4.298	7.880	-.6614	-22.21	-14.71
-23.26	6.645	5.231	12.31	9.396	-15.01	-9.592	15.13	-.2759	-42.38	-16.82
-5.636	4.054	-1.406	10.58	9.057	-15.08	-7.487	23.99	-2.701	-43.49	-10.42
0.	4.453	-2.107	8.647	7.521	-11.87	-4.686	35.00	-3.631	-37.41	0.
0.	0.	0.	4.709	2.417	-1.257	1.636	33.66	-4.355	-9.840	0.
0.	0.	0.	0.	0.	0.	3.898	19.99	-2.324	0.	0.
0.	0.	0.	0.	0.	0.	0.	1.143	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

5	4	3
-9.005	-13.70	-6.528
-17.11	-27.45	-12.42
-13.84	-32.55	-10.19
-9.521	-37.58	-6.099
0.	-36.71	0.6064
0.	-19.29	0.
0.	-.8208	0.
0.	0.	0.

2	1	20
-4.897	0.3386	-4.654
-8.865	0.7561	-9.083
-11.37	0.4860	-17.12
-15.69	0.6293	-29.05
-24.29	1.162	-45.84
-17.57	0.8111	14.49
-2.778	0.	2.456
0.	0.	0.

TYPICAL DRY SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 230

X-1D-DISCHARGES (cumec)

							19	18	17	
							-13.19	9.194	3.998	
16	15	14	13	12	11	10	9	8	7	6
0.	0.	0.	0.	0.	0.	12.29	66.11	-3.399	0.	0.
						5	4	3		
						0.	71.63	3.370		
							2	1	20	
							75.00	0.	75.00	

Y-1D-DISCHARGES (cumec)

							19	18	17	
							0.	13.19	3.998	
16	15	14	13	12	11	10	9	8	7	6
0.	65.00	65.00	65.00	65.00	65.00	65.00	52.71	-26.59	-14.00	-10.00
						5	4	3		
						0.	12.29	6.768		
							2	1	20	
							0.	-3.370	0.	

LATERAL INFLOWS (cumec)

							19	18	17	
							0.	0.	0.	
16	15	14	13	12	11	10	9	8	7	6
65.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	10.00
						5	4	3		
						0.	0.	0.		
							2	1	20	
							0.	0.	0.	

TYPICAL DRY SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 230

FB stream conc.s (ppm) Typical dry season conditions

							19	18	17	
							0.	0.	0.	
16	15	14	13	12	11	10	9	8	7	6
0.1300	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.500
						5	4	3		
						0.	0.	0.		
							2	1	20	
							0.	0.	0.	

SB stream conc.s (ppm) Typical dry season conditions

							19	18	17	
							0.	0.	0.	
16	15	14	13	12	11	10	9	8	7	6
0.7500	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.500
						5	4	3		
						0.	0.	0.		
							2	1	20	
							0.	0.	0.	

DO stream conc.s (ppm) Typical dry season conditions

							19	18	17	
							0.	0.	0.	
16	15	14	13	12	11	10	9	8	7	6
6.210	0.	0.	0.	0.	0.	0.	0.	0.	0.	9.200
						5	4	3		
						0.	0.	0.		
							2	1	20	
							0.	0.	0.	

TYPICAL DRY SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 230

ON stream conc.s (ppm) Typical dry season conditions

							19	18	17	
							0.	0.	0.	
16	15	14	13	12	11	10	9	8	7	6
0.2500	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.1000
						5	4	3		
						0.	0.	0.		
							2	1	20	
							0.	0.	0.	

MUD stream conc. (ppm) Typical dry season conditions

							19	18	17	
							0.	0.	0.	
16	15	14	13	12	11	10	9	8	7	6
25.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	40.00
						5	4	3		
						0.	0.	0.		
							2	1	20	
							0.	0.	0.	

AC stream conc.s (ppm) Typical dry season conditions

							19	18	17	
							0.	0.	0.	
16	15	14	13	12	11	10	9	8	7	6
0.2650E-01	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.5000E-01
						5	4	3		
						0.	0.	0.		
							2	1	20	
							0.	0.	0.	

TYPICAL DRY SEASON CONDITIONS IN LOW GRAND FALLS RESERVOIR DAY 230

PH stream conc.s (ppm) Typical dry season conditions

							19 0.	18 0.	17 0.	
16 0.1000E-01	15 0.	14 0.	13 0.	12 0.	11 0.	10 0.	9 0.	8 0.	7 0.	6 0.2000E-01
						5 0.	4 0.	3 0.		
							2 0.	1 0.	20 0.	

TP stream conc.s deg. C Typical dry season conditions

							19 0.	18 0.	17 0.	
16 25.00	15 0.	14 0.	13 0.	12 0.	11 0.	10 0.	9 0.	8 0.	7 0.	6 20.00
						5 0.	4 0.	3 0.		
							2 0.	1 0.	20 0.	

Table A14-5 **Dry Season Physicochemical/Nutrients and Plankton Concentrations of Kiambere Dam/Reservoir on 27/9/95**

Station No.	Depth M	Temp °C	pH	DO mg/l	BOD5 mg/l	Cond uS/cm	Turb NTU		Color TDSS mg/l	N.N03 mg/l	N.NO2 mg/l	N.NH4 mg/l	P.PO4 Ug/l	Chl.a mg/m3	Zoop mg/m3	
KQ 1	18m		25													
Secci	1.8m															
		1	21	7.5	11.6	2	100	3	Clear	1	0.3	0.01	0	0.01	4.9	0.019
		5	22	7.5	6.9	3	100	4	Clear	22	0.25	0.01	0	0.01	8.9	0.03
		15	24	8	7.8	2	100	4	Clear	28	0.2	0.01	0	0.01	0.8	0.033
KQ2	40m		26													
Secci	1.6m															
		1	28	8	10.3	3	105		Clear	1	0.21	0.01	0		5.9	0.014
		5	26.5	8	7.5	3.5	105		Clear	6	0.2	0.01	0		2.1	0.043
		15	25.5	7.5	7.4	2.5	105		Clear	8	0.3	0.01	0		1.8	0.021
		35	24.5	7.5	6.5	2.5	105		Brown	43	0.2	0.01	0		1.8	0.001
KQ3	86m		26													
Secci	1.5m															
		1	28	8	9.5	2.5	105	3	Clear	8	0.21	0.01	0	0.01	4.7	0.021
		5	26	8	7.1	3	110	4	Clear	6	0.2	0.01	0	0.01	5	0.042
		15	24	7.9	7.5	2	106	4	Clear	8	0.3	0.01	0	0.01	1.7	0.042
		35	24	8	9.8	2.5	105	10	Grey	18	0.2	0.01	0	0.01	2	0.036
		50	24	7.5	7.9	3	110	20	Brown	85	0.25	0.01	0	0.02	1	0.001
		70	24	8.5	5.1	3	110	30	Brown	87	0.35	0.01	0	0.02	1	0.001
KS1	River		25	7.5	9	2	100	30	Brown	20	0	0	0	0.02		
KS2	River		25	7.5	8.6	2.4	100	35	Brown	25	0	0	0	0.02		

KEY:

KQ1 Kiambere Reservoir Station 1 at 15 km from the Dam wall and about 2 km from the River mouth

KQ2 Kiambere Mid Reservoir Station 2 at about 6 km from the Dam wall

KQ3 Kiambere Reservoir Station at about 1 km from the Dam wall

KS1 and KS2 are River sampling stations at the reservoir entrance and the outflow at the plunge pool

Table A14-6 Wet Season Physicochemical/Nutrients/Plankton Concentrations of Kiambere Dam/Reservoir on 13/11/95

Station No.	Depth M	Temp °C	pH	DO mg/l	BOD5 mg/l	Cond uS/cm	Turb NTU	Color	TDSS mg/l	N.N03 mg/l	N.NO2 mg/l	N.NH4 mg/l	P.PO4 Ug/l	Chl.a mg/m3	Zoop mg/m3
KQ 1															
	1	27	8	10.5	1	100	3	Clear	1	0.01	0.01	0.01	0.01	13.34	0.002
	5	26.5	8	9.9	1.2	100	4	Clear	22	0.01	0.01	0.01	0.01	9.28	0.075
	15	26	7.5	4.8	1.5	100	5	Clear	28	0.05	0.01	0.01	0.01	8.12	0.023
KQ2															
	1	27	8	11.2	1	100	3	Clear	3	0.01	0.01	0	0.01	17.04	0.015
	5	26.5	8	9.1	2	105	3	Clear	19	0.01	0.01	0.1	0.01	17.23	0.003
	15	26	7.5	5.2	0.8	105	4	Clear	30	0.01	0.01	0.1	0.05	5.9	0.007
	35	26	7.8	5.6	2.1	105	5	Clear	50	0.01	0.01	0.1	0.05	4.06	0.006
KQ3															
	1	28	7.5	10.6	1	100	3	Clear	4	0.2	0.01	0.01	0.01	14.14	0.009
	5	27.5	7.5	9.8	2	110	4	Clear	20	0.2	0.01	0.01	0.01	13.05	0.008
	15	26.5	7.9	6.2	2.1	105	6	Clear	40	0.3	0.01	0.01	0.01	10.63	0.006
	35	25.5	8	4.9	2	105	10	Grey	60	0.2	0.01	0.2	0.01	4.64	0.007
	50	25.5	7.5	4.1	2.1	110	20	Brown	70	0.2	0.01	0.2	0.05	5.6	0
	70	25.5	7.5	5.4	2.5	110	60	Brown	80	0.2	0.01	0.2	0.05	2.07	0
KS1	River	25	7.5	8.4	3.1	100	50	Brown	70	0.15	0.01	0	0.05		
KS2	River	26	7.5	9.3	3.5	100	60	Brown	80	0.15	0.01	0	0.05		

KEY: KQ1 Kiambere Reservoir Station 1 at 15km from the Dam wall and about 2km from the River mouth

KQ2 Kiambere Mid Reservoir Station 2 at about 6km from the Dam wall

KQ3 Kiambere Reservoir Station at about 1km from the Dam wall

KS1 and KS2 are River sampling stations at the reservoir entrance and the outflow at the plunge pool

Table A14-7 Late Wet Season Physicochemical/Nutrients/Plankton Concentrations of Kiambere Dam/Reservoir on 27/11/95

Station No.	Depth M	Temp oC	pH	DO mg/l	BOD5 mg/l	Cond uS/cm	Turb NTU	Color	TDSS mg/l	N.N03 mg/l	N.NO2 mg/l	N.NH4 mg/l	P.PO4 Ug/l	Chl.a mg/m3	Zoop mg/m3
KQ 1															
	1	28	8	10	1	100	2	Clear	1	0.01	0.01	0.01	0.01	14.6	0.001
	5	27	8.5	11	1.6	100	2	Clear	10	0.01	0.01	0.01	0.01	15.2	0.003
	15	25	8.5	6	2.1	105	4	Clear	25	0.01	0.01	0.05	0.04	9	0.002
KQ2															
	1	27	7.5	11	1.1	100	3	Clear	4	0.02	0.01	0.01	0.01	16.2	0.002
	5	26	8	10	1.6	100	2	Clear	4	0.01	0.01	0.01	0.01	18.2	0.004
	15	25.5	8	5	1.3	105	5	Grey	15	0.31	0.01	0.06	0.01	10.1	0.009
	35	24.5	8.5	3	1.4	105	10	Brown	40	0.4	0.01	0.05	0.07	9	0.001
KQ3															
	1	26	7.5	10.8	2	100	3	Clear	5	0.05	0.01	0.01	1.01	18.2	0.002
	5	25	8	10.5	3	100	2	Clear	4	0.1	0.01	0.01	0.01	17.3	0.004
	15	24.5	8.5	8.5	1.1	110	4	Clear	10	0.2	0.01	0.05	0.01	10.1	0.1
	35	24	8.5	4.2	2.6	105	10	Grey	18	0.2	0.01	0.05	0.04	5	0.005
	50	24	8.5	3.1	2.7	110	25	Brown	50	0.2	0.01	0.08	0.09	2	0.001
	70	24	8.5	2	3	110	25	Brown	80	0.5	0.01	0.08	0.09	1	0.001
KS1	River	25.5	7	8.6	3	100	30	Brown	60	0.15	0.01	0	0.05		
KS2	River	25	7.5	9.6	3.5	100	30	Brown	70	0.2	0.01	0	0.05		

KEY:

KQ1 Kiambere Reservoir Station 1 at 15km from the Dam wall and about 2km from the River mouth

KQ2 Kiambere Mid Reservoir Station 2 at about 6km from the Dam wall

KQ3 Kiambere Reservoir Station at about 1km from the Dam wall

KS1 and KS2 are River sampling stations at the reservoir entrance and the outflow at the plunge pool

Annex to Chapter 16

A-16. ANNEX TO CHAPTER 16

A-16.1 RATING CURVES

A-16.1.1 Review of Existing Curves

Rating curves for the Tana at Grand Falls, Garissa, Garsen, Saka and Nanigi are given in DHV (1986). These curves were fitted by MOWD except for the curves for Saka which were fitted by consultants. The equations of the curves are given in imperial units except for those at Saka and Nanigi which are in metric. The following errors were detected:

- In table 3-2a the rating for Garissa 01/08/79-30/06/85 is in metric units not imperial as stated.
- In table 3-2b the range is in metres not feet as stated.
- In table 3-2b part 1 of the rating for Saka 01/12/84-30/06/85 is actually part 3 of the rating for 05/10/83-30/11/84. The dates of the second rating have been typed one line above the correct position in the table.

The rating equations and curves for the Tana at Grand Falls and Garissa are reproduced in Nippon Koei (1995a) although converted into metric units. As part of the present study a check was performed by converting the original imperial unit equations given in DHV (1986) to metric units. The results agreed with the Nippon Koei (1995) equations in all but one instance (part 3 of the rating for Garissa 28/11/45-16/04/50). The only other difference between the two sets of ratings is that those given in Nippon Koei (1995) cover the period of time since the DHV(1986) study was published.

The existing MOWD rating equations are given in table A.16-1 and are reviewed below for each station in turn. The curves are plotted in figures A.16-1 to A.16-14 which compare the existing curves with the new ratings fitted on HYDATA.

4F13 Tana at Grand Falls

R (01/08/62-15/11/63) The gaugings provided for this period are in two clusters. The curve fits both clusters but there are no gaugings to check the fit at other levels, particularly high stages.

S (16/11/63-04/12/68) The curve fits the gaugings well apart from a small number which lie some way below the curve.

T (05/12/68-31/12/93) The gaugings provided suggest a good fit at low stages. However, the curve may be overestimating at higher stages due to the influence of two suspected erroneous gaugings.

4G01 Tana at Garissa

J (01/04/41-27/11/45) In the data provided there are only four gaugings during this period. These suggest a good fit for part 1 of the curve but do not provide a check on part 2.

K (28/1145-16/04/50) The curve fits the scatter of gaugings although there is one outlier.

L (17/04/50-30/04/58) The gaugings suggest a good fit for part 1 of the curve but do not provide a check on part 2.

M (01/05/58-21/12/61) Parts 1 and 2 fit the gaugings well but part 3 is poor, overestimating flows.

N (01/01/62-20/04/63) No gaugings were provided for this period to check the curve.

O (21/04/63-09/04/70) The gaugings suggest a good fit for part 1 of the curve but only allow a check on the lower end of the range of part 2.

P (10/04/70-18/04/73) The gaugings suggest a good fit for parts 1 and 2 of the curve but do not provide a check on part 3 .

Q (19/04/73-31/07/91) Part 1 fits the gaugings well but part 2 may be underestimating flows. One suspected erroneous gauging was amended (see Table A.16-2).

R (01/08/79-30/06/85) and S (01/08/79-29/03/85) These curves are identical except that the period covered by S is slightly shorter due to the inclusion of data after 29/03/85 with more recent gaugings for curve T. Both parts of the curve appear to fit the gaugings well.

T (30/03/85-31/12/94) The gaugings suggest a good fit for both parts 1 and 2 although most of the scatter lies above the rating curve.

4G02 Tana at Garsen

S (16/09/50-11/12/62) The rating curve fits the gauging data well.

T (12/12/62-31/12/80) Part 1 of the curve fits the gaugings well at low values of stage but may be overestimating flows above this. The gaugings provided do not allow a check on part 2 of the rating. Four suspected erroneous gaugings were amended (see Table A.16-2).

4G08 Tana at Nanigi

T (15/10/73-05/12/78) Both parts 1 and 2 of the curve fit the gaugings well except for four outliers. These four gaugings were amended (see Table A.16-2).

4G10 Tana at Saka

S (05/10/83-30/11/84) The curve appears to fit the gaugings well although perhaps overestimating flow at low stages.

T (01/12/84-30/06/85) The curve fits the three gaugings provided for this period well but does not allow estimation of flows at stages below 2.0 metres.

A-16.1.2 Fitting of curves on HYDATA

New rating curves were fitted to the gauging data of each station. The gaugings were first assessed for any possible shifts in the relationship between stage and discharge and split into what appeared to be periods during which this relationship remained consistent. These periods are broadly the same as those used in the existing MOWD ratings although in the case of

Grand Falls and Garissa several of the new rating periods span two or more of those used in the development of the existing ratings (eg rating A is concurrent with ratings J,K and L). The rating periods for curves at Garsen are also slightly different to the existing ones, starting earlier and finishing more recently, reflecting the provision of both earlier and later gaugings than were covered by the existing rating periods.

Rating curves were fitted to each of the periods of gauging data using the automatic fitting procedure on the Institute of Hydrology's HYDATA hydrological database and analysis software. Curves were fitted with between one and three parts with the goodness of fit judged by an automatically computed error function but with an experienced hydrologist also exercising some degree of judgement. The rating equations are of the form

$$Q = a\,(h - c)^{b}$$

where Q is flow (or discharge) in m^3s^{-1}, h is stage (or level) in m, and a, b and c are constants.

The new HYDATA rating equations are given in table A.16-3. In most cases it was clear which curve (1,2 or 3 parts) gave the best fit with the gauging data and only one curve is given for these rating periods. In two instances, however, more than one curve is given for a single rating period. These are curves B and C for Garsen and curves A, C, D, and E for Nanigi. In the former case a 1 part and a 2 part curve are compared. In the latter case the comparison is also between 1 part and 2 part curves with two of each fitted, one with the amendments to gauging data suggested in table A.16-2 and one with this data excluded.

The new HYDATA rating curves are plotted Figures A.16-1 to A.16-14 where they are compared with the existing MOWD curves.

Table A-116-1 Existing ratings

Station	Rating	Period	Range (metres)		Constants		
			Low	High	a	b	c
Grand Falls	R	01/08/62-15/11/63	0.000	99.990	28.082	1.882	
	S	16/11/63-04/12/68	0.762	2.118	49.880	1.007	
			2.118	5.059	28.617	1.747	
			5.059	13.715	15.368	2.130	
	T	5/12/68-31/12/93	0.003	2.865	58.655	1.060	
			2.865	12.191	19.893	2.087	
Garissa	J	01/04/41-27/11/45	0.244	3.075	75.008	1.519	
			3.075	5.486	22.121	2.606	
	K	28/11/45-16/04/50	0.305	2.012	52.798	1.408	
			2.012	3.414	32.992	2.081	
			3.414	5.181	12.151	2.895	
	L	17/04/50-30/04/58	0.549	2.194	61.177	1.459	
			2.194	4.191	43.810	1.884	
			4.191	7.010	4.257	3.511	
	M	01/05/58-31/12/61	0.792	1.524	45.657	1.310	
			1.524	3.962	33.692	2.031	
			3.962	7.010	4.739	3.455	
	N	01/01/62-20/04/63	0.640	4.191	101.896	1.294	
			4.191	7.010	4.257	3.511	
	O	21/04/63-09/04/70	0.610	3.261	55.710	1.849	
			3.261	6.096	32.478	2.305	
	P	10/04/70-18/04/73	0.152	1.451	86.566	1.322	
			1.451	3.109	75.336	1.695	
			3.109	4.572	39.730	2.259	
	Q	19/04/73-31/07/79	0.305	1.829	59.681	1.677	
			1.829	5.791	56.471	1.768	
	R	01/08/79-30/06/85	0.100	3.000	26.580	2.359	
			3.000	6.000	41.260	1.959	
	S	01/08/79-29/03/85	0.000	3.000	26.580	2.359	
			3.000	99.000	41.260	1.959	
	T	30/03/85-31/12/94	0.000	1.800	38.910	1.931	
			1.800	99.000	30.531	2.343	
Garsen	S	16/09/50-11/12/62	0.914	6.096	26.319	1.401	
	T	12/12/62-31/12/80	0.914	4.572	13.976	1.816	
			4.572	6.096	26.319	1.401	
Saka	S	05/10/83-30/11/84	0.000	1.000	75.000	1.710	0.500
			1.000	1.250	150.000	1.561	0.000
	T	01/12/84-30/06/85	1.250	2.000	144.640	1.724	0.000
			2.000	2.400	26.150	2.579	0.000
			2.400	3.000	18.290	2.987	0.000
Nanigi	T	15/10/73-05/12/78	0.020	1.070	16.840	2.020	1.000
			1.070	5.500	66.990	1.270	0.000

Sources: DHV (1986)
and Nippon Koei (1995)

Table A16-2 Suspected errors and amendments to gauging data

Station	Date of gauging	Suspected error	Suggested amendment
4F13	17/08/63	h = 2.21m	h = 1.21 m
Grand Falls*	04/05/66	h = 4.15 m	h = 5.98 m
	03/06/66	h = 1.17 m	h = 3.00 m
	15/04/71	h = 2.44 m	h = 1.44 m
	18/10/71	Q = 4.01 m^3s^{-1}	h = 40.01 m^3s^{-1}
	19/02/74	h = 3.42 m	h = 1.03 m
	03/08/77	h = 2.33 m	h = 3.33 m
	01/08/79	h = 2.78 m	h = 1.78 m
4G01 Garissa	11/05/73	Q = 523.78 m^3s^{-1}	Q = 123.78 m^3s^{-1}
4G02 Garsen	06/03/74	h = 2.009 m	h = 1.009 m
	07/03/74	h = 1.999 m	h = 0.999 m
	08/03/74	h = 1.999 m	h = 0.999 m
	20/08/82	h = 0.79 m	h = 2.79 m
4G08 Nanigi	10/06/78	h = 3.94 m	h = 2.94 m
	17/07/78	h = 3.34 m	h = 2.34 m
	25/08/78	h = 0.9 m, V = 2.68 ms^{-1}	h = 1.68 m, V = 0.9 ms^{-1}
	28/09/79	h = 0.41 m, V = 2.05 ms^{-1}	h = 1.05 m, V = 0.41 ms^{-1}

* Suggested amendments to gaugings at Grand Falls were made on the basis of evidence supplied by staff at MOWD whilst the consultant was in Nairobi.

Table A16-3 Rating equations fitted on HYDATA

Station	Rating	Period	Range (metres)		Constants		
			Low	High	a	b	c
Grand Falls	A	27/07/62-28/01/81	0.000	2.100	13.842	1.706	1.310
			2.100	4.000	69.384	1.300	-0.690
			4.000	10.000	39.494	1.763	-0.690
Garissa	A	27/03/45-04/04/59	0.000	1.900	55.225	1.344	0.009
			1.900	3.750	64.200	1.718	-0.368
			3.750	7.000	17.624	2.800	-0.368
	B	05/04/59-03/03/64	0.000	3.500	6.528	2.800	0.965
			3.500	7.000	104.562	1.567	-1.035
	C	04/03/64-22/04/70	0.000	2.150	106.199	1.300	-0.385
			2.150	7.000	57.847	1.835	-0.089
	D	23/04/70-10/05/73	0.000	7.000	10.040	2.800	1.062
	E	11/05/73-11/02/80	0.000	1.700	78.740	1.300	-0.189
			1.700	7.000	107.184	1.508	-0.500
	F	12/02/80-02/03/95	0.000	3.100	9.262	2.800	0.569
			3.100	7.000	14.472	2.800	0.046
Garsen	A	31/03/46-15/01/63	0.000	6.000	22.860	1.483	0.056
	B	16/01/63-30/11/91	0.000	6.000	3.230	2.503	1.011
	C	16/01/63-30/11/91	0.000	2.750	3.190	2.512	1.011
			2.750	6.000	43.340	1.300	-0.989
Saka	A	09/02/84-13/11/84	0.000	1.150	165.860	1.300	-0.019
			1.150	2.340	98.520	2.037	0.232
	B	14/11/84-29/05/85	2.340	3.000	49.600	2.300	-0.330
Nanigi	A	30/10/74-09/06/78	0.000	1.750	5.150	2.800	1.552
			1.750	5.500	14.731	1.855	1.770
	B	10/06/78-29/09/79	0.000	5.500	44.633	1.300	-0.642
	C	30/10/74-09/06/78	0.000	5.500	28.660	1.711	0.715
	D	30/10/74-09/06/78	0.000	5.500	34.070	1.576	0.611
	E	30/10/74-09/06/78	0.000	1.750	4.740	2.800	1.614
			1.750	5.500	12.840	1.899	1.770

A.3 COMPARISON AND SELECTION OF CURVES

The new HYDATA rating curves are plotted against the existing MOWD curves in figures A.1 to A.14. The existing and new curves for each rating period at each station were compared in term of the goodness of fit with the gauging data provided. In the majority of cases the HYDATA curves appear to fit the gauging data more closely. Where both existing and new curves gave a good fit it was decided to adopt the new ratings for consistency. Details of the comparison are given below.

4F13 Tana at Grand Falls

Comparison of A with R, S and T	Although curves R, S and T all fit the gauging data provided reasonably well it was felt that there was enough cause for concern in the ratings R and T (due to lack of gaugings and presence of possible erroneous gaugings) to fit a single curve to the whole period. Curve A provides a satisfactory fit through the gaugings provided.

4G01 Tana at Garissa

Comparison of A with J,K and L	The gaugings over the existing rating periods for curves J, K and L appear to be consistent. The single curve A fits this combined set of gaugings better than any of the existing curves.
Comparison of B with M and N	There are no gaugings provided for the rating period of curve N and curve M does not give a good fit across the full range of gaugings. Curve B provides the best fit.
Comparison of C with O	Curve C provides the best fit.
Comparison of D with P	There are no gaugings to guide the upper part of the rating. D gives the best fit with the gaugings provided.
Comparison of E with Q	Curve E provides the best fit.
Comparison of F with R/S and T	Curves R/S and T both fit the individual rating periods reasonably well but curve F gives the best fit for the period as a whole.

4G02 Tana at Garsen

Comparison of A with S	Both curves give a good fit, use A for consistency.
Comparison of B and C with T	Curve C gives the better fit of the two HYDATA curves for this period. Curve T gives poor fit in region of part 2. Use curve C.

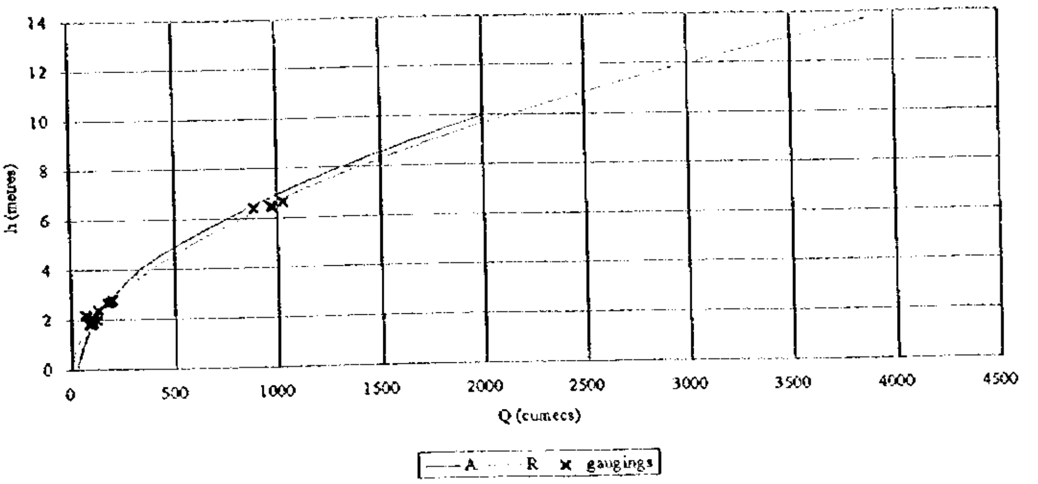
4G08 Tana at Nanigi

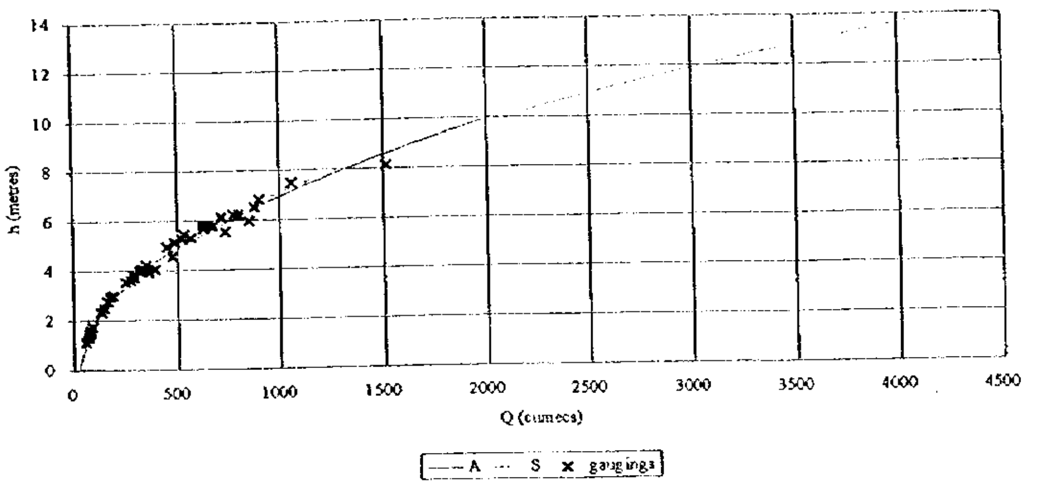
Comparison of A and C with T	With the suspected errors listed in table A.2 excluded the best fit is given by curve A.
Comparison of D and E with T	With the suspected errors listed in table A.2 amended the best fit is given by curve E but note that the amended gaugings do not lie on any of the fitted curves. The decision was therefore taken to exclude these gaugings and accept curve A as the best fit.
	Curve B for Nanigi is not concurrent with any existing MOWD curve and is fitted against only two points. It is unlikely to be used in converting stages to discharges.

4G10 Tana at Saka

Comparison of A with S	Both curves give a good fit, use A for consistency.
Comparison of B with T	Both curves give a good fit, use B for consistency.

Figure A-16-1 Rating Curves: Grand Falls





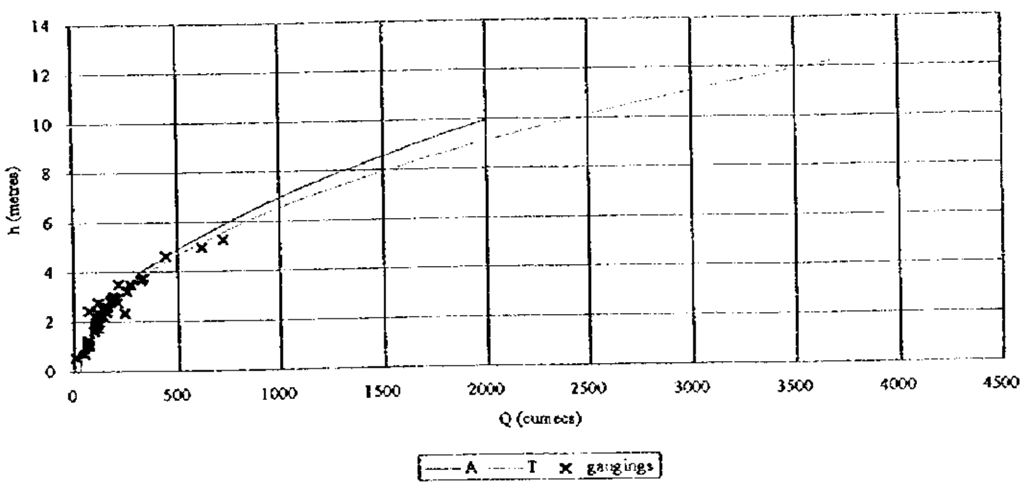
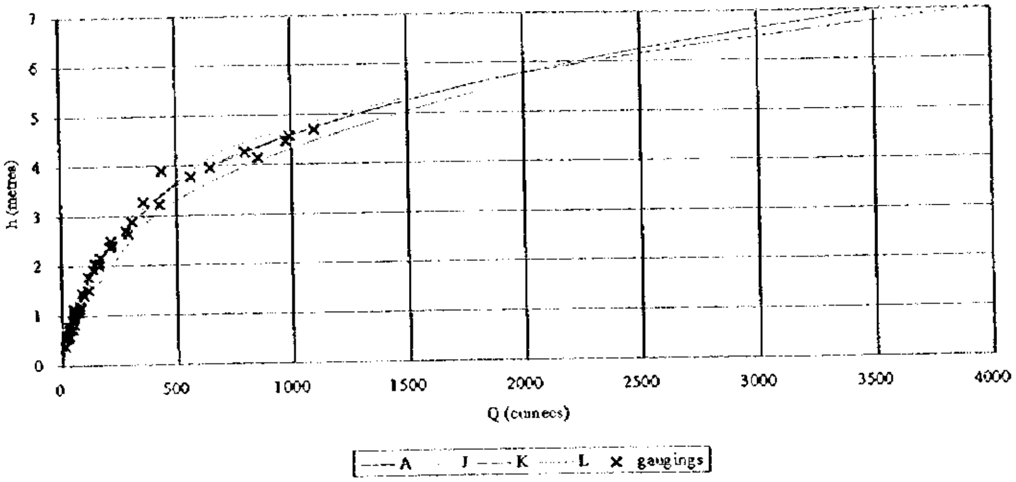
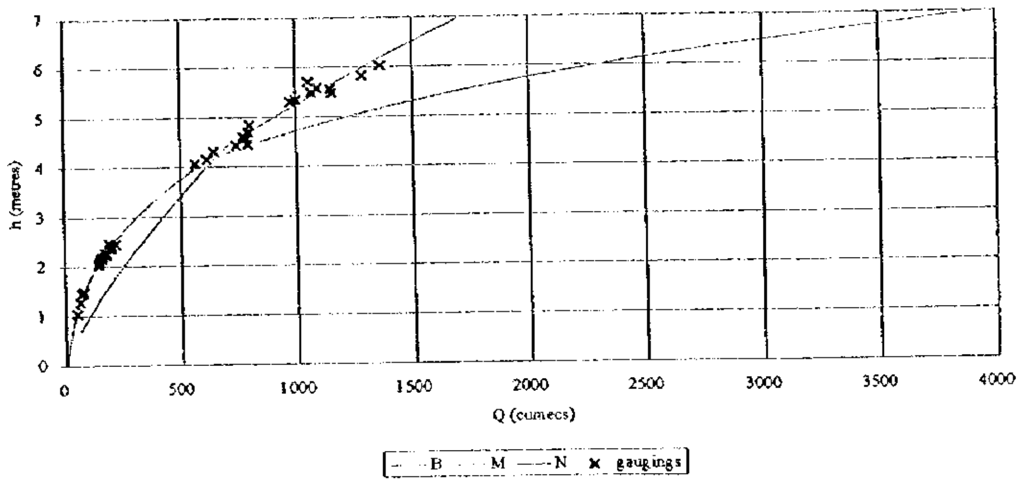


Figure A-16-2 Rating Curves: Garissa





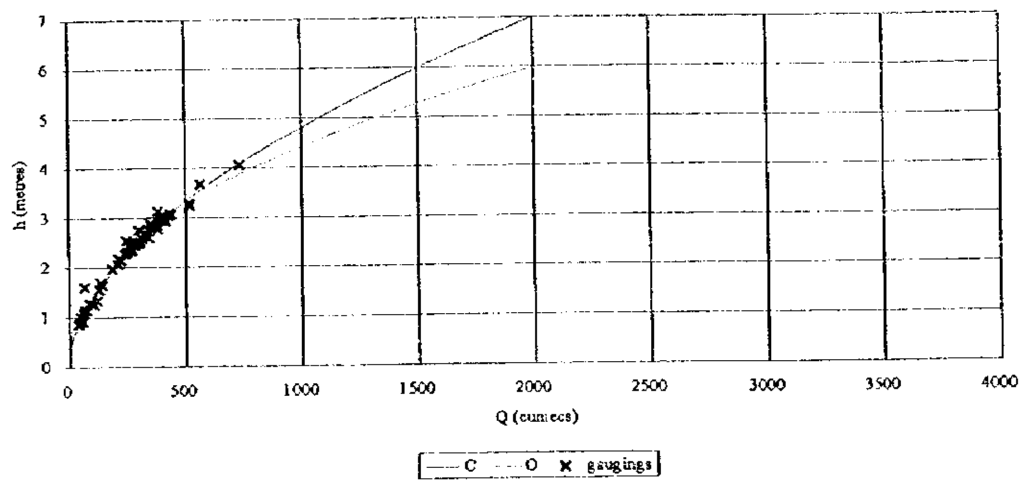
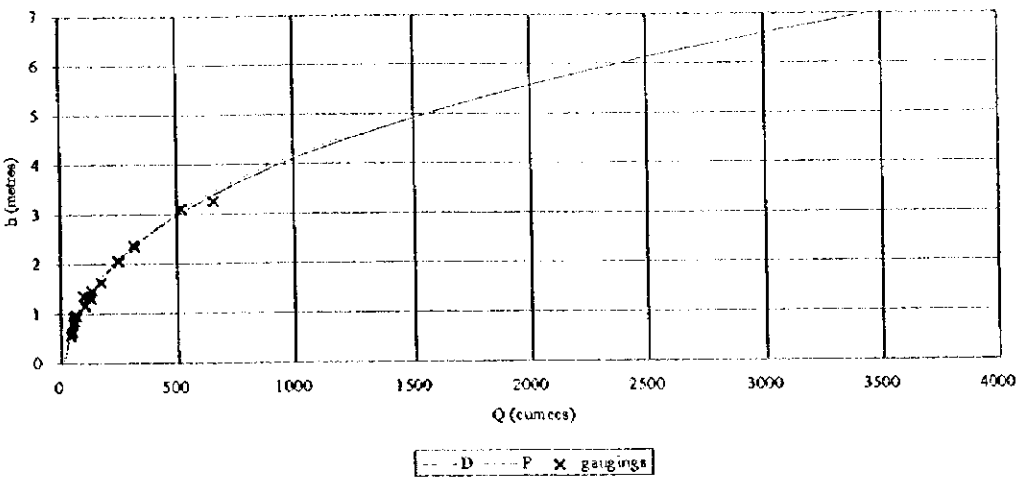
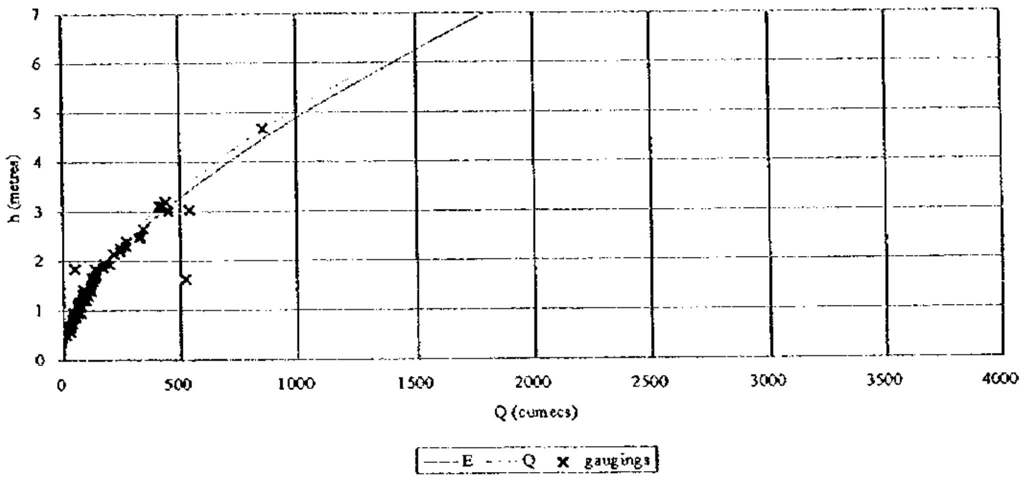


Figure A16-2 Rating Curves: Garissa (continued)


h (metres)
Q (cumecs)
D
P
gaugings


h (metres)
Q (cumecs)
E
Q
gaugings

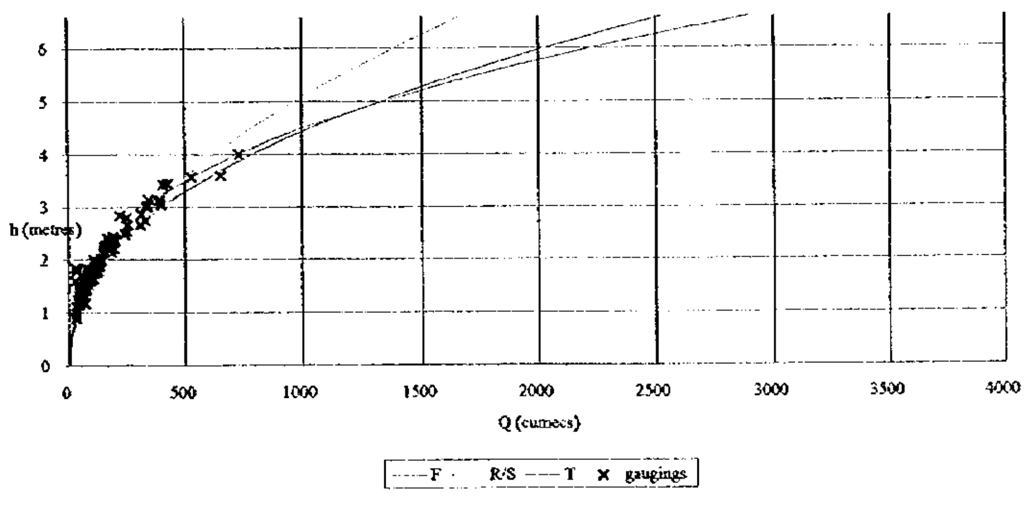
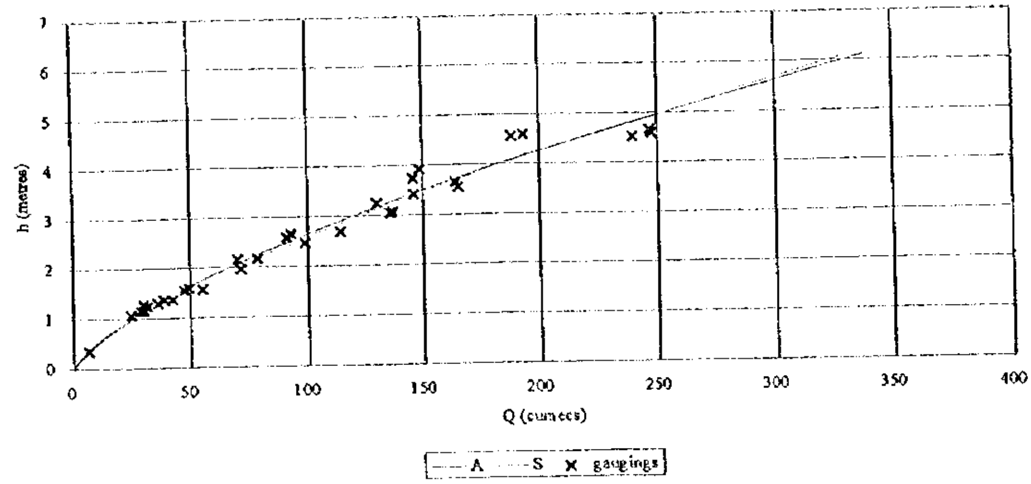

h (metres)
Q (cumecs)
F
R/S
T
gaugings

Figure A-16-3 Rating Curves: Garsen



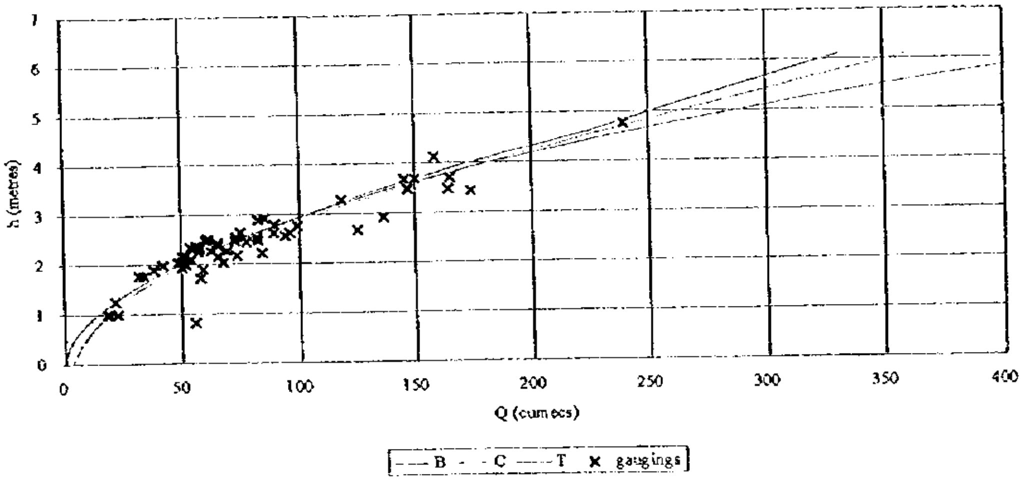
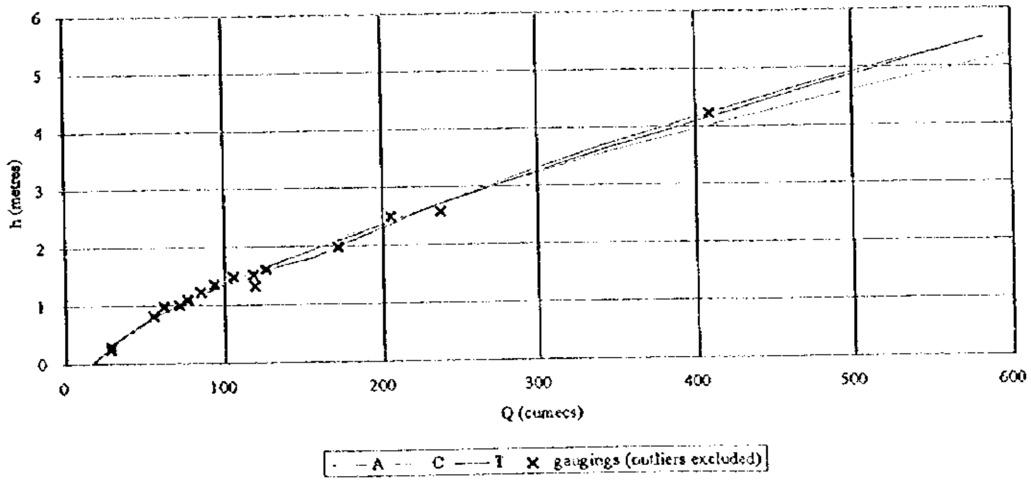


Figure A-16-4 Rating Curves: Nanigi



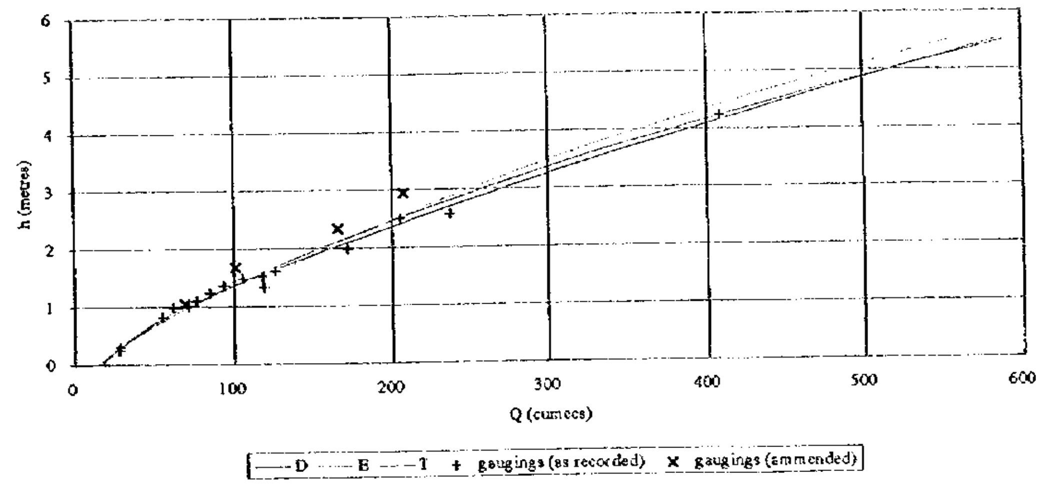
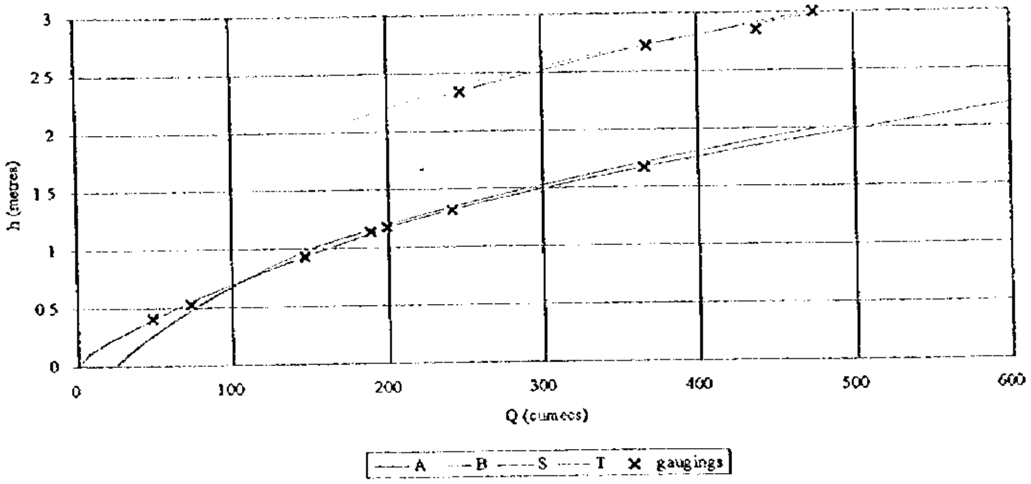


Figure A-16-5 Rating Curves: Saka



A-16.2 DAILY DISCHARGE SERIES

Figure A16-6 Plots of mean daily discharges: 4F13 - Tana at Grand Falls

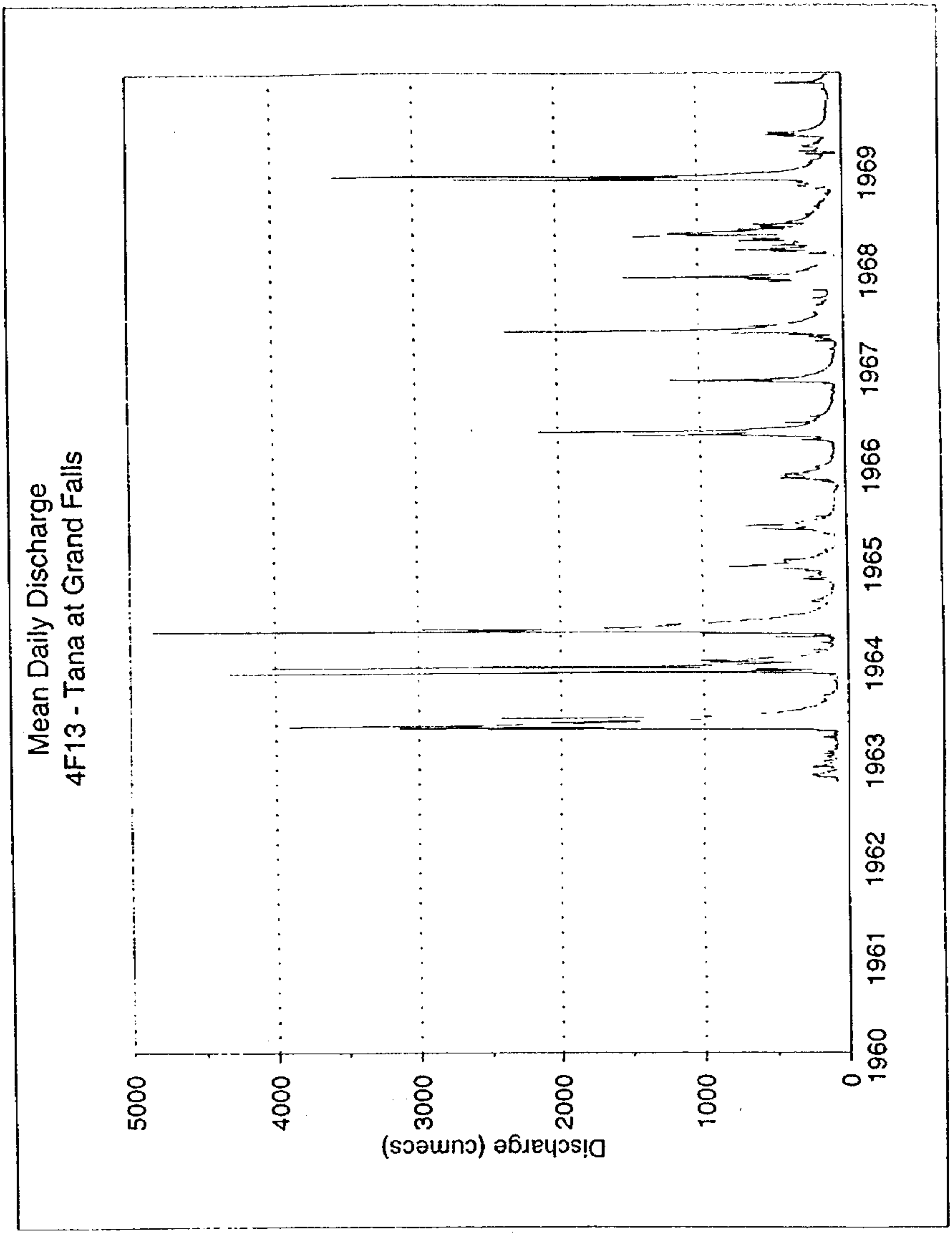


Figure A16-6   4F13 - Tana at Grand Falls (continued)

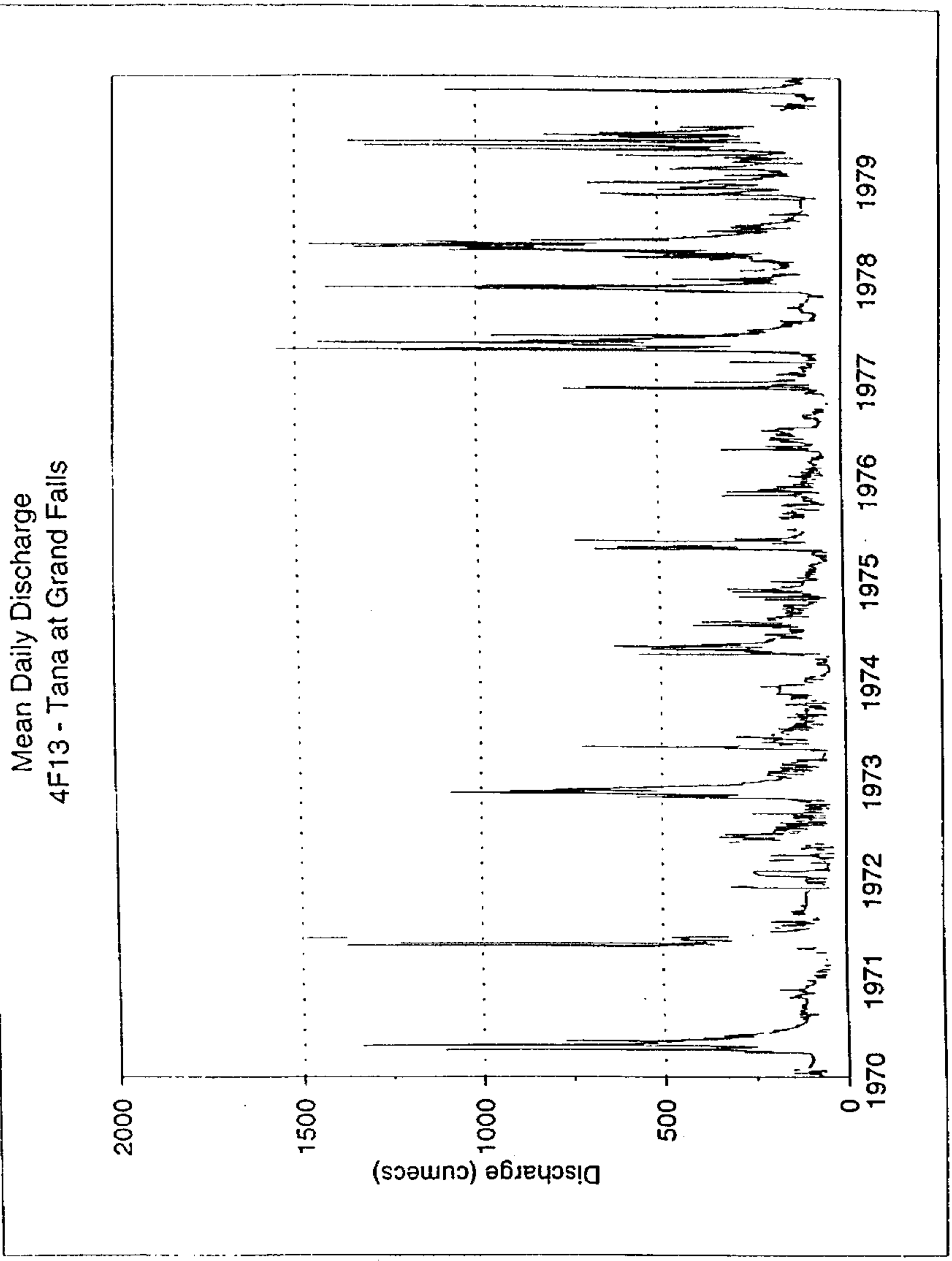


Figure A16-6 4F13 - Tana at Grand Falls (continued)

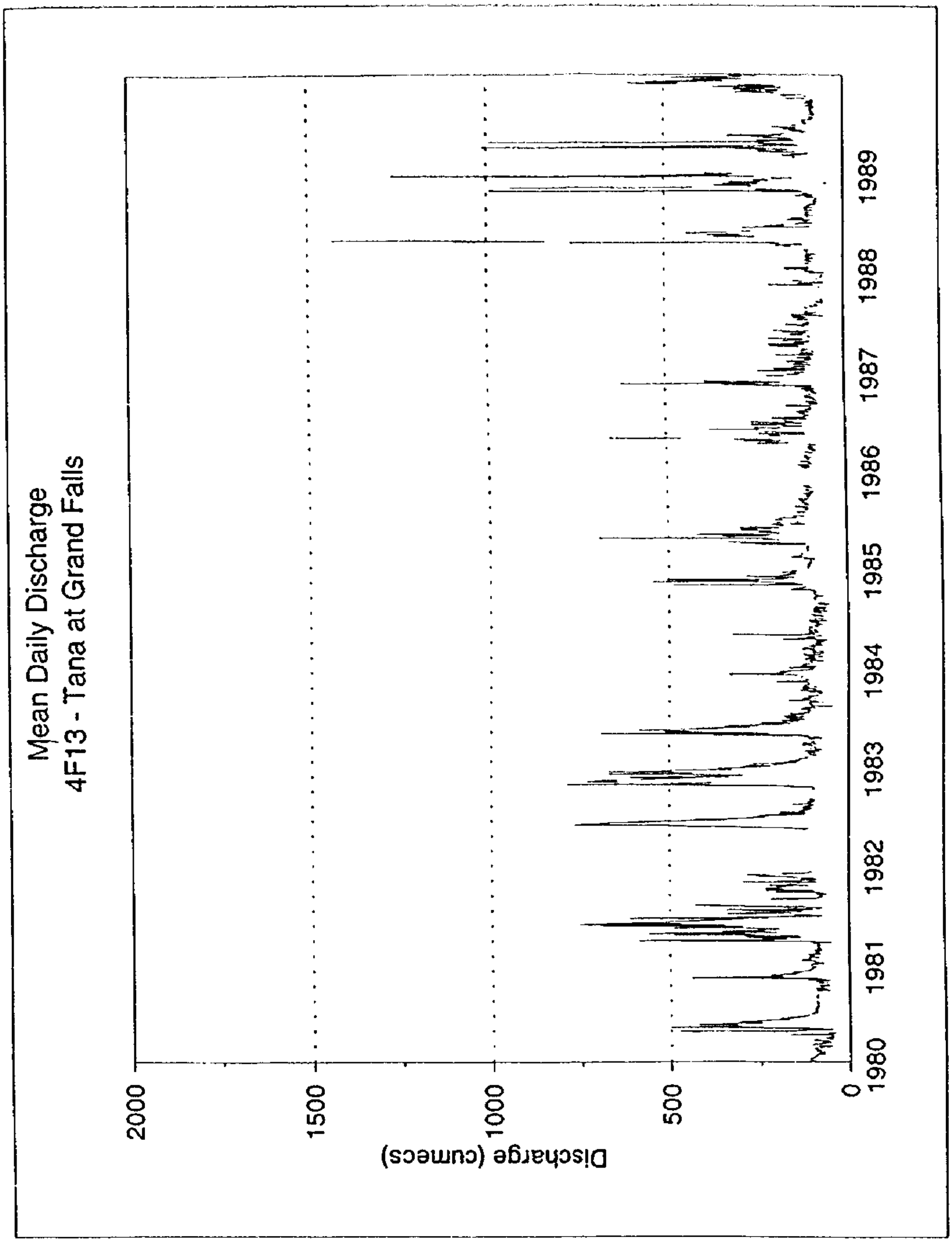


Figure A16-6 4F13 - Tana at Grand Falls (continued)

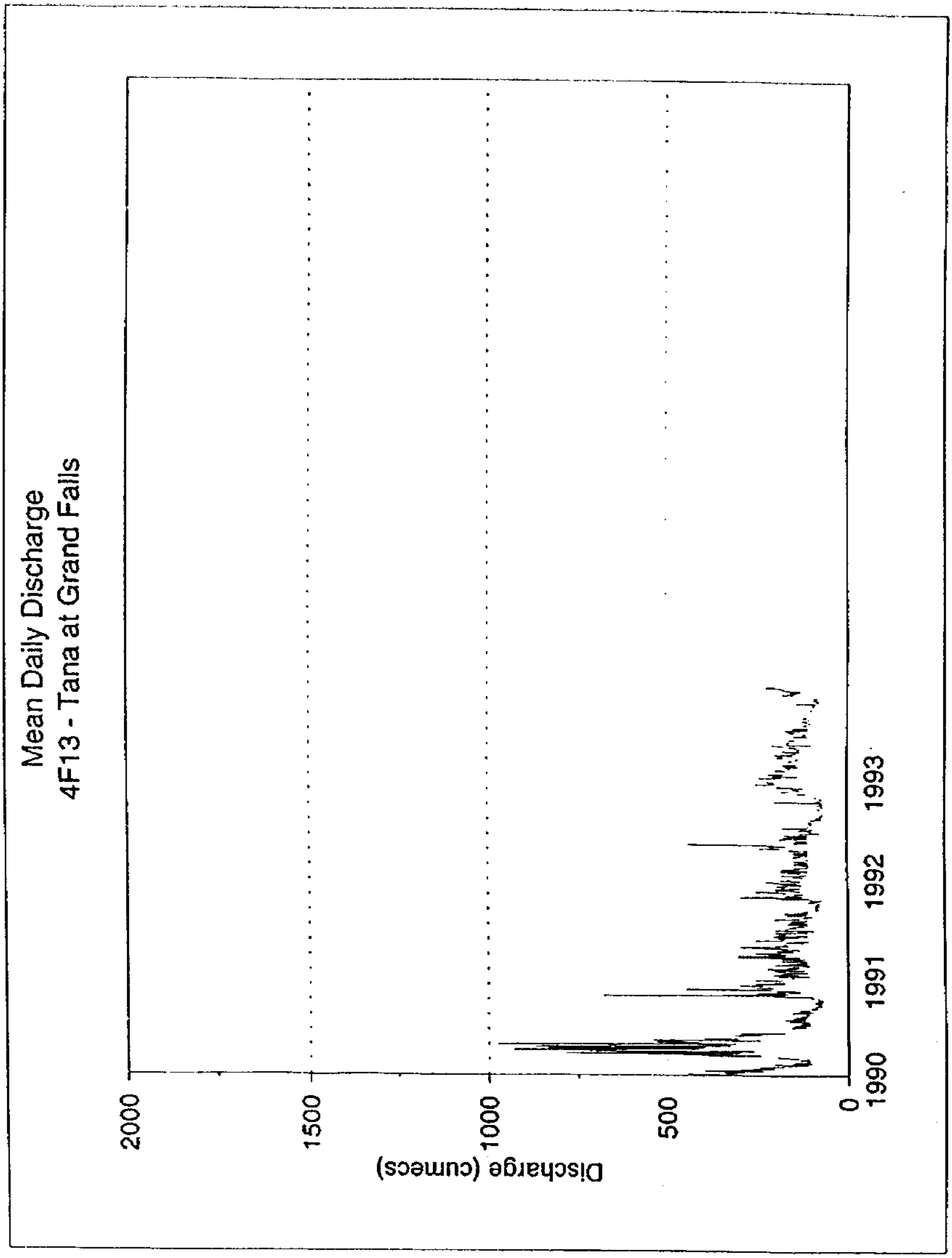


Figure A16-7 Plots of mean daily discharges: 4G1 - Tana at Garissa

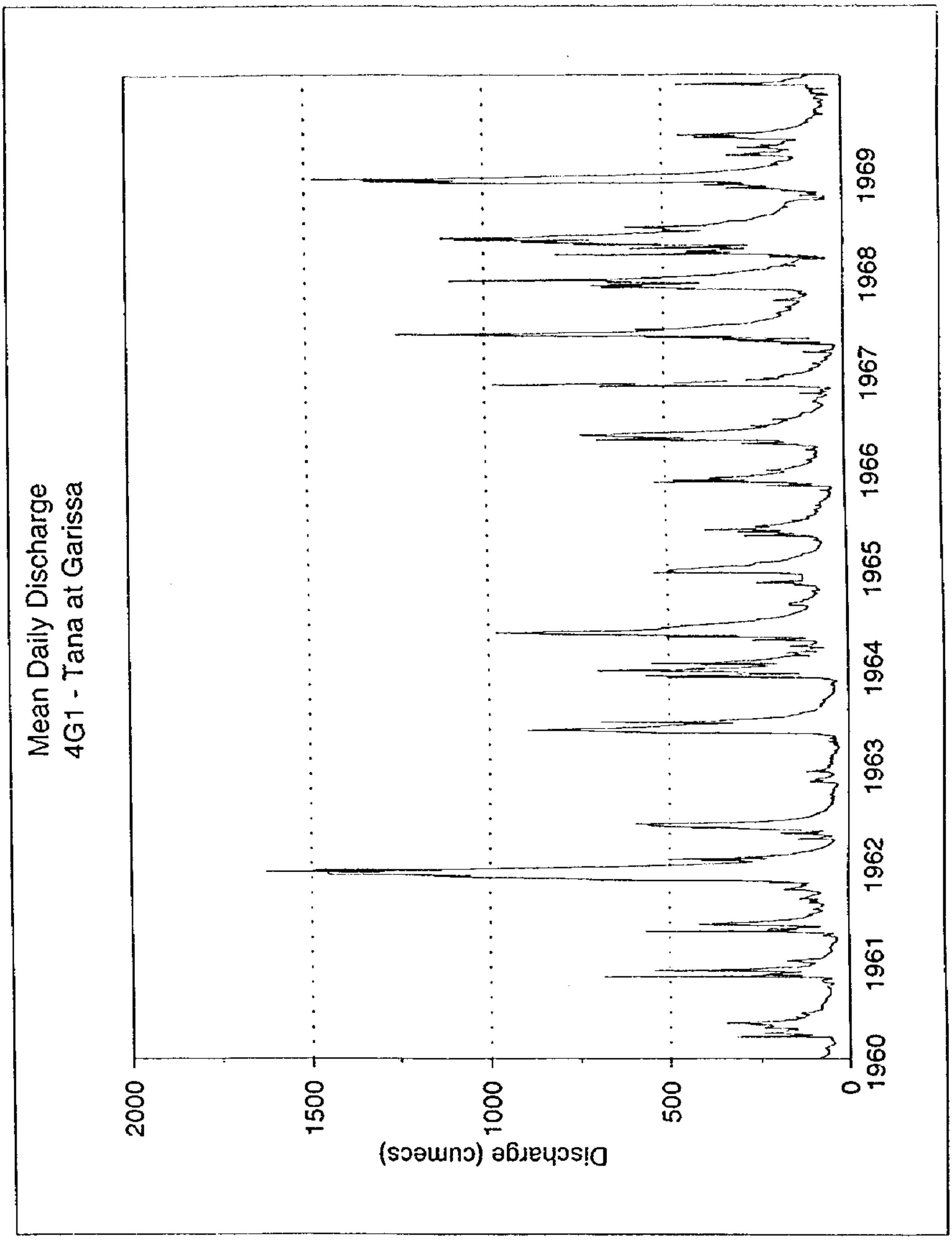


Figure A16-7 4G1 - Tana at Garissa (continued)

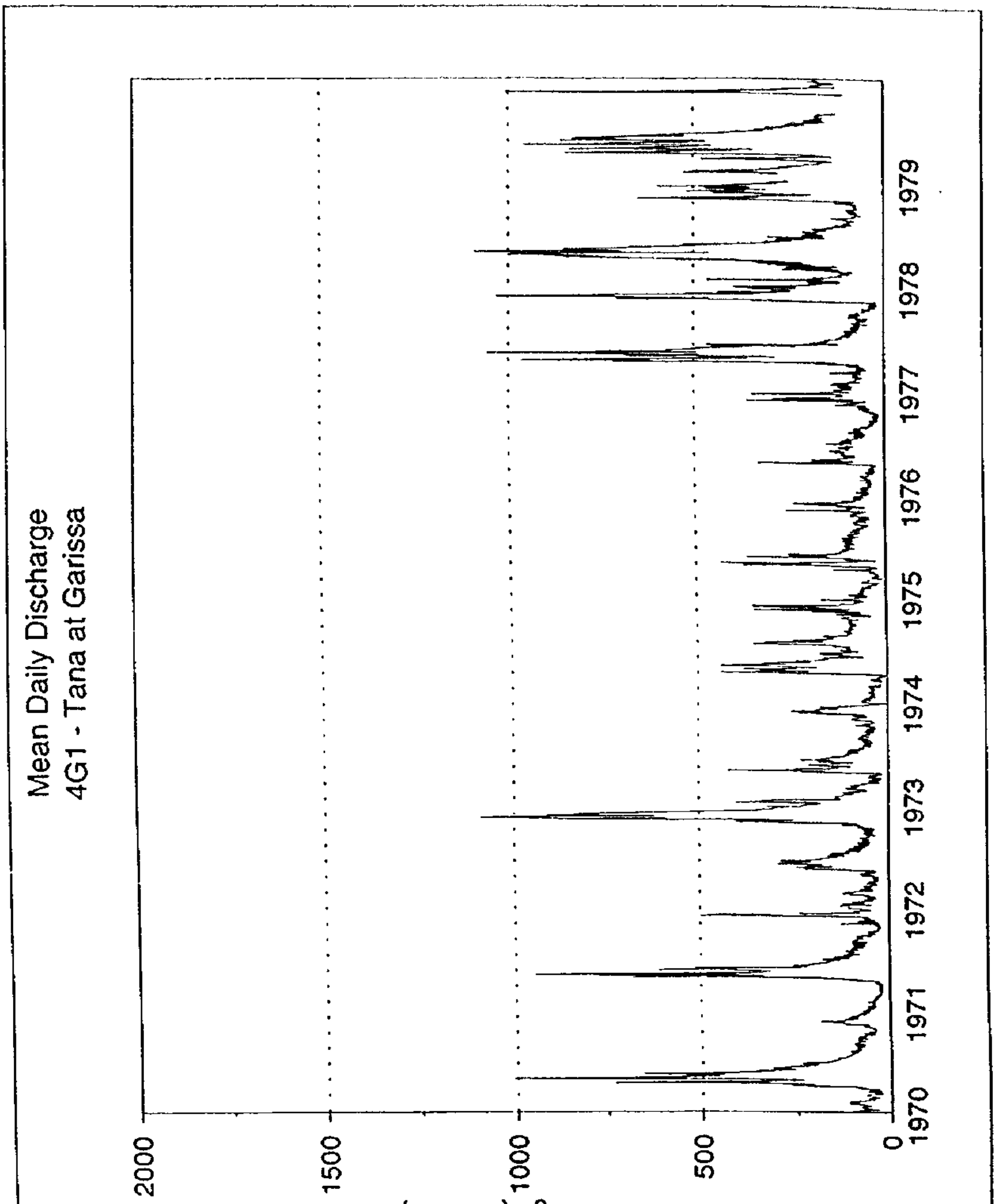


Figure A16-7 4G1 - Tana at Garissa (continued)

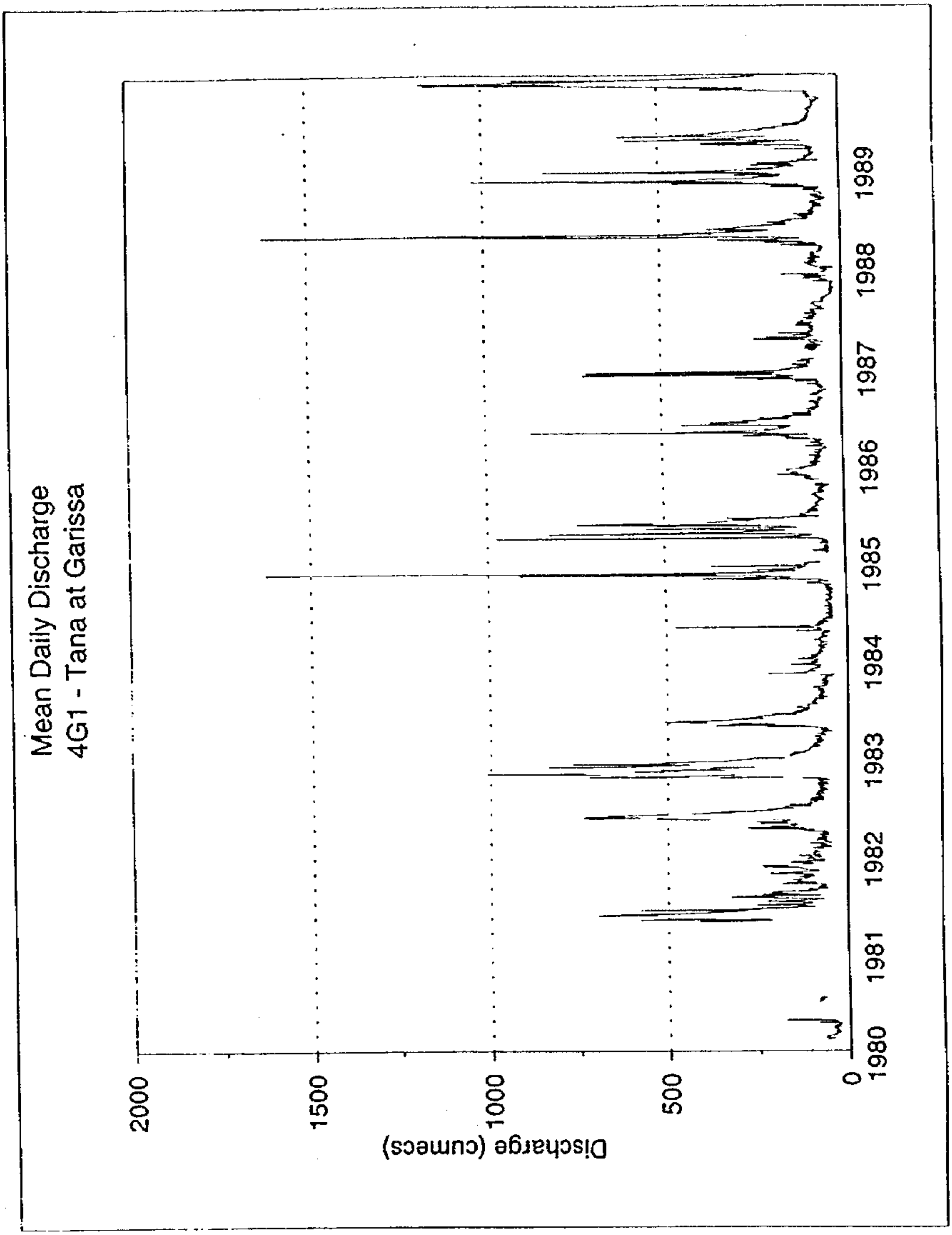


Figure A16-7 4G1 - Tana at Garissa (continued)

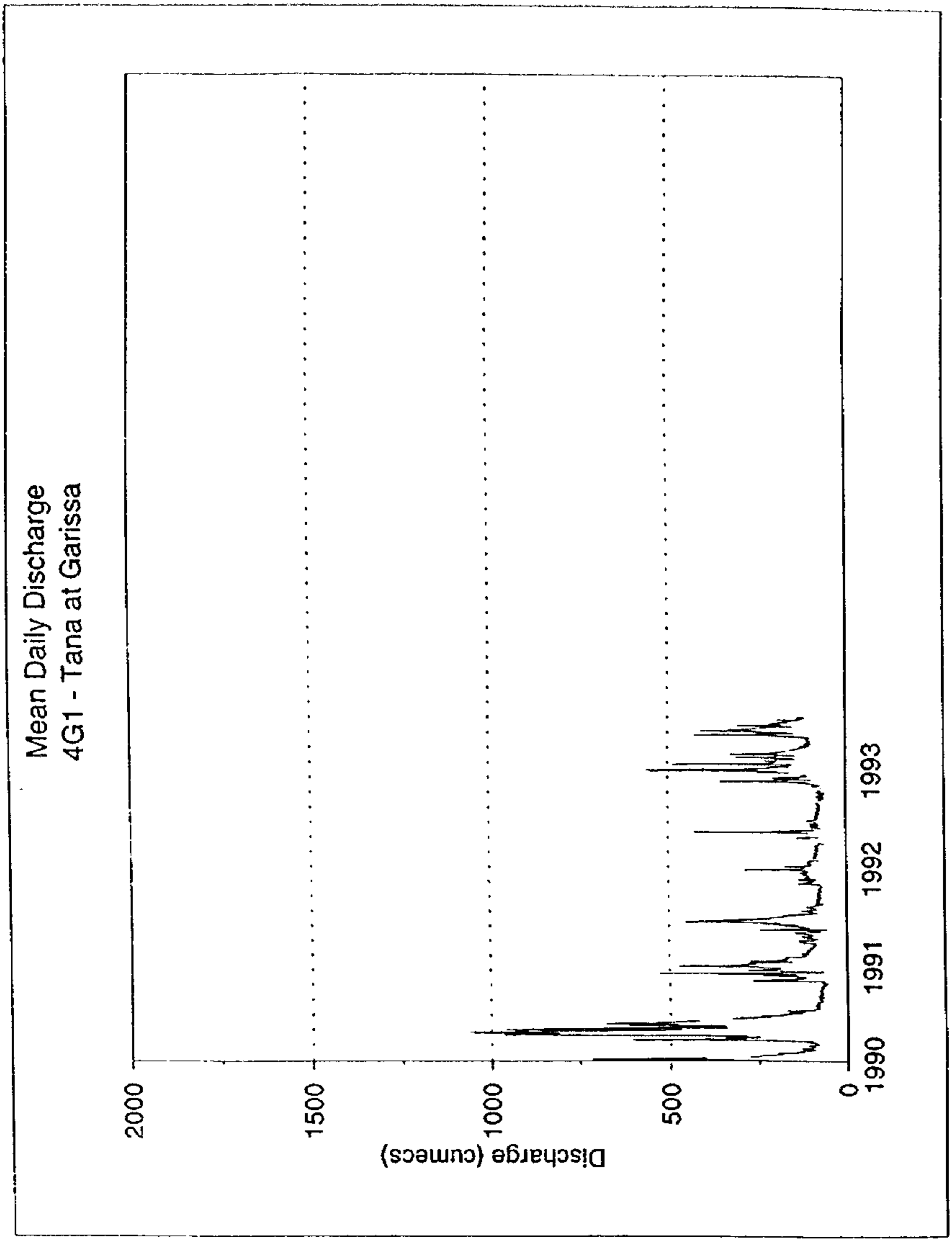


Figure A16-8 Plots of mean daily discharges: 4G8 - Tana at Nanigi

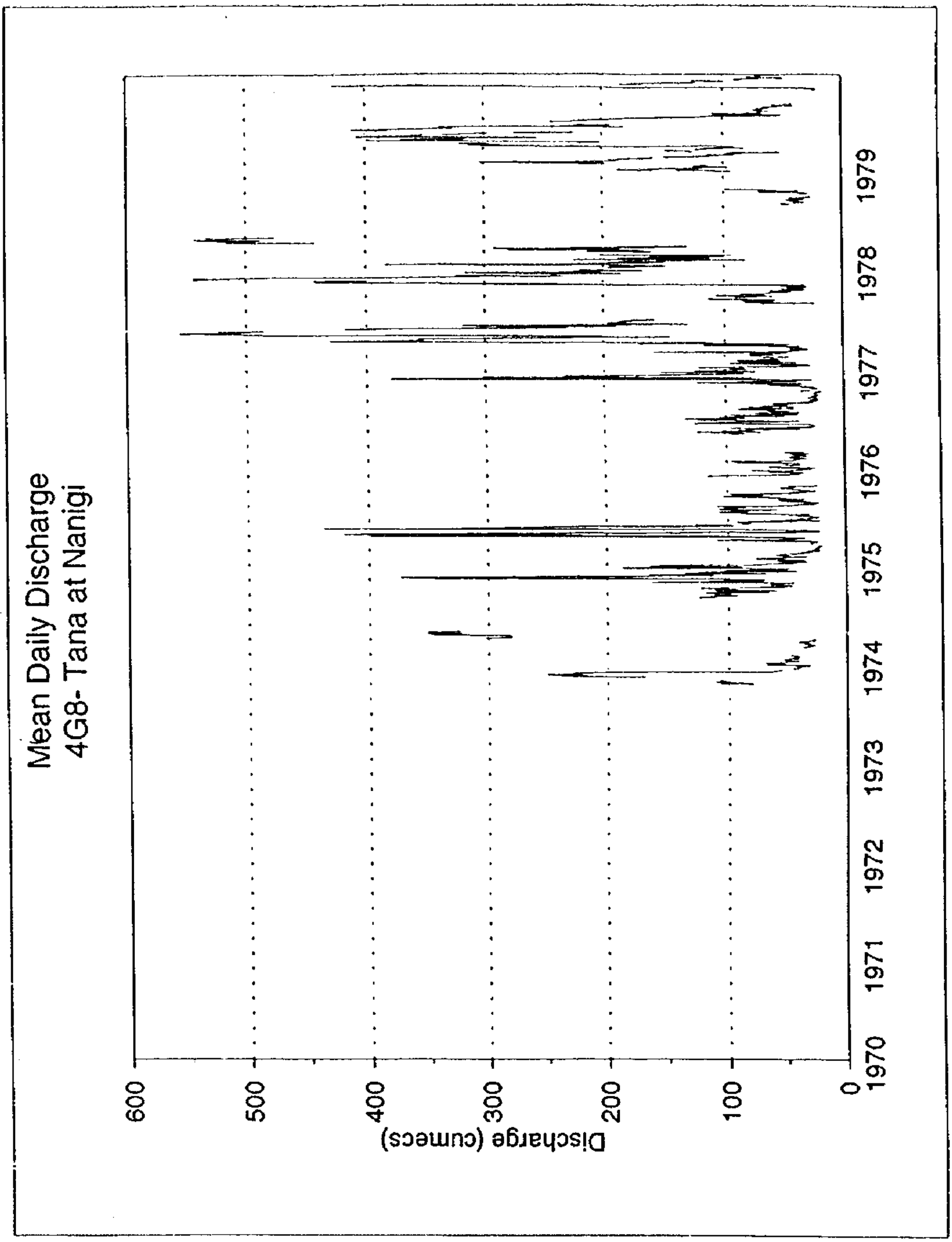


Figure A16-8   4G8 - Tana at Nanigi (continued)

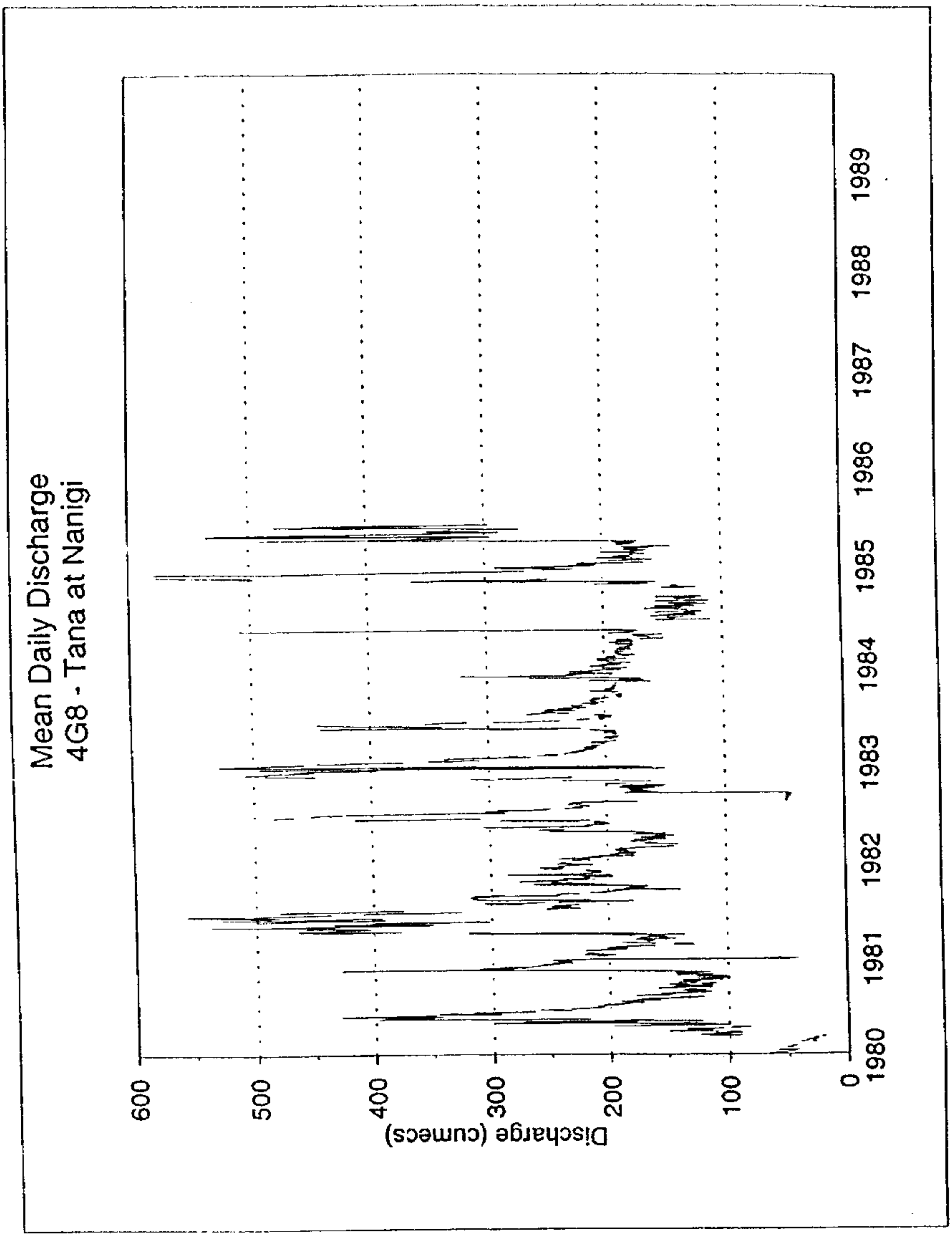


Figure A16-9 Plots of mean daily discharges: 4G2 - Tana at Garsen

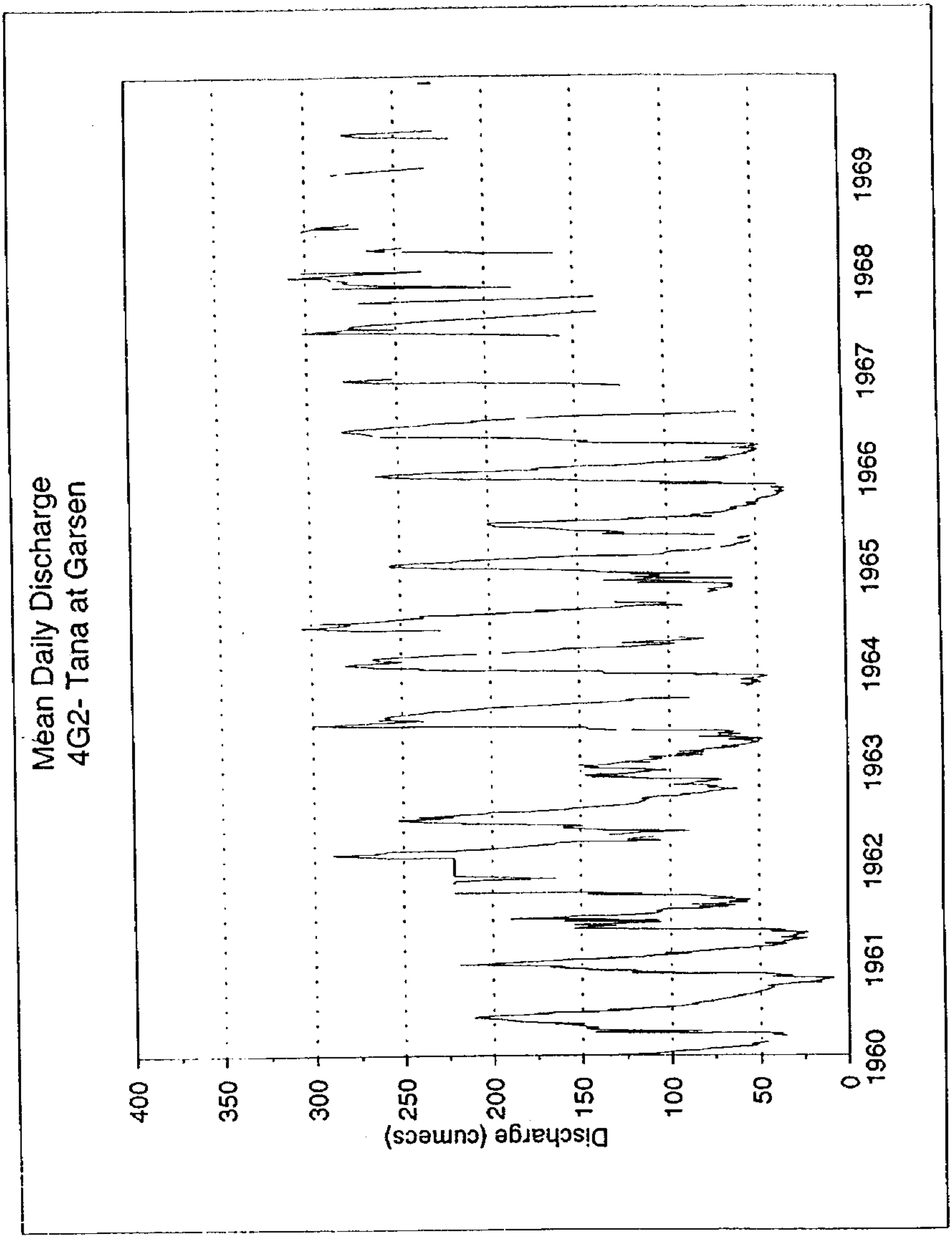


Figure A16-9 4G2 - Tana at Garsen (continued)

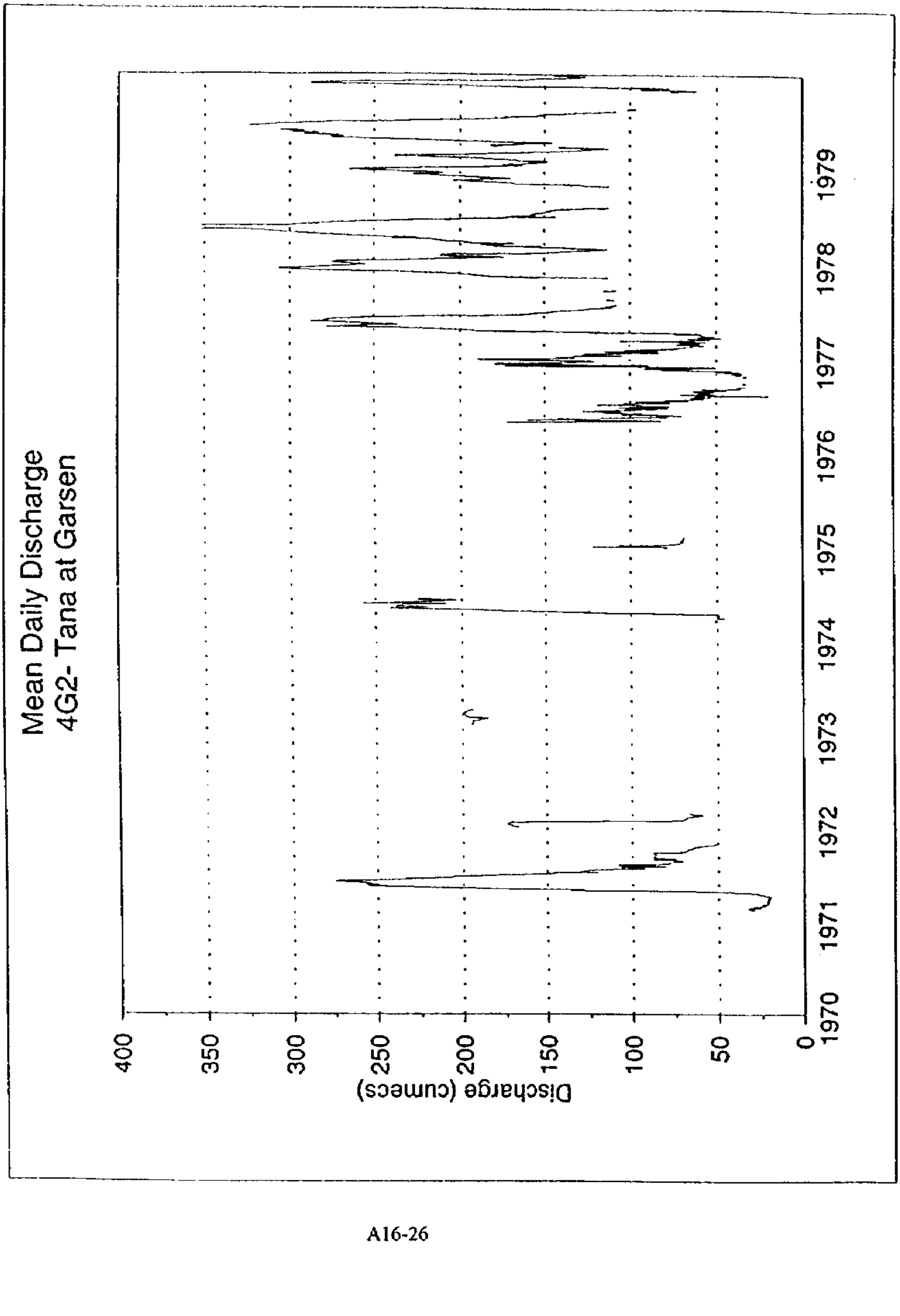


Figure A16-9 4G2 - Tana at Garsen (continued)

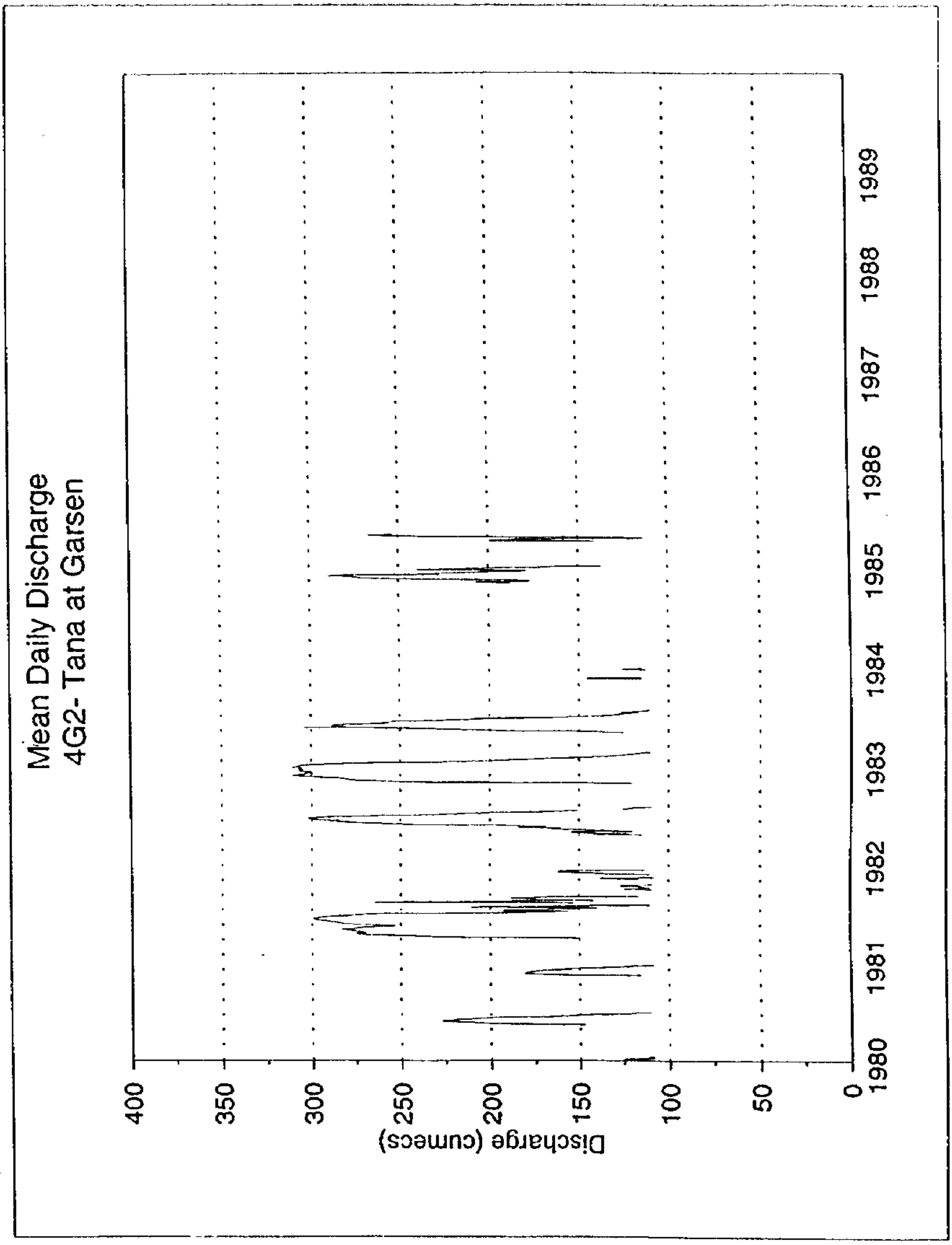


Figure A16-10 **Comparison of Mean Monthly Discharges: Tana at Grand Falls**

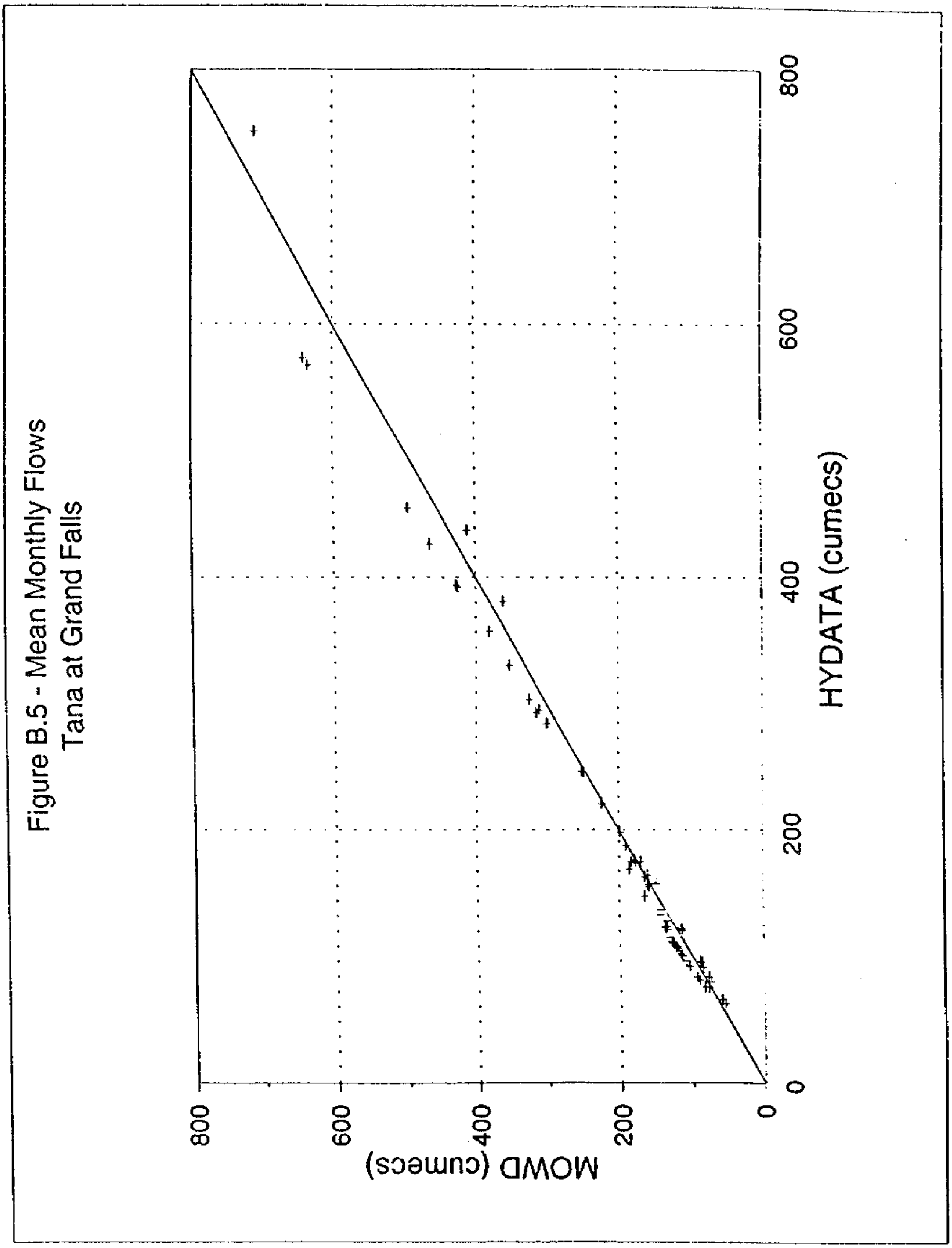
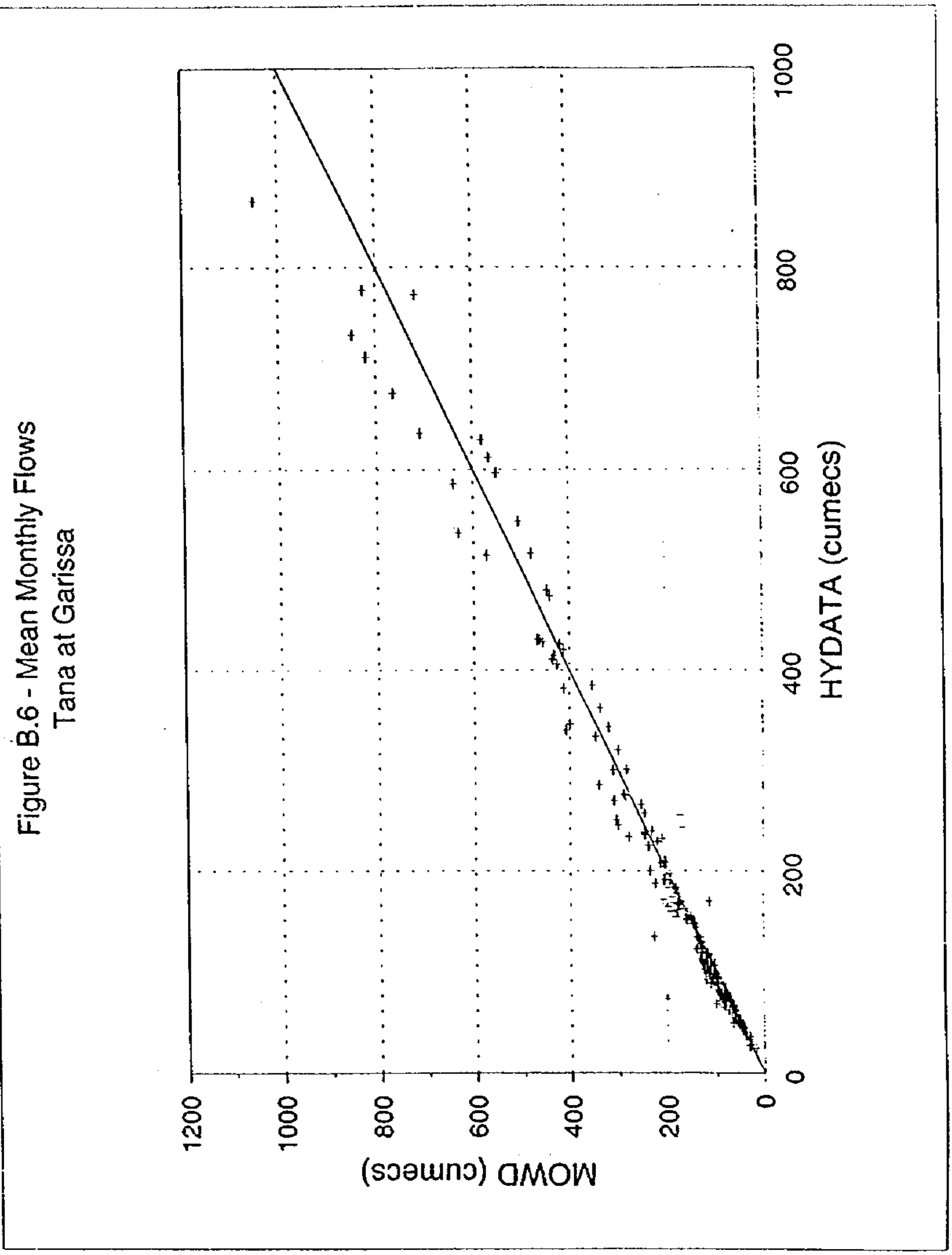


Figure A16-11 Comparison of Mean Monthly Discharges: Tana at Garissa



A-16.3 CHARACTERISTICS OF FLOOD EVENTS ANALYSED

Table A-16-4 Characteristics of floods > 500 cumecs at Garissa

Start Date	Peak flow (cumecs)	Duration (days)	Cum vol (MCM)	Start Date	Peak flow (cumecs)	Duration (days)	Cum vol (MCM)
24/04/63	894.65	29	1638.64	29/10/78	648.09	5	201.54
06/12/63	701.74	5	277.66	02/02/79	528.32	1	167.23
10/04/64	506.18	3	130.1	10/04/79	845.78	10	546.55
17/04/64	982.56	25	1591.26	26/04/79	835.4	9	507.93
14/04/66	693.32	6	317.3	01/05/79	958.49	21	1186.92
24/04/66	740.03	18	991.53	24/05/79	860.45	26	1477.53
02/11/66	978.7	11	660.77	11/11/79	1004.48	6	436.33
06/05/67	1247.31	22	1554.13	24/05/81	700.25	7	365.41
10/11/67	657.6	2	113.08	19/05/82	740.02	18	960.85
19/11/67	1097.15	22	1307.82	28/11/82	840.04	6	322.46
01/03/68	798.6	3	167.92	08/12/82	770.92	7	334.39
24/03/68	594.86	3	142.65	09/11/84	1631.48	9	620.35
05/04/68	1119.5	47	3208.59	16/05/85	519.26	1	87.81
30/05/68	504.73	2	86.97	19/05/85	678.13	1	58.59
06/06/68	608.73	5	243.49	21/05/85	750.41	6	341.6
10/04/70	733.27	3	160.57	24/04/88	1626.2	1	874.35
25/04/70	1010.81	8	509.66	20/11/88	1029.75	6	360.09
06/05/70	657.19	10	446.7	23/12/88	525.21	1	85.08
22/04/71	686.53	5	247.56	27/12/88	830.77	2	115.15
29/04/71	946.75	8	422.91	17/11/89	1173.61	27	1948.68
20/05/71	616.68	6	254.81	05/01/90	716.38	4	220.22
01/11/72	1089	29	1968.38	04/04/90	1061.15	26	1901.33
07/04/77	963.85	10	623.85	01/05/90	680.54	7	348.86
27/04/77	1054.72	23	1378.54	10/05/90	680.54	14	668.97
12/11/77	1032.09	17	1095.94	14/12/92	551.13	1	47.62
31/03/78	1088.05	47	3070.38	19/12/92	562.67	1	48.61

Table AA-16-5 Characteristics of flood events at Grand Falls and Garissa

Start Date at Garissa	Grand Falls flood statistics Peak flow (cumecs)	Duration (days)	Cum vol (MCM)	Lag (days)	Garissa flood statistics Peak flow (cumecs)	Duration (days)	Cum vol (MCM)
Type A floods							
14/04/66	1476.7	6	617.4	1	693.3	6	317.3
13/05/67	2377.9	15	1350.9	3	1247.3	15	1014.1
22/11/68	2720.14	12	1616.1	2	1332.5	12	1138.4
04/12/68	3570.4	21	1916.9	2	1479.6	21	1756
10/04/70	1108.8	4	264	2	733.2	4	198.4
09/04/77	1554.3	8	581.8	1	963.9	8	523.1
01/05/77	1436.9	9	717.3	2	1054.7	9	615.8
10/05/77	854.7	10	579.8	2	780.4	10	545.3
06/04/78	1342.6	19	1415.4	1	1002.7	19	1249
26/04/78	1460.1	21	1570.5	1	1088.1	21	1410.1
26/04/79	1306.2	8	518.8	1	835.4	8	461.8
Type C floods							
02/11/66	1208	11	692.5	2	978.7	11	660.8
19/11/67	1523.8	20	1198.5	2	1097.2	20	1192.5
25/04/70	1342.6	8	520.6	1	1010.8	8	509.7
06/05/70	559.9	5	224.8	2	504.9	5	217.2
13/05/70	774.7	3	156.6	2	657.2	3	144.7
12/11/77	993.6	4	214.8	1	703.4	4	203.2
16/11/77	1417.2	13	895.8	1	1032.1	13	869.9
09/05/79	1355.5	14	729.9	1	958.5	14	795.9
11/11/79	1085.3	6	376.2	1	1004.5	6	436.3
24/05/81	681.4	7	336.6	1	700.3	7	365.4
22/05/82	769.7	15	857.1	1	740	15	813.2
09/12/82	671.9	8	358.1	2	770.9	8	374.7
Type D floods							
01/11/72	1085.3	9	578	1	1089	9	626
14/11/72	802.7	16	864	1	910.6	16	974
11/06/79	655.3	8	375.4	2	641.3	8	387.3
28/11/82	671.9	6	243.8	2	840	6	322.5
09/11/84	506.3	9	249.2	1	1631.5	9	620.4

A-16.4 CHARACTERISTICS OF RAINFALL EVENTS ANALYSED

Table AA-16-6 Rainfall event characteristics

Start date of flood at Garissa	Nyambene Hills Duration (days)	Nyambene Hills Peak rainfall (mm)	Nyambene Hills Total rainfall (mm)	Nyambene Hills Mean per day (mm)	Nyambene Foothills Duration (days)	Nyambene Foothills Peak rainfall (mm)	Nyambene Foothills Total rainfall (mm)	Nyambene Foothills Mean per day (mm)	d/s Grand Falls Duration (days)	d/s Grand Falls Peak rainfall (mm)	d/s Grand Falls Total rainfall (mm)	d/s Grand Falls Mean per day (mm)	Garissa Duration (days)	Garissa Peak rainfall (mm)	Garissa Total rainfall (mm)	Garissa Mean per day (mm)
Type A floods																
14/04/66	5	84.7	184.9	37.0	8	2.1	2.1	0.3	8	9.9	24.2	3.0	5	15.1	16.1	3.2
13/05/67	8	62.8	177.7	22.2	m	m	m	m	m	m	m	m	8	54.1	65.8	8.2
22/11/68	9	78.1	394	43.8	m	m	m	m	m	m	m	m	9	0	0	0.0
04/12/68	6	113.3	444.1	74.0	m	m	m	m	m	m	m	m	6	50.7	158.4	26.4
10/04/70	4	43.1	111.7	27.9	m	m	m	m	m	m	m	m	4	14.1	38.2	9.6
09/04/77	4	77.5	245.8	61.5	4	0	0	0.0	m	m	m	m	4	13.7	15.5	3.9
01/05/77	4	71.9	231.7	57.9	4	42.3	110.65	27.7	4	39.9	57.3	14.3	4	106.9	106.9	26.7
10/05/77	6	75.7	226.6	37.8	6	12.8	26.6	4.4	6	15	42.1	7.0	6	1.4	1.4	0.2
06/04/78	3	55.9	150.5	50.2	3	0	0	0.0	3	4	4	1.3	3	0	0	0.0
26/04/78	15	53.9	423.3	28.2	15	24.1	69.5	4.6	15	20	39.5	2.6	15	0	0	0.0
26/04/79	4	19.4	59.3	14.8	4	44.3	47.6	11.9	4	18.2	22.1	5.5	4	0	0	0.0
Type C floods																
02/11/66	3	69.8	163.9	54.6	3	19.6	55.8	18.6	3	27.4	41.6	13.9	3	25.8	38.3	12.8
19/11/67	3	6.8	9.8	3.3	3	0	0	0.0	3	2.7	3.6	1.2	m	m	m	m
25/04/70	2	26.6	51.7	25.9	2	20.3	30.9	15.5	m	m	m	m	2	6.7	11.4	5.7
06/05/70	9	137.4	627.5	69.7	m	m	m	m	m	m	m	m	9	65.8	96.9	10.8
13/05/70	17	100.4	550.9	32.4	m	m	m	m	m	m	m	m	17	46.9	206.4	12.1
12/11/77	3	71.9	139.7	46.6	3	24.3	32.5	10.8	m	m	m	m	3	0	0	0.0
16/11/77	3	5.6	10.3	3.4	3	0	0	0.0	m	m	m	m	3	0	0	0.0
09/05/79	3	21	21	7.0	3	0	0	0.0	m	m	m	m	3	0	0	0.0
11/11/79	3	84.6	165.2	55.1	3	19.7	24.3	8.1	m	m	m	m	3	3.6	4.2	1.4
24/05/81	12	47	312.5	26.0	12	44.9	133.8	11.2	3	14	18.3	6.1	12	12.6	32	2.7
22/05/82	10	70.6	103.6	10.4	10	0	0	0.0	12	87.7	230.6	19.2	10	0	0	0.0
09/12/82	11	34.9	127.3	11.6	11	0.6	1.9	0.2	11	2.7	4.9	0.4	11	0	0	0.0
Type D floods																
01/11/72	4	41.1	97.9	24.5	4	25.5	46.5	11.6	4	74.2	124.7	31.2	4	40	52.3	13.1
14/11/72	7	134.4	369.1	52.7	7	93.8	141	20.1	m	m	m	m	7	9.5	23.7	3.4
11/06/79	15	46.7	253.9	16.9	15	53.3	61.8	4.1	m	m	m	m	15	5.5	8.8	0.6
09/11/84	10	75.2	351.7	35.2	10	53.6	141.5	14.2	10	80.6	205.2	20.5	10	89.6	154.5	15.5

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Table AA-16-7 Median rainfall characteristics

Start date of flood at Garissa	Nyambene Hills Duration (days)	Nyambene Hills Peak rainfall (mm)	Nyambene Hills Total rainfall (mm)	Nyambene Hills Mean per day (mm)	Nyambene Foothills Duration (days)	Nyambene Foothills Peak rainfall (mm)	Nyambene Foothills Total rainfall (mm)	Nyambene Foothills Mean per day (mm)	d/s Grand Falls Duration (days)	d/s Grand Falls Peak rainfall (mm)	d/s Grand Falls Total rainfall (mm)	d/s Grand Falls Mean per day (mm)	Garissa Duration (days)	Garissa Peak rainfall (mm)	Garissa Total rainfall (mm)	Garissa Mean per day (mm)
Common events																
Type A	4.5	63.9	205.8	37.4	5	18.5	37.1	4.5	5	16.6	31.9	4.3	4.5	0.7	0.7	0.1
Type C/D	10	58.4	145.6	25.3	10	22.6	51.2	11.4	7	50.8	83.2	16.5	10	19.2	35.2	7.7
All events																
Type A	5	71.9	226.6	37.8	4	12.8	26.6	4.4	5	16.6	31.9	4.3	5	13.7	15.5	3.2
Type C	3	58.4	133.5	25.9	3	10.1	13.1	4.1	3	14.0	18.3	6.1	3	3.6	4.2	1.4
Type D	8.5	61.0	302.8	29.8	8.5	53.5	101.4	12.9	7	77.4	165.0	25.8	8.5	24.8	38.0	8.2

Table A16-8 Discharge Data, Garissa 4G01: January to May 1995.

Date	Jan		Feb.		Mar.		Apr.		May	
	A.M	P.M	A.M	P.M	A.M	P.M	A.M	P.M	A.M	P.M
1	307.45	296.81	-	-	96.44	95.28	124.18	122.58	278.70	276.16
2	276.16	268.64	-	-	129.02	127.40	129.02	127.40	740.44	771.95
3	249.16	242.07	-	-	121.00	121.00	127.40	127.40	701.03	638.07
4	228.25	223.74	-	-	117.21	115.93	-	-	613.83	597.97
5	219.29	219.29	-	-	122.58	122.58	121.00	-	574.63	582.35
6	249.16	246.79	-	-	149.49	169.79	108.42	-	559.36	536.90
7	223.74	214.88	-	-	185.48	173.64	109.66	-	465.81	455.64
8	219.29	214.88	-	-	121.00	122.58	-	-	445.61	459.02
9	214.88	221.51	-	-	118.49	117.21	171.70	-	372.87	375.87
10	251.55	237.41	-	-	137.34	139.04	-	-	394.22	381.93
11	208.37	201.98	-	-	139.04	133.98	130.66	500.63	381.93	375.87
12	201.98	199.87	-	-	193.63	185.48	-	140.75	352.19	335.01
13	199.87	199.87	-	-	165.99	147.72	-	-	323.82	307.45
14	201.98	199.87	-	-	147.72	142.48	214.88	-	671.22	654.53
15	206.23	201.98	-	-	118.49	119.78	165.99	-	590.13	500.63
16	199.87	197.78	-	-	124.18	121.00	-	286.38	497.08	500.63
17	193.63	187.50	-	-	137.34	129.02	249.16	-	445.61	422.68
18	185.48	181.48	-	-	125.78	124.18	181.48	154.88	388.05	388.05
19	173.64	173.64	-	-	113.40	117.21	185.48	183.48	381.93	394.22
20	181.48	183.48	-	-	113.40	124.18	162.24	158.53	483.04	472.66
21	187.50	183.48	-	-	121.00	118.49	169.79	162.24	533.21	483.04
22	173.64	169.79	-	-	115.93	114.66	185.48	195.70	445.61	438.98
23	167.88	164.10	-	-	109.66	107.19	251.55	242.07	529.53	518.58
24	164.10	160.38	-	-	103.55	103.55	223.74	206.23	483.04	465.81
25	158.53	156.70	-	-	113.40	113.40	185.48	181.48	479.57	493.55
26	38.91	140.75	-	-	206.23	206.23	179.50	173.64	476.11	452.28
27	145.96	145.96	-	-	177.53	169.79	169.79	162.24	419.46	406.73
28	145.96	142.48	-	-	153.07	149.49	162.24	165.99	388.05	375.87
29	151.28	149.49	-	-	137.34	135.66	154.88	162.24	400.45	400.45
30	145.96	144.21			118.49	115.93	195.70	302.10	394.22	381.93
31	151.28	149.49			122.58	124.18			432.42	388.05

Annex to Chapter 26

Annex 26

A-26. TECHNICAL REQUIREMENTS FOR ESTABLISHING A MONITORING SYSTEM

A-26.1 GENERAL CONSIDERATIONS

A-26.1.1 Facilitating Monitoring of Downstream Environments

In order to obtain the required long-term studies, it will be necessary to fund a number of Kenyan students for higher degrees. The proposal is for eight students, registered with Kenyan institutions (University of Nairobi, Moi University), coupled with additional external supervision by experts from overseas institutions. The students would be encouraged to continue working on these and related monitoring topics after the culmination of their studies, linked to continued monitoring of downstream systems by TARDA or other relevant authority. Students would work towards higher degrees in the following areas/topics:

1. Hydrologist - flood dynamics
2. Hydrologist - river morphology
3. Groundwater studies (recharge of groundwater by floods)
4. Tana River Forests (specifically the importance of floods)
5. Floodplain and Delta grazing lands (species composition and nutrient quality)
6. Social issues - pastoral groups
7. Social issues - flood recession farming
8. Social issues - floodplain and delta fisheries

A-26.1.2 Technology Transfer

It will be absolutely necessary to ensure that the facilities necessary for continued monitoring and study of the downstream hydrology are available to TARDA and other institutions in Kenya. Accordingly, it is proposed that ALL the hydrological models used, both in Phase 3 of the feasibility study and in the "Separate Study", are transferred to Kenya - together with the necessary computer facilities to run these models. These facilities will be installed in the most relevant institution.

A-26.1.3 Training

It will be necessary to ensure that adequate training is given in the use of the above facilities. This will be need to be linked to 1.1 above and also with on-the-job training supplied by the consultants installing the equipment and models.

Training will be required at a number of levels, including:

- Data entry and data management
- Maintenance of the models

- Verification of the Models
- Setting-up new hydrological models to study new or changed conditions.

A-26.2 TECHNICAL REQUIREMENTS

A-26.2.1 Downstream Hydrology and River Morphology

Set up and run flood simulations using a dynamic model of the Tana River floodplain from the site of the last rapids, at Kora Rapids, to the mouth of the Tana at Kipini. Topographic data will need to be digitised at 0.5 metre (or less) contour intervals in order to produce a topographic model (digital elevation model, DEM) of the floodplain. Input of river cross-section data (at between 10 and 20 km intervals along the Tana).

These topographic and river morphology data will need to be coupled with information on habitat and vegetation types within the floodplain, as well as settlements, infrastructure (bridges, polders, dykes), facilities (e.g. irrigation intakes), and cultivated land. These data will be obtained by a combination of field survey and photo-interpretation of the 1:20,000 aerial photography, and should also take account of planned structures on the floodplain such as TDIP. Habitat and vegetation data will be obtained from satellite imagery (SPOT and Landsat TM - see Section 26.2.6 below), coupled with ground truthing.

These data will form the basis of a dynamic model of the Tana River and floodplain, enabling detailed analysis of flood extent, levels, and timing associated with different river flows.

A-26.2.2 Verifying the Model

The models and simulations will be verified by use of remotely sensed imagery obtained during flood seasons. Images will be analysed using specialised image analysis software (e.g. Erdas). These data will need to be coupled with flow measurements at as many recording stations on the lower Tana as possible (Garissa, Bura, Hola, Garsen, Ngao etc.). Two levels of analysis are feasible:

A-26.2.2.1 High Resolution Satellite Imagery

SPOT (or Landsat TM, IRS-1/2) satellite imagery will be obtained for suitable sites during the flood seasons. These data have the advantage of high spatial resolution and the ability to detect detailed flooding patterns. However, due to the time interval between different passes of the satellites, it is easily possible to miss peak flood events. It will therefore be necessary to carry out this analysis in conjunction with the use of Low Spatial Resolution - High Temporal Resolution Satellite Imagery.

A-26.2.2.2 Low Spatial Resolution - High Temporal resolution Satellite Imagery

Satellite images are available free from polar orbiting and geostationary weather satellites, and receivers for these images are available at relatively low cost. The two systems provide complimentary information.

NOAA-AVHRR imagery

This imagery, from the AVHRR sensor on board the NOAA series of polar orbiting satellites, produces imagery at a spatial resolution of 1 km. These images are available on a daily basis (several times every 24 hours, both night and day) from each of the current orbiting satellites. Very detailed temporal resolution is therefore possible.

It is proposed to install a low-cost local receiving station (total cost in the region of US$50,000 for a complete receiving station plus software, built by NRI/BURS[1] and to-date installed in many countries world-wide). This will enable a complete set of AVHRR imagery to be obtained for verification of the models, and will enable a higher frequency of observation than through the use of existing image capture facilities. Flooding is detected both by the spectral signatures on a individual image, as well as by the change in spectral signature with time (e.g. one day to the next). Flooding will be detected by this system within areas down to about 1 km^2, and it will therefore be feasible to verify the models on areas throughout the Tana Delta, and over significant parts of the lower Tana.

Meteosat Imagery

Data from the geostationary Meteosat weather satellites can be received every 30 minutes. The spatial resolution of the data is approximately 5 x 5 km, equivalent to a weather station for every 25 km^2. These data provide information for use in weather forcasting and monitoring, measuring cloud temperatures, ground temperatures and so on. Recent advances in analytical techniques mean that this imagery can be used to provide daily estimates of rainfall within entire river basin catchments. The case of the Kenya highlands is complicated by orographic effects and a certain amount of research will be required in order to calibrate the satellite imagery and derive a model for estimating either rainfall or catchment runoff. Accordingly, it is proposed to carry out the necessary research, in collaboration with the Kenya Met. Dept., and to install the receiving equipment and computer software[2] in the relevant institution together with the NOAA receving equipment referred to above. Once calibrated, these data will be capable of providing an important component of the flow forecasting system necessary for optimum management of the reservoirs.

A-26.2.3 Importance of Laghas

A-26.2.3.1 Lagha flows

Lagha flows and runoff may be estimated through the use of runoff-models coupled to satellite imagery. Calibration through field measurements will be required. Direct measurement of lahga flows is unlikely to be successful but data may be obtained by measurements made in the main Tana River above and below the junction with laghas.

A-26.2.3.2 Lagha sediment

As above.

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[1] (BURS) Bradford University Remote Sensing.
[2] Also built by NRI/BURS in collaboration with the UK Met. Office and Reading University, U.K.

A-26.2.4 Upper Catchment Land Use Patterns

A-26.2.4.1 Modelling the Impact of Land Use Change on Runoff and Stream Flow

A runoff and stream flow model will need to be constructed, taking account of land use, vegetation cover, slope, land management practices and other factors affecting runoff and erosion. The potential impacts of changes to land use, vegetation cover, and land management practice can then be evaluated.

A-26.2.4.2 Current Land Use in the Upper Catchment

This will need to incorporate, in a GIS, current land use, topographic maps at 1:50,000 scale, geology, soils, infrastructure, settlements and population, as well as the rainfall data and hydrological system. Land use will need to be determined from either SPOT or Landsat TM images. Runoff models that incorporate or are linked to raster GIS systems will need to be used, and may include. distributed rainfall-runoff models, combined interflow and overland flow models.

It is considered that industry standard software rurring on either (a) several powerful Pentium-based networked PC computers, or (b) a Sun workstation system will be required. In general a PC-based system running under Windows NT and Windows 95 will be preferable. Printers, digitisers and plotters and other peripherals will also be required. Software is likely to include Erdas, ArcInfo, and Idrisi in addition to specialist modelling software packages.

A-26.2.4.3 Previous and Potenital Future Land Use Patterns

Older Satellite images will need to be analysed together with up-to-date imagery for analysis of recent land use changes. New imagery will need to be acquired for the project. Together with discussions with District and Regional planning officers, details of existing and planned irrigation, and other relevant land use, this will form the basis for an assessment of potential future land use changes. Past changes in land use will need to be related to observed river flows at these times.

A-26.2.4.4 Changes in Water Abstraction / Use

Exisiting water abstraction (and return flows) will need to be documented for the whole basin - both upstream and downstream of the proposed reservoirs- together with predicted future trends. At the same time, the water quality of abstracted and return flows will need to be evaluated, together with potential changes in these parameters. This study will build on work carried out during phase 3 of the feasibility study.

A-26.2.4.5 Impacts of Land Use Change on Runoff and Stream Flow

Based on the above - assess the impacts of potential land use changes on runoff, sediment and river flow. Assess possible mitigation measures. Assess critical factors affecting development potential.

A-26.2.5 Impact of Global Climate Change on Catchment Rainfall.

Predictions of the effects of climate change vary. Potential effects in the East African Highlands may be an overall increase, or decrease, in rainfall. The pattern is considered unlikely to remain unchanged. A literature survey needs to be carried out by a combination of Kenyan and international experts and the results incorporated in the analysis of potential land use changes, above. These studies will include evaluation of the possible changes in rainfall, temperature, and CO_2 (increased CO_2 is likely to result in a decrease in the nutritive value of plants and an overall decrease in the carrying capacity of the land).

A-26.2.6 Downstream Habitat, Vegetation and Land Use analysis

A-26.2.6.1 Floodplain Forests

The floodplain forests of the Lower Tana are of special importance, both nationally and internationally as centres of biodiversity and as habitats for rare and endangered species. Their continued survival is seen as being of vital importance.

All forest areas of the lower Tana will be mapped using a combination of the the 1:20,000 scale aerial photography and high resolution satellite imagery to be obtained by the project. Also mapped will be all areas of riverine forest along the remainder of the Tana River below Kora Rapids. By use of earlier photographic data and satellite imagery it will be possible, through the use of GIS analysis, to map changes in forest cover over time.

This information (essentially land cover), coupled with the detailed topographic survey, will be used as input data for the dynamic floodplain modelling. These data will also be processed and made available to other studies working on the Lower Tana Forests (e.g. KWS GEF project, IUCN, Tana Delta studies) and will form a comprehensive baseline for future monitoring studies.

A-26.2.6.2 Floodplain Grasslands

The great majority of the Tana floodplain is composed of floodplain grasslands. This is the habitat that is therefore most likely to suffer the greatest impact following any changes to the hydrological regime of the river. It is also the habitat on which there is the greatest social and economic dependence. The floodplain grasslands constitute vital dry season grazing for livestock (and wildlife), and also forms the habitat most suitable for both large and small-scale cultivation.

Importance of floodplain grass species:

The high rate of production in floodplains is certainly a factor in the overall productivity of these areas, especially in Africa where they support large numbers of domestic and wild animals. Another important factor is the quality of floodplain grasses. Floodplain grasses are known to be of high fodder quality, containing a relatively high content of crude protein. They are also highly palatable, even when dry. In contrast, grass species from non-flooded areas generally lose their palatability on drying. Thus even in regions of similar grass production, the floodplain species will always be more attractive to herbivores and be able to support higher numbers during dry seasons.

The most impressive aspect of floodplains under normal conditions is the integration of physical and biological components within the system. The traditional integrations of biological and human activities which make up the ecology of the floodplain river can only work if there is a community of micro-organisms, plants and animals which are adapted to the particular frequency of the environmental event which is fluctuating - in this case the flood.

However, because of their high rate of natural production, floodplains are attractive to developers and in many places in Africa, floodplains are being brought under management.

Proposed studies:

Through the use of the 1:20,000 scale aerial photography to be obtained by Photomap, together with digital analysis and ground truthing of SPOT satellite imagery, the total extent and important characteristics of the floodplain grasslands will be determined. This analysis will also make use of the digital terrain model derived for the hydrological studies.

Floristic composition will be determined by sampling in representative sections of the floodplain, both within the Tana Delta and in suitable areas of the Lower Tana above the delta (Garissa to Garsen).

Nutritional qualities of the grass species will be determined (nutrient quality, palatability) at different times during the hydrological season. Comparisons will be made with non-floodplain grasses from adjacent hinterland areas.

Through social and economic surveys within local settlements, using Participatory Rural Appraisal methods (PRA), the social, economic and cultural importance of the different components of the floodplain and delta grasslands will be determined.

Soils are a major determinant of grassland communities and it may be necessary to link this study to studies of soils. The availability and lvel of detail of current soil information is not known.

This information (land cover), coupled with the detailed topographic survey, will be used as input data for the dynamic floodplain modelling. These data will also be processed and made available to other studies working on the Lower Tana Forests (e.g. KWS GEF project, IUCN, Tana Delta studies).

A-26.2.6.3 Other Floodplain Vegetation/Habitat Types

Characteristics of other floodplain vegetation types. Economic uses. Biodivdersity. Potential impacts resutlingt from changed hydrological regime.

A-26.2.6.4 Livestock Numbers and Centres of Distribuition

It will be necessary to assess livestock numbers (cattle, camels, sheep, goats, donkeys), in areas dependant of the Tana River, downstream of the proposed reservoirs. Assessment of numbers, ownership, trends in populations sizes, and seasonal distribution patterns, together with their nutitional and other requirements, will enable an assessment of impacts following changes to the hydrological and groundwater regimes.This analysis will also enable an assessment of the carrying capacity of the Tana River floodplain under different sets of criteria.

A-26.2.7 Sediments and Nutrient Transport

Building on the studies carried out during Phase 3 of the feasibility study, this study will collect field data over an extended period, from areas both above the proposed Grand Falls dam site and in the Tana River floodplain.

It will be necessary to collect sediment and water samples from as many sites along the Tana as realistically possible, in order to obtain data with which to analyse the changes in sediment and nutrient quality both throughout the hydrological cycle and with distance along the river. Data to be collected will include: total dissolved solids, sediment particle sizes, nutrient qualities, organic components.

Efforts will need to be made, if this is feasible, to analyse the origins of components of the total dissolved solids, at different points along the Tana.

These data will be used, together with the detailed dynamic hydrological models, to develop a model of sediment and nutrient transport down the Tana River.

A-26.2.8 Guaranteed River Flow

Releases necessary to maintain a certain quantity or biological quality, physical and chemical conditions or requirements downstream.

A-26.2.8.1 Requirements of Downstream Users

Requirements of downstream users (e.g. public water supplies, groundwater, large scale irrigation, small scale irrigation, flood recession farming). Existing abstraction, increase resulting from population expansion, planned future uses.

A-26.2.8.2 Ecological Requirements

1. Floodplain and Lower Tana Forests
2. Mangroves
3. Estuarine Conditions
4. Floodplain Grasslands
5. Groundwater Recharge
6. Fisheries

A-26.2.9 Biodiversity

This section will need to be fully discussed and worked out with KWS, IUCN and EAWLS.

Different components will need to be studied:

- Lower Tana River Forests (including Tana River Primate Reserve)
- Grassland communities
- Soil microbiology (including fungi) and their dependence on the flooding regime. (Soil microbiological activity is the basis for soil fertility).
- Aquatic flora
- Aquatic fauna (including economic fish species and other fish species, as well as other aquatic fauna).
- Pytoplankton and Zooplankton

- Mangroves
- The dependence of "hinterland" communities, especially wildlife, on the Tana River floodplain.

Within each major habitat attention to the major biological groups will be necessary: higher plants, lower plants, fungi, birds, mammals, insects, reptiles, amphibians, fish, macro-invertebrates, phytoplankton, zooplankton, soil microbiology.

Special attention will be needed for rare and endangered species, and species of potential economic importance (e.g. wild coffee).

A-26.2.10 Groundwater Studies

Many of the settlements and villages on the Tana are entirely or largely dependant on groundwater supplies.

Distribution of, and rates of abstraction from existing wells and boreholes. Geological formations in which groundwater aquifers are found. Mechanism and rates of groundwater recharge.

It will be necessary to study the relationship between the flooding regime and groundwater recharge, both within the floodplain itself and in adjacent areas. This can be carried out by establishing a series of boreholes located along transects across the floodplain at different localities (a minimum of eight to ten transects will be required). These will be monitored for groundwater depth and the chemical properties of the water.

In addition to the transects used for monitoring changes, it will also be necessary to obtain additional, single date, samples at selected (shallower) sites within the floodplain, both in order to verify the model and to provide additional information.

It may be necessary to link this study to studies of the soils and the underlying geology. The extent and detail of currently available data are not known. (see also under Grassland Habitats, where soils are a major determinant of grassland types).

These data will be incorporated within groundwater models in order to determine the impact / importance of the flooding regime of the Lower Tana on groundwater supplies.

A-26.2.11 Tidal Systems and potential salinization

Existing conditions in the delta:

1. Extent of saline water intrusion at different points in the hydrological cycle.
2. Location, depth and distribution of saline soils in the delta.
3. Location of water abstractions and returns in relation to 1 and 2 above.

Changed flow conditions are likely to have a long-term effect on tidal / estuarine systems.

In other hydropower projects, salinization of downstream systems on the floodplain has been a significant, and often largely unforseen, impact of reduced flows. It will be important to examine this question in detail with respect to the Tana Delta. An impact of large-scale irrigation is also an increased tendency for salinization and the combination of the two factors may have far-reaching implications for the long-term sustainability of production systems on the Tana Delta.

A-26.2.12 Influences on Marine and Inshore Systems

1. What is the impact of current sediment outflow from the Tana at Kipini?
2. Is the nutritional value of the sediment important for fisheries?
3. Do the sediments provide an important habitat component for marine communities?
4. Are existing sediment loads beneficial, harmful or neutral in their impact?
5. What is the physical impact of sediments, i.e. where are they deposited? If sediment flows decrease, will this result in a gradual erosion of the Tana deltaas a result of wave action? The delta shoreline has obviously been advancing (evidence from old dune systems) - Are these sediments derived primarily from marine or from riverine sources?

A-26.2.13 Health Effects for Riparian Settlements / Villages: Human and Livestock Diseases

A-26.2.13.1 Downstream

Changes in the flow regime may have impacts on the transmission cycles of some water-borne and other diseases. Such effects could be either positive or negative.

Potenital water-borne or water-related diseases include: schistosomiasis, malaria, intestinal worms, diarrhoeal diseases, cholera, filariasis, and other water-borne or water-related diseases.

The effects on livestock diseases needs to be assessed. This includes effects due to potential changes in habitat resulting from altered hydrological, groundwater and flooding regimes. For example, bush encroachment may result in changes to the tsetse fly distribution.

A-26.2.13.2 Reservoir Area

Effects of potential water-borne diseases: The presence of a large water body, possible irrigation structures, and changes in the flow regime of the river will have impacts on the transmission cycles of some water-borne and other water related diseases. Such effects could be either positive or negative.

Changes in land use due to resettlement, and the resulting changes in disease transmission, both human and livestock, that might occur. This includes such diseases as trypanosomiasis - not normally associated with water development schemes - since the habitat suitable for tsetse fly is likely to be altered.

Are there any human health programmes in the area? What will the impact of the proposed reservoirs be on them? Requirements for additional medical staff.

Effects of other diseases introduced as a direct or indirect result of the project.

A-26.2.14 Crop Pests

What are the main pests or weeds which threaten crops in the Project and what method of control is used or envisaged? (Compare with nearby existing projects with similar crops.)

A-26.2.15 Fisheries

A-26.2.15.1 Reservoir Fisheries

Short-term success and long-term failure has characterised reservoir fisheries. What can be done to ensure a sustainable fishey in the reservoir?

A-26.2.15.2 Delta and Floodplain Fisheries

Potential for replacement of floodplain fisheries that will be impacted by the changes in hydrological regime by alternative fisheries - e.g. development of fish ponds. Possible alternaitves need to be examined. If no suitable alternative fisheries exist, then alternative sources of employment and income need to be generated.

A-26.2.15.3 Fisheries Dependant on Mangroves

Estuarine and offshore fisheries depend on mangroves. How will these, and commercial prawn farming, be affected?

A-26.2.16 Communications / warning of timing of flood events

It will be necessary to establish a system for communication of the timing of both natural and man-made flood events. This will involve:

- The development of a flood warning and forecasting system, as well as
- The development of a suitable means of communication with the riverine farmers and other people affected by the floods.

The system will need to incorporate:

- Long-range, regional weather forecasting
- Short-term national weather forecasting
- Near real-time rainfall and river flow measurements, and telemetry systems for delivering these data.
- The use of geostationary satellite information (Meteosat satellites) for provision of half-hourly images, combined with models relating cloud cover, cloud temperature and other environmental/physical variables to rainfall and/or runoff.
- Rainfall-runoff models used to produce warnings and forecasts.

A-26.2.17 Economic evaluation incorporating environmental costs and benefits.

This analysis needs to take into account, cultural, social, economic and environmental factors, including: changes to disease risks and incidence; loss of downstream agricultural land;

changes to the quality of downstream livestock grazing resources; the total costs of resettlement, including the costs associated with land use change, changes to soil erosion; political repercussions of social changes; changes in fisheries potential; changes to reservoir area and downstream groundwater potential. New ideas on the evaluation of environmental costs and benefits, by the World Bank and others, will also need to be taken into account (wildlife, rare species, biodiversity, tourism potential, erosion of genetic diversity). In addition, it is important that potential disasters are taken into account as an integral part of cost-benefit analysis.

A-26.2.18 Other Projects

A-26.2.18.1 Existing Projects

Existing projects in or near the Tana River floodplain which may impact floodplain habitats, either in a positive or negative manner. An evaluation of the relative importance of these projects compared to potential impacts from the Mutonga/Grand Falls Hydropower Project, as well as an evaluation of any synergistic effects.

- Roads, bridges
- Large-scale irrigation
- Small-scale irrigation
- Commercial fisheries/prawn developments
- Salt extraction
- Tourism and Protected Areas
- Wildlife and Biodiversity related programmes
- Any other projects

A-26.2.18.2 Proposed Projects

Any proposed projects, or extensions to existing projects which may have either positive or negative effects on the floodplain environment and economic production systems.