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Report No. 10

Freshwater Fluxes from Continents into the World Oceans based on Data of the Global Runoff Data Base

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GRDC

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1. Preface

This report has been prepared in response to the request of the Global Energy and Water Cycle Experiment (GEWEX) of the World Climate Research Programme (WCRP) of the World Meteorological Organization (WMO) and the International Council of Scientific Unions (ICSU). For GEWEX, "Estimates of the quantitative runoff of fresh water from continents into the oceans or from one large land area to another are an important requirement.." (WCRP 1995). The rational behind this statement is that the knowledge of river runoff into the oceans is an important component to understand the land-ocean interaction processes which ultimately can enhance the skill to predict climate behaviour. Likewise important, the river runoff into the oceans is presently not included in General Circulation Models (GCMs). The knowledge of river runoff into the oceans allows the closure of the global hydrological cycle.

A major client of this report is the Global Environment Monitoring System - Water (GEMS-Water) of the United Nations Environment Programme (UNEP). GEMS-Water with regard to this report is concerned with the computation of global fluxes of suspended and dissolved matter including pollutants into the oceans. An issue in this respect is also the quantification and closure of the carbon cycle between land surfaces, atmosphere and the oceans.

The providers of the data have the primary responsibility for the quality of the data. Though efforts have been made to avoid errors, this possibility cannot be entirely excluded. The staff of the GRDC welcomes comments which help to correct possible errors and could enhance the utility of the presented information in a future update of this report.

2. Introduction

The freshwater runoff from continents into the oceans is of major interest in research concerned with global monitoring of freshwater resources, the flux of matter into coastal areas and the open oceans, and the influence of freshwater fluxes for climate circulation patterns on regional and global scales. For clarification: While in climatology the term "freshwater flux" is used for both, precipitation and river runoff, this term is exclusively used in this report for river runoff.

Two target groups can be identified for this GRDC Report:

- Research groups involved in climate modelling, ocean-atmosphere interactions and hydrological research of the global hydrological cycle.

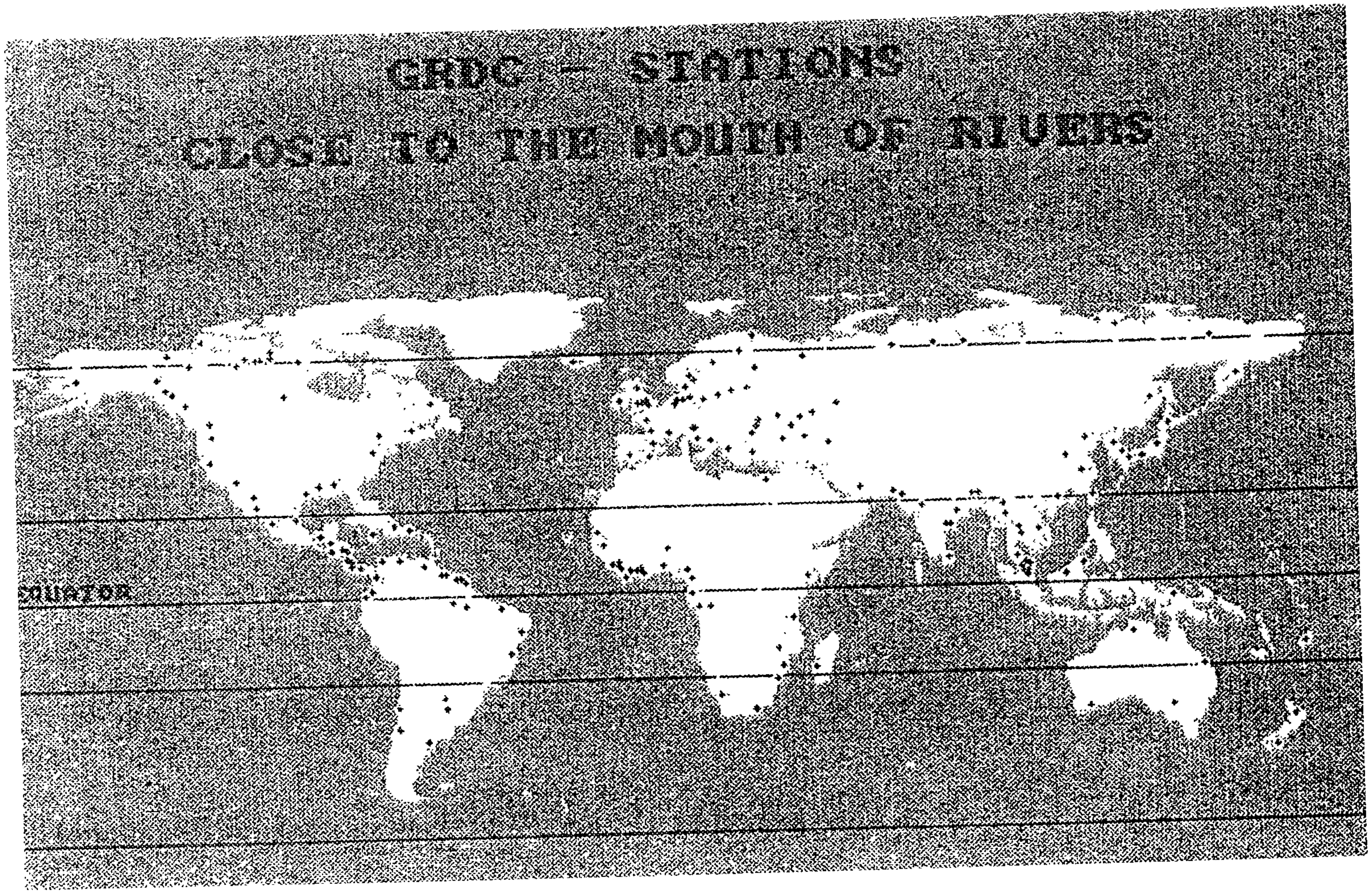
- Research groups involved in the assessment of fluxes of matter including pollutants from continents into the oceans and research which aims at an assessment of the consequences of pollution for coastal and marine environments, regional and continental freshwater assessments and land-ocean interface processes in a wider sense.

The viewpoint in this report is two-fold: From the view of continental freshwater resources (excluding groundwater) and from the ocean side to give an assessment of continental fluxes into the world oceans. The key question which has been tried to answer on the basis of the GRDC database was: *How much water is flowing from the continents into the world oceans?* Three numbers for gauging stations are used in the report: While 194 stations were used for the calculation of the fluxes from the continents, a subset of 161 stations were used for the computation of fluxes to the oceans, excluding stations of rivers draining into the Baltic and the Mediterranean Sea. An analysis of the number of stations needed to represent the freshwater runoff from contintents into the oceans reveals (chapter 8), that less than 150 stations are required.

3. Areal coverage and presentation of the database

Map 1 shows the location of all stations used for the runoff calculations. Altogether, 194 river gauging stations close to the mouth of the rivers have been identified for the computations.

Figure 1 gives an overview of the areal coverage of drainage basins in the GRDC database in relation to the size of the continents. Australia in this context includes also Oceania (New Zealand and the islands). While for Europe and South America the percent coverage exceeds 50 %, the territory of North and Central America as well as Asia is not reaching the 50% mark. Low coverage is achieved for Africa and Australia, largely because of the extensive desert areas. The drainage basin of the Nile in Egypt for example has not completely been accounted for because the desert area does not contribute to the runoff of the Nile. Rather, a net loss occurs until the discharge of the Nile into the sea because of evaporation from the water surface and extensive use of water for irrigation.



Map 1

Table 1 shows the influence of desert areas on the percentage coverage of GRDC basins: When the desert areas are considered, the coverage increases markedly for Africa and Australia from 22% to 31% and 15% to 33%, respectively. The term "desert" is used here with the meaning of natural deserts and not deserts due to environmental degradation. Depending on the various definitions, the quantification of desert areas is largely varying.

For the interpretation of the results it is necessary to consider that for the flux computations the GRDC basin areas were used and not the continental land areas as is practice with other authors. Principally, the flux figures reflect the strictly observed values of only those basins where information was available. The rational is, that only parts of the land area are actually contributing to the observed flux. From a hydrological viewpoint the extrapolation of basin-referenced fluxes from partial areas to continental areas is problematic, while in climatology the areal extrapolation of precipitation and evaporation is standard practice. In figure 3 the GRDC flux values are re-calculated for the total land areas to make them comparable to values cited in the literature. When related to the total land areas, the re-calculated GRDC values correspond well with values of other authors. Especially the re-calculated total flux of 42.3 x 10^{15} kg/year from GRDC data corresponds with the value 40 x 10^{15} kg/year cited in CAHINE (1992). Generally, the GRDC values related to observed basin areas are somewhat lower than from other authors, in part because groundwater fluxes into the oceans were not considered here. As can be shown in chapter 8, the number of selected GRDC stations is sufficient to represent the average annual runoff from river into the oceans.

In annex 1, maps show for each continent the location of the gauging stations used for the computations, followed by a catalog with station and time-series information. This is followed by a table showing the overlap of time series of rivers. The tables demonstrate that for all continents, the time series are not homogenous and that in fact there are only few rivers with completely overlapping time-series. This underlines the need to call for data to close these time gaps. The next two tables show principal hydrological characteristics for selected rivers. In annex 2, the hydrographs of selected rivers together with the flow variability are presented for each continent.

4. Mainstream problems in the context of this report

A few remarks are made here to outline mainstream problems for which information about river fluxes from continents into the oceans is needed. In this context, problems in climate modelling taking into account land-based hydrological and ocean-atmosphere processes as well as issues of land-based sources of pollution of the oceans and especially the coastal areas are briefly mentioned. It is not attempted to be exhaustive or complete in the context of this data-based report.

4.1 Ocean-atmosphere processes

The mixing of fresh water with saline water is mainly driven by density differences between fresh water and salt water bodies and the resulting buoancy behaviour, temperature and the effect of wind fields which disturb the thin upper layer of ocean waters (WEBSTER, 1994).

These interactions influence to a large extend the evaporation from ocean surfaces which in return is the driving mechanism for lateral energy transport into the atmosphere. Thus, the ocean-atmosphere interaction has a key role in the formation of local, regional and global climate circulation patterns. The quantitative aspects of these general processes are still not fully understood. As can be seen from table 4, the Arctic Sea can be understood as the freshwater pool for the other oceans.

It can be demonstrated, that an increase of the freshwater fluxes into the Arctic Sea (e.g. by increased river runoff and/or increase of meltwater from the polar cap) would reduce the atmospheric warming effect of northward driven Atlantic ocean currents (e.g. the Gulf Stream) which would result in a dramatic cooling of most of Northern Europe.

The flux of freshwater from river runoff generally decreases the density of the oceanic salt water, thus increases the buoyancy and stabilizes the upper surface water layer which then can be heated by solar radiation. This effect is expected to be effective in coastal areas with large river fluxes (e.g. the Amazon or the Brahmaputra especially because the discharge of the Brahmaputra into the relatively narrow Bay of Bengal, where brackish water can be detected for almost 300 km out in the bay during low tide). Changes of freshwater discharge into coastal areas are thus effectively influencing the salinity, mixing patterns and ecological conditions of coastal waters.

4.2 Global climate behaviour and modelling

Due to its unique physical properties, water is the most important medium for energy exchange processes between land, oceans and the atmosphere.
Until presently, the understanding of the role of water is not sufficient to quantify with sufficient accuracy its role in the formation and maintenance of climatic patterns and changes. Noting this deficiency, CAHINE (1992) states that the Global Energy and Water Cycle Experiment (GEWEX) was initiated "to observe and model the hydrological cycle and energy fluxes to the atmosphere, at the land surface and in the upper oceans". To simulate the present climate and with a view to predict regional and global climatic changes under influences viz: greenhouse gas emissions, atmospheric global circulation models (GCM) have been constructed. Though good progress has been made in the accuracy of GCMs on a global scale there are several deficiences some of them are outlined below: Amongst other deficiencies (see below) present GCMs do not adequatley reproduce the water and energy budget of large cloud systems which are a major component of the extra-tropical region. The accuracy of these GCMs determine the accuracy of water resources assessments and their impact on the socio-economic conditions of mankind. Despite great progresses made in the last few years in the development and accuracy of GCMs, there is a strong need to validate model-generated streamflow into the oceans against observed runoff.

The deficit in the availability of global data sets of river discharge until recently is probably one of the reasons, why in most GCMs river runoff is not explicitly used or only in a simplified way. Attempts have been made to estimate global runoff using atmospheric water balances (RUSSELL and MILLER, 1990; OKI et al 1993) and compare the results with observed river runoff. OKI et al (1993) have used a four dimensional global data assimilation to estimate the world water balance and compare it with the GRDC database. The rather good coincidence of estimated and observed runoff for a number of basins in the northern hemisphere and the large error in basins elsewhere indicate the "importance of accurate routine observations of both atmosphere and river runoff" (OKI et al (1993)).

The presently observed broad bandwidth of estimates of precipitation, evaporation, river runoff calculated from climatic water balances is evident from table 5 and figures 2-5 and 9-16. A few reasons for these differing estimates are outlined: Precipitation fields over the continents are still inaccurate, e.g. recent studies show, that precipitation over the southeastern United States has been overestimated.

Overestimation of precipitation and underestimation of evapotranspiration however leads to an overestimation of computed river runoff. LEGATES and MATHER (1992) point to an important source of error in modelling: If large values of corrected precipitation measurements (which increase the corrected precipitation value by 23% for Europe but only 5.8% for Africa) are used without adaptions of the gauge-observed potential evaporation, the modeled runoff is overestimated. Present GCMs seem to be deficient to simulate lateral atmospheric moisture transport when the topography of high mountain ranges which form a dominant control in moisture transport is inadequately represented in the models. Orographic effects have not been treated adequately, mainly because of the low grid-resolution of most current GCMs (WCRP 1996). RUSSEL and MILLER (1990) noted that an improved parametrization of groundwater storage and evapotranspiration is needed to improve model runoff. This statement gains importance when considering the fact, that ground-based evaporation measurement programmes have been halted by a number of governments and ground-based evaporation observations become more scarce. ROWNTREE and LEAN (1994) note that groundwater storage needs to be modeled to simulate runoff more precisely. The literature review on coupled land-atmosphere models with regard to the energy and water cycle processes strongly indicates that knowledge about the space-time and status of soil moisture/wetness is crucial.

A particular short-coming of many present GCMs is their insufficient ability to simulate realistically lateral water transport from one grid-cell into another (MARENGO et al (1994)). This means that the inter-grid transport of surplus water into neighboring grids is ignored which leads to the modeling of an incomplete hydrological cycle.

Recognizing this short-coming, KITE, DALTON and DION (1994) have published a hydrological model for the Mackenzie river that shows that the use of a hydrological model together with GCM data provide a better representation of the observed river discharge. Similarly, SAUSEN, SCHUBERT and DÜMENIL (1994) have presented a linear advection model of river runoff for use in coupled atmosphere-ocean models which qualitatively rather well represents the observed river runoff.

Macroscale hydrologic models gain importance in their linkage to climate simulations. A promising approach in macroscale hydrological modeling is a hierarchical nested system of models including physically-based hydrological models, a soil-vegetation-atmosphere transfer scheme (SVAT), a mesoscale atmospheric model and a GCM which has been successfully applied inter alia to the Amazon river (VÖRÖSMARTY et al (1993)).

In line with this approach, a simplified vertical process description and a statistical representation of the runoff and energy balance has been proposed by FAMIGLIETTI and WOOD (1994), who propose the resulting macroscale model as input for atmospheric models. The practical use of GCMs and macroscale hydrological models for operational hydrology is often underestimated owing to the fact that present GCMs were not developed to assist hydrologists and decision makers in water resources management on regional scale and the nested approach to macroscale hydrological models is quite recent and under rapid development. LOAICIGA (1996) cites such models which have been used to predict conditions for flood control, water storage and water supply in semiarid midlatidudinal climates of the United States under greenhouse warming scenarios. The International Commission of the Rhine basin (CHR) also implemented a project to quantify the impacts of climate change on water resources management on the Rhine river, using GCM-derived climate change scenarios and the approach to use catchment and macroscale hydrological models to quantify the consequences of changes in the hydrological regimes with regard to floodflows and lowflows (GRABS (1995)).

Aside from river flux calculations into the oceans it is also important to obtain more information about fluxes into closed basins of continents to account for the lag-time of water in basins. This information is crucial to calculate regional water and energy budgets: The example of the Niger river shows that about 50% of the river discharge is stored and partially evaporated in the inner delta of the Niger. Likewise, the influence of large lakes and reservoirs on regional water vapour and energy fluxes is not known.

4.3 Fluxes of matter and pollutants

Rivers are the major transport media for matter and pollutants from the continents into the oceans and are sensitive indicators for land use changes, e.g. deforestation which result in an increase of sediment and suspended matter transport. Major pollution sources are large industrialized conurbations with associated waste water discharges into rivers, agriculture through release of fertilizers, pest and weed-control chemicals and to a largely unknown degree pollutants dissolved and suspended in precipitation which enter the river through interflow and groundwater transport. Increasingly, persistent organic chemicals can be traced in river discharges which may severely impair reproduction in aquatic ecosystems. To study these problems and assess their impacts the International Geosphere-Biosphere Programme (IGBP) has launched a project "Land-Ocean Interactions in the Coastal Zone" (LOICZ).

Considering, that the coastal zones (200 m above to 200 m below the sea surface) are home to more than 60% of the world's population, supply 90% of the world fish catch and account for 8% of the ocean surface (all figures from IGBP (1994)), the importance of discharge and associated water quality information from rivers into the oceans becomes evident. One of the objectives of LOICZ, to "assemble an electronic, global database of existing river discharge data" (ibid. 1994) is already realized in the GRDC. Likewise, the GRDC is well capable to contribute to task 1.1.2 of the LOICZ project "Determination of temporal variations in discharge characteristics for selected and representative rivers". The second phase of the Global Environment Monitoring System-Water (GEMS/Water) identified as one priority area the study and monitoring of land- based sources of pollution for which continental river fluxes close to the mouth is a conditional requirement (UNEP 1995).

5. Computation of freshwater fluxes

The GRDC database was searched for all rivers draining into the world oceans. The gauging stations closest to the mouth of each of the selected rivers were then used for the computations. For each selected gauging station the entire time series was used for the computation. Only original, observed data were used, data gaps were not statistically filled up. In the selection routine, all years with missing mean monthly values were excluded from the computation. Runoff was computed as mean monthly runoff for the available time series of each selected station.

This method has two principal consequences:

- The entire database for the selected rivers and gauging stations could be used.

- The time series for the computation is not homogenous as the time series for each gauging station are not completely overlapping in time, and the duration of the time series varies for each station. Thus, deviations in the results can be expected for the yet theoretical case that for all rivers homogenous time series had been available.

The average length of time series for the computation is 26 years.

Continent	Africa	Asia	Australia	Europe	North and Central America	South America
Average length of times series (years)	21	24	11	53	24	20

Table: 2 Average length of time series for the computation of continental runoff into the oceans.

Rivers discharging into the Caspian Sea were excluded from the runoff calculations. Specifically, from Asia, the Ural river at Kushum with a mean annual discharge of 9 km^3/a, and from Europe the Volga at Volgograd Powerplant (255 km^3/a) and the Kura at Surra (17 km^3/a) were excluded. For the computation of freshwater fluxes into the world oceans, the Mediterranean and the Baltic Sea have also been excluded (see also remarks in chapter 7).

6. Computation of the continental runoff

The computation of the runoff from each continent was carried out using the mean monthly discharge for the respective stations and for the entirely available time series without missing values and relating it to the size of the entire continent.

In table 3 the mean annual runoff has been calculated as well as the total annual volume of discharge. Due to the influence mainly of the Amazon river, South America has the largest freshwater flux into the Atlantic Ocean.

Australia and Oceania on the other hand have the lowest yield since most of the rivers have relatively small drainage basin sizes with the exception of the Sepik river in New Zealand. The computed runoff from continents is compared with results from several other authors (table 5 and figures 2-5). The data from BAUMGARTNER and REICHEL and SELLERS is cited in PEIXOTO (1993). Except for SHIKLOMANOV (cit. in GLEICK (1993)) who has used observed data, the other considered authors calculated continental runoff as difference between precipitation and evaporation. The resulting runoff estimates differ largely from each other, mainly because of largely differing precipitation and evaporation estimates. This is especially visible in the estimates for Australia.

The discrepancies between the runoff calculated by SHIKLOMANOV (ob. cit.) and the GRDC can be partly explained by the different calculation methods and database uses: While SHIKLOMANOV has used time series with interpolated values where observed values were missing, the GRDC has used only complete time series and excluded series with missing values.

The database of the GRDC is also more comprehensive, which is especially valid for the African river basins, where the GRDC holds a rather complete data set of the Niger river. The discrepency between runoff computations for North America is explained in chapter 8).

In general, GRDC-runoff and runoff computed as difference between precipitation and evaporation (R = (P-E)) coincide well for Europe and Asia after BAUMGARTNER and REICHEL (fig. 2), and with a somewhat less good fit after SHIKLOMANOV (fig. 4) and for Asia after SELLERS (fig. 3).

7. Computation of freshwater fluxes into the oceans

The Baltic Sea has been excluded from the flux calculations into the oceans as the Baltic Sea is not treated in this report as seperate "ocean" or part of the Atlantic. However, if one views the Baltic Sea and its surrounding landmasses and rivers as the "Baltic Basin" with a size of 2.1 x 10^6 km^2 with its main outlet being the narrow Skakerrak Strait, the flux of low salinity water into the Atlantic is estimated at 470 km^3/year (BALTEX (1995)), which contributes to the circulation pattern of the North Atlantic. Likewise, the Mediterranean Sea has been excluded for this calculation.

The continental runoff as described in chapter 6 had been seperated to compute the freshwater flux from the rivers into the world oceans. Figures 6 and 7 graphically display the mean annual runoff and discharge, respectively, into the oceans from GRDC data and table 4 shows the freshwater fluxes from the land surfaces into the different oceans and relates that figure to the findings of BAUMGARTNER and REICHEL as well as to the surfaces of basin areas draining into the oceans and the ocean surfaces. It is apparent, that the Arctic Ocean receives about a third of its total freshwater flux (P+R) from river runoff and in comparison to its size receives the largest freshwater runoff of all oceans. The Atlantic Ocean receives the largest freshwater flux from rivers of all oceans but shows also the greatest net deficit Precipitation - Evaporation (P-E). The Indian Ocean receives the least freshwater flux from rivers and also shows a P-E deficit, whereas the Pacific Ocean being the largest in size is the only ocean besides the Arctic Ocean with a positive P - E balance but receives the least freshwater flux from rivers.

Table 4 therefore indicates the dominant role of the Arctic ocean as main recipient of freshwater fluxes from river runoff and - relative to its basin size - from precipitation.

Figure 8 shows the continental freshwater fluxes into the oceans based on 161 GRDC stations. For this calculation, the mean volume of discharge for the available time-series has been cumulated for all rivers draining into the specific oceans. The numbers shown in the figure are therefore dependant on the number of stations used for the calculation.

Based on figure 8, table 6 displays the absolute freshwater volumes discharged into the oceans in different latitude bands. No data are available in the GRDC from freshwater fluxes from the Antarctic ice shield.

83% of the freshwater fluxes flow into the northern oceans while only 17% of freshwater fluxes flow into the southern oceans, where the Amazon dominates the freshwater flux into the Atlantic.

It is of climatological importance, that 65% of the calculated freshwater volume discharge into the oceans in the tropics in the latitude band 0° - 23° both sides of the equator and 13% into the Arctic. 22% of the freshwater volume occurs in the latitudes 23° - 60°. The latitude bands 23° - 40° North and South of the equator receive a total of 13.2% of the global total freshwater flux and thus can be compared with the flux into the Arctic Ocean. However, the subtropical latitudes account for most of the evaporation over the oceans.

8. Validity of the GRDC database

For the interpretation of the results it is important to show, how representative the database is for the computations. In a number of cases, the gauging stations of rivers draining into the oceans are quite far away from the actual mouth of the river. This has pragmatic reasons, as it is very difficult or barely impossible to gauge rivers in tidal influenced delta areas. The consequence is that discharge from upstream stations does not account for the downstream hydrological processes in areas extending over often several 1000 km^2. Likewise, streamflow from stations at the mouth of the rivers do not always account for upstream hydrological processes e.g. evaporation from wetlands, lakes and reservoirs which in return have to be calculated as transport losses in GCMs (ARNELL (1995). From the viewpoint of the GRDC it would be important to initiate a global discharge measuring programme for selected large rivers at the nearest possible site near or at the mouth of large rivers.

In this way the runoff contribution of the area not gauged by regular stations could be assessed and statistically correlated to the gauge height - discharge relationship at the nearest regular gauging station.

For several rivers however, e.g. the Niger river, the station in the GRDC database is not the nearest station to the mouth of the river: A large part of the drainage basin of the Niger could not be considered because the station available nearest to the mouth of the Niger is at Gaya, well in the upper middle course of the river. In these cases, it must be tried to obtain the data for the station which actually is closest to the mouth of the river. In the database are also rivers which receive a substantial increase in runoff from tributaries below the station nearest to the mouth of the river. In these cases, the tributary river discharging below that station into the main stem of a river has also to be taken into account for the flux computations: The Obidos station is the closest station to the mouth of the Amazone; however, below that station the Xingu river discharges into the Amazone and thus is included in the computations.

To indicate the number of necessary rivers and gauging stations globally and for each contintent which are necessary to monitor global/continental runoff, the following method was used: From the information presently available in the GRDC database, the size of drainage basins of rivers draining into the oceans has been ranked in decreasing order on a global scale and for each continent. Following a suggestion of M. MEYBECK (personal communication), for all stations close to the mouth of the rivers, the runoff was computed and then cumulated. The results have been plotted into the graphs of figures 9-16. The common characteristic of all figures is, that the curve reaches a near-asymptotical stage with increasing numbers of rivers. This indicates, that once the curve is asymptotic, an increase in the number of rivers does not significantly increase the information content with regard to runoff from continents into the oceans.

The validity of the continental and global runoff obtained from GRDC data has been checked against runoff estimates from other authors and indicated in the graphs. Except for the data from BAUMGARTNER and REICHEL, cited in PEIXOTO (1993)) all other authors are cited in LEGATES and MATHER (1992)). On a global scale, the 10 largest rivers overestimate global runoff, whereas for the 25 largest rivers the GRDC-runoff is at the upper limit of estimates of the other authors (fig.9). For Africa, the computed runoff is in general higher than the estimated runoff of most other authors. This is explained by the fact that the GRDC database for Africa is perhaps the most complete database of all and therefore contains more valid information (fig.10).

In chapter 4, the difficulties of runoff estimates from climate observations and GCM's is briefly discussed. For Asia, the 15 largest rivers underestimate the average runoff and are then concurrent with the estimates of other authors (fig.11). For Australia and Oceania, the runoff of the Sepik river gives very different results. With the inclusion of the Sepik river, the runoff in that region is much higher than the estimates from other authors (fig.13). For Europe, the GRDC-runoff is at the lower limit of the estimates of other authors (fig. 14). The highest deviation between GRDC-runoff and estimates from other authors is evident for North and Central America, where the GRDC-runoff calculation of 170 mm is lower than the estimates of all other authors (fig. 15). This discrepency can most likely be attributed to the influence of rivers with a large drainage basin but very low rnoff as is the case for the Colorado river which ranks no. 5 in figure 15. Omitting all rivers with less than 100 km^3/a, the runoff calculated from then 24 rivers would be 189 mm and is thus well within the bandwidth of estimates of other authors. The high estimates of other authors may in part be attributed to the use of largest rivers in terms of discharge and not area. Another reason for the low estimate of the GRDC-runoff for North and Central America is that a part of the freshwater flow into the Arctic Sea is not monitored with the available gauging stations as the station density in the northern areas is low (1 station per 200.000 - 500.000 km^2) and discharge measurements during ice conditions are extremely difficult while the operation of gauging stations is not always reliable. In this way, a considerable part of the discharge from permafrost areas may presently not be measured which could account for the deficit in observed runoff in North America. In this respect it is noted here that present estimates of runoff into the Arctic Sea show differences of 50% and more (ACSYS (1992) and GRDC (1995)). For South America again, the GRDC-runoff is somewhat higher than the estimates of most other authors (fig. 16).

9. Monitoring of freshwater fluxes into the oceans

A long-term objective for climate modeling and coastal/oceanic pollution control is to establish a network of monitoring stations to observe in near real-time river runoff into the oceans. The present global network density of the GRDC is about 2 stations per 2.5° grid. Many of these stations need to be continuously updated (GRABS, WILKE (1994)). While a dense network is required for regional and local hydrological studies, a selection must be made for hydrological monitoring on a global scale in near real-time as indicated above. The identification of a global network requires an indicator to determine the minimum number of stations to calculate representatively the freshwater fluxes from each continent into the oceans. It is apparent from the figures, that 143 gauging stations are required to represent river runoff from continents into the oceans.

The selected rivers and gauging stations which thus could be used for the monitoring of continental freshwater fluxes as well as for global fluxes into the oceans are listed in tables 7-12. In this context it is necessary to cross-reference to the World Hydrological Cycle Observing System (WHYCOS) which is a joint project of WMO and the World Bank. Eventually, WHYCOS is intended to consist of a global network of hydrological stations with near-real time reporting capability.

Building on GRDC experience, the next steps to arrive at a continental and global monitoring system can be broadly outlined:

- Quality control of the station data selected for the monitoring system and corrective measures where necessary and feasible.

- Acquisition of data to obtain homogenous time series for all network stations to allow a consistent analysis of the data.

- Arrangements with the hydrological organizations which run the selected stations to transmit the data to a global monitoring centre. The arrangement package will have to include provisions for technical assistance to upgrade the stations and the data transmission facilities.

Continent	Minimum number of gauging stations
Africa	25
Asia	35
Australia	7
Europe	36
North and Central America	30
South America	10
Total for all continents	143

Table: 13 Number of gauging stations necessary for global runoff monitoring

For the monitoring of freshwater fluxes into the world oceans from all continents combined, 25 stations would suffice. The 25 stations are a subset of the 143 stations identified above. The compilation of the database for the 20 largest rivers has been a first step to achieve a global observing system (GRDC (1994)). However, the spatial resolution is too coarse for large scale or regional evaluations.

10. Conclusions

On the basis of the GRDC database the freshwater flux has been computed for each continent and the flux calculated for the world oceans. The information presented serves as baseline information for use in research of the role of freshwater fluxes in ocean-atmosphere processes for a better understanding of the ocean circulation patterns and climatological implications of freshwater fluxes into the oceans.

The data are also the basic information for the computation of transport rates and volumes of matter including pollutants into the coastal areas and the open oceans. It is found, that a moderate system of about 150 stations would suffice to allow a representative monitoring of river runoff and matter transport from continents into the oceans if the institutional capability and technical facilities are in a long-term working condition which in itself may be the critical boundary condition for a global monitoring system.

11. Outlook

There is a short-term and a long-term view for an outlook:

The computations presented here give a general overview of river runoff from continents into the world oceans. From the material presented in annex 2, a large variability of the runoff can be observed for each of the rivers which tends to be most pronounced during the rainy season. On a short-term basis, this report needs to be updated and the attempt made to compute river runoff into the oceans taking into account discharge variability. This will give researchers the opportunity to account for variability in their general circulation models and computations of fluxes of matter and pollutants. The demand for global hydrological information has been increasing in the past few years for a multitude of research and operational applications. To satisfy the demand for information, the GRDC is supplying information from its global network of contributing stations. However, more general information with fast update and response cycles is required on regional and global scales which makes a selection of stations necessary. In a long-term view, the conception and implementation of global hydrological observation and monitoring systems in conceptional analogy to the World Weather Watch (WWW) of WMO will require near real-time (in the order of weekly updates) discharge information of selected river gauging stations. If operational, the monitoring system can be used in an integrated system to detect early warning signals for water deficit/surplus predictions and the prediction of the hydrologic impact of climatic anomalies.

Where gauge data and discharge information are not sufficiently available or are subject to tidal influences which are difficult to correct, discharges should be determined (and in any way cross-checked) using water balance calculations. A research project is presently being carried out at the Federal Institute of Hydrology, Koblenz. In the project, a water balance model using monthly data is developed and tested on the basis of a Geographical Information System using precipitation and air temperature as principal inputs. In the course of the project it is planned to apply this model for Europe.

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Note

Maps produced by the GRDC are not to be taken as necessarily representing the view of the GRDC on boundaries or the political status.

GLOBAL RUNOFF DATA CENTRE (GRDC)

Percent of Drainage Basin Areas from GRDC in Relation to Size of Continents with Regard to Desert Areas

	Continent Size	GRDC Basin Area	Desert Area	Percent of Desert to Size of Continent	GRDC Drainage Area as Percent of Continent Size	GRDC Drainage Area as Percent of Continent Size minus Desert Area
	1000 Km²	1000 Km²	1000 Km²	%	%	%
North America	25349	11521	340	1.34	45.45	46.07
South America	17611	9748	400	2.27	55.35	56.64
Africa	30335	6641	8740	28.81	21.89	30.75
Asia	43608	17958	9140	20.96	41.18	52.10
Australia	8923	1381	4730	53.01	15.48	32.94
Europe	10498	5726	0	0.00	54.54	54.54

Literature:

Continent Sizes:
Knaurs Großer Weltatlas
Lexikographisches Institut ,München 1992
Desert Areas:
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Georg Westermann Verlag
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Table 1

GLOBAL RUNOFF DATA CENTRE (GRDC)

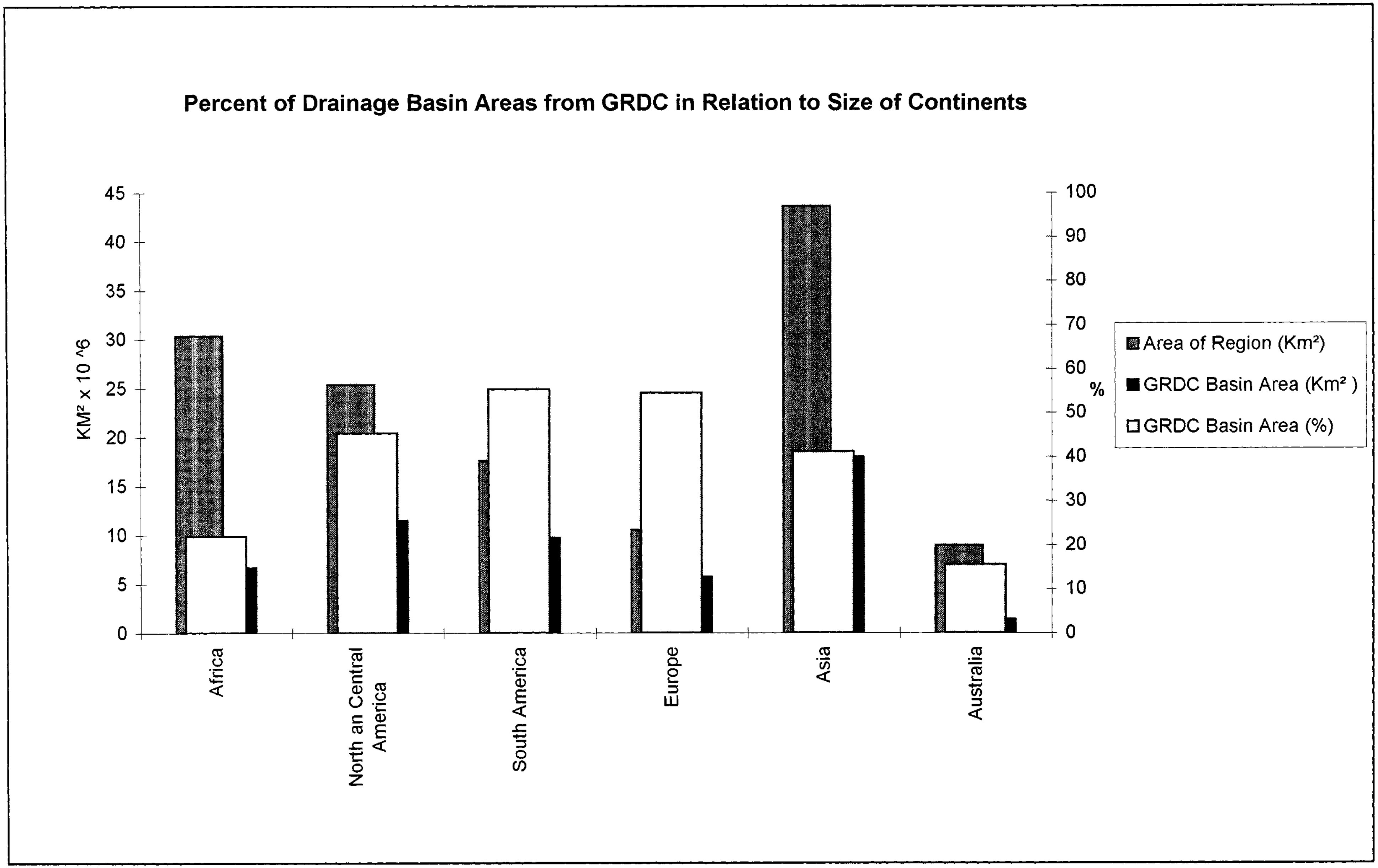


Figure 1

GLOBAL RUNOFF DATA CENTRE (GRDC)

Total annual discharge from continents
computed from mean annual discharge from GRDC stations
(including Mediterranean Sea)

	Number of Stations	Basin Area	Continent. Area	Mean annual Runoff	Total annual Discharge *1	Total annual Discharge * 2
		1000 Km^2	1000 Km^2	mm/a	Km^3	Km^3
North America	42	11521	25349	170	1954	4309
South America	23	9748	17611	771	7519	13578
Africa	27	6641	30335	283	1879	8585
Asia	45	17958	43608	288	5173	12559
Europe	47	5726	10498	233	1334	2446
Australia	9	1381	8923	138	190	1231
Sum (Continents)	193	52975	136324		18049	42709

* 1 : Total annual Discharge of Continent,computed from Mean annual values of Discharge from available Stations related to GRDC Basin Areas
* 2 : Total annual Discharge of Continent,computed from Mean annual values of Discharge from available Stations related to Continental Areas

Table 3

GLOBAL RUNOFF DATA CENTRE (GRDC)

Fresh Water Fluxes into the Oceans
based on Mean Annual Values

	River Discharge from Land Surfaces	Surface of Basin Areas draining into the Oceans	Precipitation	P-E	Surface of Oceans
	GRDC	GRDC	Baumg./Reichel	Baumg./Reichel	Baumg/Reichel
	km^3/a	$10^6\ km^2$	km^3/a	km^3/a	$10^6\ km^2$
Arctic Ocean	110	11.21	825	374	8.50
Atlantic Ocean	151	20.44	74578	-36456	98.00
Indian Ocean	79	6.18	81041	-19503	77.70
Pacific Ocean	59	8.45	228555	15921	176.90

Table 4

GLOBAL RUNOFF DATA CENTRE (GRDC)

COMPARISON OF THE ELEMENTS OF THE WATER BALANCE AFTER DIFFERENT AUTHORS

Continent	Precipitation			Evaporation			P-E			Annual River Runoff	
	Baumg./Reich	Sellers	Shikloman.	Baumg./Reich.	Sellers	Shikloman.	Baumg./Reich.	Sellers	Shikloman.	Shikloman.	GRDC
	mm/a	mm/a	mm/a	mm/a	mm/a	mm/a	mm/a	mm/a	mm/a	mm/a	mm/a
Africa	696	670	740	582	510	587	114	160	153	151	283
North America	645	670	756	403	400	418	242	270	338	339	170
South America	1564	1350	1600	946	860	910	618	490	690	661	771
Europe	657	600	790	375	360	507	282	240	283	306	233
Asia	696	610	740	420	390	416	276	220	324	332	288
Australia	447	470	791	420	410	511	27	60	280	45	138

Table 5

GLOBAL RUNOFF DATA CENTRE (GRDC)

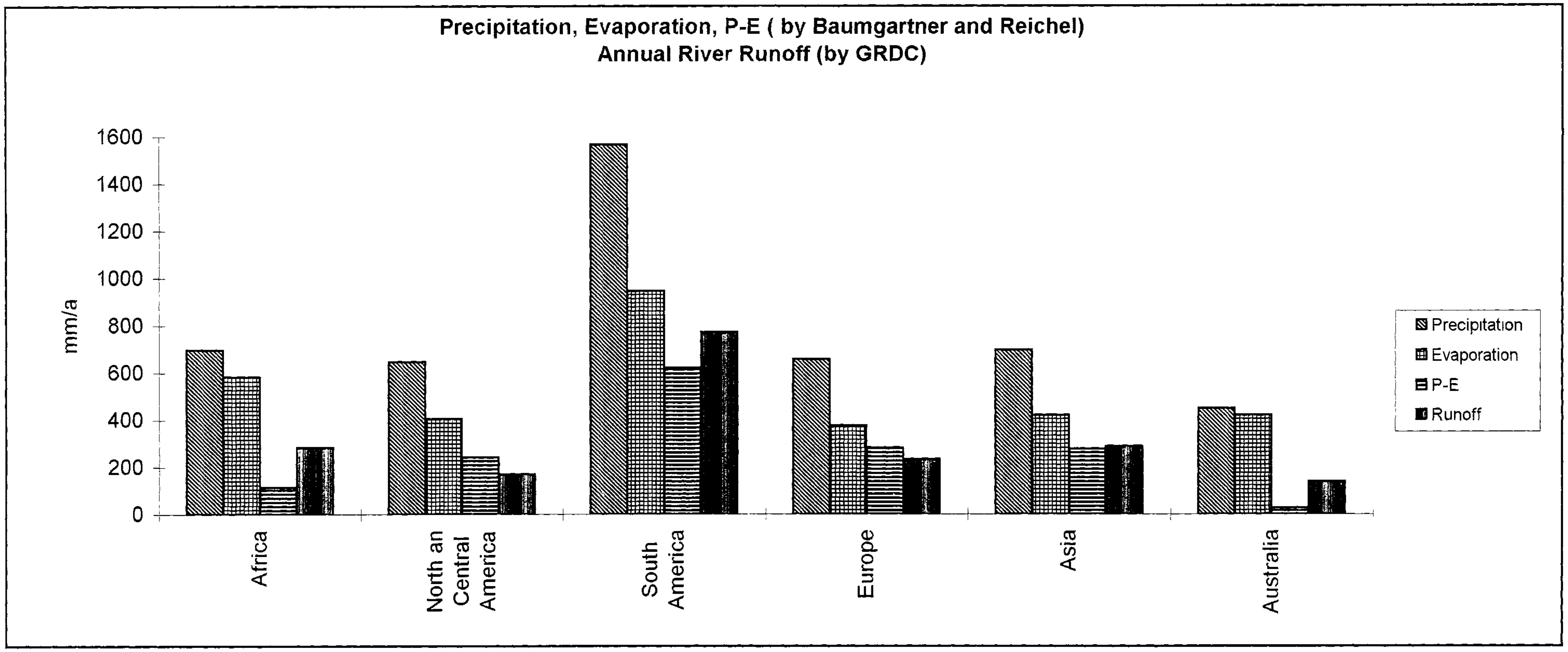


Figure 2

GLOBAL RUNOFF DATA CENTRE (GRDC)

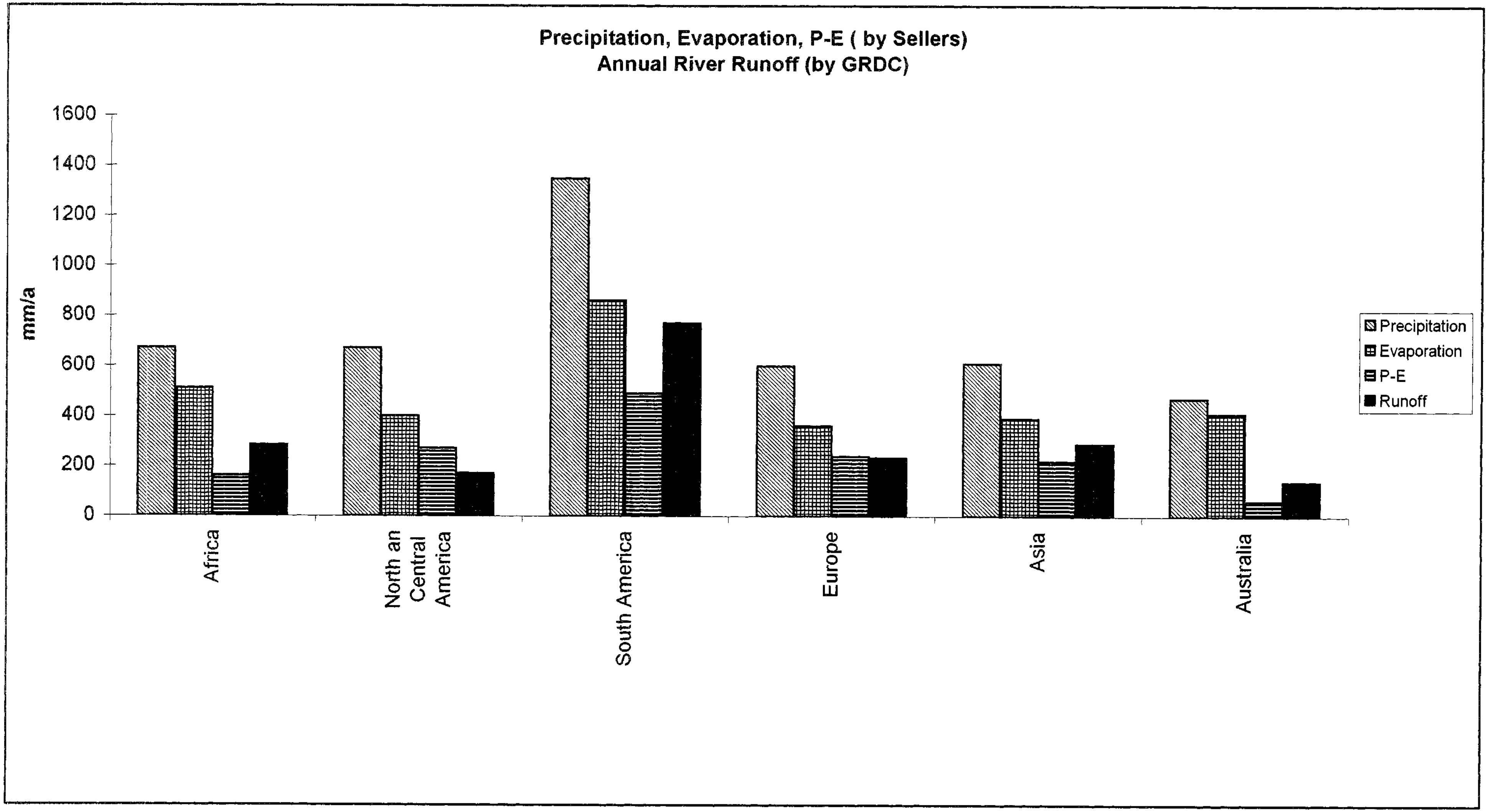


Figure 3

GLOBAL RUNOFF DATA CENTRE (GRDC)

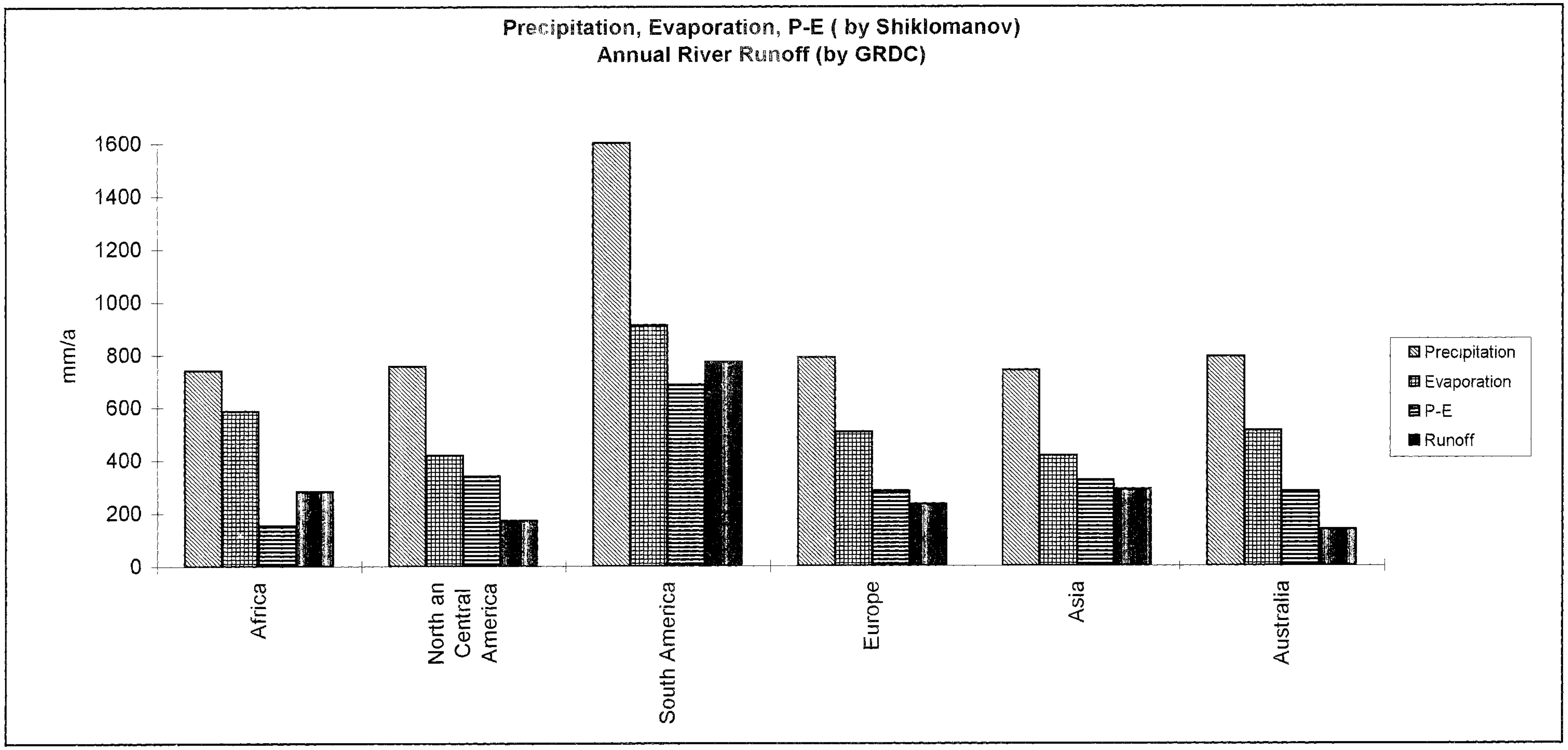


Figure 4

GLOBAL RUNOFF DATA CENTRE (GRDC)

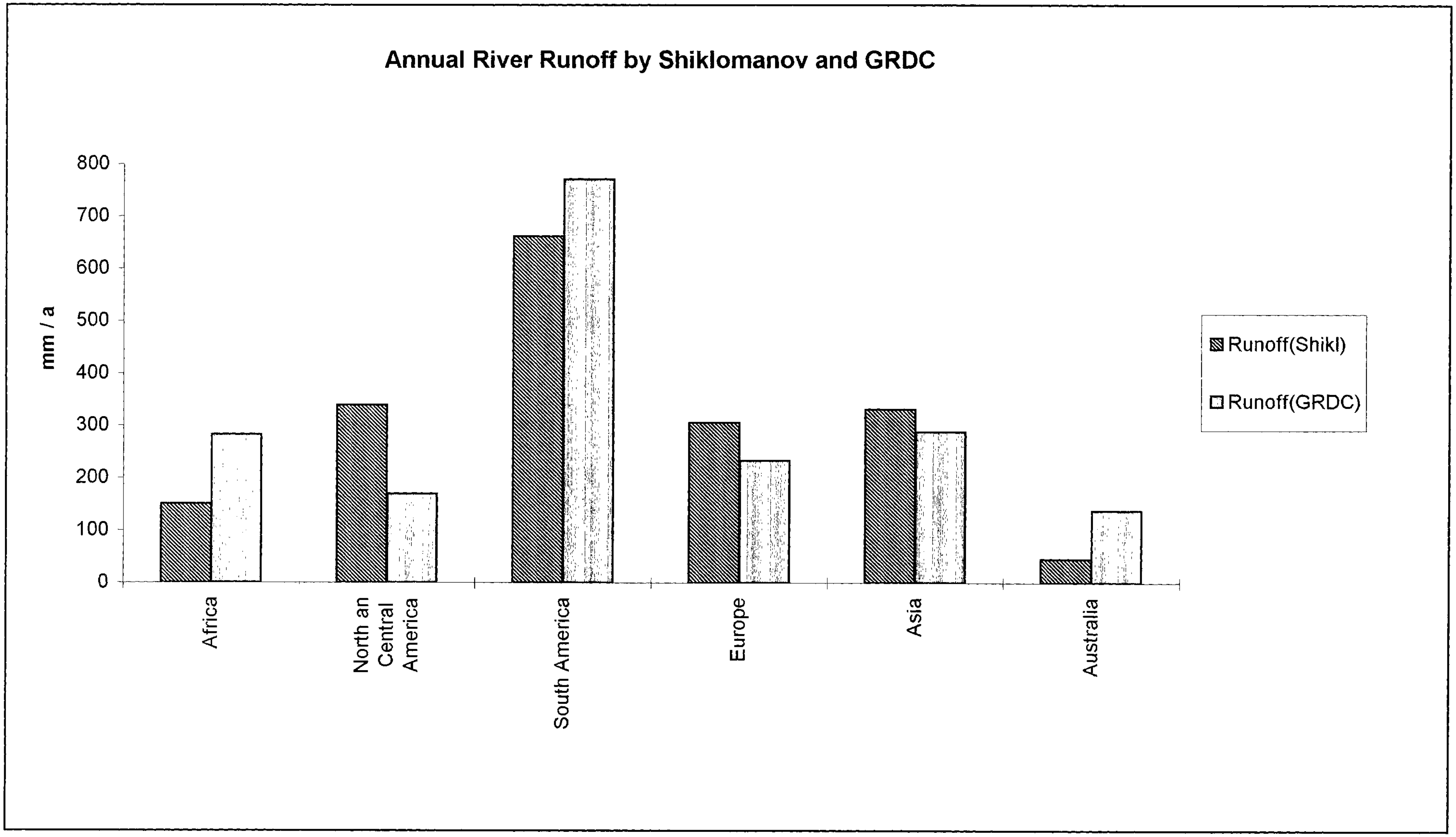


Figure 5

GLOBAL RUNOFF DATA CENTRE (GRDC)

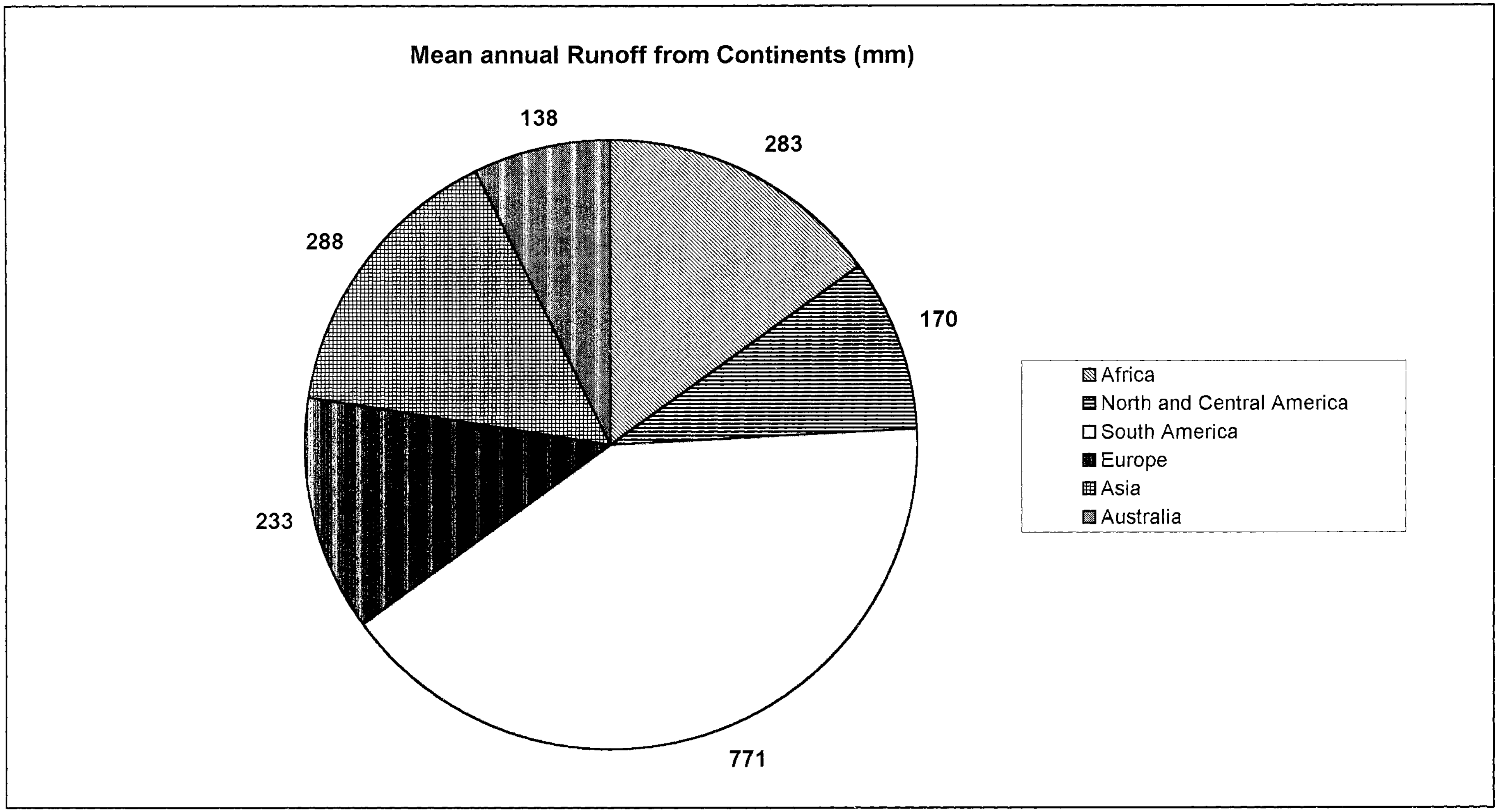


Figure 6

GLOBAL RUNOFF DATA CENTRE (GRDC)

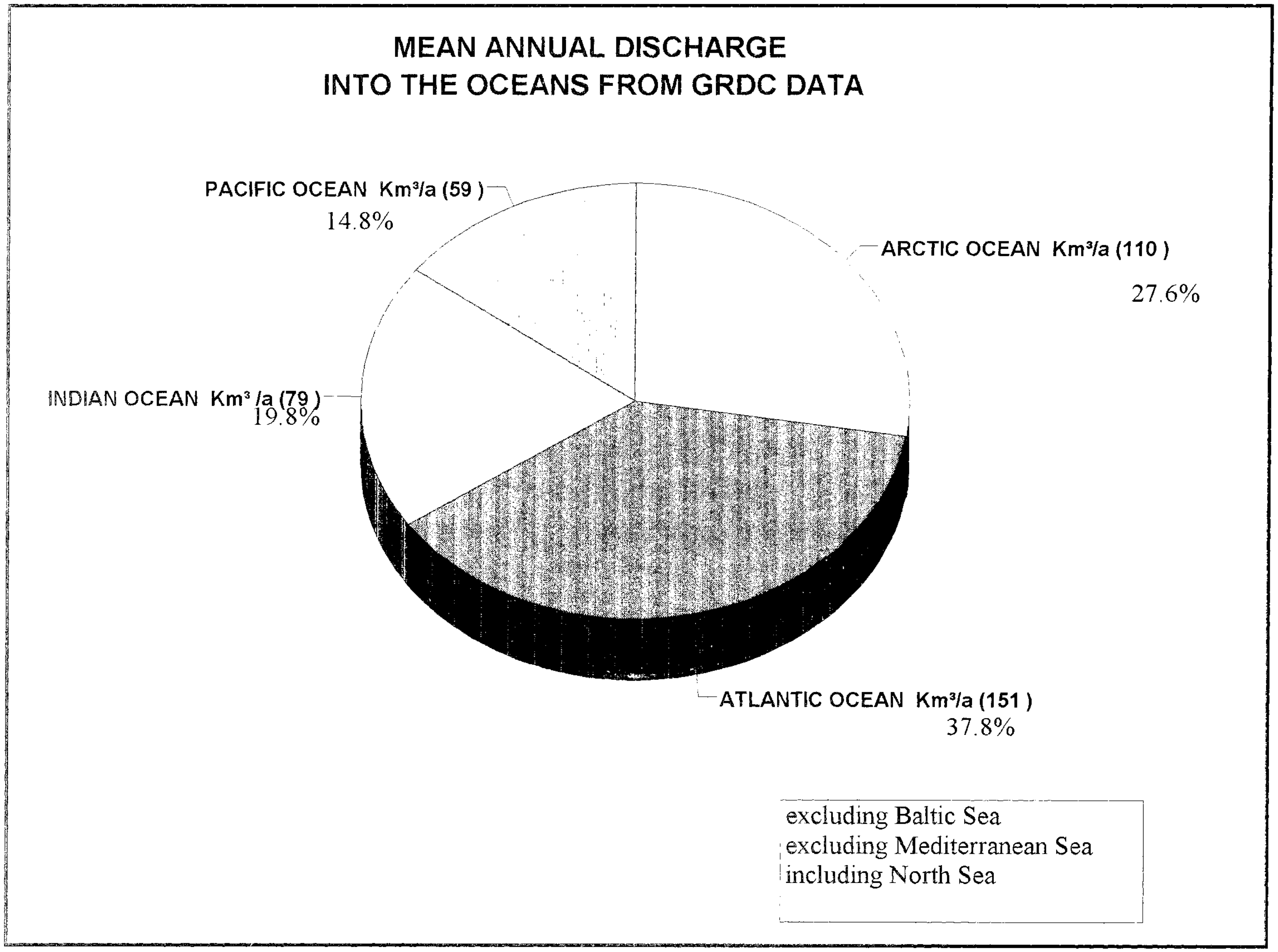


Figure 7

GLOBAL RUNOFF DATA CENTRE (GRDC)

CONTINENTAL FRESHWATER FLUXES INTO THE OCEANS

FROM GRDC DATA (Based on 161 Stations)

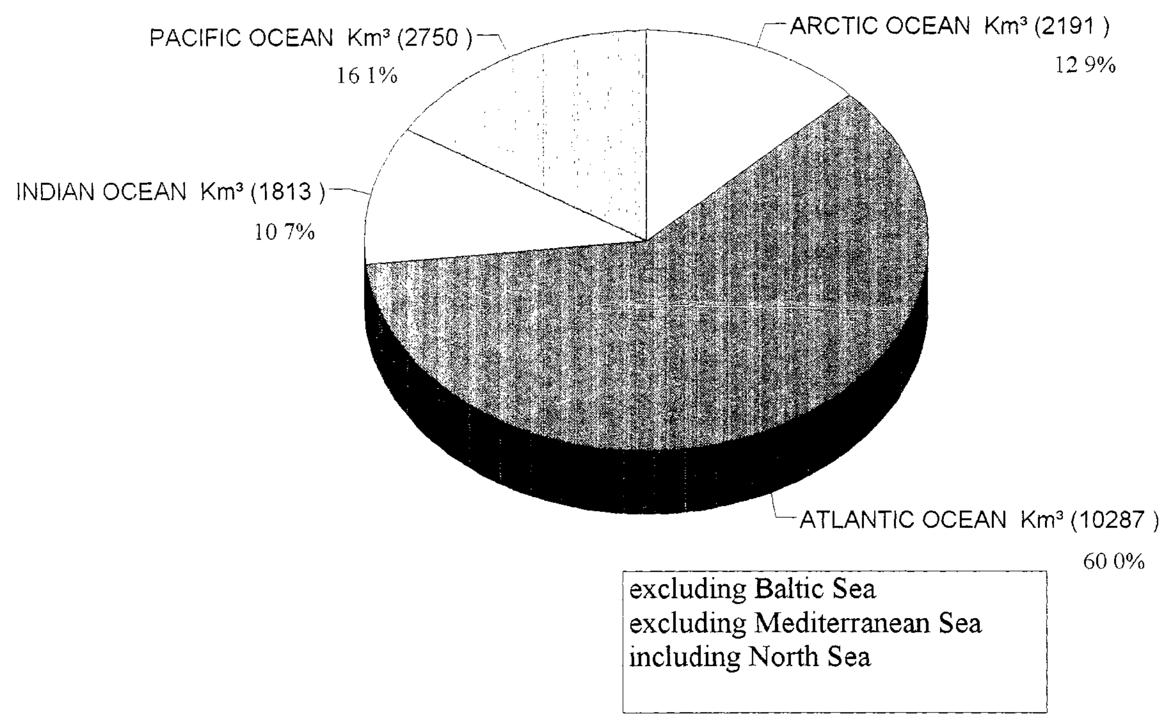


Figure 8

GLOBAL RUNOFF DATA CENTRE (GRDC)

Fresh Water Fluxes into the Oceans distributed to its geographical Latitude
(based on 161 GRDC - Stations)

Latitude	Arctic Ocean	Atlantic Ocean	Indian Ocean	Pacific Ocean	SUM
	km^3	km^3	km^3	km^3	km^3
00 - 23° N	-	6617	1557	727	8901
23°- 40° N	-	529	76	920	1525
40°- 60° N	-	589	-	860	1449
60°- 90° N	2191	-	-	35	2226
00 - 23° S	-	1844	172	146	2162
23°- 40° S	-	680	8	44	733
40°- 60° S	-	27	-	18	45
60°- 90° S	-	-	-	-	-
SUM	2191	10287	1813	2750	17041

Table 6

GLOBAL RUNOFF DATA CENTRE (GRDC)

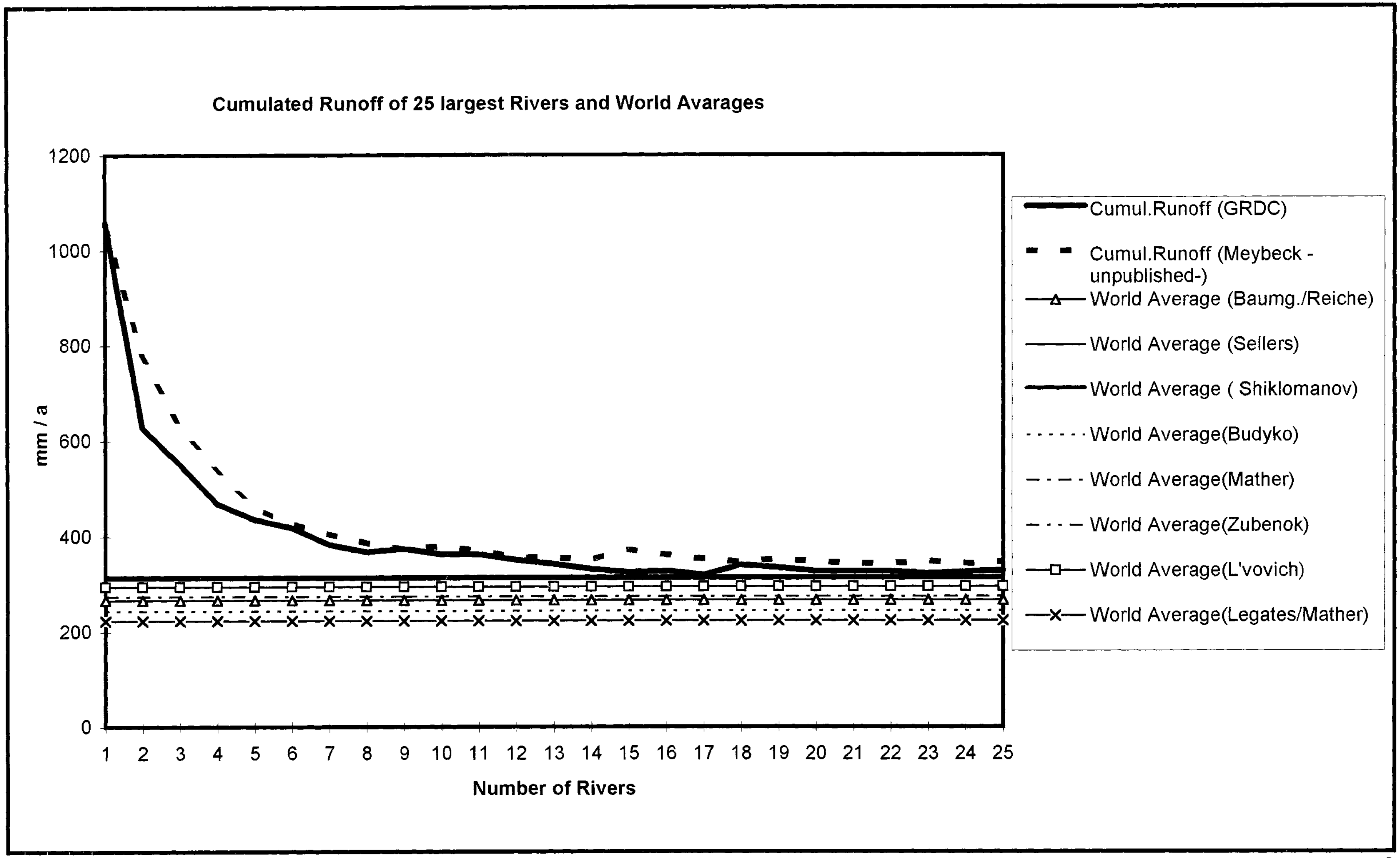


Figure 9

GLOBAL RUNOFF DATA CENTRE (GRDC)

Africa

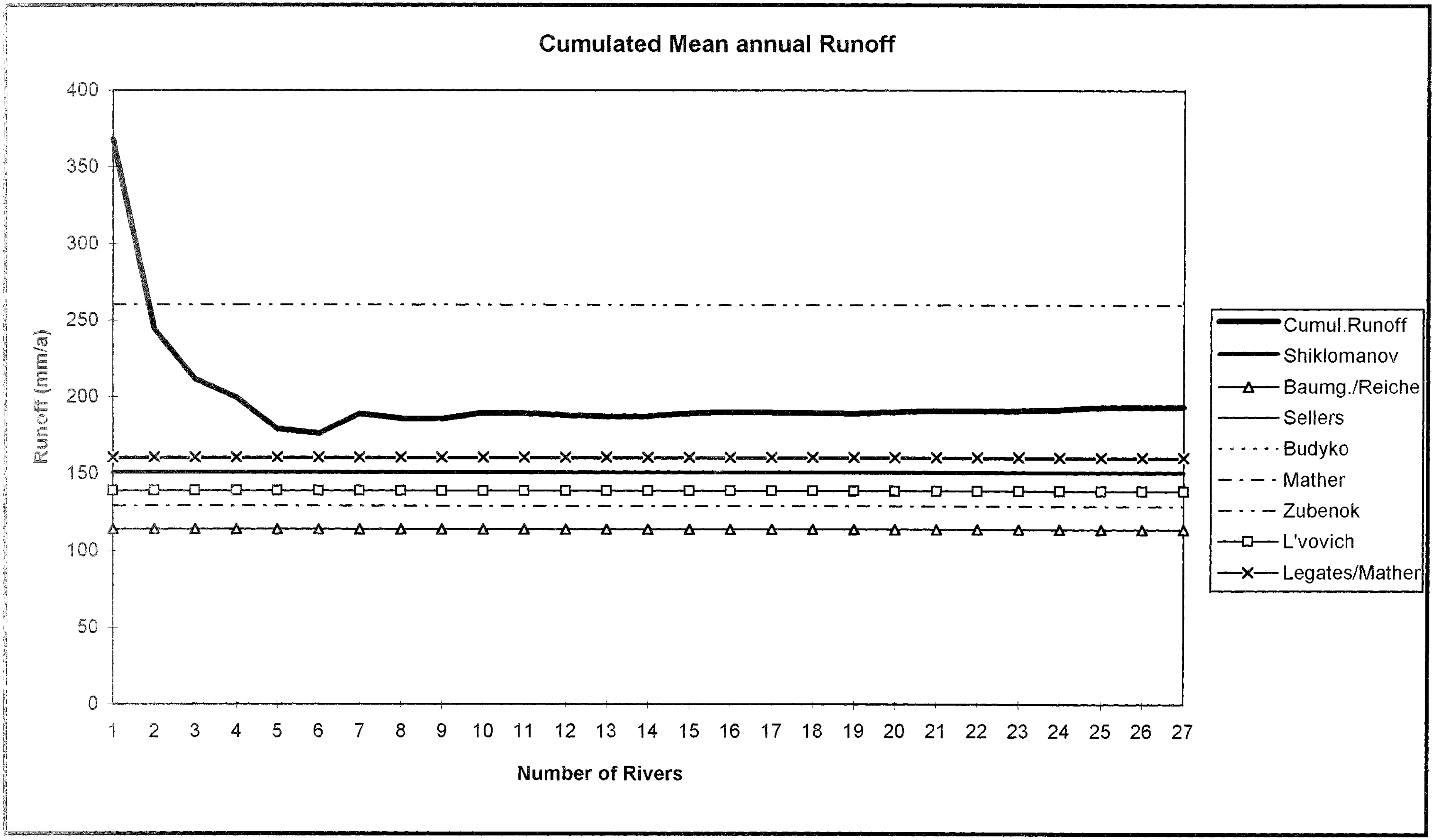


Figure 10

GLOBAL RUNOFF DATA CENTRE (GRDC)
ASIA

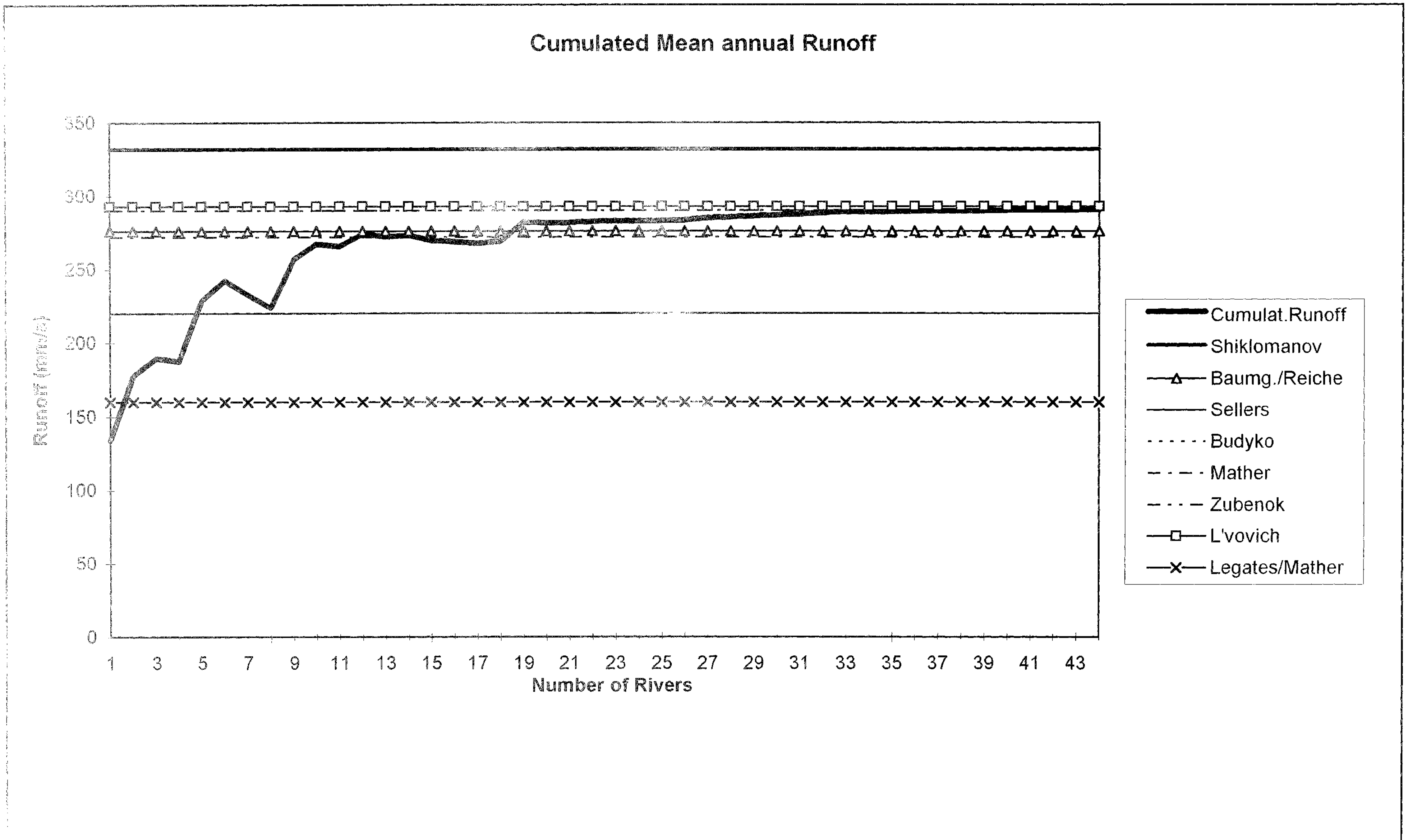


Figure 11

GLOBAL RUNOFF DATA CENTRE (GRDC)
AUSTRALIA

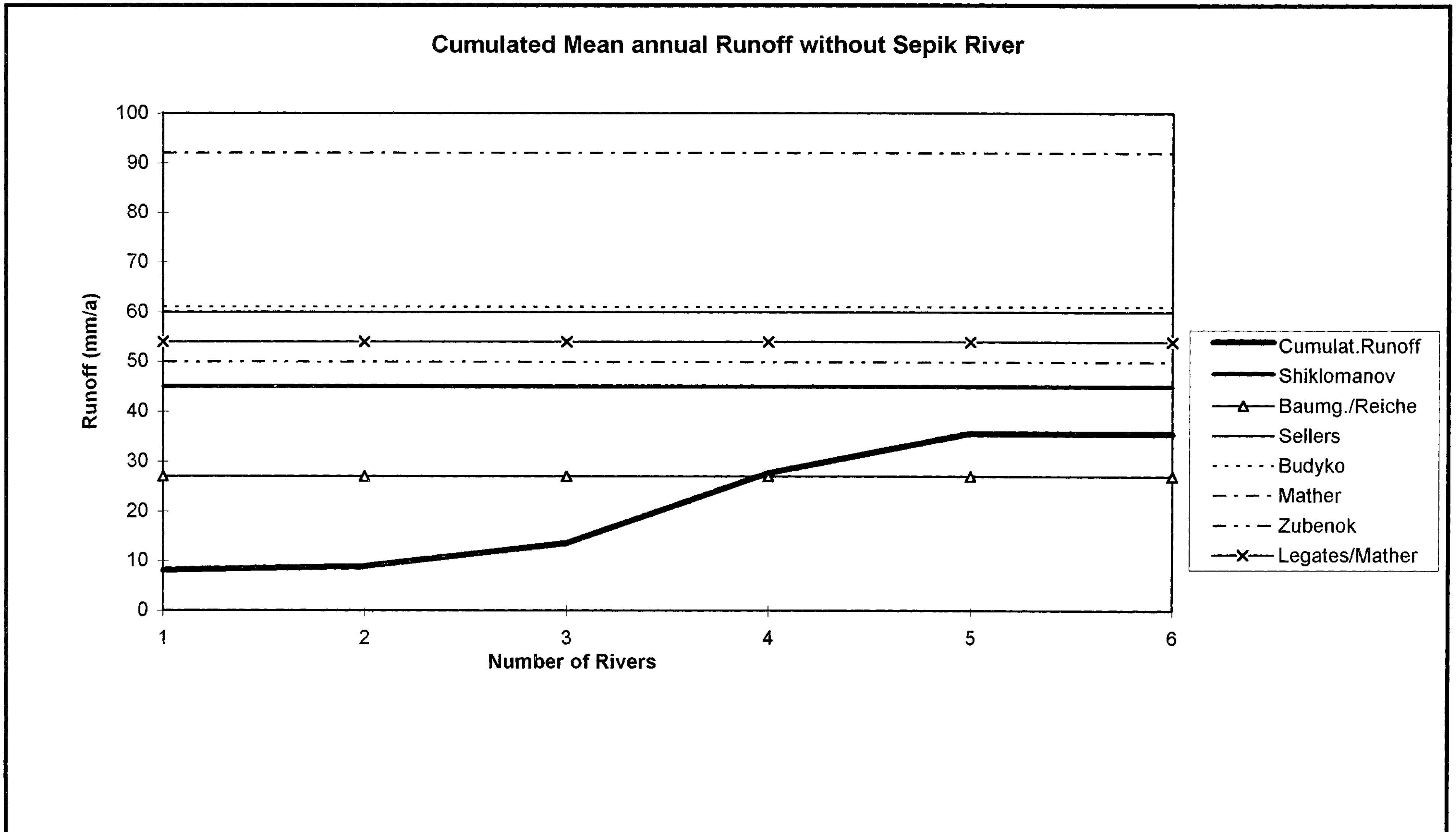


Figure 12

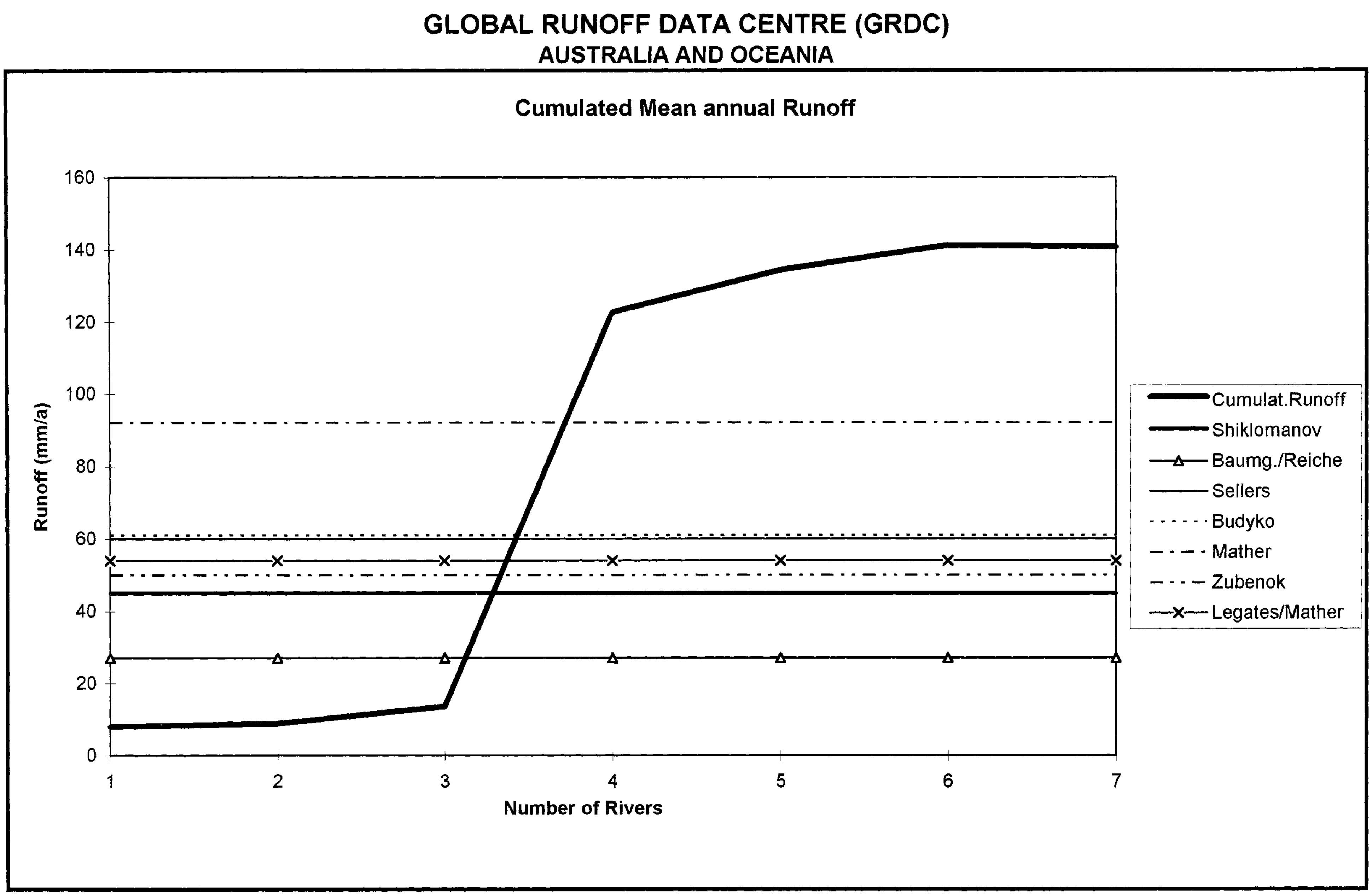

GLOBAL RUNOFF DATA CENTRE (GRDC)
AUSTRALIA AND OCEANIA
Cumulated Mean annual Runoff
Runoff (mm/a)
160
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
Number of Rivers
Cumulat.Runoff
Shiklomanov
Baumg./Reiche
Sellers
Budyko
Mather
Zubenok
Legates/Mather

Figure 13

GLOBAL RUNOFF DATA CENTRE (GRDC)
EUROPE

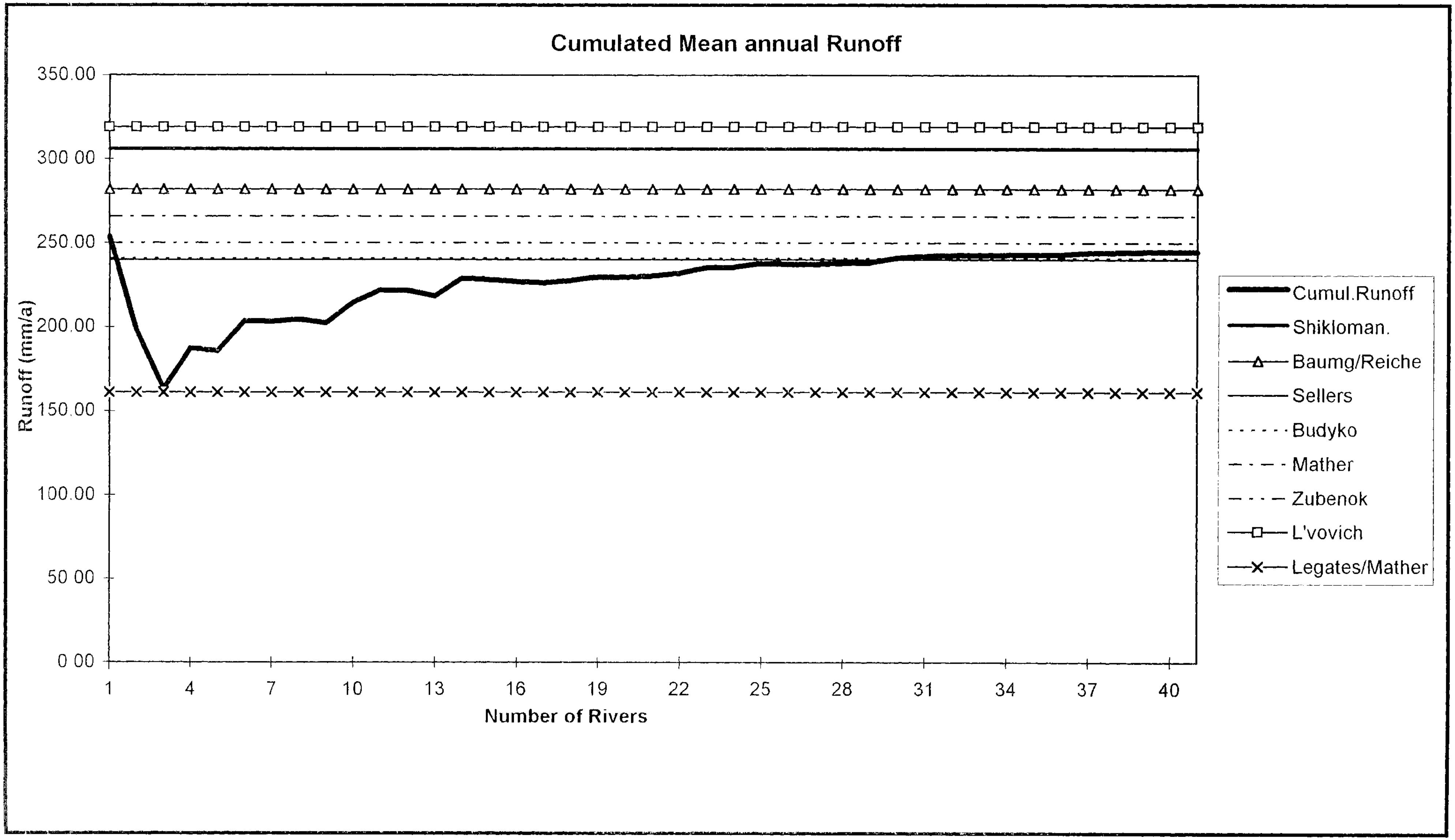


Figure 14

GLOBAL RUNOFF DATA CENTRE (GRDC)
North America

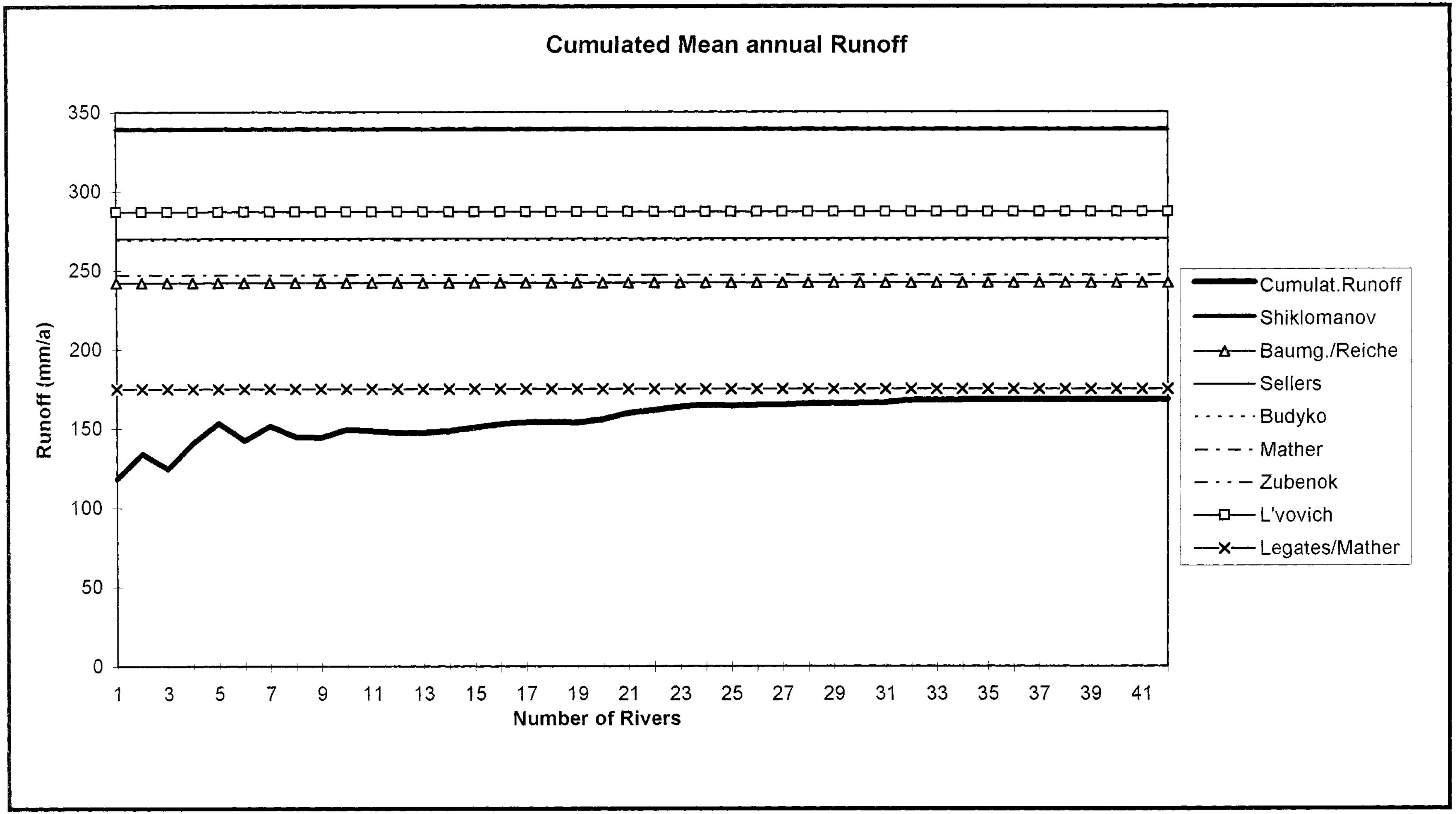


Figure 15

GLOBAL RUNOFF DATA CENTRE (GRDC)
South America

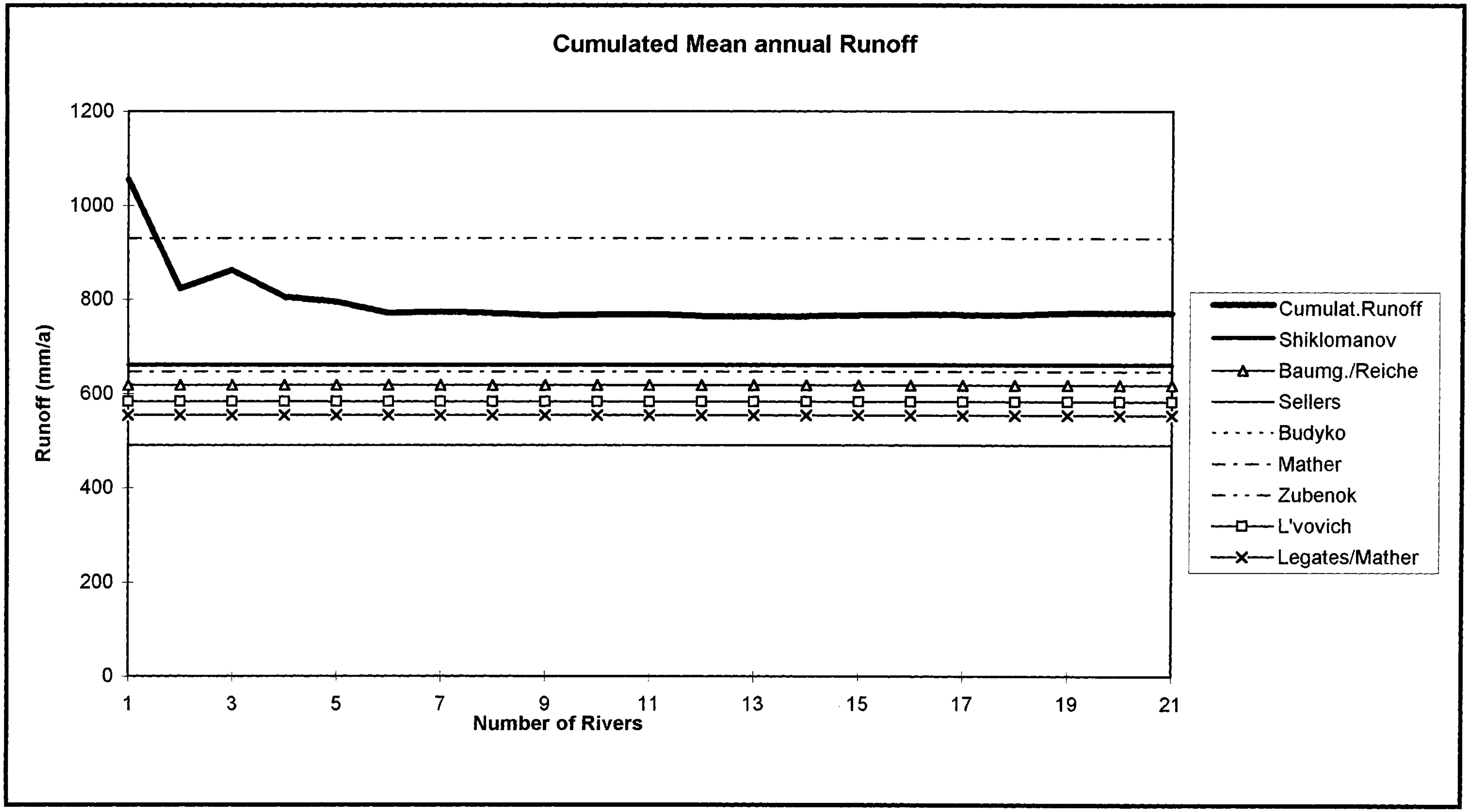


Figure 16

GLOBAL RUNOFF DATA CENTRE (GRDC)

AFRICA

Representative Gauging Stations for Continental Runoff Monitoring

Rivers sorted according to size of drainage basins

No.	River	Station	Country Code *	Latitude	Longitude	Basin Area km^2
1	Zaire	Kinshasa	ZR	430S	1530E	3475000
2	Nile	el Ekhsase	EG	2970N	3128E	1900000
3	Niger	Gaya	NR	1188N	340E	1000000
4	Zambeze	Matundo-Cais	MZ	1615S	3358E	940000
5	Oranje	Vioolsdrif	ZA	2876S	1773E	850530
6	Limpopo	Chokwe	MZ	2450S	3300E	342000
7	Senegal	Dagana	SG	1652N	1550W	268000
8	Ogooue	Lambarene	GO	068S	1023E	205000
9	Juba	Lugh Ganana	SI	356N	4232E	179520
10	Rufiji	Stigler	TN	780S	3792E	158200
11	Sanaga	Edea	CM	377N	1007E	131520
12	Save	Villafranca do Save	MZ	2110S	3468E	100885
13	Bandama	Tiassale	IV	588N	475W	95500
14	Comoe	Mbasso	IV	629N	349W	69900
15	Sassandra	Soubre	IV	576N	660W	62000
16	Kouilou	Sounda	CG	410S	1207E	55010
17	Mangoky	Bevoay	MG	2183S	4387E	53225
18	Oueme	Bonou	BJ	690N	245E	46990
19	Gambie	Gouloumbou	SG	1347N	1373W	42000
20	Groot-Vis	Outspan	ZA	3324S	2699E	29745
21	Cavally	Tate	IV	438N	759W	28800
22	Nyong	Dehane	CM	357N	1012E	26400
23	Sebou	Azib Soltane	MC	3428N	543W	17250
24	Tano	Alanda	GH	512N	275W	15800
25	St Paul	Walker Bridge	LI	733N	953W	9760

Table 7

*** Country Codes in Annex 3**

GLOBAL RUNOFF DATA CENTRE (GRDC)

NORTH AND SOUTH EAST ASIA

Representative Gauging Stations for Continental Runoff Monitoring

Rivers sorted according to size of drainage basins

No.	River	Station	Country Code	Latitude	Longitude	Basin Area
1	Ob	Salekhard	RS	6657N	6653E	2949998
2	Yenisei	Igarka	RS	6748N	8650E	2440000
3	Lena	Kusur	RS	7070N	12765E	2430000
4	Amur	Komsomolsk	RS	5063N	13712E	1730000
5	Changjiang (Yangtze)	Datong	CI	3077N	11762E	1705383
6	Ganga	Farakka	IN	2500N	8792E	935000
7	Indus	Kotri	PK	2537N	6837E	832418
8	Huanghe(Yellow River)	Huayuankou	CI	3492N	11365E	730036
9	Brahmaputra	Bahadurabad	BW	2518N	8967E	636130
10	Mekong	Pakse	LA	1512N	10580E	545000
11	Kolyma	Sredne-Kolymsk	RS	6737N	15367E	361000
12	Xijiang	Wuzhou 3	CI	2348N	11130E	329705
13	Indigirka	Vorontsovo	RS	6958N	14735E	305000
14	Godavari	Polavaram	IN	1692N	8178E	299320
15	Al-Furat (Euphrates)	Hindiya	IQ	3272N	4427E	274100
16	Krishna	Vijayawada	IN	1652N	8062E	251355
17	Olenek	7.5km Downstream of mouth Of River Pur	RS	7212N	12322E	198000
18	Ural	Kushum	KZ	5085N	5128E	190000
19	Mahanadi	Kaimundi	IN	2042N	8367E	132090
20	Irrawaddy	Sagaing	BM	2198N	9610E	117900
21	Chao Phraya	Nakhon Sawan	TH	1567N	10012E	110569
22	Pur	Samburg	RS	6708N	7815E	95100
23	Narmada	Garudeshwar	IN	2192N	7365E	89345
24	Kamchatka	Kluchi	RS	5643N	16105E	45600
25	Luanhe	Luanxian	CI	3973N	11875E	44100

Table 8

GLOBAL RUNOFF DATA CENTRE (GRDC)

NORTH AND SOUTH EAST ASIA

Representative Gauging Stations for Continental Runoff Monitoring

Rivers sorted according to size of drainage basins

No.	River	Station	Country Code	Latitude	Longitude	Basin Area
26	Han	Indogyo	KO	3752N	12697E	25046
27	Nagdong	Samnangjin	KO	3540N	12885E	22916
28	Rajang	Ng Benin	MS	215N	11307E	21192
29	Pahang	Temerloh	MS	345N	10243E	19000
30	Sittang	Toungoo	BM	1892N	9647E	14660
31	Ishikari	Ishikari-Ohashi	JP	4312N	14153E	12697
32	Kelantan	Guillemard Bridge	MS	577N	10215E	11900
33	Kinabatanang	Balat	MS	530N	11759E	10800
34	Shinano	Ojiya	JP	3730N	13880E	9719
35	Minab	Berantin	IR	2740N	5717E	9285

Table 8a

GLOBAL RUNOFF DATA CENTRE (GRDC)

AUSTRALIA AND OCEANIA

Representative Gauging Stations for Contintental Runoff Monitoring

Rivers sorted accordingto size of drainage basins

No.	River	Station	Country Code	Latitude	Longitude	Basin Area
1	Murray	Lock 9 Upper	AU	3418S	14160E	991000
2	Fitzroy	Yaamba	AU	2315S	15037E	136000
3	Daly	Mount Nancar	AU	1383S	13073E	47000
4	Sepik	Ambunti	NZ	422S	14216E	40922
5	Clutha	Balclutha	NZ	4623S	16973E	20306
6	Waikato River	Ngaruawahia	NZ	3768S	17515E	11395
7	Pallinup River	Bull Crossing	AU	3433S	11865E	3600

Table 9

GLOBAL RUNOFF DATA CENTRE (GRDC)

EUROPE

Representative Gauging Stations for Continental Runoff Monitoring

Rivers sorted according to size of drainage basins

No.	River	Station	Country Code	Latitude	Longitude	Basin Area
1	Danube	Ceatal Izmail	RO	4518N	2880E	807000
2	Dniepr	Dniepr Power Plant	UR	4792N	3515E	463000
3	Don	Razdorskaya	RS	4750N	4067E	378000
4	Northern Dvina(Severnaya Dvina)	Ust-Pinega	RS	6410N	4217E	348000
5	Wisla	Tczew	PL	5410N	1882E	194376
6	Rhein	Rees	DL	5177N	640E	159680
7	Elbe	Neu-Darchau	DL	5323N	1088E	131950
8	Loire	Montjean	FR	4738N	083W	110000
9	Odra	Gozdowice	PL	5277N	1432E	109729
10	Rhone	Beaucaire	FR	4392N	467E	95590
11	Ebro	Tortosa	SP	4082N	052E	84230
12	Neman	Smalininkai	LT	5502N	2252E	81200
13	Kizilirmak	Inoezue	TU	4138N	3580E	75121
14	Po	Pontelagoscuro	IY	4488N	1165E	70091
15	Dniestr	Bendery	MK	4680N	2937E	66100
16	Seine	Poses	FR			65000
17	Western Dvina (Daugava)	Daugavpils	LV	5588N	2668E	64500
18	Vuoksi	Imatra	FI	6115N	2877E	61275
19	Garonne	Mas-D'agenais	FR	4442N	023E	52000
20	Kuban	Tikhovsky	RS	4515N	3832E	48100
21	Guadalquivir	Alcala del Rio	SP	3752N	598W	46995
22	Vaenern-Goeta	Vaenersborg	SN	5838N	1232E	46830
23	Gloma	Langnes	NO	5960N	1112E	40221
24	Weser	Intschede	DL	5297N	913E	37788
25	Angerman	Solleftea	SN	6317N	1727E	30640

Table 10

GLOBAL RUNOFF DATA CENTRE (GRDC)

EUROPE

Representative Gauging Stations for Continental Runoff Monitoring

Rivers sorted according to size of drainage basins

No.	River	Station	Country Code	Latitude	Longitude	Basin Area
26	Bueyuek Menderes	Soeke	TU	3772N	2748E	23889
27	Jucar	Masia de Mompo	SP	3715N	065W	17876
28	Tevere	Roma	IY	4190N	1248E	16545
29	Tana	Polmak	NO	7007N	2805E	14005
30	Rioni	Sakochakidze	GG	4222N	4180E	13330
31	Adige	Boara Pisani	IY	4510N	1183E	11954
32	Shannon	Killaloe	IE	5280N	842W	11690
33	Thames	Teddington	UK	5142N	032W	9950
34	Ems	Versen	DL	5273N	725E	8345
35	Trent	Colwick	UK	5295N	107W	7490
36	Kamtehiya	Gzozdevo	BU	4303N	2783E	4857

Table 10a

GLOBAL RUNOFF DATA (CENTRE)

NORTH AND CENTRAL AMERICA

Representative Gauging Stations for Continental Runoff Monitoring

Rivers sorted according to size of drainage basins

No.	River	Station	Country Code	Latitude	Longitude	Basin Area
1	Mississippi	Tarbert Landing, Miss.	US	3102N	9162W	3923799
2	Mackenzie River	Norman Wells	CN	6528N	12685W	1570000
3	Nelson River	above Bladder Rapids	CN	5477N	9792W	1000000
4	Yukon River	Pilot Station	US	6193N	16288W	831390
5	St.Lawrence	Cornwall(Ontario), near Masse	US	4500N	7478W	774410
6	Colorado	Limite Internacional Norte	MX	3272N	11472W	631960
7	Columbia	The Dalles, Oreg.	US	4560N	12117W	613830
8	Bravo	Matamoros	MX	2590N	9752W	450902
9	Churchill River	above Granville Falls	CN	5615N	10045W	228000
10	Fraser River	Hope	CN	4938N	12145W	217000
11	Santiago	el Capomal	MX	2183N	10512W	128943
12	Brazos	Richmond, Tex.	US	2958N	9553W	116568
13	Back	below Deep Rose Lake	CN	6608N	9650W	98200
14	Churchill River	above Upper Muskrat Falls	CN	5325N	6078W	92500
15	Kuksokwim	Crooked Creek, Alas.	US	6187N	15810W	80549
16	Susquehanna	Harrisburg, Pa.	US	4025N	7688W	62419
17	Sacramento	Sacramento, Calif.	US	3858N	12150W	60886
18	Panuco	Las Adjuntas	MX	2198N	9857W	58115
19	Yaqui	el Novillo	MX	2893N	10963W	57908
20	Alabama	Claiborne, Ala.	US	3155N	8752W	56980
21	Usumacinta	Boca del Cerro	MX	1742N	9150W	50743
22	Skeena	Usk	CN	5463N	12843W	42200
23	Saint John River	below Mactaquac	CN	4597N	6583W	39900
24	Stikine	above Butterfly Creek	CN	5748N	13175W	36000
25	Fuerte	San Miquel Zapotitlan	MX	2595N	10905W	34247

Table 11

GLOBAL RUNOFF DATA (CENTRE)

NORTH AND CENTRAL AMERICA

Representative Gauging Stations for Continental Runoff Monitoring

Rivers sorted according to size of drainage basins

No.	River	Station	Country Code	Latitude	Longitude	Basin Area
26	San Juan	el Castillo	NK	1102N	8442W	32819
27	Coppermine River	Point Lake Outlet	CN	6541N	11400W	19300
28	Lempa	San Marcos	ES	1343N	8870W	18176
29	Ellice	near the Mouth	CN	6771N	10414W	16900
30	Burnside River	near The Mouth	CN	6674N	10882W	16800

Table 11a

GLOBAL RUNOFF DATA CENTRE (GRDC)

SOUTH AMERICA

Representative Gauging Stations for Contintental Runoff Monitoring

Rivers sorted according to size of drainage basins

No.	River	Station	Country Code	Latitude	Longitude	Basin Area
1	Amazone	Obidos	BZ	190S	5550W	4640300
2	Parana	Corrientes	AG	2797S	5885W	1950000
3	Orinoco	Puente Angostura	VN	815N	6360W	836000
4	Sao Francisco	Traipu	BZ	997S	3698W	622600
5	Xingu	Altamira	BZ	320S	5222W	446570
6	Rio Parnaiba	Porto Formosa	BZ	347S	4250W	290000
7	Magdalena	Calamar	CO	1027N	7492W	257438
8	Uruguay	Concordia	AG	3140S	5802W	249312
9	Negro	Primera Angostura	AG	4043S	6367W	95000
10	Essequibo	Plantain Island	GY	585N	5858W	66600

Table 12

Annex 1

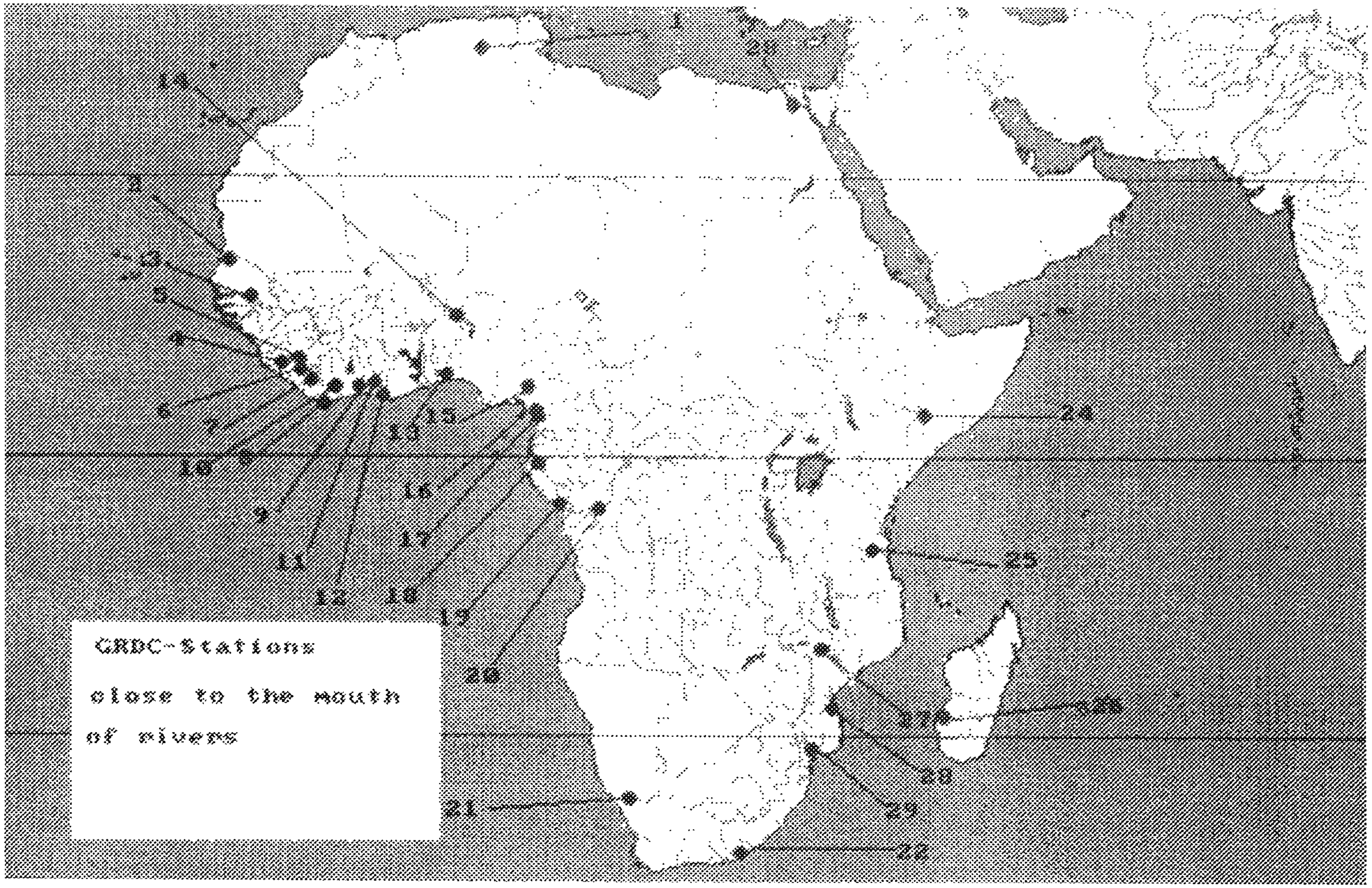
Display of gauging stations used for the computation of continental river runoff and characterization of time series of discharges of selected rivers

Explanation:

The information is presented for each continent. The numbers on the maps refer to the station numbers in the following tables. Each table is followed by an overview of the overlapping time-series. For selected rivers and stations, hydrological information is presented in the following tables.

The information is presented in this order:

Africa
Asia
Australia and Oceania
Europe
North and Central America
South America



Map 2

AFRICA

No.	River	Station	Latitude	Longitud	Aerea(km2)	First rec.	last rec.	day/mont	Remark
1	Sebou	Azib Soltane	3428N	54W	17250	9 1959	1 1989	M	
2	Senegal	Dagana	1652N	155W	268000	5 1903	10 1974	M	*
3	Gambie	Gouloumbou	1347N	137W	42000	5 1979	12 1989	D	*
4	Moa	Moa Bridge	782N	111W	17150	4 1976	5 1977	M	
5	Lofa	Dougomai	820N	97W	246	4 1973	11 1977	M	
6	St Paul	Walker Bridge	733N	95W	9760	1 1973	12 1975	M	
7	Cestos	Sawolo	643N	86W	683	1 1976	12 1979	M	
8	Cavally	Tate	438N	75W	28800	1 1979	12 1982	D	
9	Bandama	Tiassale	588N	47W	95500	1 1979	12 1982	D	
10	Sassandra	Soubre	576N	66W	62000	1 1979	12 1982	D	
11	Comoe	Mbasso	629N	34W	69900	1 1979	12 1982	D	
12	Tano	Alanda	512N	27W	15800	1 1965	7 1978	M	
13	Oueme	Bonou	690N	24E	46990	7 1948	12 1992	D	
14	Niger	Gaya	1188N	34E	1000000	7 1952	9 1990	M	*
15	Cross	Mamfe	575N	93E	6810	4 1967	12 1979	M	
16	Sanaga	Edea	377N	100E	131520	9 1943	3 1980	M	*
17	Nyong	Dehane	357N	101E	26400	2 1951	3 1977	M	
18	Ogooue	Lambarene	068S	102E	205000	1 1930	12 1975	M	
19	Kouilou	Sounda	410S	120E	55010	1 1969	12 1982	M	
20	Zaire	Kinshasa	430S	153E	3475000	1 1903	12 1983	D	*
21	Oranje	Vioolsdrif	2876S	177E	850530	10 1964	9 1986	M	
22	Groot-Vis	Outspan	3324S	269E	29745	7 1969	9 1986	M	
23	Nile	el Ekhsase	2970N	312E		1 1973	12 1984	M	
24	Juba	Lugh Ganana	356N	423E	179520	1 1951	1 1979	M	*
25	Rufiji	Stigler	780S	379E	158200	10 1954	12 1978	D	
26	Mangoky	Bevoay	2183S	438E	53225	11 1964	10 1983	M	
27	Zambeze	Matundo-Cais	1615S	335E	940000	1 1976	12 1979	M	*
28	Save	Villafranca do Save	2110S	346E	100885	1 1976	11 1979	M	*
29	Limpopo	Chokwe	2450S	330E	342000	1 1976	9 1979	M	

Table 1.1

Remark: * Selected Stations for general characteristics

AFRICA

Overview of overlapping timeseries of stations close to the mouth of Rivers

River	Station	Time	series
Sebou	Azib Soltane	1959	1989
Senegal	Dagana	1903	1974
Gambie	Gouloumbou	1979	1989
Moa	Moa Bridge	1976	1977
Lofa	Dougomai	1973	1977
St Paul	Walker Bridge	1973	1975
Cestos	Sawolo	1976	1979
Cavally	Tate	1979	1982
Bandama	Tiassale	1979	1982
Sassandra	Soubre	1979	1982
Comoe	Mbasso	1979	1982
Tano	Alanda	1965	1978
Oueme	Bonou	1948	1992
Niger	Gaya	1952	1990
Cross	Mamfe	1967	1979
Sanaga	Edea	1943	1980
Nyong	Dehane	1951	1977
Ogooue	Lambarene	1930	1975
Kouilou	Sounda	1969	1982
Zaire	Kinshasa	1903	1983
Oranje	Vioolsdrif	1964	1986
Groot-Vis	Outspan	1969	1986
Nile	el Ekhsase	1973	1984
Juba	Lugh Ganana	1951	1979
Rufiji	Stigler	1954	1978
Mangoky	Bevoay	1964	1983
Zambeze	Matundo-Cais	1976	1979
Save	Villafranca do Save	1976	1979
Limpopo	Chokwe	1976	1979

Table 1.2

GLOBAL RUNOFF DATA CENTRE (GRDC)
General characteristics and time series of data

River	Station	Area (km^2)	monthly discharge (m^3/s)			Mean monthly runoff (mm)	Time series	
			Mean	Max.	Min.		from	to
Senegal	Dagana	268000	730	3260	4	7	1903	1974
Gambie	Gouloumbou	42000	156	1142	1	10	1979	1989
Niger	Gaya	1000000	1066	2622	3	3	1952	1990
Sanaga	Edea	131520	1990	6950	234	39	1943	1980
Zaire	Kinshasa	3475000	40250	80833	22352	30	1903	1983
Juba	Lugh Ganana	179520	191	808	0	3	1951	1979
Rufiji	Stigler	158200	808	5098	89	13	1954	1978
Zambeze	Matundo-Cais	940000	3337	12382	540	9	1976	1979
Save	Villafranca do Save	100885	434	3022	6	11	1976	1979

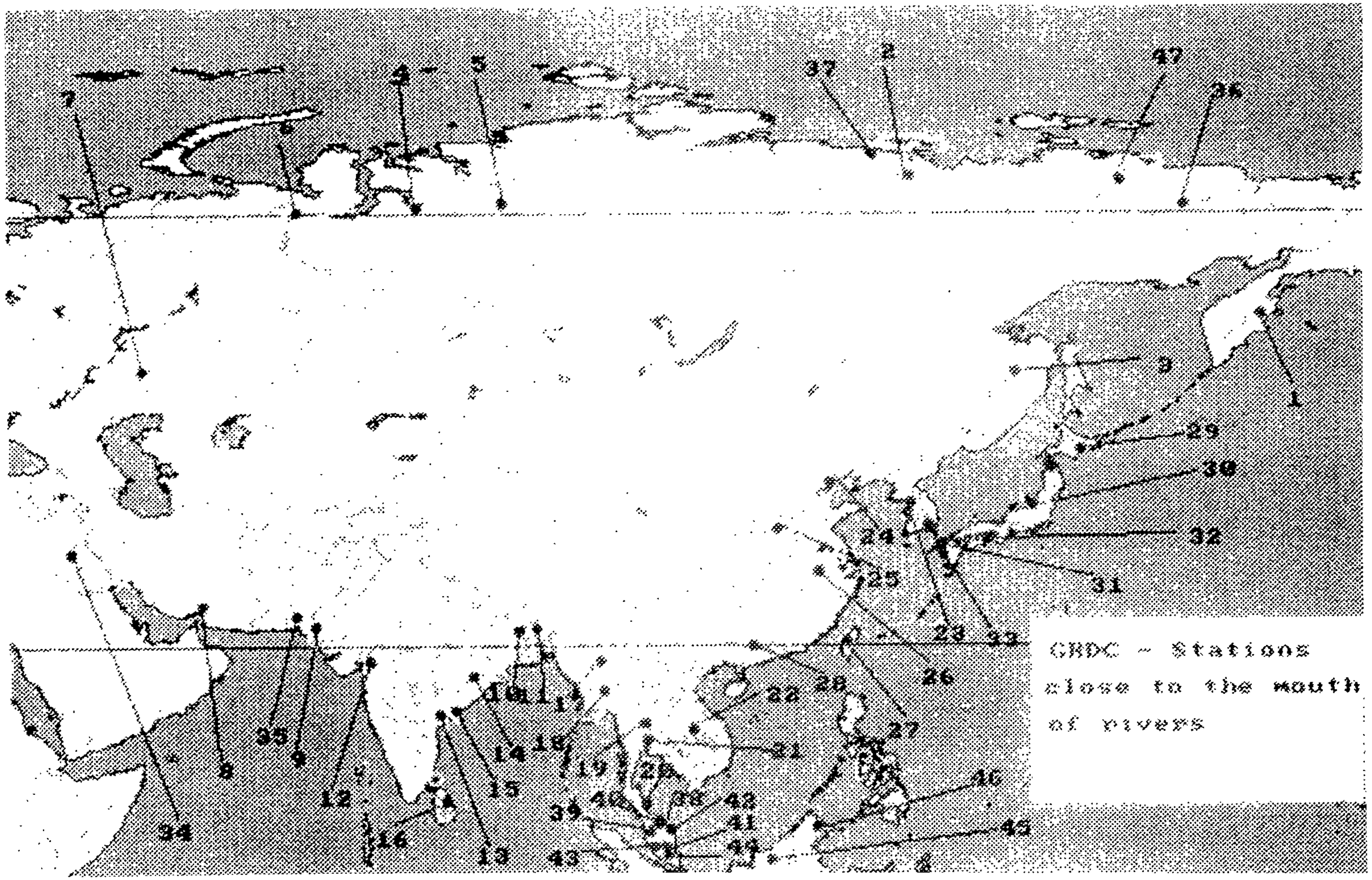
Table 1.3

GLOBAL RUNOFF DATA CENTRE (GRDC)

Africa   Stations close to the mouth of Rivers

River	mean annual discharge (m^3/s)	mean annual runoff (mm)	Minimum annual discharge (m^3/s)	Minimum annual runoff mm	Maximum annual discharge (m^3/s)	Maximum annual runoff mm	Mean volume of discharge per year (km^3/a)	Year of occurrence (Mean/Min/Max) annual discharge
Senegal	691	81	313	37	944	111	22	1910/1913/1924
Gambie	150	113	67	50	272	204	5	1980/1983/1974
Niger	1153	36	559	18	1628	51	36	1957/1986/1955
Sanaga	1986	476	1440	345	2679	642	63	1965/1972/1969
Zaire	40250	3653	32873	2983	54963	4988	1269	1952/1919/1962
Juba	193	34	113	20	313	55	6	1971/1955/1961
Rufiji	790	157	513	102	1375	274	25	1957/1971/1956
Zambeze	3337	112	2322	78	5758	193	105	1977/1976/1978
Save	503	157	216	68	790	247	16	- /19761978

Table 1.4



Map 3

NORTH AND SOUTH EAST ASIA

Table 1

NO.	River	Station	Latitude	Longitude	Area(km2)	first Rec.	last Rec.	day/mont	Remark
1	Kamchatka	Kluchi	5643N	16105E	45600	1 1931	12 1984	M	*
2	Lena	Kusur	7070N	12765E	2430000	1 1935	12 1984	M	*
3	Amur	Komsomolsk	5063N	13712E	1730000	1 1933	12 1984	M	*
4	Pur	Samburg	6708N	7815E	95100	1 1965	5 1984	M	
5	Yenisei	Igarka	6748N	8650E	2440000	1 1936	12 1984	M	*
6	Ob	Salekhard	6657N	6653E	2949998	1 1930	12 1984	M	*
7	Ural	Kushum	5085N	5128E	190000	1 1915	12 1984	M	
8	Minab	Berantin	2740N	5717E	9285	1 1965	12 1984	M	
9	Indus	Kotri	2537N	6837E	832418	4 1973	12 1979	M	*
10	Ganga	Farakka	2500N	8792E	935000	1 1949	12 1973	M	*
11	Brahmaputra	Bahadurabad	2518N	8967E	636130	1 1969	12 1975	M	*
12	Narmada	Garudeshwar	2192N	7365E	89345	1 1949	12 1979	M	
13	Krishna	Vijayawada	1652N	8062E	251355	1 1901	12 1979	M	
14	Mahanadi	Kaimundi	2042N	8367E	132090	1 1965	12 1970	M	
15	Godavari	Polavaram	1692N	8178E	299320	6 1901	12 1979	M	*
16	Mahaweli Ganga	Manampitiya	792N	8108E	7343	1 1965	12 1984	M	
17	Irrawaddy	Sagaing	2198N	9610E	117900	1 1978	12 1988	D	*
18	Sittang	Toungoo	1892N	9647E	14660	1 1978	12 1988	D	
19	Chao Phraya	Nakhon Sawan	1567N	10012E	110569	1 1976	12 1984	M	*
20	Trang	Trang	777N	9954E	1801	1 1980	12 1984	M	
21	Mae Nam Prachin Buri	Kabin Buri	1397N	10070E	5330	4 1980	3 1981	D	
22	Mekong	Pakse	1512N	10580E	545000	4 1980	12 1990	D	*
23	Han	Indogyo	3752N	12697E	25046	7 1947	12 1979	M	
24	Luanhe	Luanxian	3973N	11875E	44100	1 1980	12 1983	M	
25	Huanghe(Yellow River)	Huayuankou	3492N	11365E	730036	4 1946	12 1979	M	*
26	Changjiang (Yangtze)	Datong	3077N	11762E	1705383	1 1923	12 1986	M	*
27	Cho-Shui	Chi-Chi	2383N	12075E	2311	1 1965	12 1968	M	
28	Xijiang	Wuzhou 3	2348N	11130E	329705	1 1976	12 1983	M	*
29	Ishikari	Ishikari-Ohashi	4312N	14153E	12697	1 1986	12 1986	D	*
30	Shinano	Ojiya	3730N	13880E	9719	1 1978	12 1988	D	*

Table 1.5

NORTH AND SOUTH EAST ASIA

Table 2

NO.	River	Station	Latitude	Longitude	Area(km2)	first Rec.	last Rec.	day/mont	Remark
31	Chikugo	Senoshita	3353N	13080E	2315	1 1978	12 1988	D	
32	Yoshino	Iwazu	3405N	13420E	2768	1 1978	12 1988	D	
33	Nagdong	Samnangjin	3540N	12885E	22916	1 1953	12 1972	M	
34	Al-Furat (Euphrates)	Hindiya	3272N	4427E	274100	10 1964	12 1972	M	*
35	Porali River	Sinchi Bent	2650N	6638E	4040	1 1979	12 1979	D	
36	Kolyma	Sredne-Kolymsk	6737N	15367E	361000	1 1927	12 1984	M	*
37	Olenek	7.5km Downstream of mouth of Pur	7212N	12322E	198000	1 1965	12 1984	M	*
38	Golok	Rantau Panjang	602N	10197E	761	1 1978	12 1987	D	
39	Perak	Iskandar Bridge	482N	10097E	7770	1 1965	12 1985	M	
40	Kelantan	Guillemard Bridge	577N	10215E	11900	1 1949	12 1986	M	
41	Pahang	Temerloh	345N	10243E	19000	1 1965	12 1984	M	
42	Trengganu	Kampung Tanggol	513N	10305E	3340	1 1978	11 1987	D	
43	Selangor	Rantau Panjang	340N	10143E	1450	1 1978	12 1987	D	
44	Muar	Buluh Kasap	255N	10275E	3130	1 1981	12 1985	M	
45	Rajang	Ng Benin	215N	11307E	21192	1 1981	12 1985	M	
46	Kinabatangan	Balat	530N	11759E	10800	7 1981	12 1985	M	
47	Indigirka	Vorontsovo	6958N	14735E	305000	1 1937	12 1987	M	

Remark: * Selected Stations for general characteristics

Table 1.6

NORTH AND SOUTH EAST ASIA

Overview of overlapping timeseries of stations close to the mouth of Rivers

River	Station	Time	series
Kamchatka	Kluchi	1931	1984
Lena	Kusur	1935	1984
Amur	Komsomolsk	1933	1984
Pur	Samburg	1965	1984
Yenisei	Igarka	1936	1984
Ob	Salekhard	1930	1984
Ural	Kushum	1915	1984
Minab	Berantin	1965	1984
Indus	Kotri	1973	1979
Ganga	Farakka	1949	1973
Brahmaputra	Bahadurabad	1969	1975
Narmada	Garudeshwar	1949	1979
Krishna	Vijayawada	1901	1979
Mahanadi	Kaimundi	1965	1970
Godavari	Polavaram	1901	1979
Mahaweli Ganga	Manampitiya	1965	1984
Irrawaddy	Sagaing	1978	1988
Sittang	Toungoo	1978	1988
Chao Phraya	Nakhon Sawan	1976	1984
Trang	Trang	1980	1984
Mae Nam Prachin Buri	Kabin Buri	1980	1981
Mekong	Pakse	1980	1990
Han	Indogyo	1947	1979
Luanhe	Luanxian	1980	1983
Huanghe(Yellow River)	Huayuankou	1946	1979
Changjiang (Yangtze)	Datong	1923	1986
Cho-Shui	Chi-Chi	1965	1968
Xijiang	Wuzhou 3	1976	1983
Ishikari	Ishikari-Ohashi	1986	1986
Shinano	Ojiya	1978	1988
Chikugo	Senoshita	1978	1988
Yoshino	Iwazu	1978	1988
Nagdong	Samnangjin	1953	1972
Al-Furat (Euphrates)	Hindiya	1964	1972
Porali River	Sinchi Bent	1979	1979
Kolyma	Sredne-Kolymsk	1927	1984
Olenek	7 5km Downstream of River Pur	1965	1984
Golok	Rantau Panjang	1978	1987
Perak	Iskandar Bridge	1965	1985
Kelantan	Guillemard Bridge	1949	1986
Pahang	Temerloh	1965	1984
Trengganu	Kampung Tanggol	1978	1987
Selangor	Rantau Panjang	1978	1987
Muar	Buluh Kasap	1981	1985
Rajang	Ng Benin	1981	1985
Kinabatangan	Balat	1981	1985
Indigirka	Vorontsovo	1937	1987

Table 1.7

GLOBAL RUNOFF DATA CENTRE (GRDC)
General characteristics and time series of data

River	Station	Area (km^2)	Monthly discharge (m^3/s)			Mean monthly runoff (mm)	Time series	
			Mean	Max.	Min.		from	to
Kamchatka	Kluchi	45600	777	2720	295	44	1931	1984
Lena	Kusur	2430000	16622	96600	429	18	1935	1984
Amur	Komsomolsk	1730000	9739	33100	374	15	1933	1984
Yenisei	Igarka	2440000	17847	112000	3120	19	1936	1984
Ob	Salekhard	2949998	12504	43423	2120	11	1930	1984
Indus	Kotri	832418	2626	17678	11	8	1973	1979
Ganga	Farakka	935000	12037	65072	1181	33	1949	1973
Brahmaputra	Bahadurabad	636130	18648	56190	3314	76	1969	1975
Godavari	Polavaram	299320	3058	34606	7	26	1901	1979
Irrawaddy	Sagaing	117900	8137	25608	1423	179	1978	1988
Chao Phraya	Nakhon Sawan	110569	776	3362	178	18	1976	1984
Mekong	Pakse	545000	9502	34647	1482	45	1980	1990
Huanghe(Yellow River)	Huayuankou	730036	1485	5905	64	5	1946	1979
Changjiang (Yangtze)	Datong	1705383	25032	54500	7220	38	1923	1986
Ishikari	Ishikari-Ohashi	12697	469	1889	78	96	1986	1986
Shinano	Ojiya	9719	541	2444	178	144	1978	1988
Al-Furat (Euphrates)	Hindiya	274100	706	2711	53	7	1964	1972
Kolyma	Sredne-Kolymsk	361000	2196	17300	16	16	1927	1984
Olenek	7.5km Downstream of River Pur	198000	1000	11300	0	13	1965	1984
Xijiang	Wuzhou 3	329705	7085	20400	1120	56	1976	1983

Table 1.8

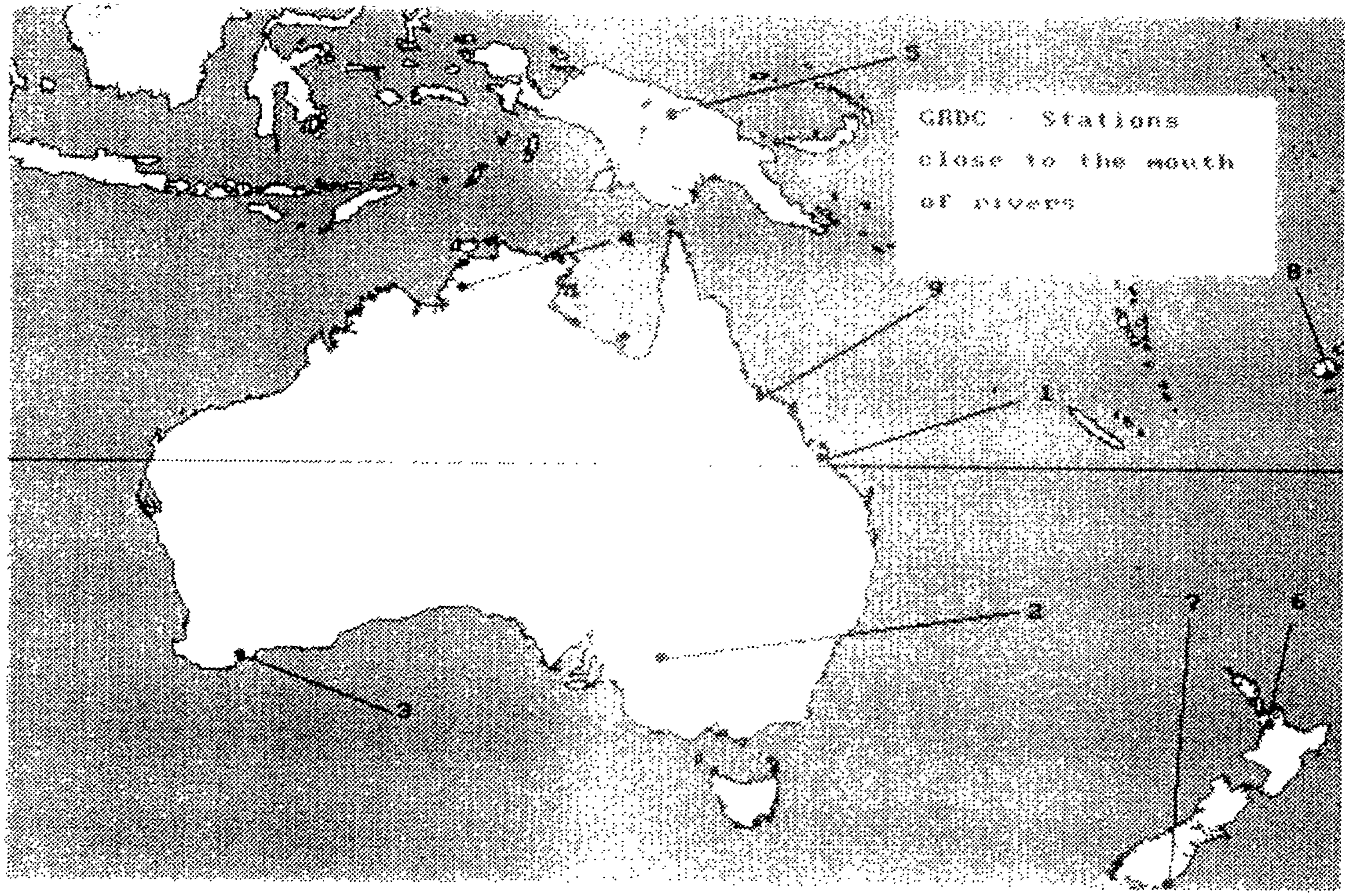
GLOBAL RUNOFF DATA CENTRE (GRDC)

North and South East Asia

Stations close to the mouth of Rivers

River	mean annual discharge (m^3/s)	mean annual runoff (mm)	Minimum annual discharge (m^3/s)	Minimum annual runoff mm	Maximum annual discharge (m^3/s)	Maximum annual runoff mm	Mean volume of discharge per year (km^3/a)	Year of occurrence (Mean/Min/Max) annual discharge
Kamchatka	780	539	595	411	1034	715	25	1983/1945/1969
Lena	16622	216	13234	172	19978	259	524	1937/1954/1961
Amur	9739	178	6087	111	14228	259	307	1935/1979/1956
Yenisei	17847	231	15543	201	20966	271	563	1981/1968/1974
Ob	12504	134	8791	94	17812	190	394	1943/1967/1979
Indus	2396	92	1572	60	3374	129	76	1976/1977/1978
Ganga	12037	406	7732	261	17217	581	380	1953/1972/1955
Brahmaputra	19674	975	18147	900	21753	1078	620	1969/1973/1974
Godavari	3061	323	873	92	6667	702	97	1954/1920/1959
Irrawaddy	8137	2176	6926	1853	9993	2673	257	1980/1986/1988
Chao Phraya	776	221	595	170	1001	286	24	1981/1984/1976
Mekong	9318	539	7707	446	11273	652	294	1983/1987/1990
Huanghe	1465	63	632	27	2715	117	46	1950/1960/1964
Changjiang	25032	463	21377	395	28882	534	789	1976/1978/1977
Ishikari	468	1163	176	437	615	1528	15	1967/1960/1973
Shinano	536	1739	394	1278	1111	3605	17	1971/1973/1966
Euphrates	678	78	473	54	1157	133	21	1967/1972/1969
Kolyma	2196	192	1337	117	3189	279	69	1931/1973/1950
Olenek	1000	159	645	103	1677	267	32	1980/1972/1973
Xijiang	7085	678	6607	632	8311	795	223	1980/1977/1979

Table 1.9



Map 4

WESTERN PAZIFIC

No.	River	Station	Latitude	Longitude	Area(km2)	first Rec.	last Rec.	day/mont	Remark
1	Fitzroy	Yaamba	2315S	15037E	136000	1 1965	12 1968	M	*
2	Murray	Lock 9 Upper	3418S	14160E	991000	1 1965	12 1984	M	*
3	Pallinup River	Bull Crossing	3433S	11865E	3600	1 1978	12 1988	D	
4	Daly	Mount Nancar	1383S	13073E	47000	1 1976	12 1984	M	
5	Sepik	Ambunti	422S	14216E	40922	1 1980	10 1984	M	*
6	Waikato River	Ngaruawahia	3768S	17515E	11395	1 1976	12 1984	M	
7	Clutha	Balclutha	4623S	16973E	20306	1 1969	12 1984	M	
8	Navua	Nakavu	1819S	17810E	963	1 1978	12 1980	D	
9	Burdekin	Clare	1977S	14723E	129660	1 1965	12 1984	M	*

Table 1.10

Remark: * Selected Stations for general characteristics

WESTERN PACIFIC / AUSTRALIA

Overview of overlapping timeseries of stations close to the mouth of Rivers

River	Station	Time	series	1880	1885	1890	1895	1900	1905	1910	1915	1920	1925	1930	1935	1940	1945	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995
Fitzroy	Yaamba	1965	1968																								
Murray	Lock 9 Upper	1965	1984																								
Pallinup River	Bull Crossing	1978	1988																								
Daly	Mount Nancar	1976	1984																								
Sepik	Ambunti	1980	1984																								
Waikato River	Ngaruawahia	1976	1984																								
Clutha	Balclutha	1969	1984																								
Navua	Nakavu	1978	1980																								
Burdekin	Clare	1965	1984																								

Table 1.11

GLOBAL RUNOFF DATA CENTRE (GRDC)
General characteristics and time series of data

River	Station	Area (km^2)	Monthly discharge (m^3/s)			Mean monthly runoff (mm)	Time series	
			Mean	Max.	Min.		from	to
Fitzroy	Yaamba	136000	69	1223	0	1	1965	1968
Murray	Lock 9 Upper	991000	257	2044	12	1	1965	1984
Sepik	Ambunti	40922	3805	5812	1865	241	1980	1984
Burdekin	Clare	129660	360	10700	0	7	1965	1984

Table 1.12

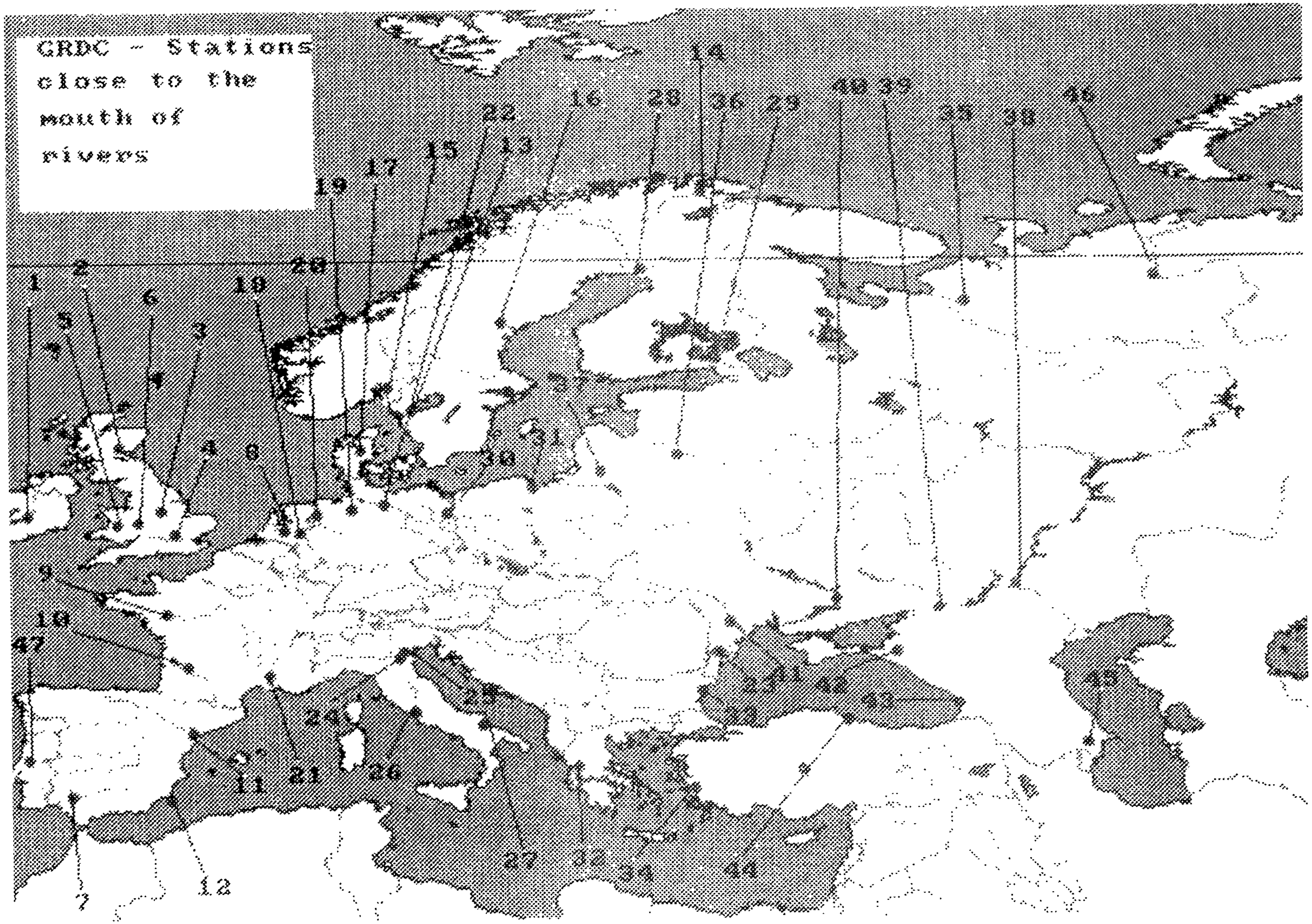
GLOBAL RUNOFF DATA CENTRE (GRDC)

Australia

Stations close to the mouth of Rivers

River	mean annual discharge (m^3/s)	mean annual runoff (mm)	Minimum annual discharge (m^3/s)	Minimum annual runoff mm	Maximum annual discharge (m^3/s)	Maximum annual runoff mm	Mean volume of discharge per year (km^3/a)	Year of occurrence (Mean/Min/Max) annual discharge
Fitzroy	69	16	24	6	184	43	2	1967/1965/1968
Murray	257	8	36	1	1107	35	8	1984/1982/1974
Sepik	4208	3242	4208	3242	4208	3242	133	1983/1983/1983
Burdekin	360	88	40	10	1639	399	11	1975/1982/1974

Table 1.13


GRDC - Stations close to the mouth of rivers
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Map 5

EUROPE

Table 1

No.	River	Station	Latitude	Longitude	Area(km2)	first Rec.	last Rec.	day/mont	Remark
1	Shannon	Killaloe	5280N	842W	11690	1 1973	12 1979	M	*
2	Tay	Ballathie	5649N	337W	4587	10 1952	12 1991	D	
3	Trent	Colwick	5295N	107W	7490	1 1991	12 1991	D	
4	Thames	Teddington	5142N	032W	9950	1 1965	12 1984	M	*
5	Wye	Ddol Farm	5224N	347W	174	1 1977	12 1991	D	
6	Severn	Bewdley	5237N	232W	4330	1 1991	12 1991	D	
7	Guadalquivir	Alcala del Rio	3752N	598W	46995	1 1913	12 1984	M	*
8	Maas	Lith	5182N	545E	29000	1 1911	12 1984	M	
9	Loire	Montjean	4738N	083W	110000	1 1863	12 1979	M	*
10	Garonne	Mas-D'agenais	4442N	023E	52000	10 1920	12 1979	M	
11	Ebro	Tortosa	4082N	052E	84230	1 1913	6 1984	M	
12	Jucar	Masia de Mompo	3715N	065W	17876	1 1913	12 1984	M	
13	Vaenern-Goeta	Vaenersborg	5838N	1232E	46830	1 1807	12 1984	M	
14	Tana	Polmak	7007N	2805E	14005	1 1912	12 1987	M	
15	Gloma	Langnes	5960N	1112E	40221	9 1901	12 1984	M	
16	Angerman	Solleftea	6317N	1727E	30640	1 1965	12 1984	M	
17	Gudena	Tvilumbro	5624N	967E	1290	1 1918	5 1970	M	
18	Rhein	Rees	5177N	640E	159680	1 1936	12 1984	M	
19	Weser	Intschede	5297N	913E	37788	1 1921	12 1984	M	*
20	Ems	Versen	5273N	725E	8345	1 1980	12 1984	M	
21	Rhone	Beaucaire	4392N	467E	95590	10 1920	12 1979	M	*
22	Elbe	Neu-Darchau	5323N	1088E	131950	1 1965	12 1988	M	
23	Danube	Ceatal Izmail	4518N	2880E	807000	1 1921	12 1984	M	*
24	Po	Pontelagoscuro	4488N	1165E	70091	1 1918	12 1979	M	
25	Adige	Boara Pisani	4510N	1183E	11954	1 1922	12 1979	M	
26	Tevere	Roma	4190N	1248E	16545	1 1921	12 1979	M	
27	Ofanto	S.Samuele Di Cafiero	4130N	1614E	2716	1 1978	12 1981	D	
28	Kemi	Taivalkoski	6595N	2470E	50790	1 1911	12 1984	M	
29	Vuoksi	Imatra	6115N	2877E	61275	1 1847	12 1984	M	
30	Odra	Gozdowice	5277N	1432E	109729	11 1900	10 1987	M	*

Table 1.14

EUROPE Table 2

No.	River	Station	Latitude	Longitude	Area(km2)	first Rec.	last Rec.	day/mont	Remark
31	Wisla	Tczew	5410N	1882E	194376	11 1900	10 1987	M	*
32	Acheloos	Avlaki	3918N	2129E	1349	1 1978	12 1980	D	
33	Kamtehiya	Gzozdevo	4303N	2783E	4857	1 1965	12 1979	M	
34	Bueyuek Menderes	Soeke	3772N	2748E	23889	10 1975	9 1982	D	
35	Northern Dvina	Ust-Pinega	6410N	4217E	348000	6 1881	12 1985	M	*
36	Western Dvina (Daugava)	Daugavpils	5588N	2668E	64500	1 1965	12 1984	M	
37	Neman	Smalininkai	5502N	2252E	81200	1 1812	12 1984	M	
38	Volga	Volgograd Power Plant	4877N	4472E	1360000	1 1879	12 1984	M	
39	Don	Razdorskaya	4750N	4067E	378000	1 1891	12 1984	M	*
40	Dniepr	Dniepr Power Plant	4792N	3515E	463000	1 1952	12 1984	M	
41	Dniestr	Bendery	4680N	2937E	66100	1 1965	12 1984	M	
42	Kuban	Tikhovsky	4515N	3832E	48100	1 1965	12 1984	M	
43	Rioni	Sakochakidze	4222N	4180E	13330	1 1965	12 1984	M	
44	Kizilirmak	Inoezue	4138N	3580E	75121	10 1975	9 1986	D	
45	Kura	Surra	4012N	4867E	178000	1 1930	12 1984	M	*
46	Pechora	Ust-Tsilma	6547N	5225E	248000	1 1932	12 1984	M	
47	Tejo	Almourol	3947N	837W	67490	1 1976	12 1984	M	

Table 1.15

Remark: * Selected Stations for general charcteristics

EUROPE

Overview of overlapping timeseries of stations close to the mouth of Rivers

River	Station	Time	series
Shannon	Killaloe	1973	1979
Tay	Ballathie	1952	1991
Trent	Colwick	1991	1991
Thames	Teddington	1965	1984
Wye	Ddol Farm	1977	1991
Severn	Bewdley	1991	1991
Guadalquivir	Alcala del Rio	1913	1984
Seine	Poses	1971	1977
Loire	Montjean	1863	1979
Garonne	Mas-D'agenais	1920	1979
Ebro	Tortosa	1913	1984
Jucar	Masia de Mompo	1913	1984
Vaenern-Goeta	Vaenersborg	1807	1984
Tana	Polmak	1912	1987
Gloma	Langnes	1901	1984
Angerman	Solleftea	1965	1984
Gudena	Tvilumbro	1918	1970
Rhein	Rees	1936	1984
Weser	Intschede	1921	1984
Ems	Versen	1980	1984
Rhone	Beaucaire	1920	1979
Elbe	Neu-Darchau	1965	1988
Danube	Ceatal Izmail	1921	1984
Po	Pontelagoscuro	1918	1979
Adige	Boara Pisani	1922	1979
Tevere	Roma	1921	1979
Ofanto	S Samuele Di Cafiero	1978	1981
Kemi	Taivalkoski	1911	1984
Vuoksi	Imatra	1847	1984
Odra	Gozdowice	1900	1987
Wisla	Tczew	1900	1987
Acheloos	Avlaki	1978	1980
Kamtehiya	Gzozdevo	1965	1979
Bueyuek Menderes	Soeke	1975	1982
Northern Dvina(Severnaya Dvina)	Ust-Pinega	1881	1985
Western Dvina (Daugava)	Daugavpils	1965	1984
Neman	Smalininkai	1812	1984
Volga	Volgograd Power Plant	1879	1984
Don	Razdorskaya	1891	1984
Dniepr	Dniepr Power Plant	1952	1984
Dniestr	Bendery	1965	1984
Kuban	Tikhovsky	1965	1984
Rioni	Sakochakidze	1965	1984
Kizilirmak	Inoezue	1975	1986
Kura	Surra	1930	1984
Pechora	Ust-Tsilma	1932	1984
Tejo	Almourol	1976	1984

Table 1.16

GLOBAL RUNOFF DATA CENTRE (GRDC)
General characteristics and time series of data

River	Station	Area (km^2)	Monthly discharge (m^3/s)			Mean monthly runoff (mm)	Time series	
			Mean	Max.	Min.		from	to
Shannon	Killaloe	11690	173	477	15	38	1973	1979
Thames	Teddington	9950	82	258	9	21	1965	1984
Guadalquivir	Alcala del Rio	46995	434	4268	0	24	1913	1984
Loire	Montjean	110000	838	4200	60	20	1863	1979
Rhein	Rees	159680	2291	6470	690	37	1936	1984
Weser	Intschede	37788	317	1439	65	22	1921	1984
Rhone	Beaucaire	95590	1693	5077	420	46	1920	1979
Danube	Ceatal Izmail	807000	6499	14520	2076	21	1921	1984
Odra	Gozdowice	109729	537	2134	134	13	1900	1987
Wisla	Tczew	194376	1054	4390	254	14	1900	1987
Northern Dvina(Severnaya Dvina)	Ust-Pinega	348000	3315	20800	319	25	1881	1985
Don	Razdorskaya	378000	789	9390	103	5	1891	1984
Kura	Surra	178000	552	2250	120	8	1930	1984

Table 1.17

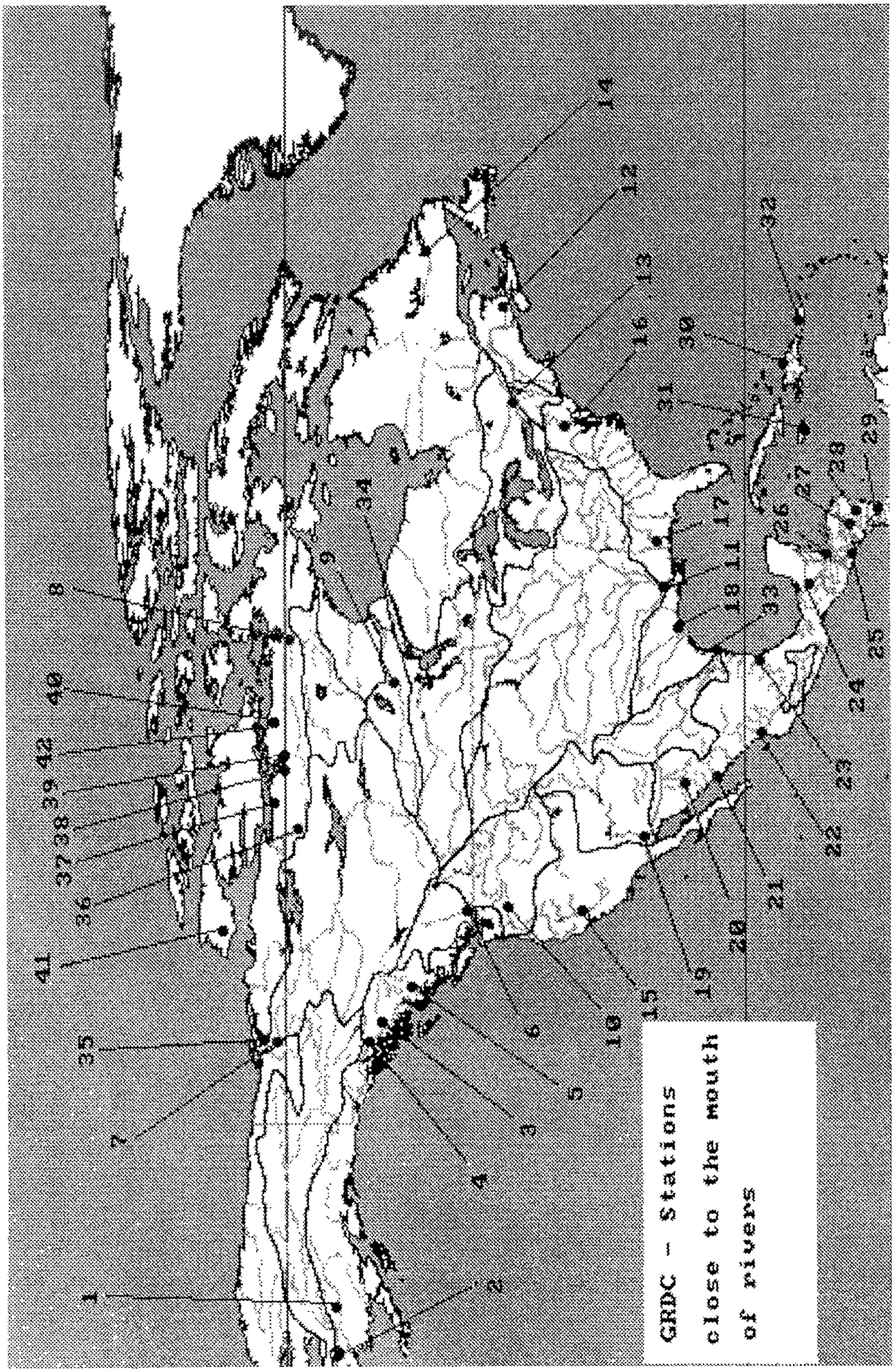
GLOBAL RUNOFF DATA CENTRE (GRDC)

Europe Stations close to the mouth of Rivers

River	mean annual discharge (m^3/s)	mean annual runoff (mm)	Minimum annual discharge (m^3/s)	Minimum annual runoff mm	Maximum annual discharge (m^3/s)	Maximum annual runoff mm	Mean volume of discharge per year (km^3/a)	Year of occurrence (Mean/Min/Max) annual discharge
Shannon	173	466	138	372	205	553	5	1977/1975/1979
Thames	82	259	42	132	112	355	3	1982/1976/1968
Guadalquivir	434	291	27	18	1306	876	14	1946/1981/1915
Loire	838	240	282	81	1967	563	26	1877/1949/1910
Rhein	2291	453	1246	246	3280	647	72	1974/1949/1970
Weser	317	264	150	125	532	444	10	1942/1934/1961
Rhone	1695	559	723	239	2465	813	53	1932/1921/1960
Danube	6499	254	4024	157	9417	368	205	1958/1921/1941
Odra	536	154	285	82	890	256	17	1956/1934/1941
Wisla	1055	171	600	97	1780	289	33	1923/1943/1980
Northern Dvina	3315	300	1785	162	5245	475	105	1932/1937/1923
Don	787	66	300	25	1666	139	25	1902/1972/1942
Kura	547	97	244	43	814	144	17	1973/1971/1940

Table 1.18

Map 6



GLOBAL RUNOFF DATA CENTRE (GRDC)

NORTH AND CENTRAL AMERICA

Table 1

No.	River	Station	Latitude	Longitude	Area(km2)	first Rec.	last Rec.	day/mont	Remark
1	Kuksokwim	Crooked Creek	6187N	15810W	80549	1 1965	12 1984	M	
2	Yukon River	Pilot Station	6193N	16288W	831390	10 1975	9 1993	D	*
3	Stikine	above Butterfly Creek	5748N	13175W	36000	9 1971	12 1984	M	
4	Taku	near Tulsequah	5864N	13354W	15500	6 1953	12 1984	M	
5	Skeena	Usk	5463N	12843W	42200	6 1928	12 1984	M	
6	Fraser River	Hope	4938N	12145W	217000	3 1912	12 1990	D	*
7	Mackenzie River	Norman Wells	6528N	12685W	1570000	5 1943	12 1990	D	*
8	Back	below Deep Rose Lake	6608N	9650W	98200	1 1966	12 1984	M	
9	Churchill River	above Granville Falls	5615N	10045W	228000	2 1946	12 1990	D	*
10	Columbia	The Dalles	4560N	12117W	613830	6 1878	9 1988	M	
11	Mississippi	Tarbert Landing	3102N	9162W	3923799	1 1965	12 1984	M	*
12	Saint John River	below Mactaquac	4597N	6583W	39900	1 1973	12 1984	M	
13	St.Lawrence	Cornwall(Ontario)	4500N	7478W	774410	1 1973	8 1984	M	*
14	Churchill River	above Upper Muskrat Falls	5325N	6078W	92500	1 1966	12 1984	M	
15	Sacramento	Sacramento	3858N	12150W	60886	10 1948	9 1984	M	
16	Susquehanna	Harrisburg	4025N	7688W	62419	10 1890	9 1987	D	
17	Alabama	Claiborne	3155N	8752W	56980	4 1930	9 1984	M	*
18	Brazos	Richmond	2958N	9553W	116568	1 1965	12 1984	M	*
19	Colorado	Limite Internacional Norte	3272N	11472W	631960	1 1976	12 1979	M	*
20	Yaqui	el Novillo	2893N	10963W	57908	1 1976	12 1979	M	
21	Fuerte	San Miquel Zapotitlan	2595N	10905W	34247	1 1976	12 1981	M	
22	Santiago	el Capomal	2183N	10512W	128943	1 1965	12 1981	M	*
23	Panuco	Las Adjuntas	2198N	9857W	58115	1 1965	12 1979	M	*
24	Usumacinta	Boca del Cerro	1742N	9150W	50743	1 1965	12 1983	M	
25	Lempa	San Marcos	1343N	8870W	18176	1 1969	4 1978	M	
26	Motagua	Morales	1567N	8880W	12998	1 1976	12 1977	M	
27	Coco	Corriente Lira	1354N	8583W	6830	1 1978	12 1980	D	
28	Grande	San Pedro del Norte	1305N	8472W	15073	1 1976	11 1979	M	
29	San Juan	el Castillo	1102N	8442W	32819	11 1969	12 1978	M	
30	Yaque del Norte	Palo Verde	1975N	7107W	6718	1 1976	12 1979	M	

Table 1.19

GLOBAL RUNOFF DATA CENTRE (GRDC)
General characteristics and time series of data

River	Station	Area (km²)	Monthly discharge (m³/s)			Mean monthly runoff (mm)	Time series	
			Mean	Max.	Min.		from	to
Yukon River	Pilot Station	831390	5987	23667	985	19	1978	1993
Fraser River	Hope	217000	2709	10752	482	32	1912	1990
Mackenzie River	Norman Wells	1570000	9080	27703	2129	15	1943	1990
Churchill River	above Granville Falls	228000	859	1970	496	10	1946	1990
Mississippi	Tarbert Landing, Miss.	3923799	14737	38900	4670	10	1965	1984
St.Lawrence	Cornwall(Ontario), near Massena, N.Y.	774410	7944	9910	6020	27	1973	1984
Alabama	Claiborne, Ala.	56980	946	4675	75	43	1930	1984
Brazos	Richmond, Tex.	116568	200	1229	15	4	1965	1984
Colorado	Limite Internacional Norte	631960	73	182	23	0	1976	1979
Santiago	el Capomal	128943	291	2113	10	6	1965	1981
Panuco	Las Adjuntas	58115	481	3042	72	21	1965	1979

Table 1.20

GLOBAL RUNOFF DATA CENTRE (GRDC)

NORTH AND CENTRAL AMERICA

Overview of overlapping timeseries of stations close to the mouth of Rivers

River	Station	Time	series	1880	1885	1890	1895	1900	1905	1910	1915	1920	1925	1930	1935	1940	1945	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995
Kuksokwim	Crooked Creek, Alas	1965	1984																								
Yukon River	Pilot Station	1975	1993																								
Stikine	above Butterfly Creek	1971	1984																								
Taku	near Tulsequah	1953	1984																								
Skeena	Usk	1928	1984																								
Fraser River	Hope	1912	1990																								
Mackenzie River	Arctic Red River	1972	1992																								
Back	below Deep Rose Lake	1966	1984																								
Churchill River	above Granville Falls	1946	1990																								
Columbia	The Dalles, Oreg	1878	1988																								
Mississippi	Tarbert Landing, Miss	1965	1984																								
Saint John River	below Mactaquac	1973	1984																								
St Lawrence	Cornwall(Ontario), near Massena	1973	1984																								
Churchill River	above Upper Muskrat Falls	1966	1984																								
Sacramento	Sacramento, Calif	1948	1984																								
Susquehanna	Harrisburg, Pa	1890	1987																								
Alabama	Claiborne, Ala	1930	1984																								
Brazos	Richmond, Tex	1965	1984																								
Colorado	Limite Internacional Norte	1976	1979																								
Yaqui	el Novillo	1976	1979																								
Fuerte	San Miquel Zapotitlan	1976	1981																								
Santiago	el Capomal	1965	1981																								
Panuco	Las Adjuntas	1965	1979																								
Usumacinta	Boca del Cerro	1965	1983																								
Lempa	San Marcos	1969	1978																								
Motagua	Morales	1976	1977																								
Coco	Corriente Lira	1978	1980																								
Grande	San Pedro del Norte	1976	1979																								
San Juan	el Castillo	1969	1978																								
Yaque del Norte	Palo Verde	1976	1979																								
Milk River	Rest	1968	1970																								
Rio Culebrinas	Highway 404 near Moca	1978	1990																								
Bravo	Matamoros	1976	1979																								
Nelson River	above Bladder Rapids	1958	1990																								
Trail Valley Creek	near Inuvik	1977	1992																								
Coppermine River	Point Lake Outlet	1965	1992																								
Tree River	near the mouth	1968	1992																								
Burnside River	near the mouth	1976	1992																								
Gordon River	near the mouth	1977	1992																								
Ellice River	near the mouth	1971	1992																								
Big River	above Egg River	1975	1988																								
Freshwater Creek	near Cambridge Bay	1970	1992																								

Table 1.21

GLOBAL RUNOFF DATA CENTRE (GRDC)

North and Central America

Stations close to the mouth of Rivers

River	mean annual discharge (m^3/s)	mean annual runoff (mm)	Minimum annual discharge (m^3/s)	Minimum annual runoff mm	Maximum annual discharge (m^3/s)	Maximum annual runoff mm	Mean volume of discharge per year (km^3/a)	Year of occurrence (Mean/Min/Max) annual discharge
Yukon River	6296	239	4890	185	7165	272	199	1981/1978/1985
Fraser River	2709	394	1938	282	3674	534	85	1925/1929/1976
Mackenzie River	9099	173	7583	144	10603	201	287	1990/1980/1974
Churchill River	865	120	578	80	1118	155	27	1971/1982/1974
Mississippi	14703	118	10202	82	20420	164	464	1966/1976/1973
St.Lawrence	7931	323	7328	298	8727	355	250	1975/1977/1973
Alabama	943	522	497	274	1539	852	30	1972/1931/1975
Brazos	200	54	54	15	386	104	6	1981/1967/1968
Colorado	73	4	57	3	120	6	2	1977/1976/1979
Santiago	291	71	154	38	494	121	9	1966/1979/1967
Panuco	481	261	271	147	708	384	15	1966/1977/1976

Table 1.22

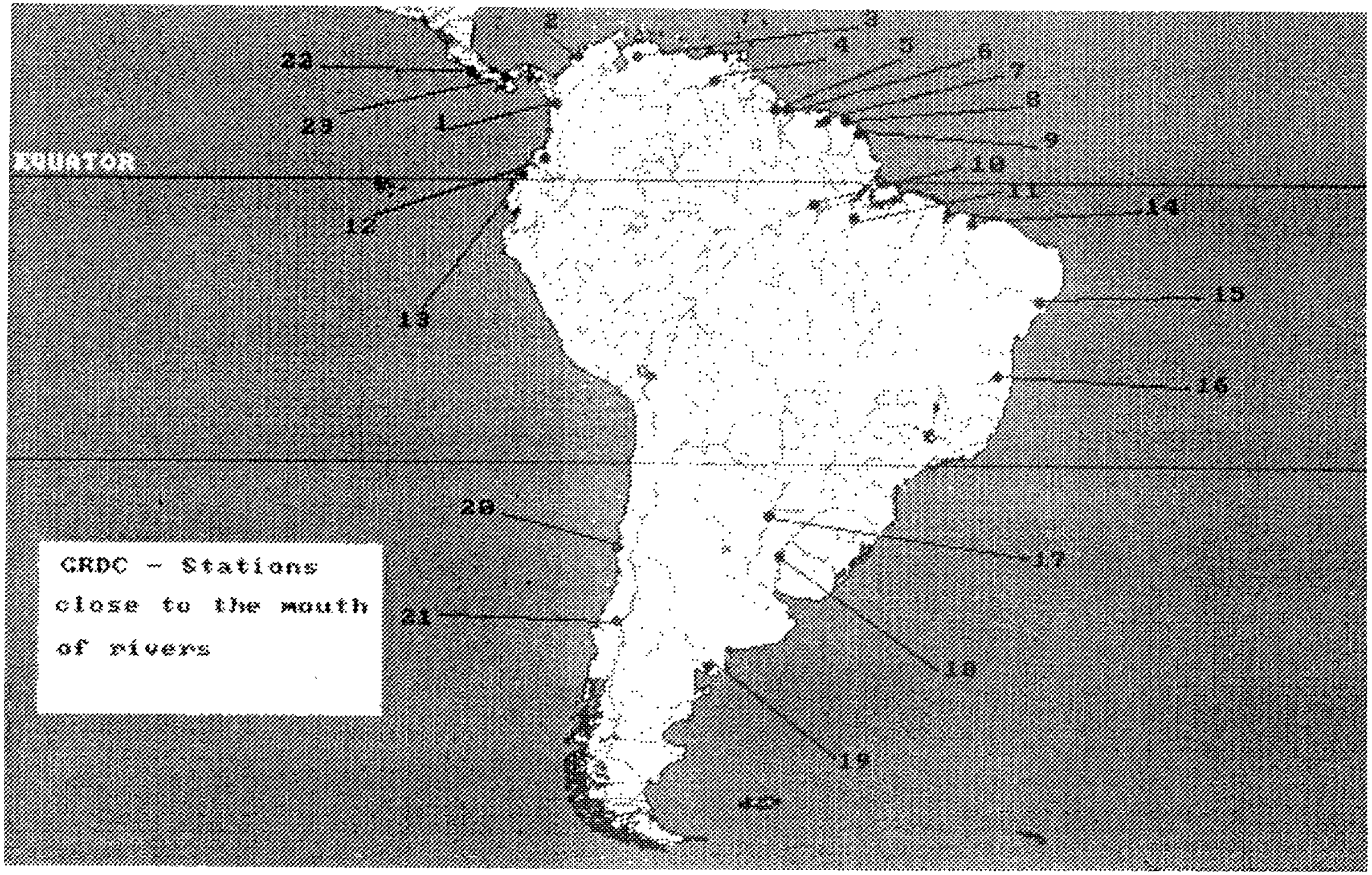
GLOBAL RUNOFF DATA CENTRE (GRDC)

North and Central America

Stations close to the mouth of Rivers

River	mean annual discharge (m^3/s)	mean annual runoff (mm)	Minimum annual discharge (m^3/s)	Minimum annual runoff mm	Maximum annual discharge (m^3/s)	Maximum annual runoff mm	Mean volume of discharge per year (km^3/a)	Year of occurrence (Mean/Min/Max) annual discharge
Yukon River	753	29	525	20	1049	40	24	1987/1958/1962
Fraser River	2709	394	1938	282	3674	534	85	1925/1929/1976
Mackenzie River	9099	173	7583	144	10603	201	287	1990/1980/1974
Churchill River	865	120	578	80	1118	155	27	1971/1982/1974
Mississippi	14703	118	10202	82	20420	164	464	1966/1976/1973
St.Lawrence	7931	323	7328	298	8727	355	250	1975/1977/1973
Alabama	943	522	497	274	1539	852	30	1972/1931/1975
Brazos	200	54	54	15	386	104	6	1981/1967/1968
Colorado	73	4	57	3	120	6	2	1977/1976/1979
Santiago	291	71	154	38	494	121	9	1966/1979/1967
Panuco	481	261	271	147	708	384	15	1966/1977/1976

Table 1.23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Map 7

SOUTH AMERICA

No.	River	Station	Latitude	Longitude	Area(km2)	first Rec.	last Rec	day/mont	Remark
1	Atrato	Tagachi	622N	7672W	9432	1 1976	12 1979	M	
2	Magdalena	Calamar	1027N	7492W	257438	1 1971	12 1979	M	*
3	Tocuyo	Puente Torres	1020N	6990W	3590	1 1978	12 1988	D	
4	Orinoco	Puente Angostura	815N	6360W	836000	5 1923	12 1989	D	*
5	Essequibo	Plantain Island	585N	5858W	66600	1 1965	12 1979	M	
6	Corantijin	Mataway	580N	5765W	51600	1 1973	12 1979	M	
7	Marowijne	Langa Tabbetje	500N	5440W	63700	1 1976	11 1979	M	
8	Sinnamary	Saut Tigre	497N	5303W	5150	1 1978	12 1980	D	
9	Oyapock	Maripa	382N	5188W	25100	1 1973	12 1979	M	
10	Amazonas	Obidos	190S	5550W	4640300	1 1928	11 1983	M	*
11	Xingu	Altamira	320S	5222W	446570	1 1976	12 1979	M	*
12	Patia	Pte Pusmeo	170N	7762W	13147	1 1971	12 1984	M	
13	Esmeraldas	D.J.Sade	053N	7942W	18800	1 1979	12 1979	D	
14	Rio Parnaiba	Porto Formosa	347S	4250W	290000	8 1963	12 1975	D	*
15	Sao Francisco	Traipu	997S	3698W	622600	1 1977	12 1979	M	*
16	Jequitinhonha	Jacinto	1613S	4030W	62365	1 1943	12 1978	M	
17	Parana	Corrientes	2797S	5885W	1950000	9 1904	8 1983	M	*
18	Uruguay	Concordia	3140S	5802W	249312	1 1968	12 1979	M	*
19	Negro	Primera Angostura	4043S	6367W	95000	4 1927	3 1980	M	*
20	Limari	Panamericana	3063S	7157W	11343	1 1966	12 1984	M	
21	Bio Bio	Desembocadura	3683S	7150W	24029	1 1966	12 1984	M	
22	Grande de Terraba	Palmar	897N	8347W	4767	5 1973	4 1987	D	
23	Santa Maria	San Francisco	822N	8097W	1505	1 1978	12 1988	D	

Table 1.24

Remark : * Selected Stations for general characteristics

SOUTH AMERICA

Overview of overlapping timeseries of stations close to the mouth of Rivers

River	Station	Time	series
Atrato	Tagachi	1976	1979
Magdalena	Calamar	1971	1979
Tocuyo	Puente Torres	1978	1988
Orinoco	Puente Angostura	1923	1989
Essequibo	Plantain Island	1965	1979
Corantijin	Mataway	1973	1979
Marowijne	Langa Tabbetje	1976	1979
Sinnamary	Saut Tigre	1978	1980
Oyapock	Maripa	1973	1979
Amazonas	Obidos	1928	1983
Xingu	Altamira	1976	1979
Patia	Pte Pusmeo	1971	1984
Esmeraldas	D J Sade	1979	1979
Rio Parnaiba	Porto Formosa	1963	1975
Sao Francisco	Traipu	1977	1979
Jequitinhonha	Jacinto	1943	1978
Parana	Corrientes	1904	1983
Uruguay	Concordia	1968	1979
Negro	Primera Angostura	1927	1980
Limari	Panamericana	1966	1984
Bio Bio	Desembocadura	1966	1984
Grande de Terraba	Palmar	1973	1987
Santa Maria	San Francisco	1978	1988

Table 1.25

GLOBAL RUNOFF DATA CENTRE (GRDC)
General characteristics and time series of data

River	Station	Area (km^2)	Monthly discharge (m^3/s)			Mean monthly runoff (mm)	Time series	
			Mean	Max.	Min.		from	to
Magdalena	Calamar	257438	6977	11957	1800	70	1971	1979
Orinoco	Puente Angostura	836000	31157	85964	3512	97	1923	1989
Amazonas	Obidos	4640300	155702	246000	14400	87	1928	1983
Xingu	Altamira	446570	8610	26984	1007	50	1976	1979
Rio Parnaiba	Porto Formosa	290000	815	5081	254	7	1963	1975
Sao Francisco	Traipu	622600	2645	11718	1460	11	1977	1979
Parana	Corrientes	1950000	16595	54500	4092	22	1904	1983
Uruguay	Concordia	249312	5218	18268	501	54	1968	1979
Negro	Primera Angostura	95000	870	2892	90	24	1927	1980

Table 1.26

GLOBAL RUNOFF DATA CENTRE (GRDC)

South America **Stations close to the mouth of Rivers**

River	mean annual discharge (m^3/s)	mean annual runoff (mm)	Minimum annual discharge (m^3/s)	Minimum annual runoff mm	Maximum annual discharge (m^3/s)	Maximum annual runoff mm	Mean volume of discharge per year (km^3/a)	Year of occurrence (Mean/Min/Max) annual discharge
Magdalena	6974	854	5718	700	9638	1181	220	1976/1977/1971
Orinoco	31061	1172	21540	813	37593	1418	980	1978/1926/1954
Amazonas	155432	1056	133267	906	176067	1197	4901	1935/1936/1975
Xingu	8610	608	6539	462	10454	738	272	1979/1976/1978
Rio Parnaiba	785	85	502	55	1464	159	25	1973/1972/1974
Sao Francisco	2645	134	1916	97	4019	204	83	1977/1978/1979
Parana	16358	265	9413	152	15583	414	516	1907/1944/1905
Uruguay	5218	660	2573	326	8589	1086	165	1979/1968/1973
Negro	865	287	357	118	1407	467	27	1967/1972/1951

Table 1.27

Annex 2

Display of hydrological characteristics of selected rivers used for the computation of continental river runoff

Explanation:

The information is presented for each continent. For the selection of rivers see annex 1. For each selected river a figure is presented for runoff, average discharge, trend of runoff and in a seperate figure the absolute variability of discharge observed from GRDC data. The trend line of runoff is omitted in cases with considerable gaps in the time series. For several long time series with intermittent gaps in the time series, two graphs are presented for the partial time series.

The information is presented in this order:

Africa

GLOBAL RUNOFF DATA CENTRE (GRDC)

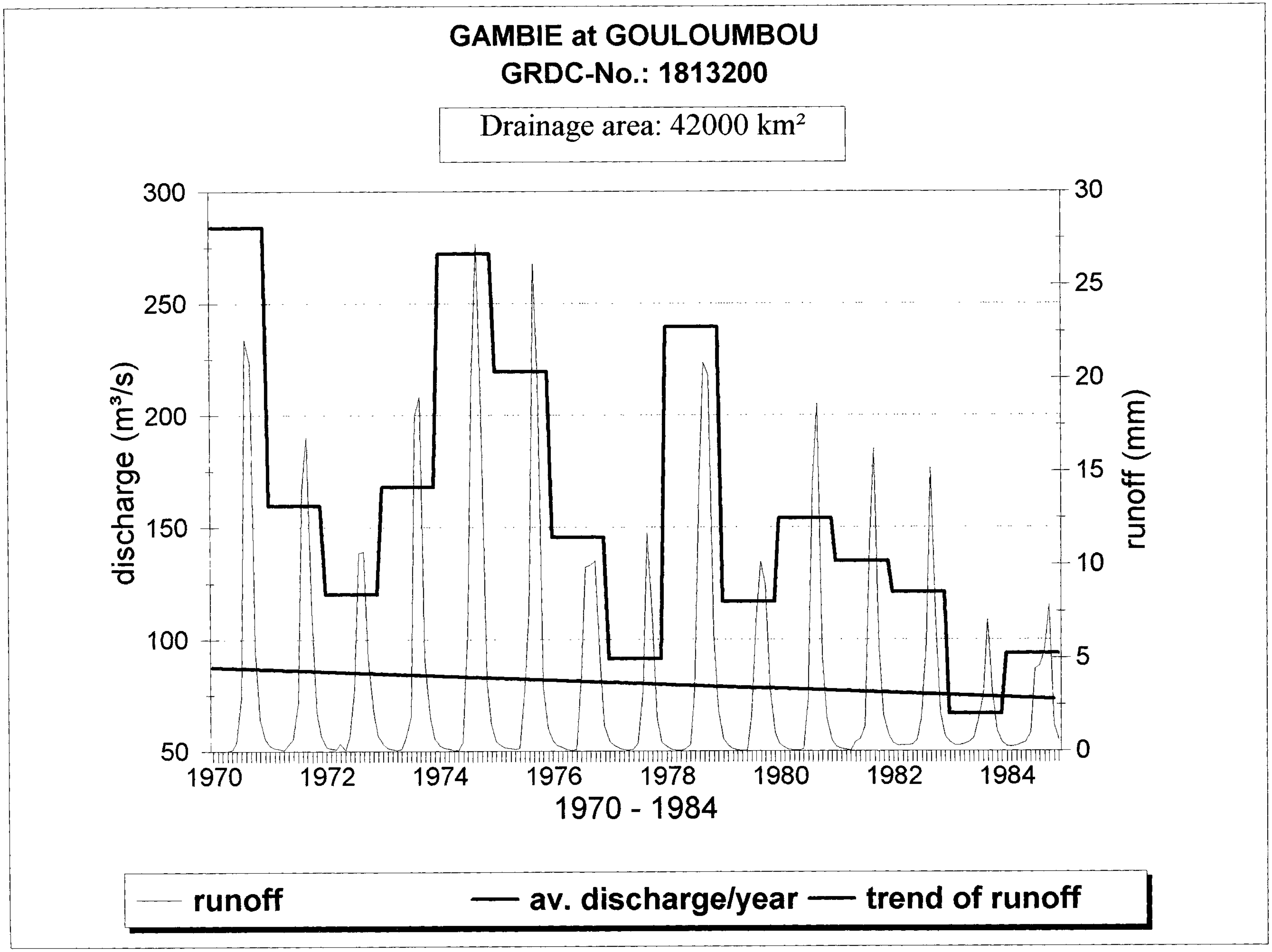
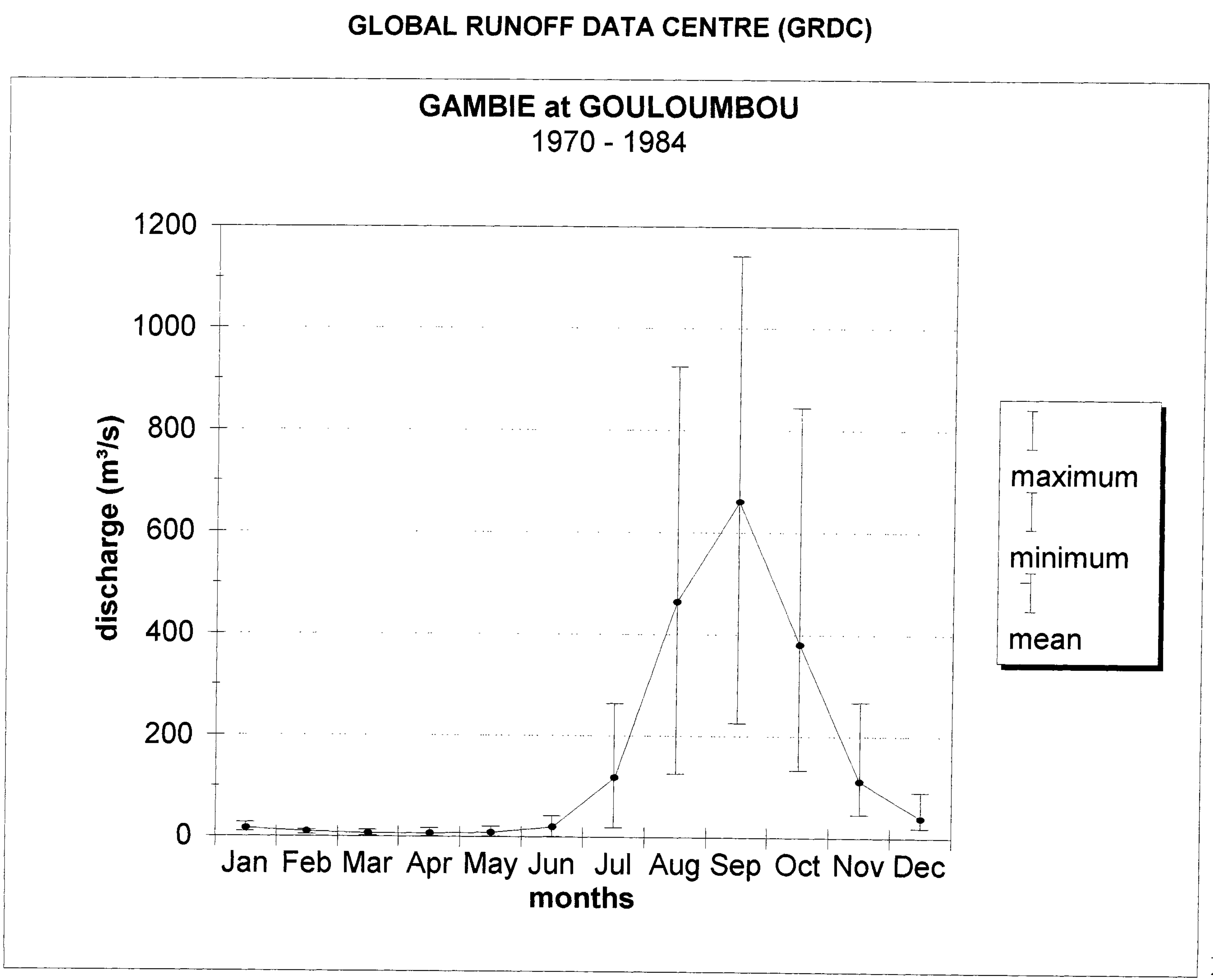


Figure 2.1



GLOBAL RUNOFF DATA CENTRE (GRDC)
GAMBIE at GOULOUMBOU
1970 - 1984
discharge (m³/s)
1200
1000
800
600
400
200
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
months
maximum
minimum
mean

Figure 2.2

GLOBAL RUNOFF DATA CENTRE (GRDC)

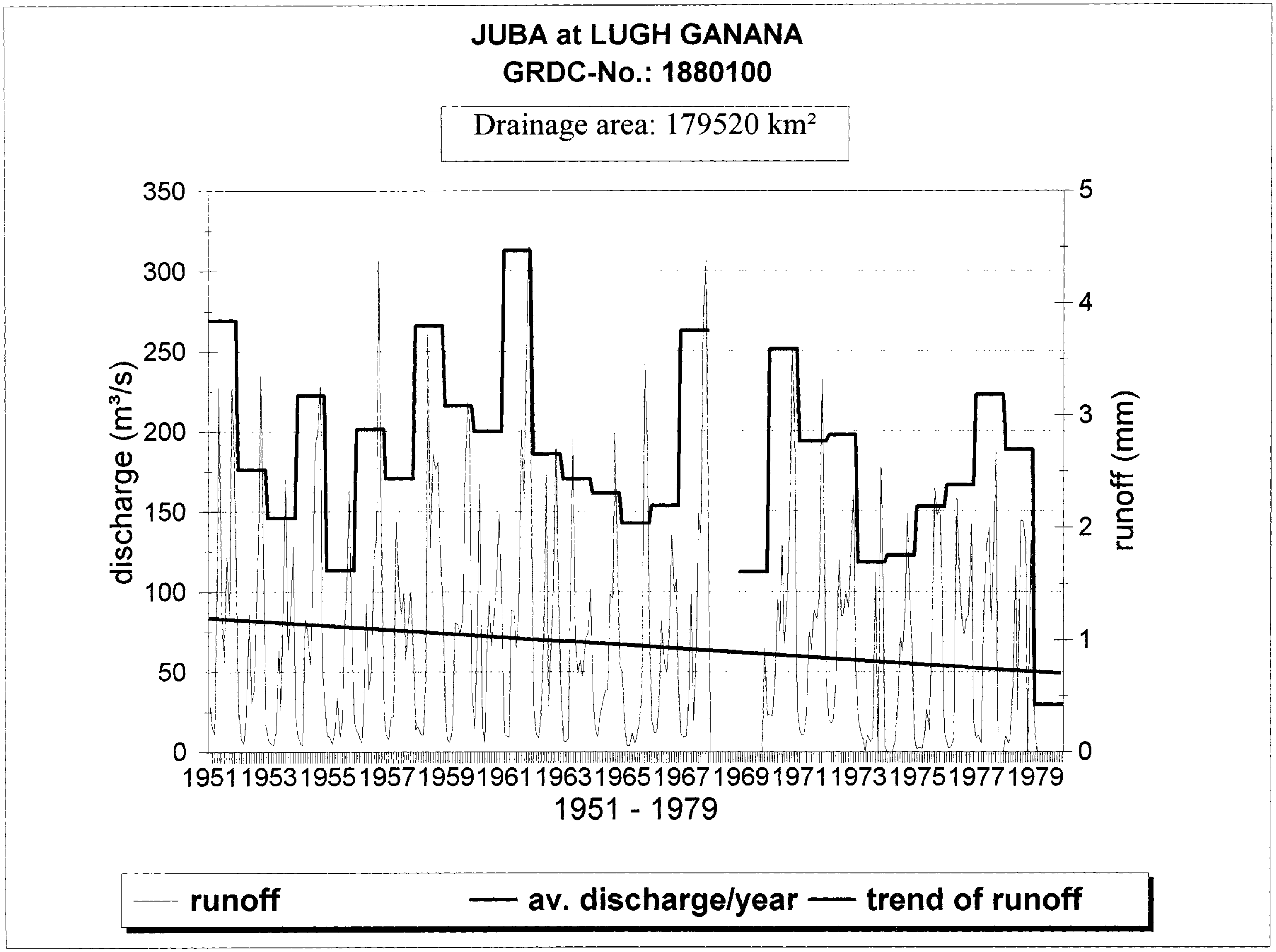


Figure 2.3

GLOBAL RUNOFF DATA CENTRE (GRDC)

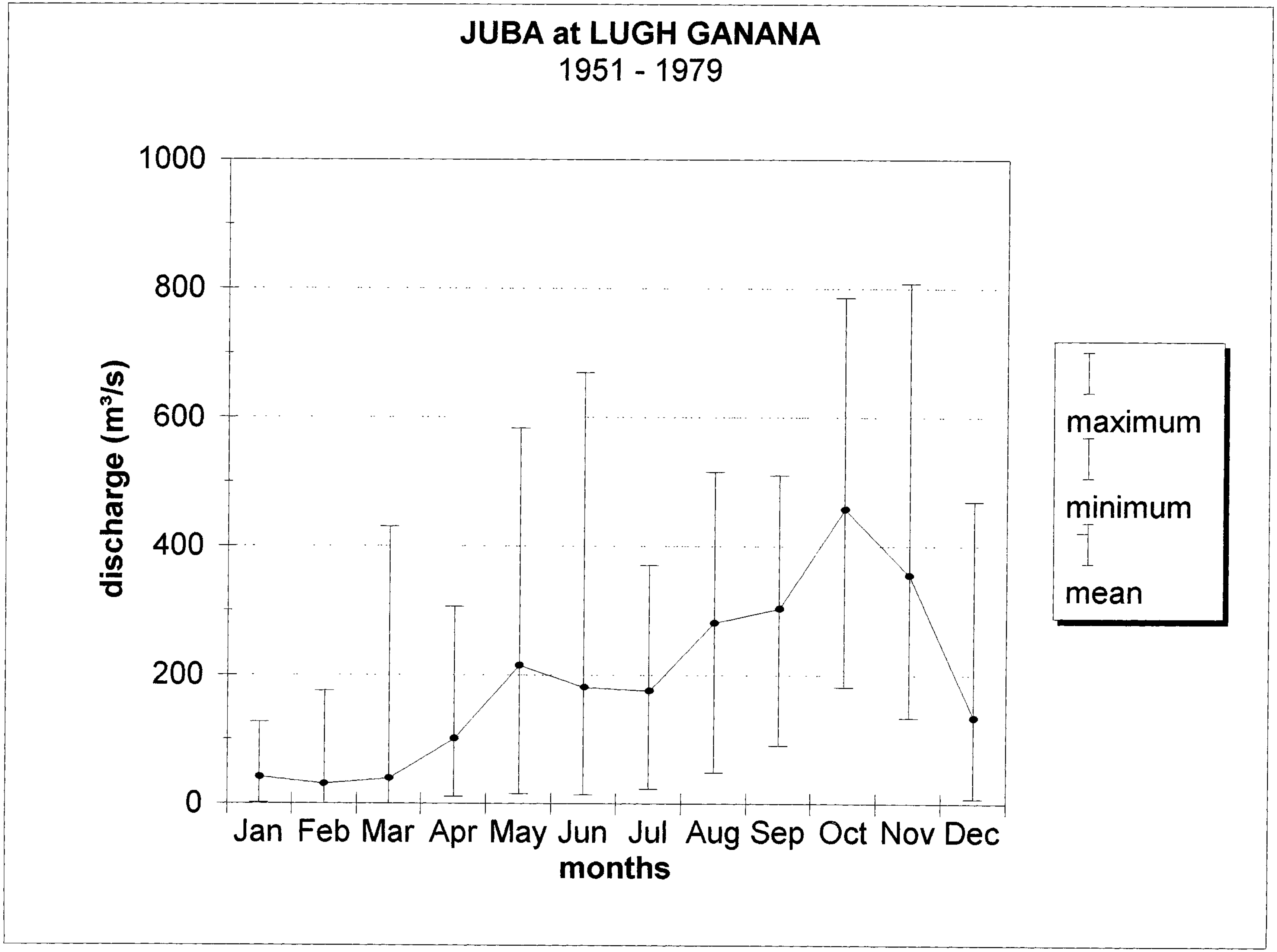


Figure 2.4

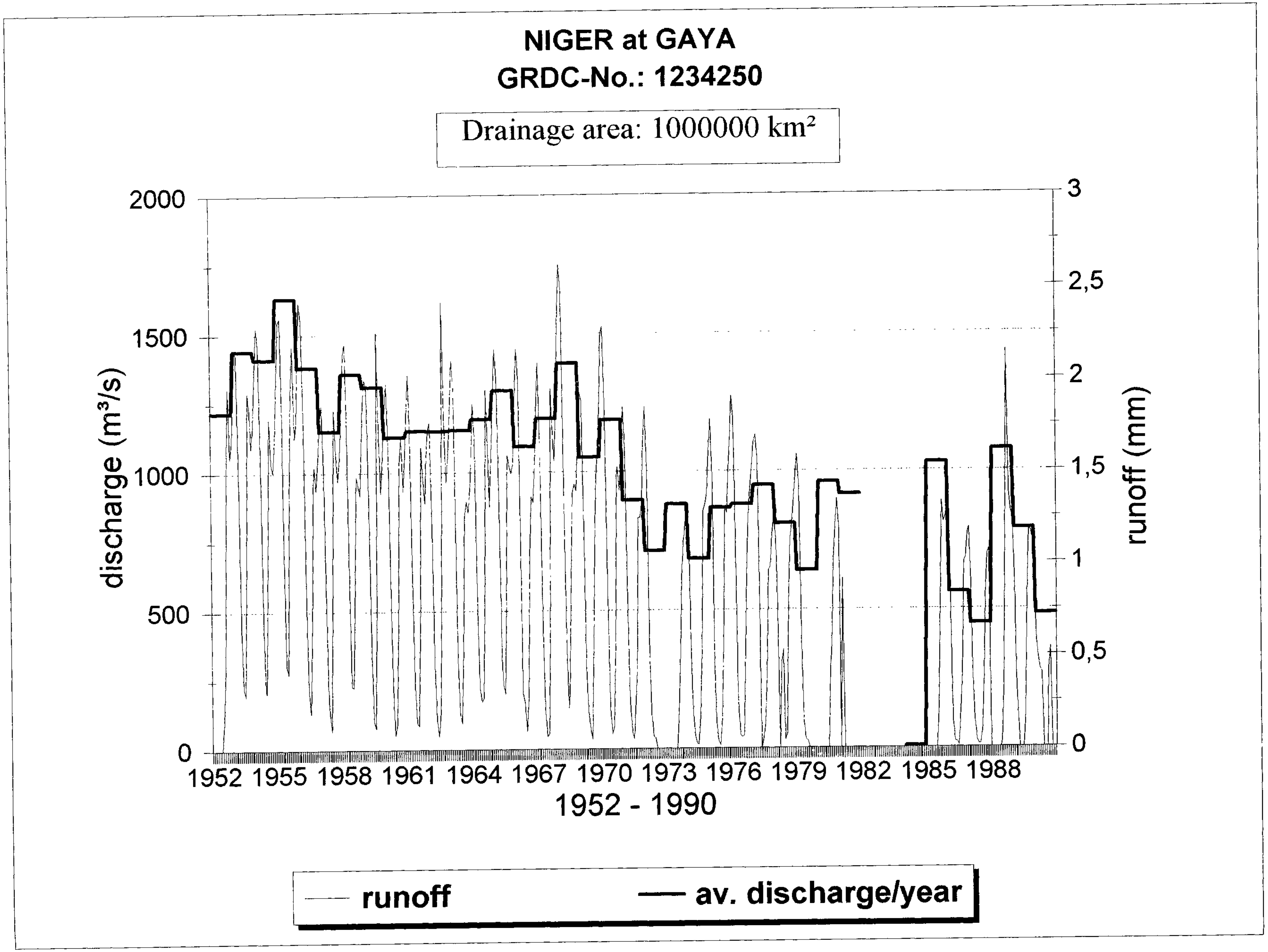

NIGER at GAYA
GRDC-No.: 1234250
Drainage area: 1000000 km²
2000
1500
1000
500
0
discharge (m³/s)
3
2,5
2
1,5
1
0,5
0
runoff (mm)
1952 1955 1958 1961 1964 1967 1970 1973 1976 1979 1982 1985 1988
1952 - 1990
runoff
av. discharge/year

Figure 2.5

GLOBAL RUNOFF DATA CENTRE (GRDC)

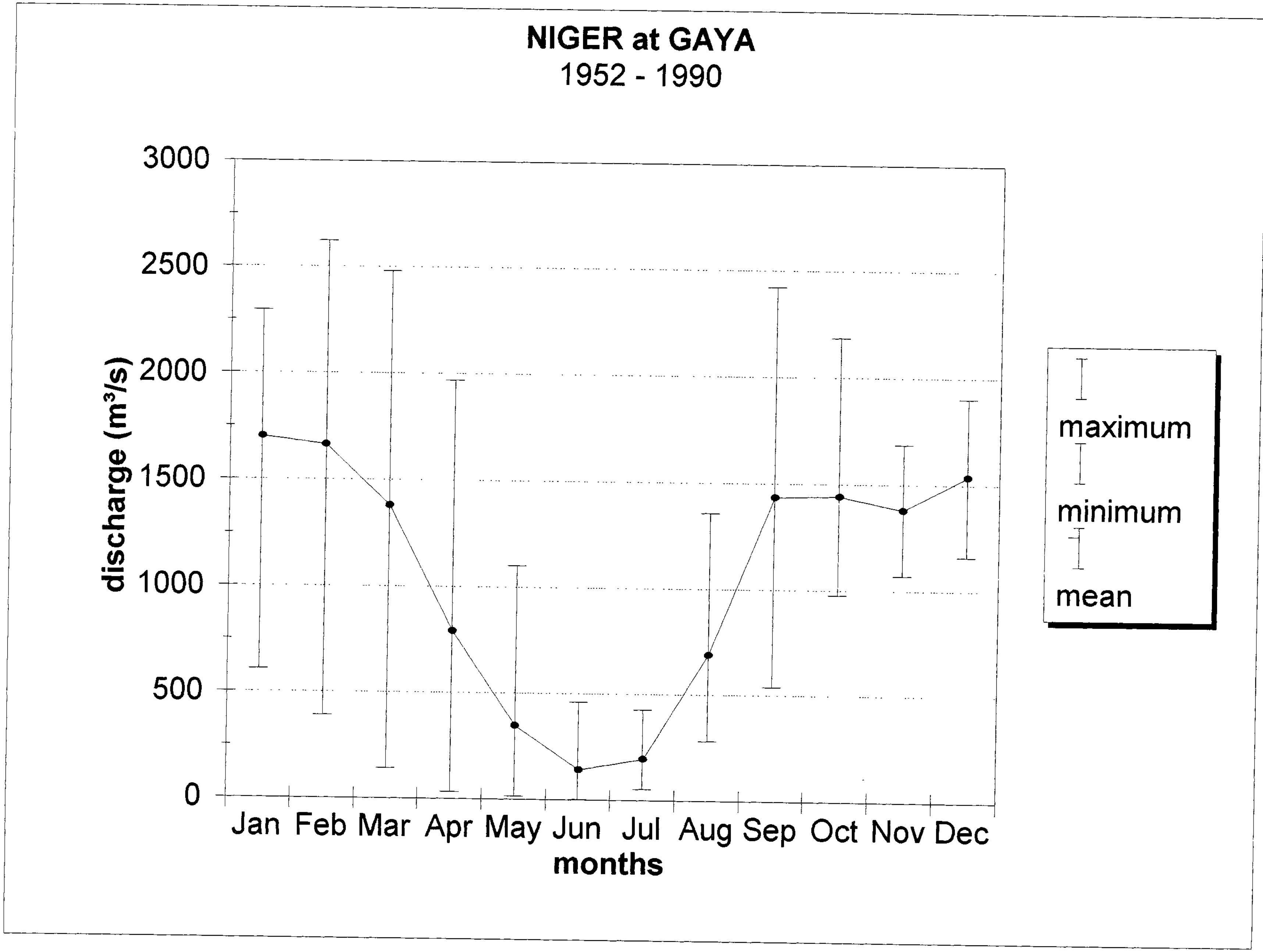


Figure 2.6

GLOBAL RUNOFF DATA CENTRE (GRDC)

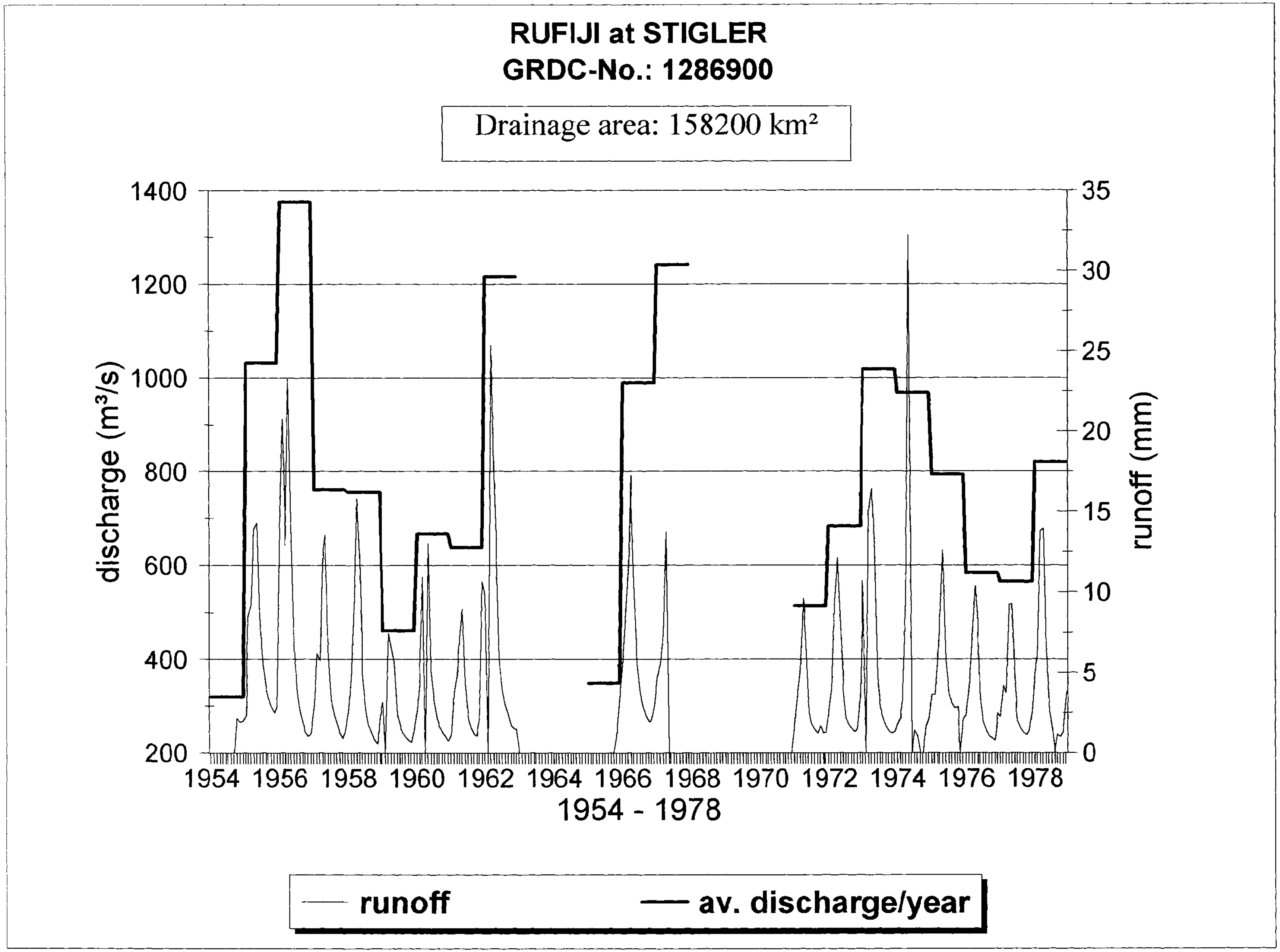


Figure 2.7

GLOBAL RUNOFF DATA CENTRE (GRDC)

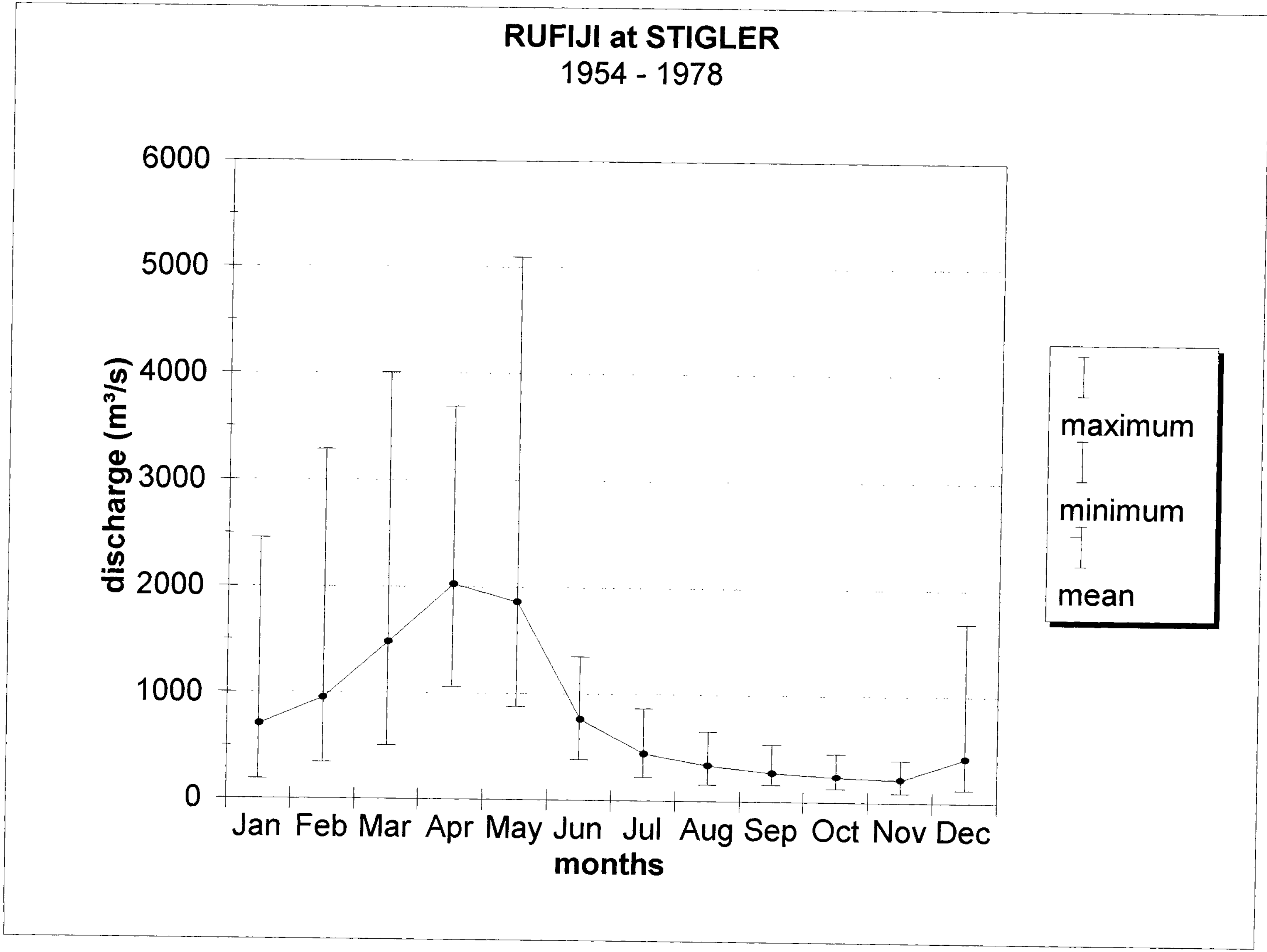


Figure 2.8

GLOBAL RUNOFF DATA CENTRE (GRDC)

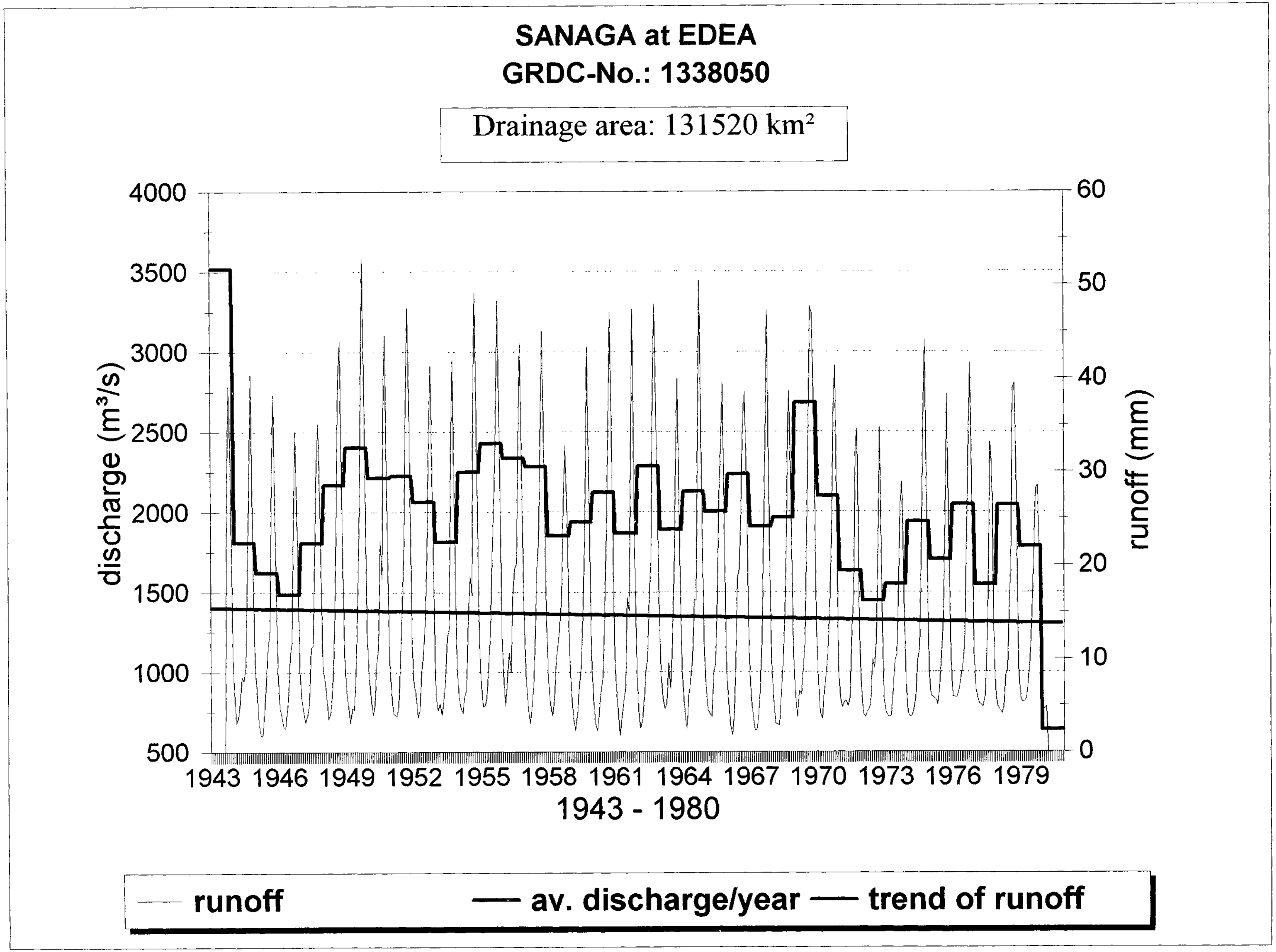


Figure 2.9

GLOBAL RUNOFF DATA CENTRE (GRDC)

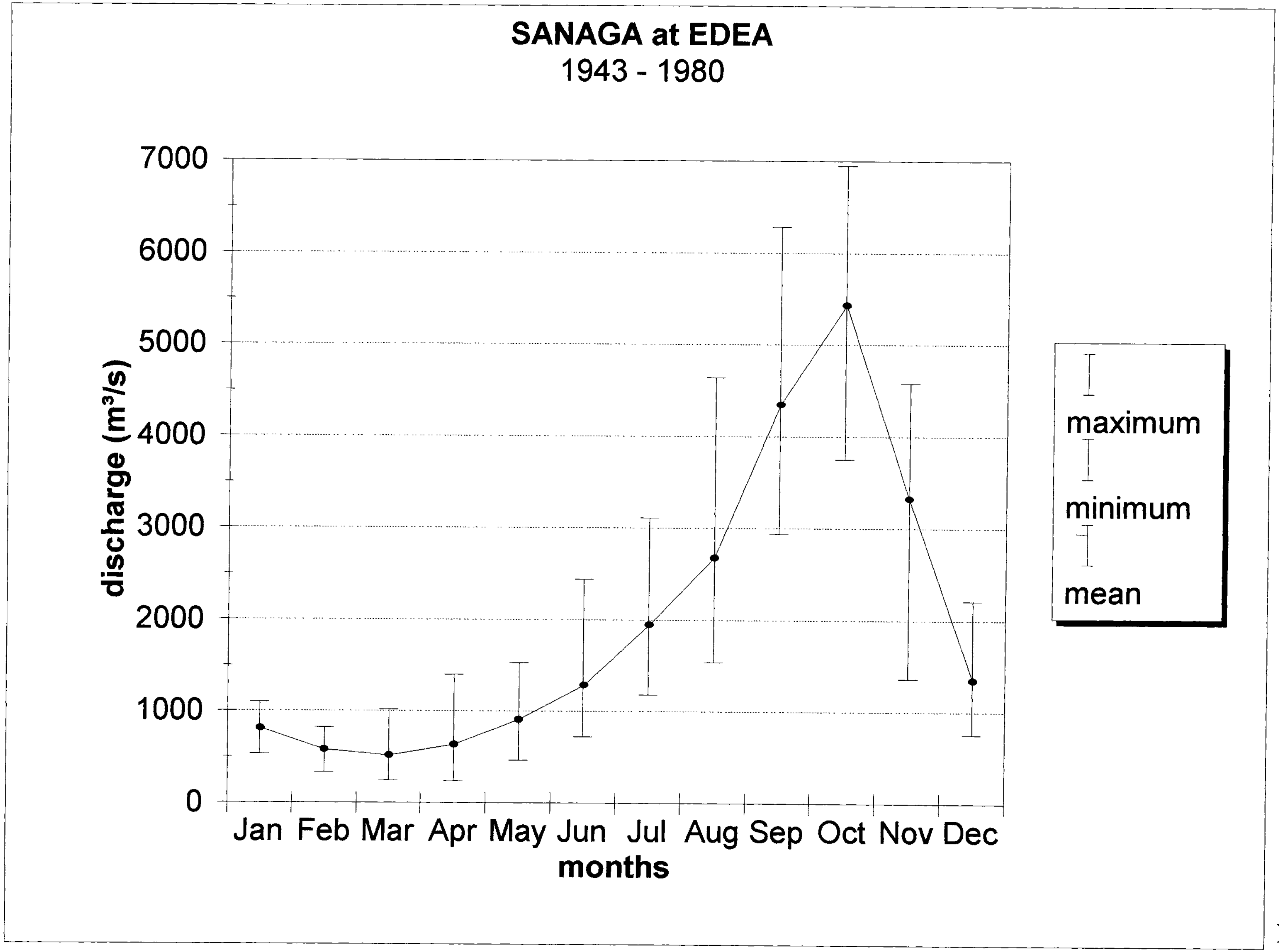


Figure 2.10

GLOBAL RUNOFF DATA CENTRE (GRDC)

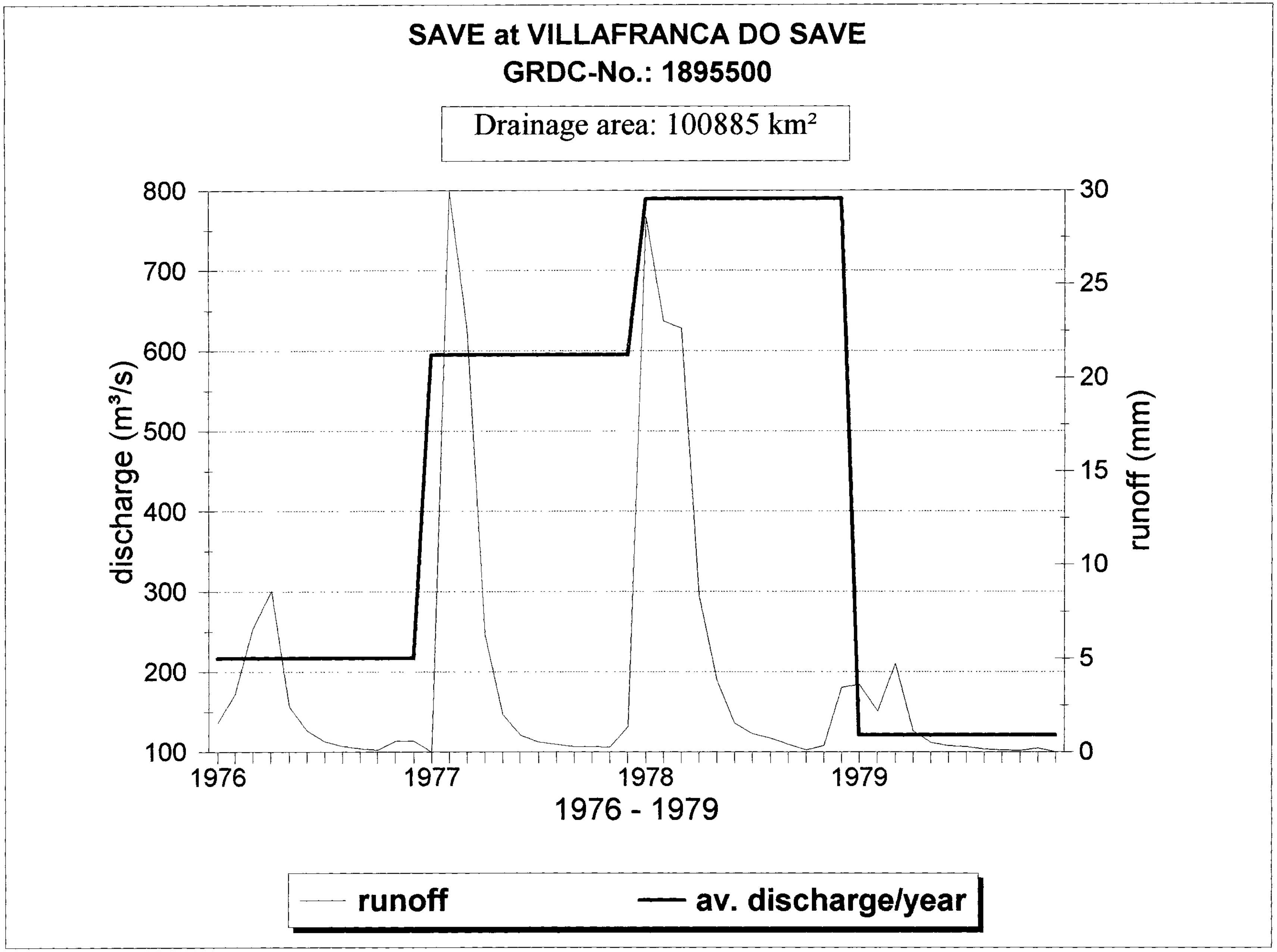


Figure 2.11

GLOBAL RUNOFF DATA CENTRE (GRDC)

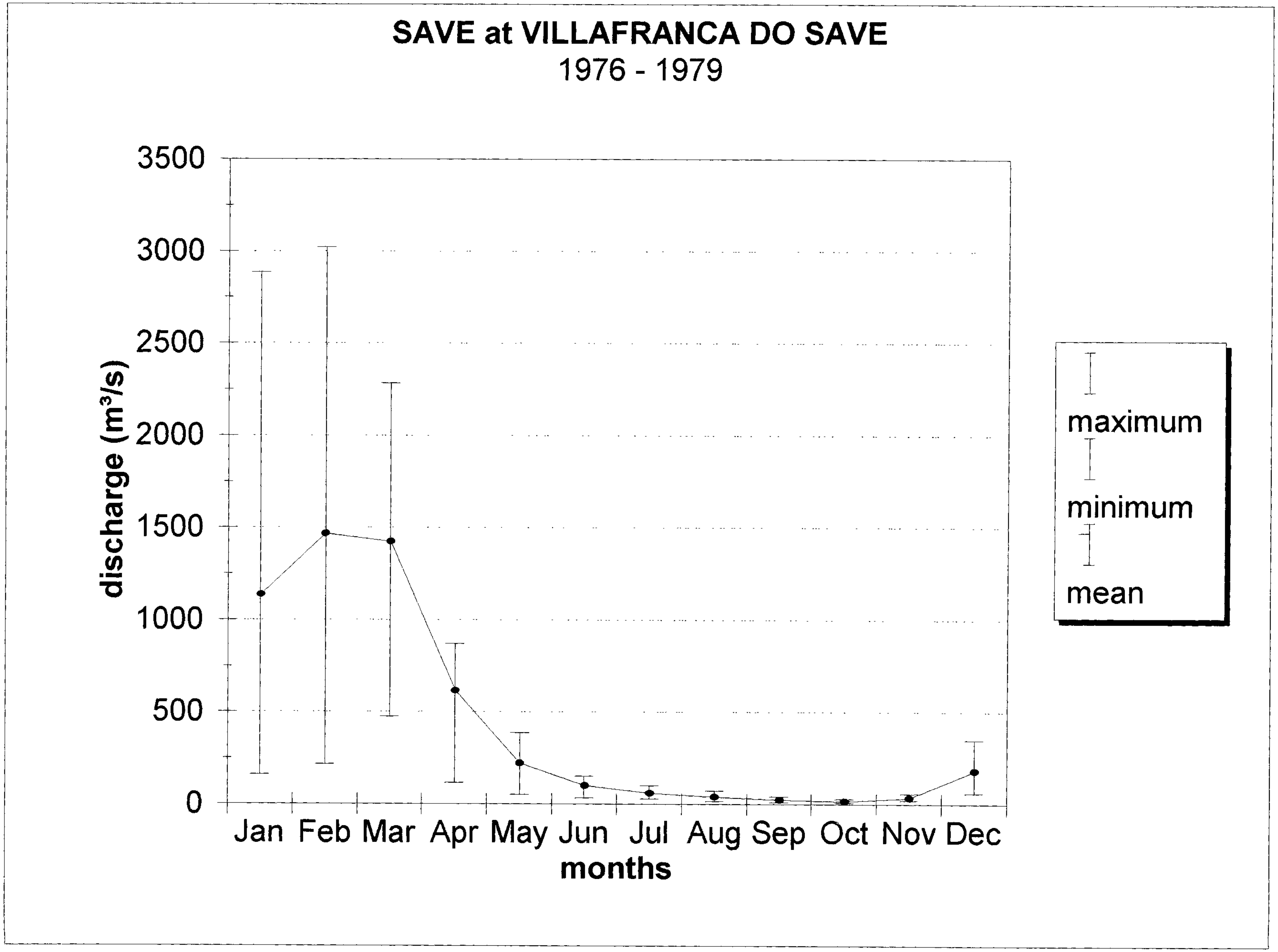


Figure 2.12

GLOBAL RUNOFF DATA CENTRE (GRDC)

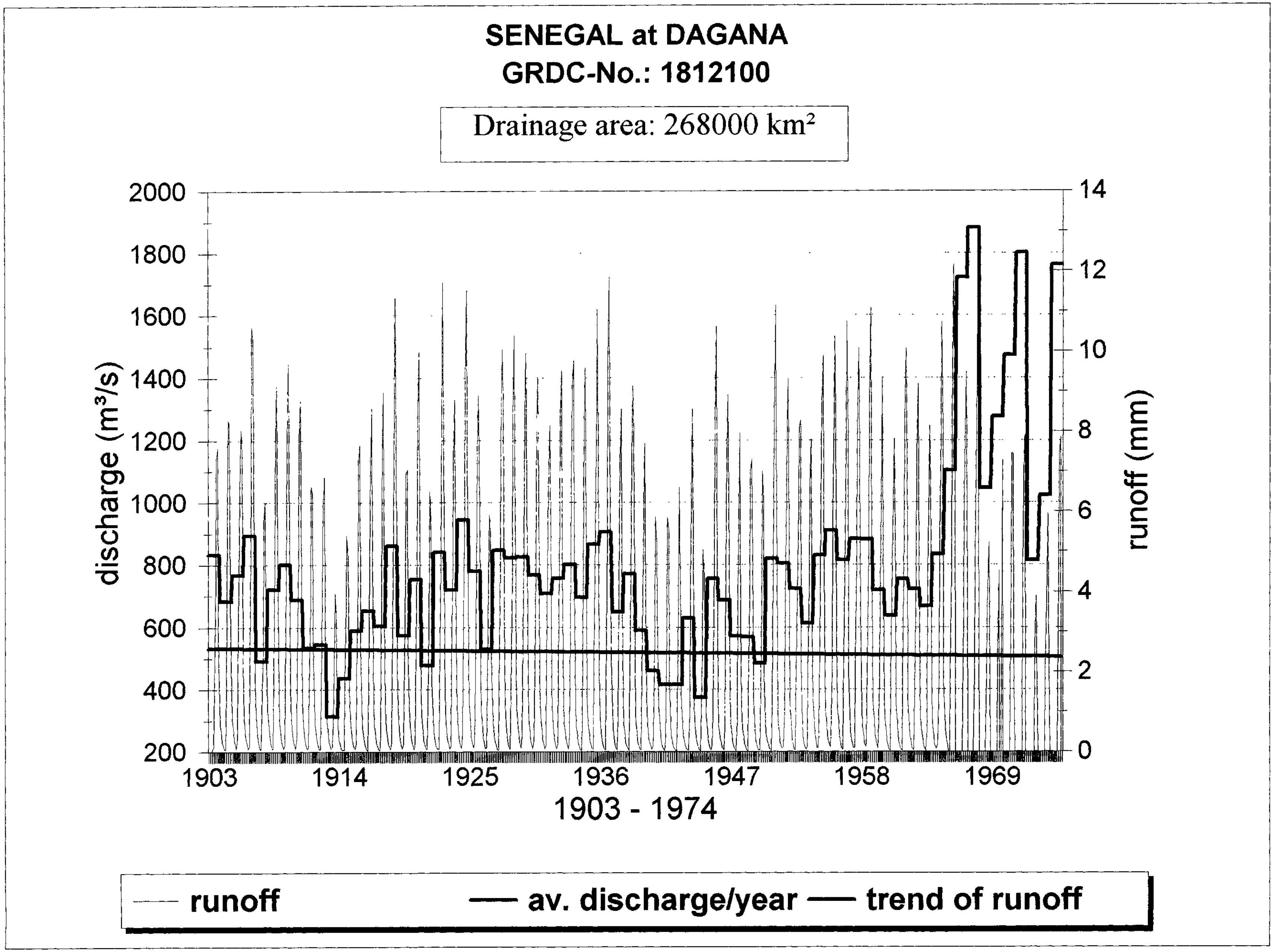


Figure 2.13

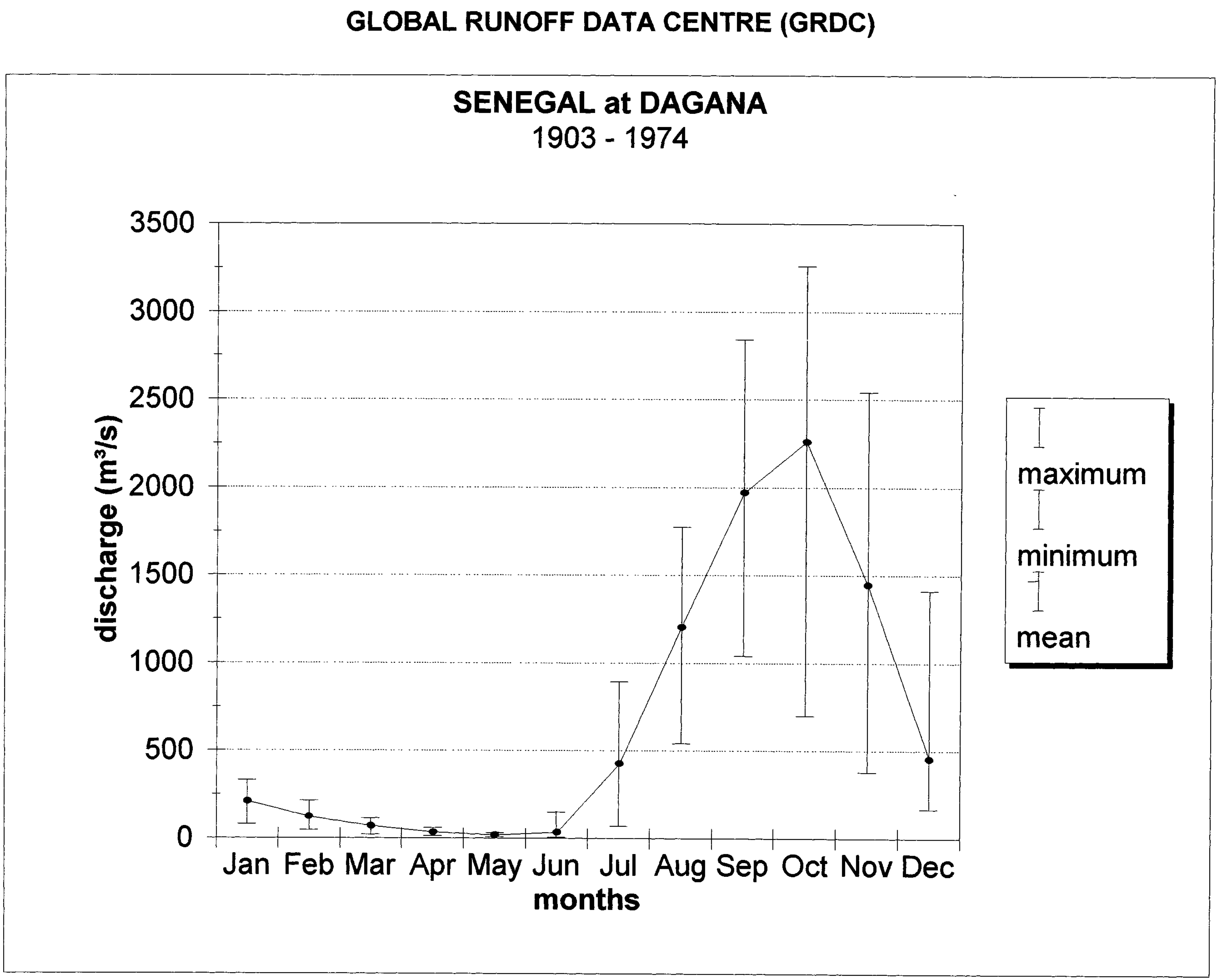

GLOBAL RUNOFF DATA CENTRE (GRDC)
SENEGAL at DAGANA
1903 - 1974
3500
3000
2500
2000
1500
1000
500
0
discharge (m³/s)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
months
maximum
minimum
mean

Figure 2.14

GLOBAL RUNOFF DATA CENTRE (GRDC)

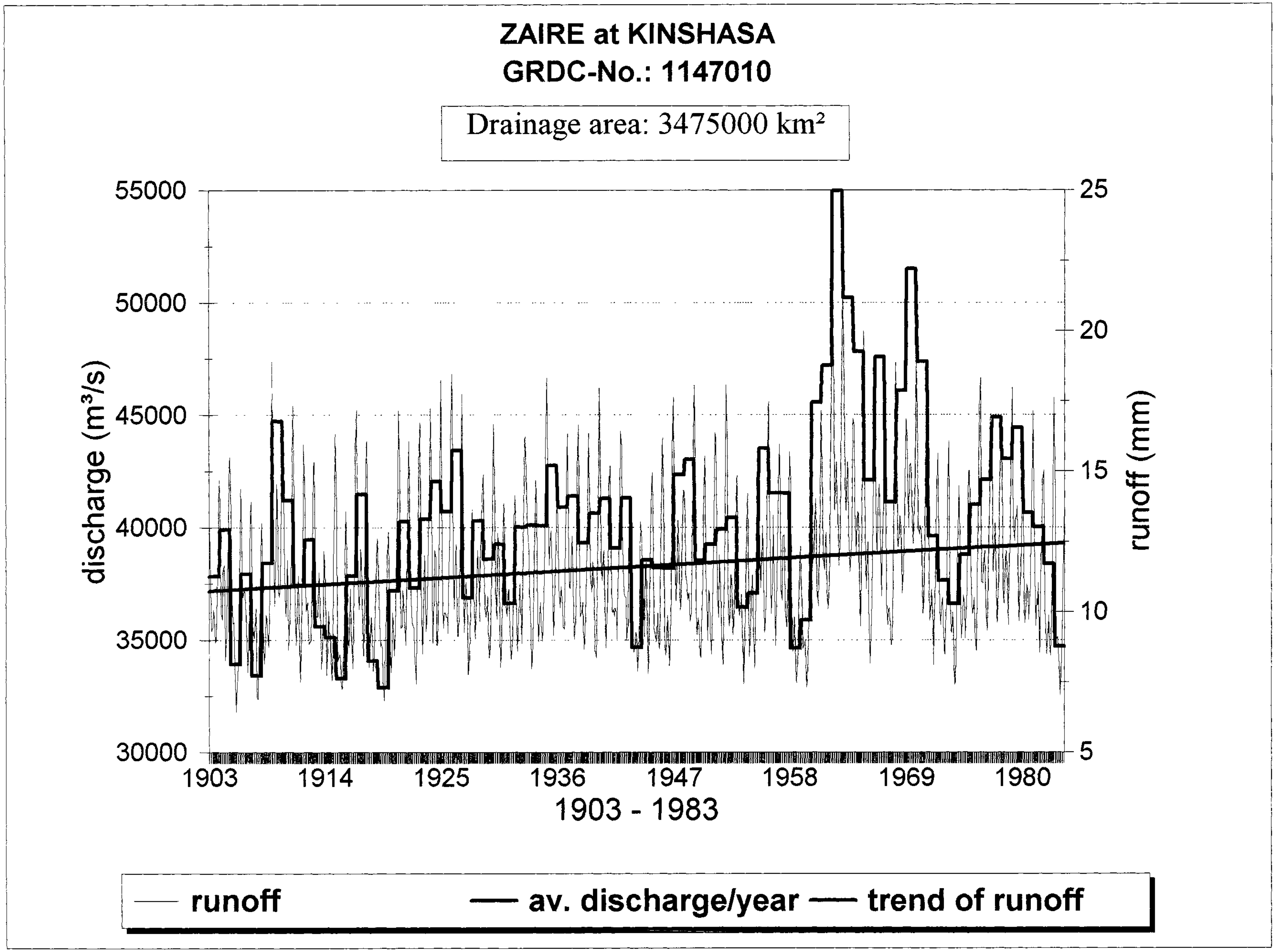


Figure 2.15

GLOBAL RUNOFF DATA CENTRE (GRDC)

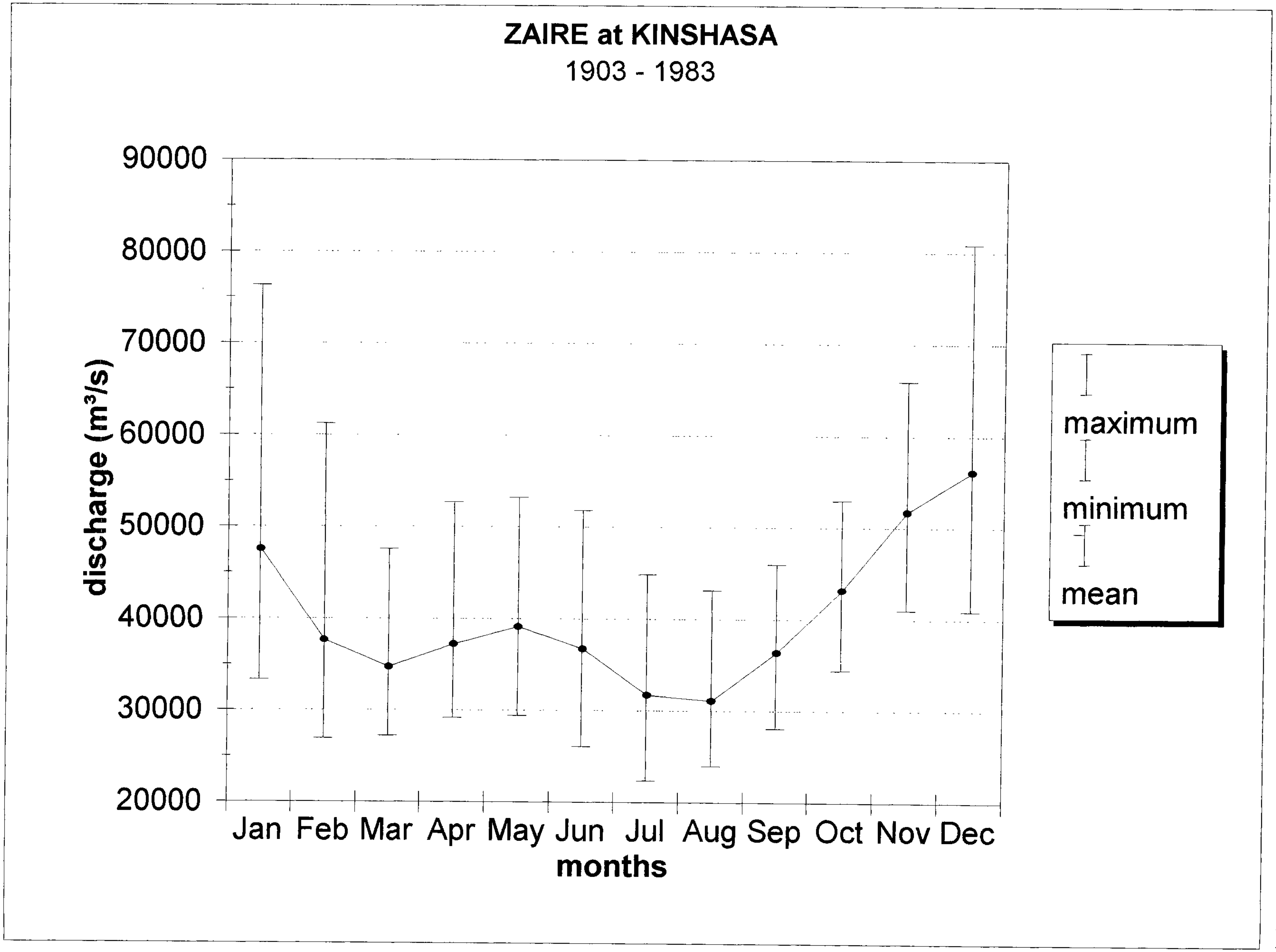


Figure 2.16

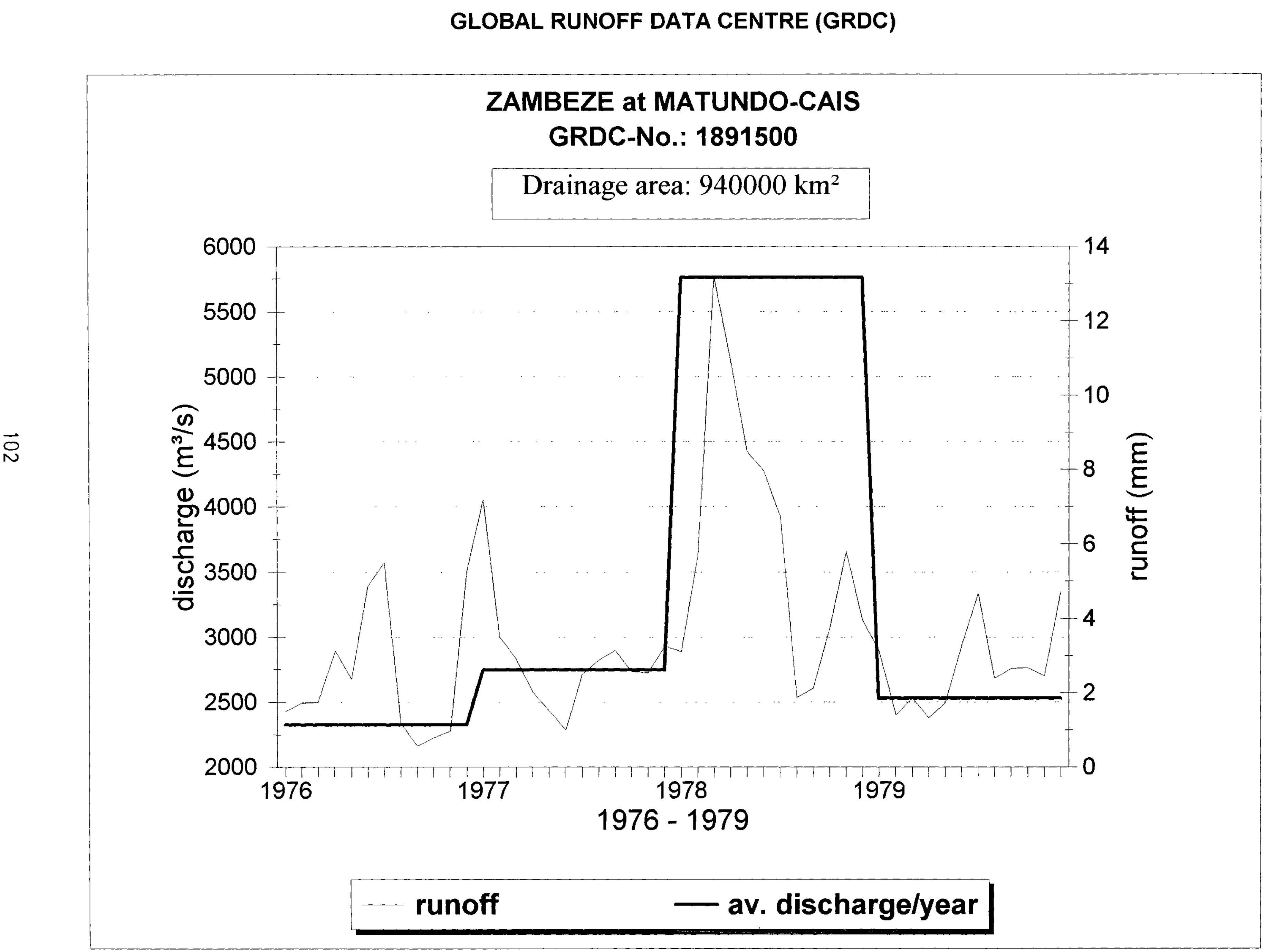

GLOBAL RUNOFF DATA CENTRE (GRDC)
ZAMBEZE at MATUNDO-CAIS
GRDC-No.: 1891500
Drainage area: 940000 km²
discharge (m³/s)
6000
5500
5000
4500
4000
3500
3000
2500
2000
runoff (mm)
14
12
10
8
6
4
2
0
1976
1977
1978
1979
1976 - 1979
runoff
av. discharge/year

Figure 2.17

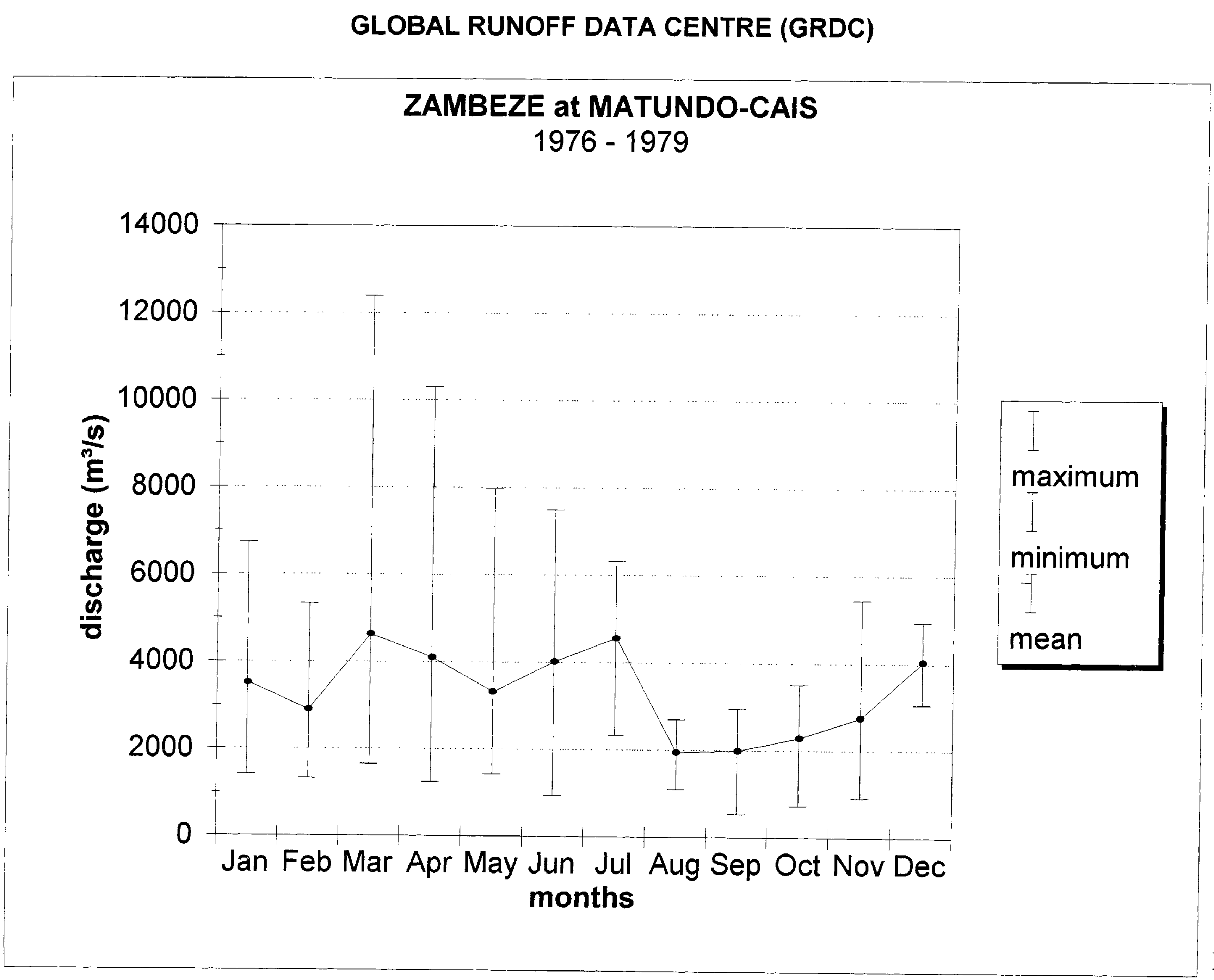

GLOBAL RUNOFF DATA CENTRE (GRDC)
ZAMBEZE at MATUNDO-CAIS
1976 - 1979
discharge (m³/s)
14000
12000
10000
8000
6000
4000
2000
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
months
maximum
minimum
mean

Figure 2.18

Asia

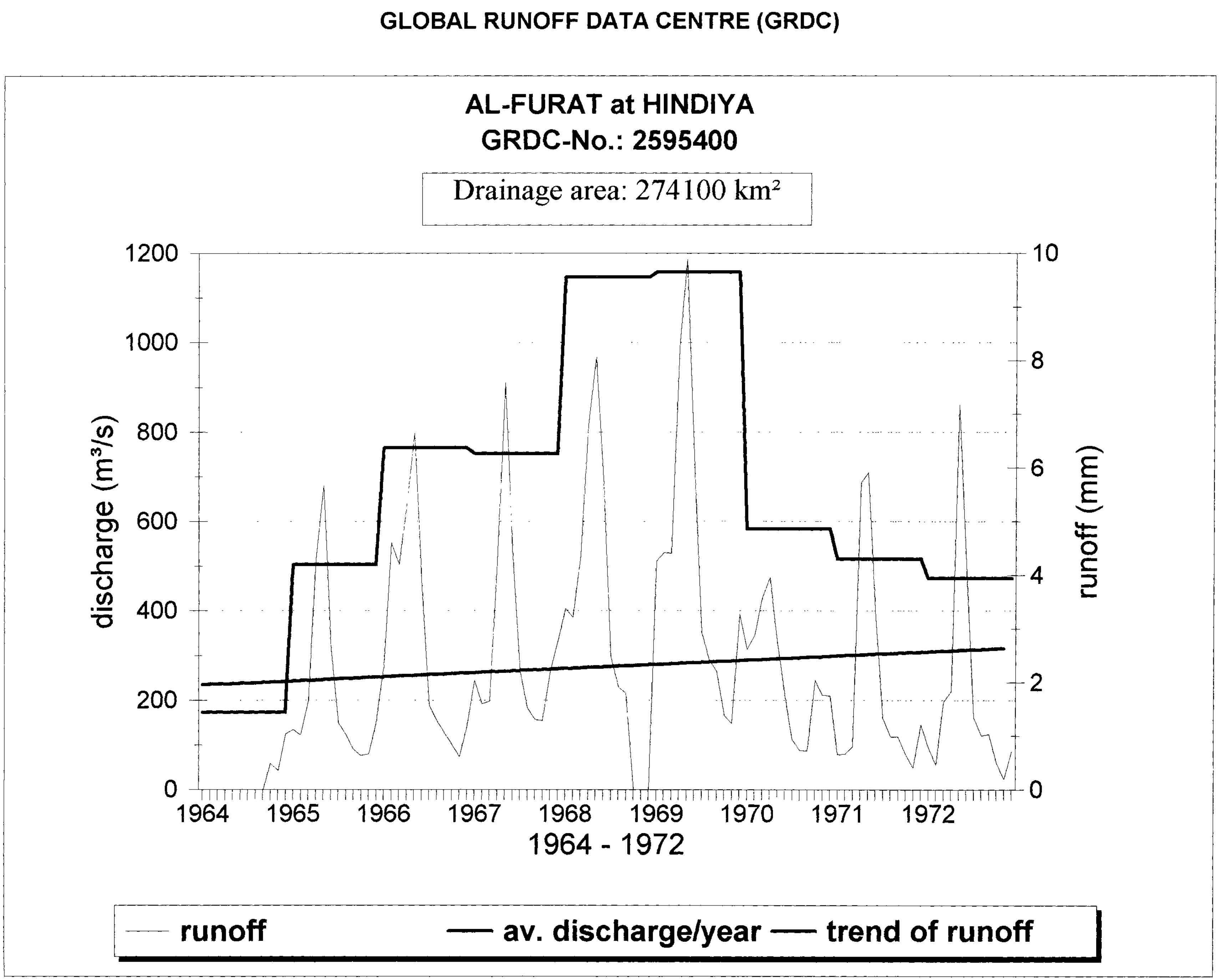

GLOBAL RUNOFF DATA CENTRE (GRDC)
AL-FURAT at HINDIYA
GRDC-No.: 2595400
Drainage area: 274100 km²
discharge (m³/s)
runoff (mm)
1964 - 1972
1200
1000
800
600
400
200
0
10
8
6
4
2
0
1964
1965
1966
1967
1968
1969
1970
1971
1972
runoff
av. discharge/year
trend of runoff

Figure 2.19

GLOBAL RUNOFF DATA CENTRE (GRDC)

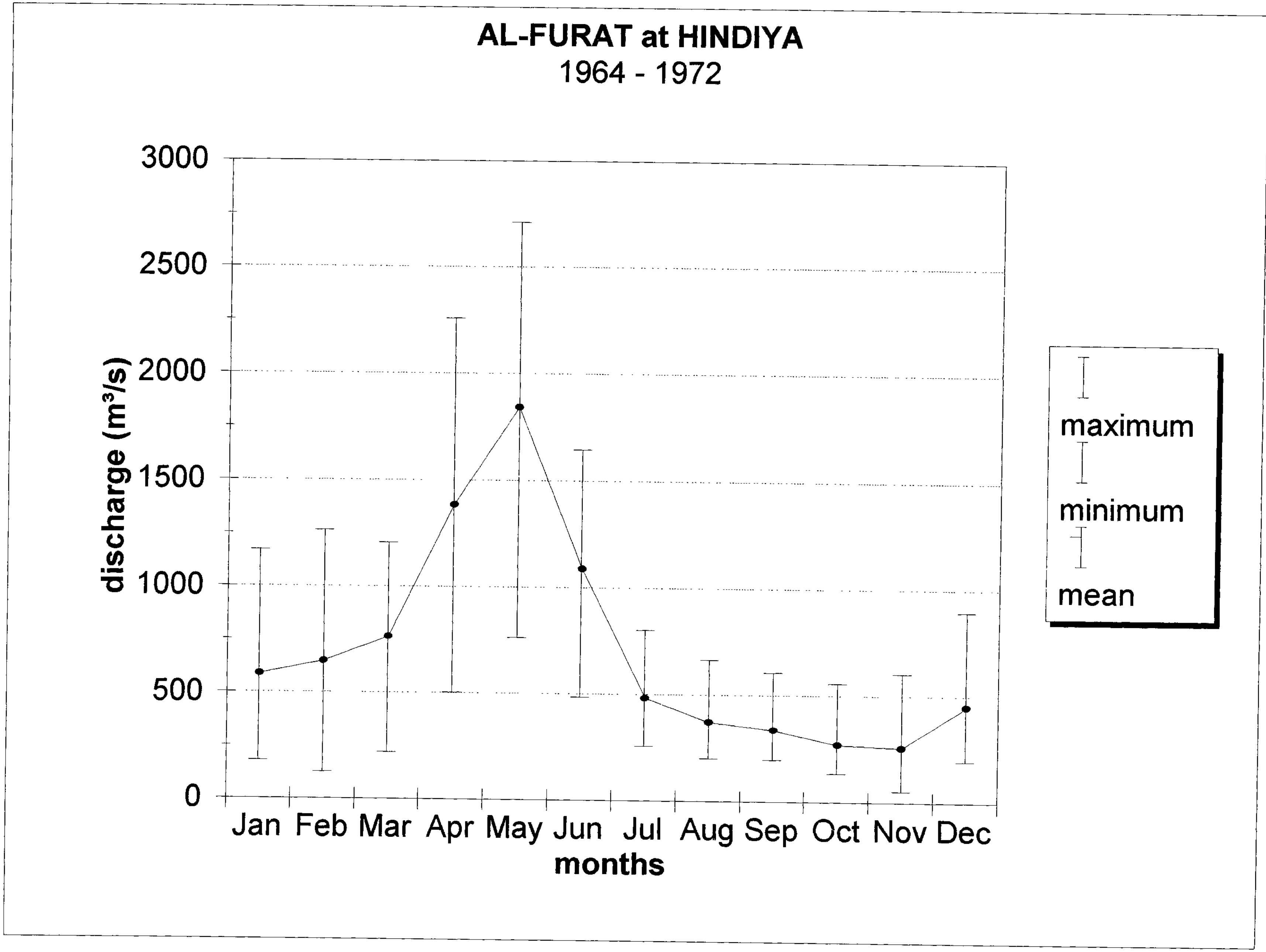


Figure 2.20

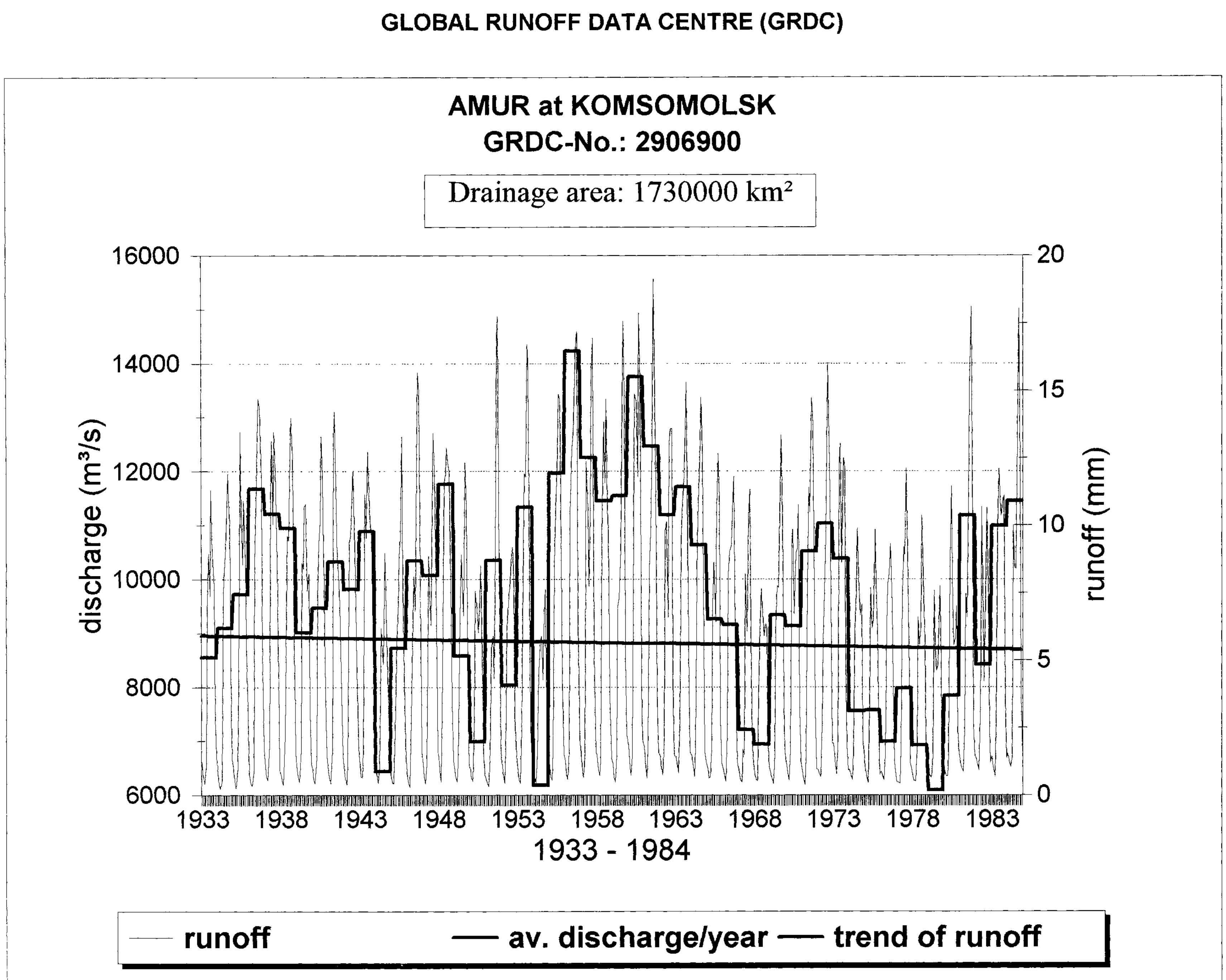

GLOBAL RUNOFF DATA CENTRE (GRDC)
AMUR at KOMSOMOLSK
GRDC-No.: 2906900
Drainage area: 1730000 km²
discharge (m³/s)
runoff (mm)
16000
14000
12000
10000
8000
6000
20
15
10
5
0
1933
1938
1943
1948
1953
1958
1963
1968
1973
1978
1983
1933 - 1984
runoff
av. discharge/year
trend of runoff

Figure 2.21

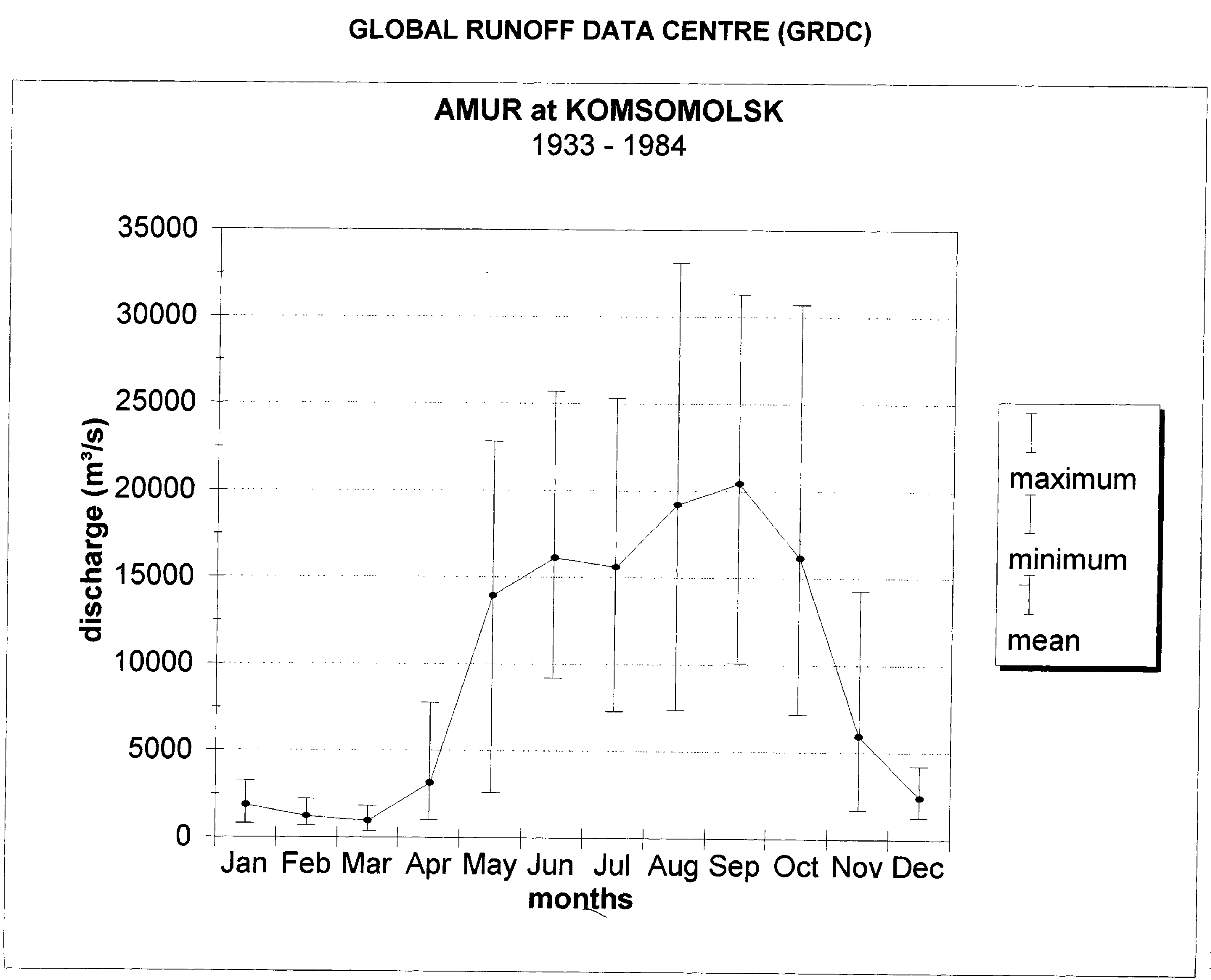

GLOBAL RUNOFF DATA CENTRE (GRDC)
AMUR at KOMSOMOLSK
1933 - 1984
discharge (m³/s)
35000
30000
25000
20000
15000
10000
5000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
months
maximum
minimum
mean

Figure 2.22

GLOBAL RUNOFF DATA CENTRE (GRDC)

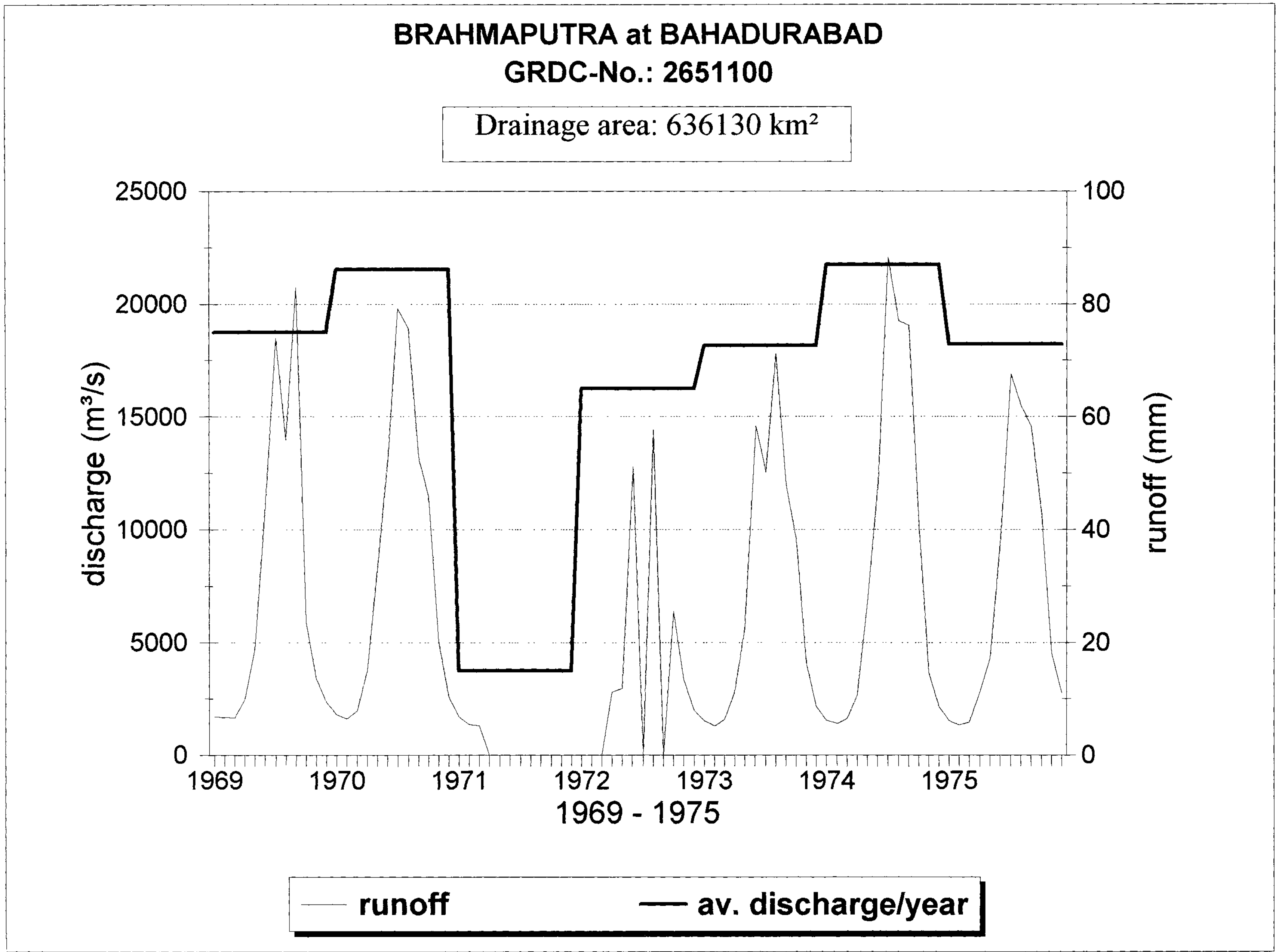


Figure 2.23

GLOBAL RUNOFF DATA CENTRE (GRDC)

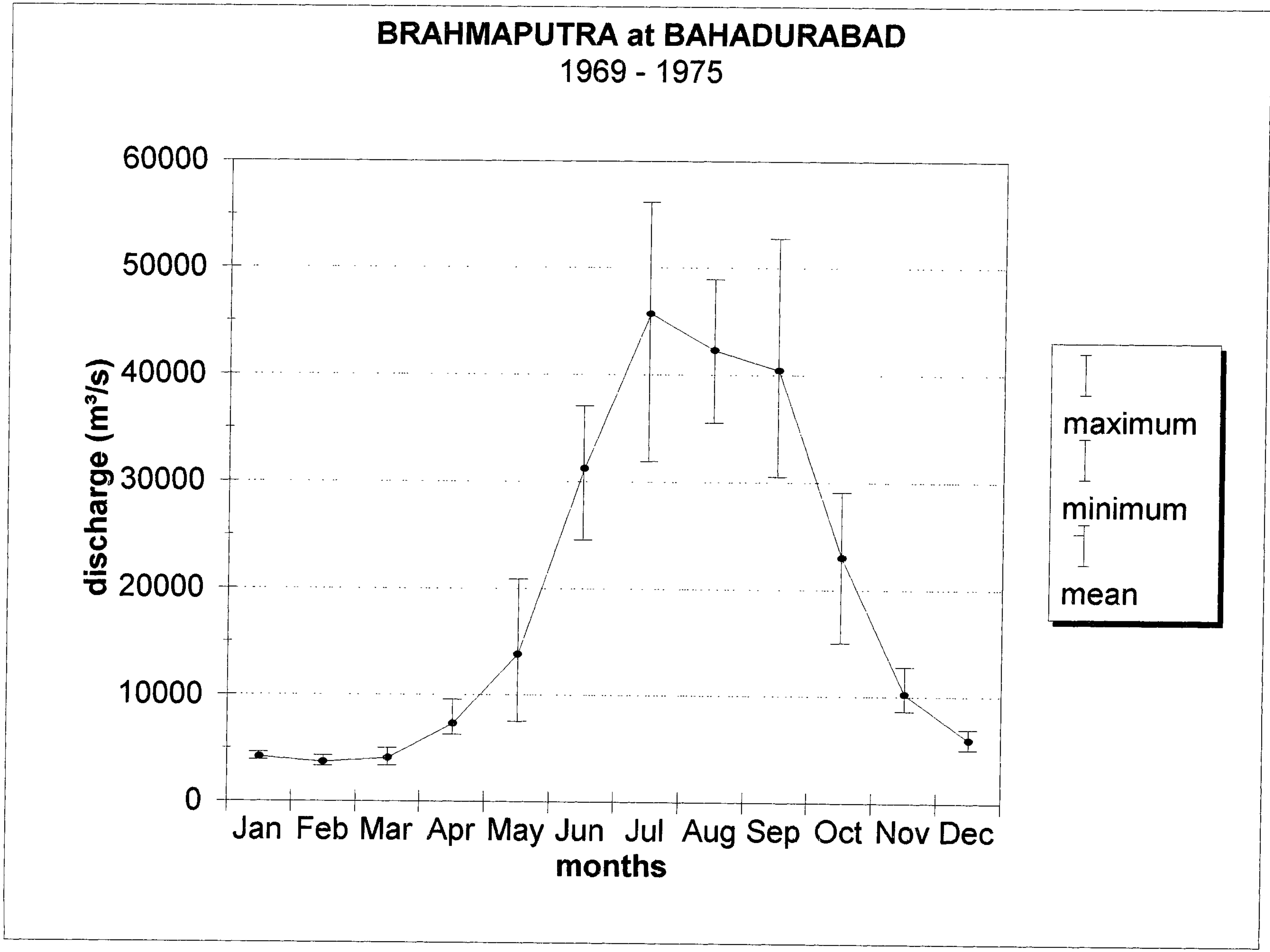


Figure 2.24

GLOBAL RUNOFF DATA CENTRE (GRDC)

CHANGJIANG (YANGTZE) at DATONG
GRDC-No.: 2181900

Drainage area: 1705383 km²

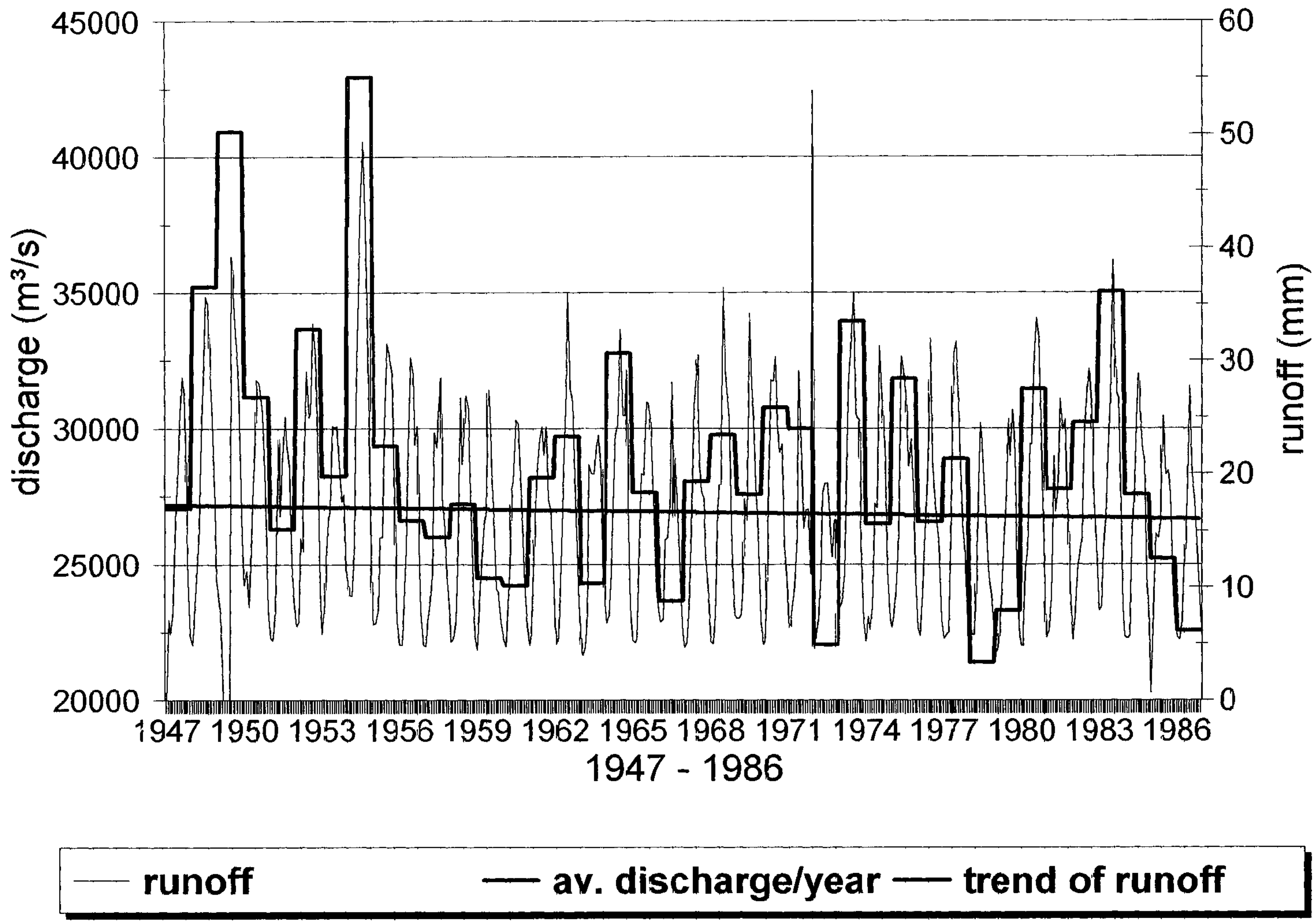


Figure 2.25

GLOBAL RUNOFF DATA CENTRE (GRDC)

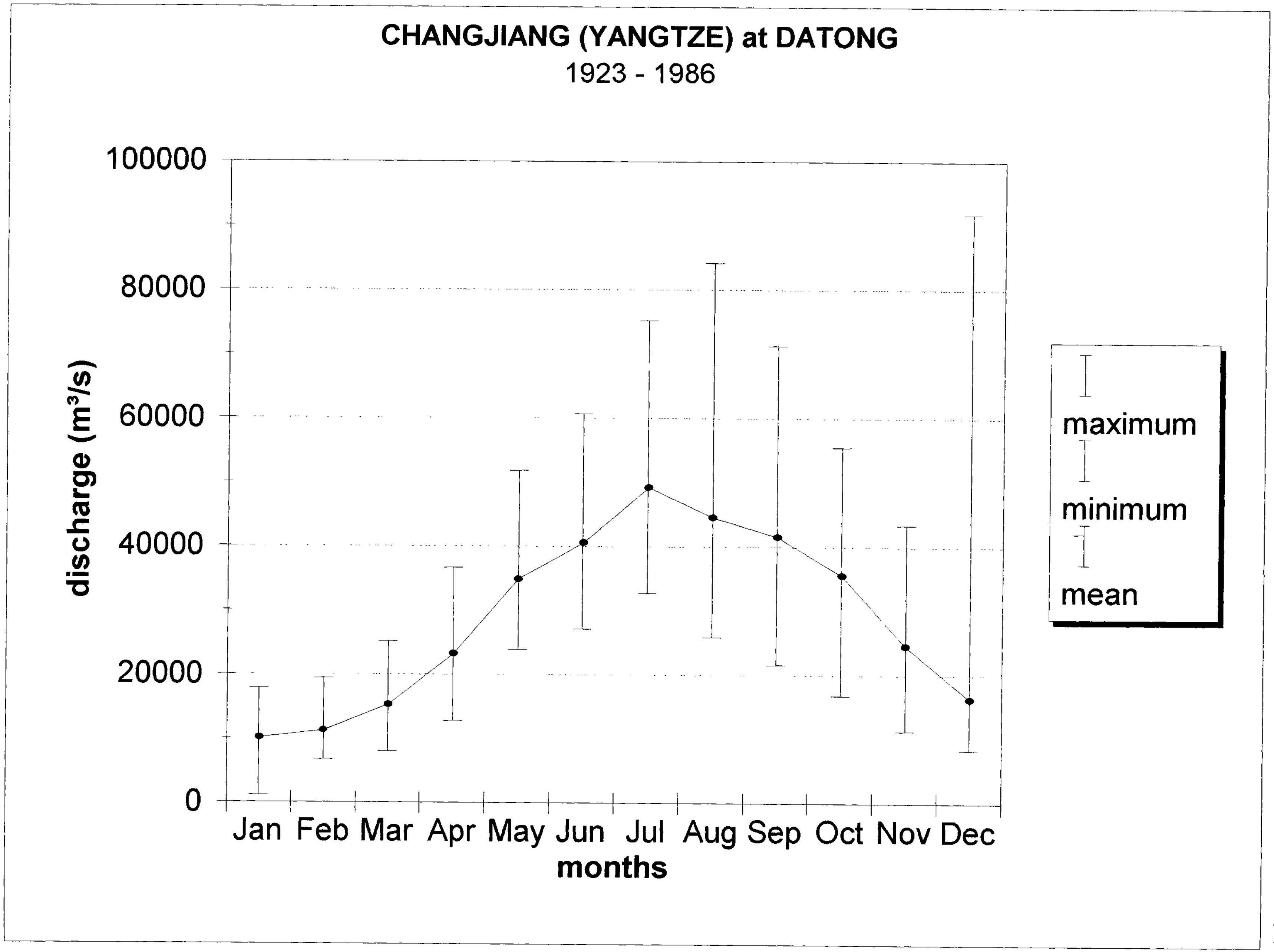


Figure 2.26

GLOBAL RUNOFF DATA CENTRE (GRDC)

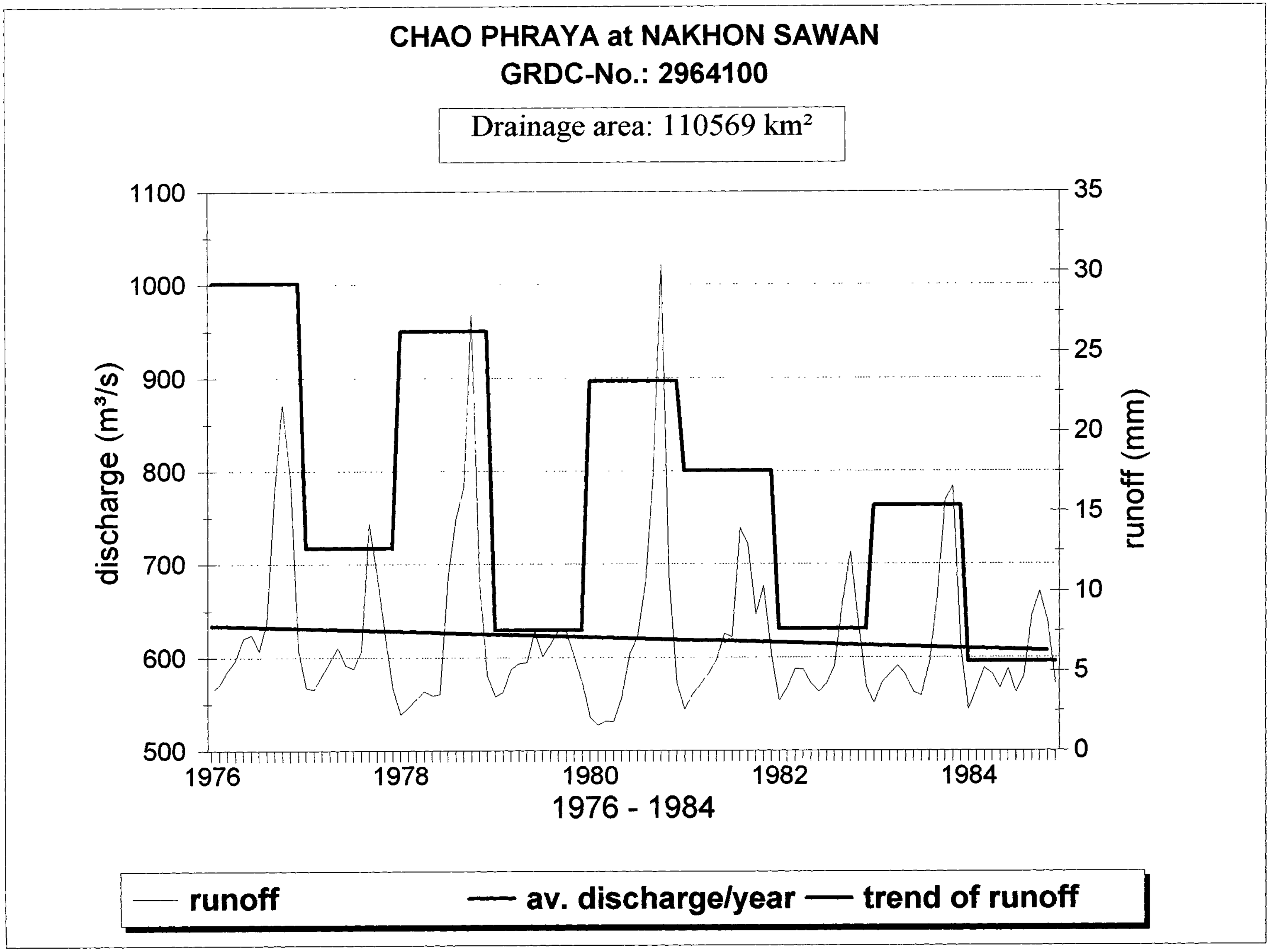


Figure 2.2

GLOBAL RUNOFF DATA CENTRE (GRDC)

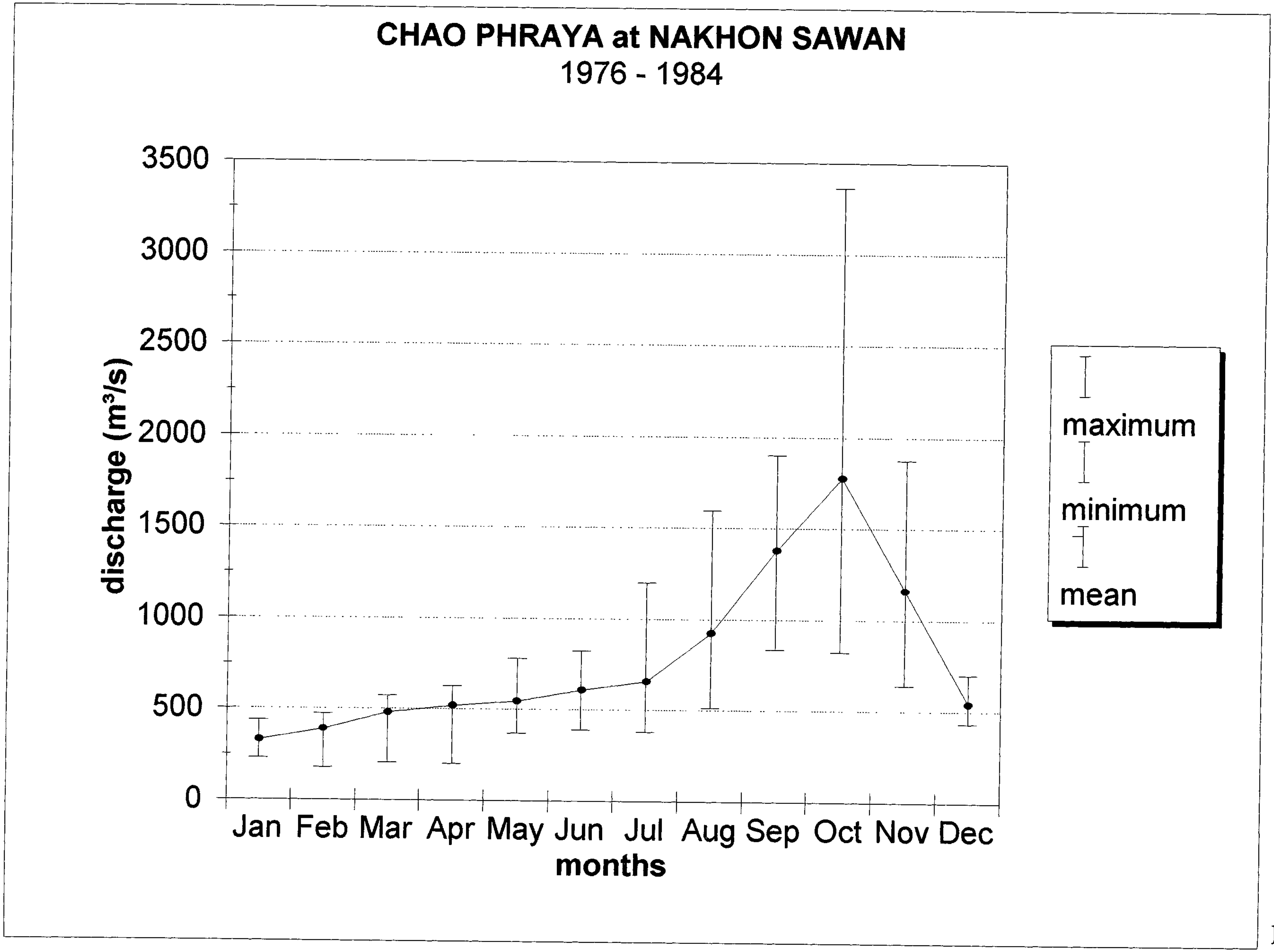


Figure 2.27

GLOBAL RUNOFF DATA CENTRE (GRDC)

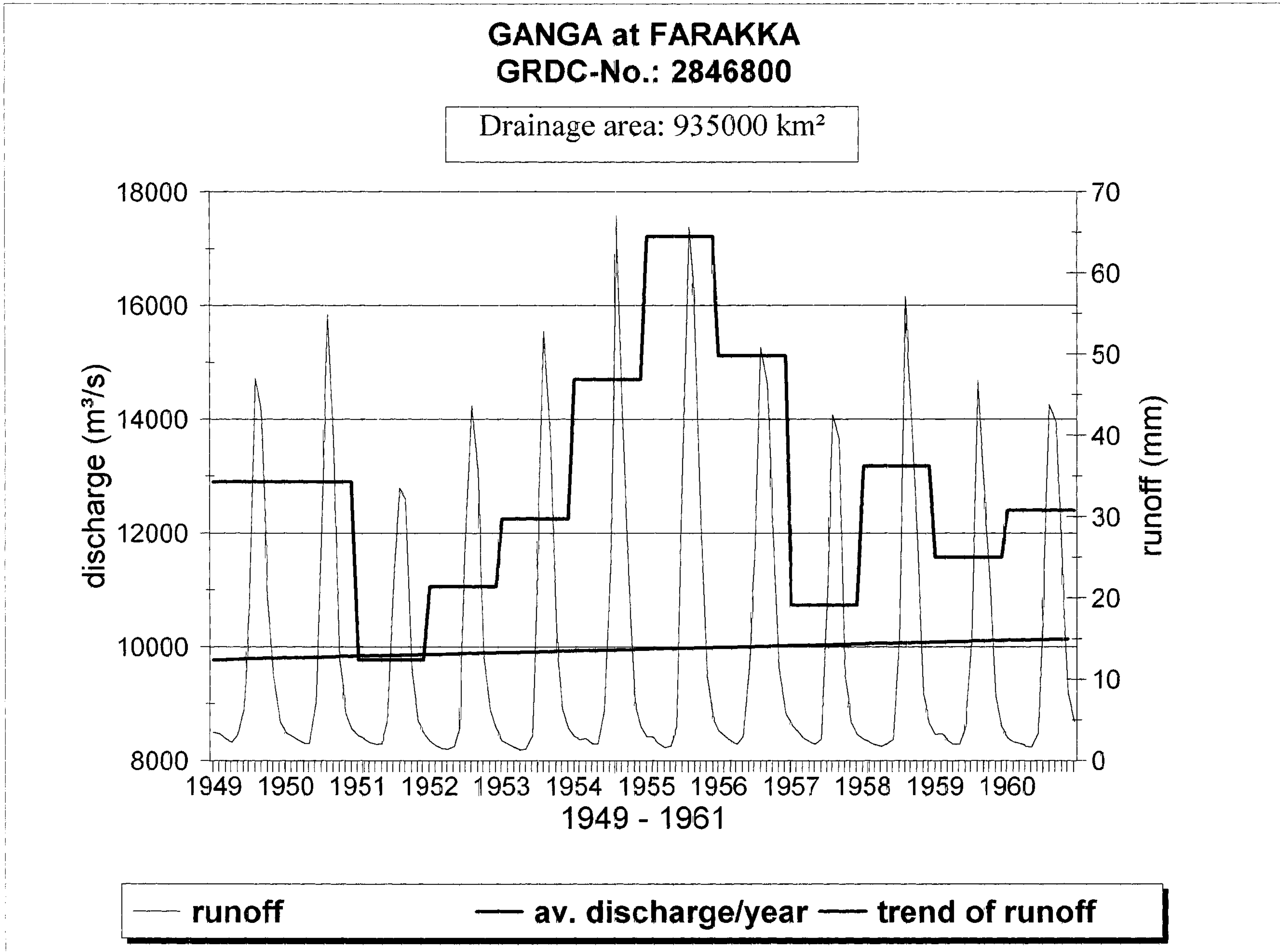


Figure 2.28

GLOBAL RUNOFF DATA CENTRE (GRDC)

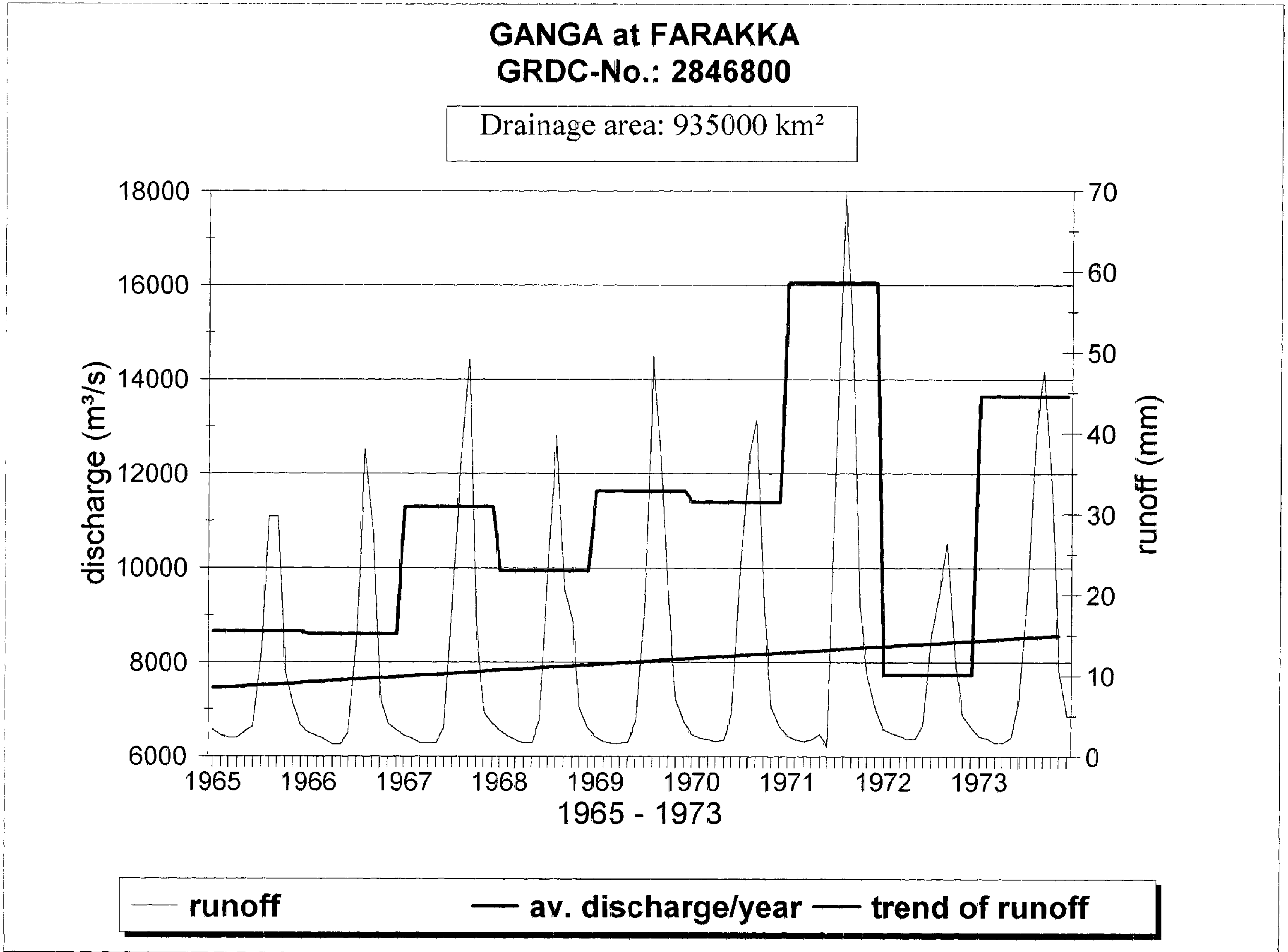


Figure 2.29

GLOBAL RUNOFF DATA CENTRE (GRDC)

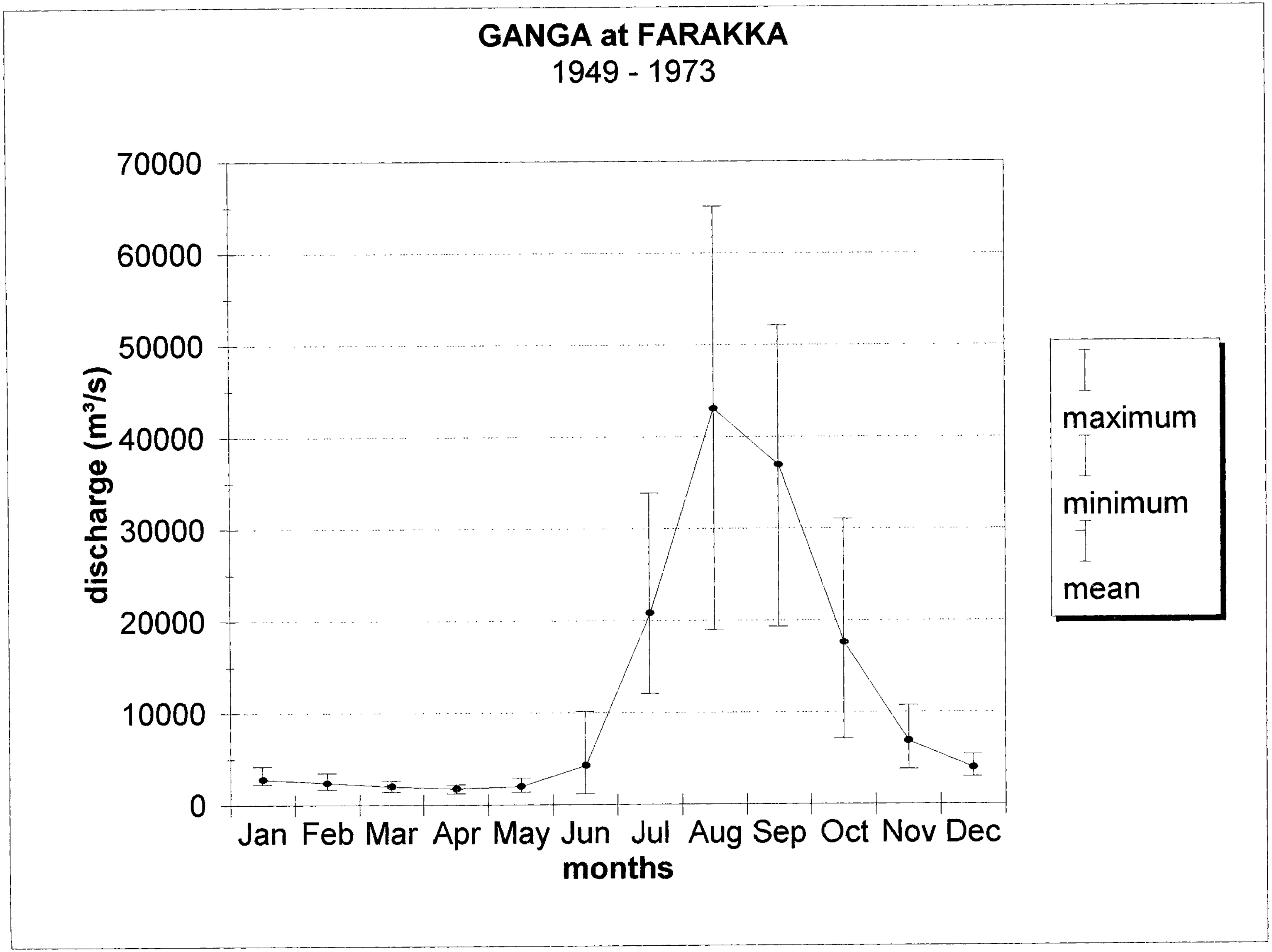


Figure 2.30

GLOBAL RUNOFF DATA CENTRE (GRDC)

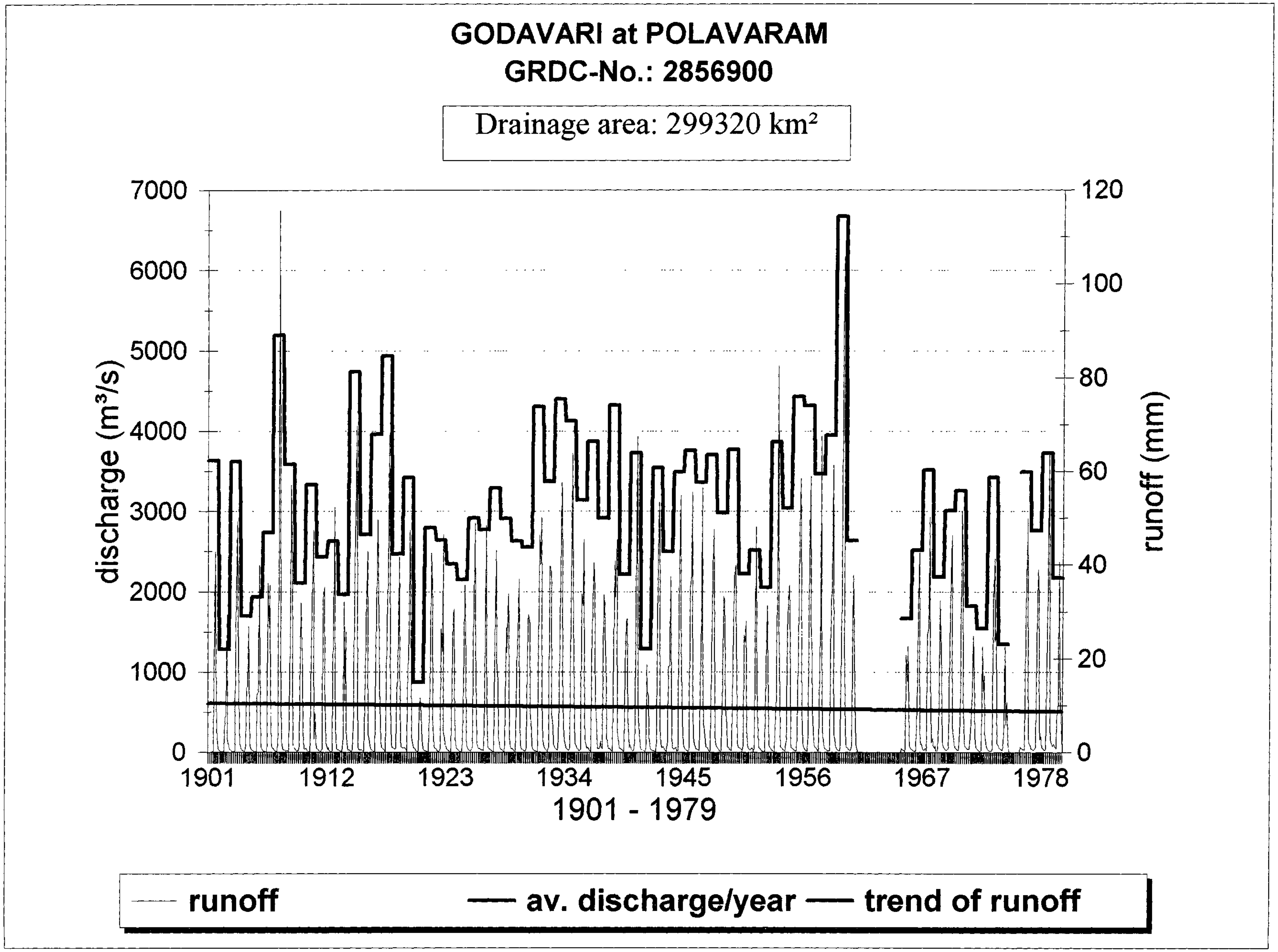


Figure 2.31

GLOBAL RUNOFF DATA CENTRE (GRDC)

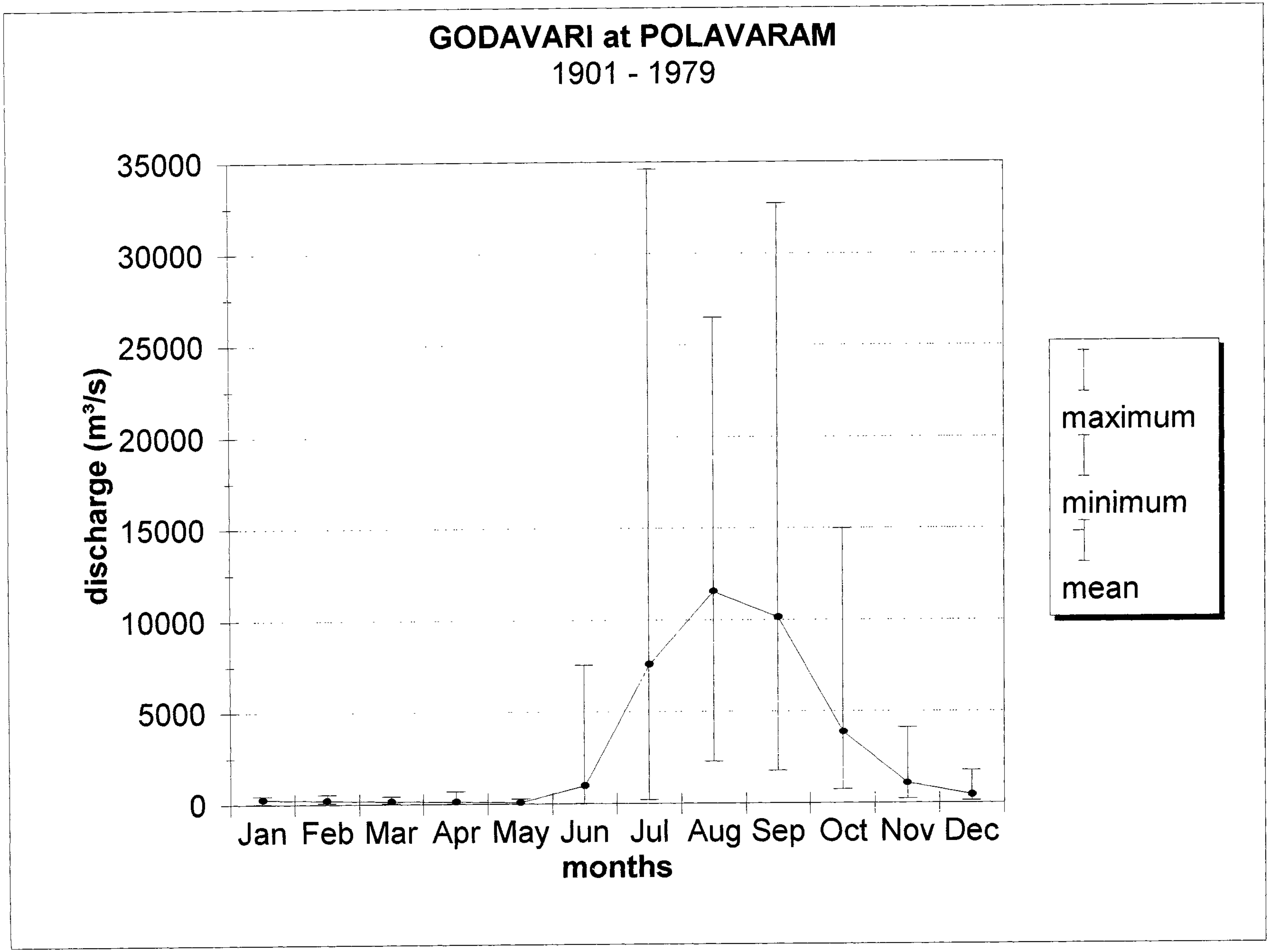


Figure 2.32

GLOBAL RUNOFF DATA CENTRE (GRDC)

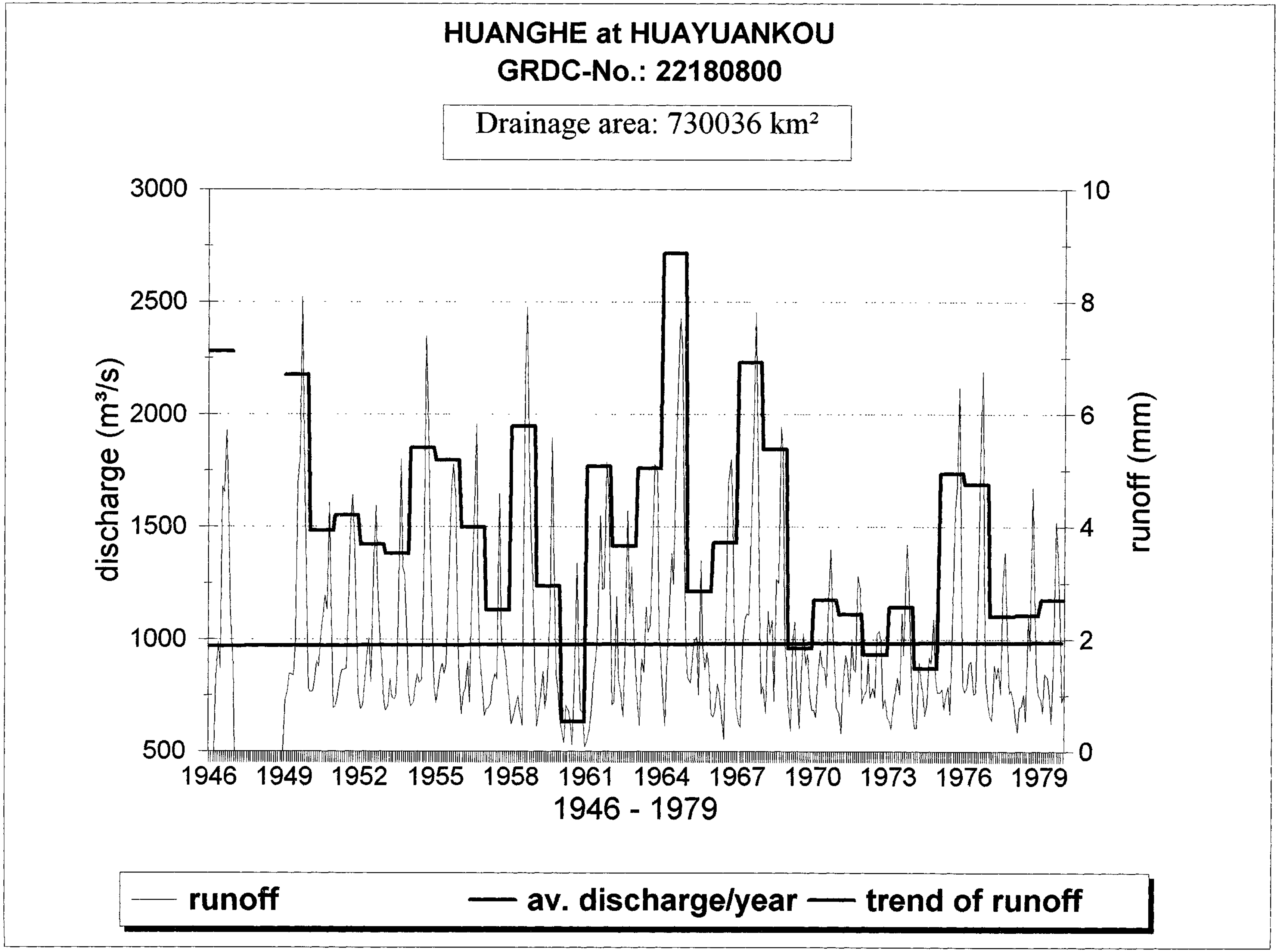


Figure 2.33

GLOBAL RUNOFF DATA CENTRE (GRDC)

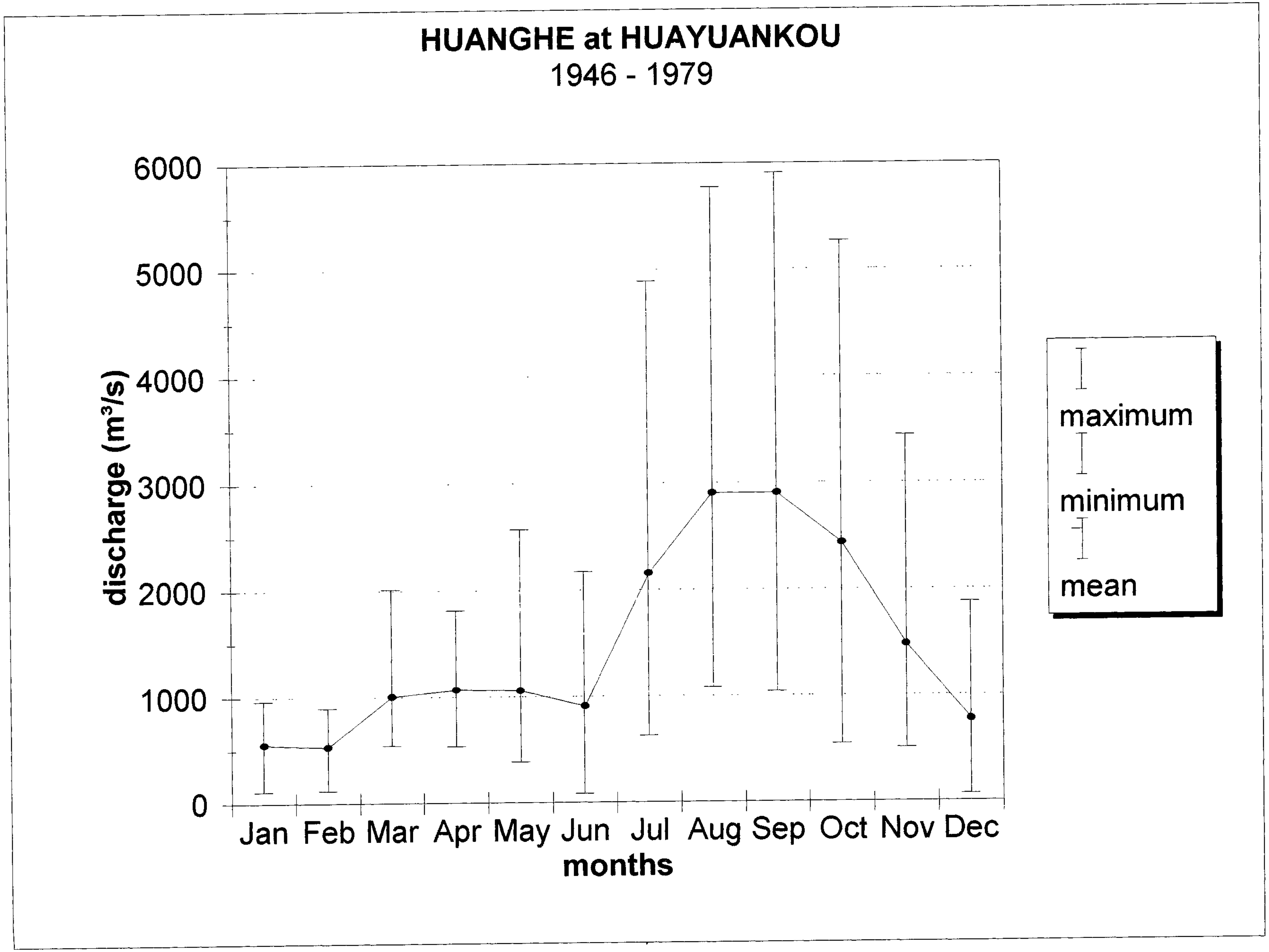


Figure 2.34

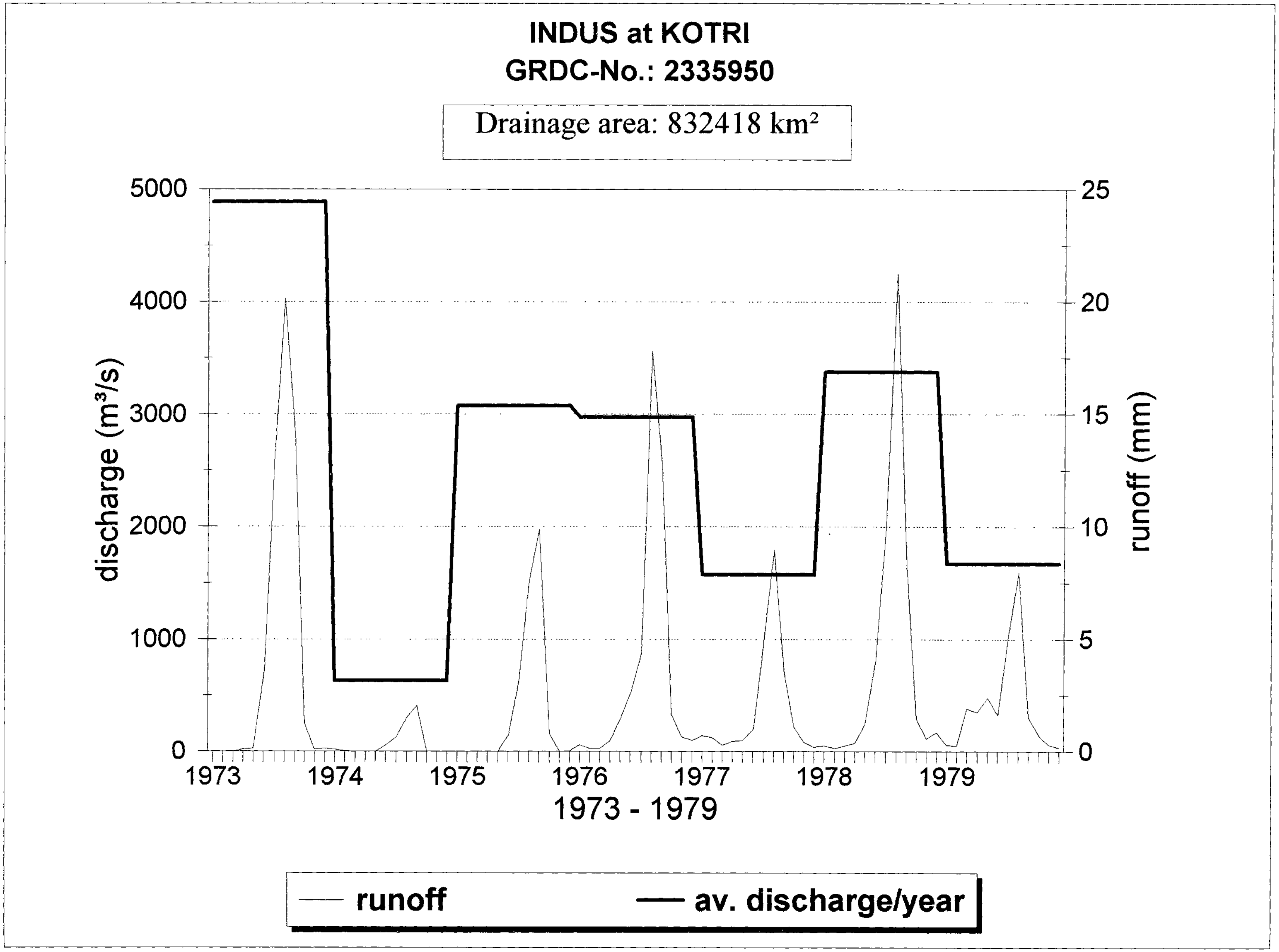

INDUS at KOTRI
GRDC-No.: 2335950
Drainage area: 832418 km²
5000
4000
3000
2000
1000
0
discharge (m³/s)
25
20
15
10
5
0
runoff (mm)
1973
1974
1975
1976
1977
1978
1979
1973 - 1979
runoff
av. discharge/year

Figure 2.35

GLOBAL RUNOFF DATA CENTRE (GRDC)

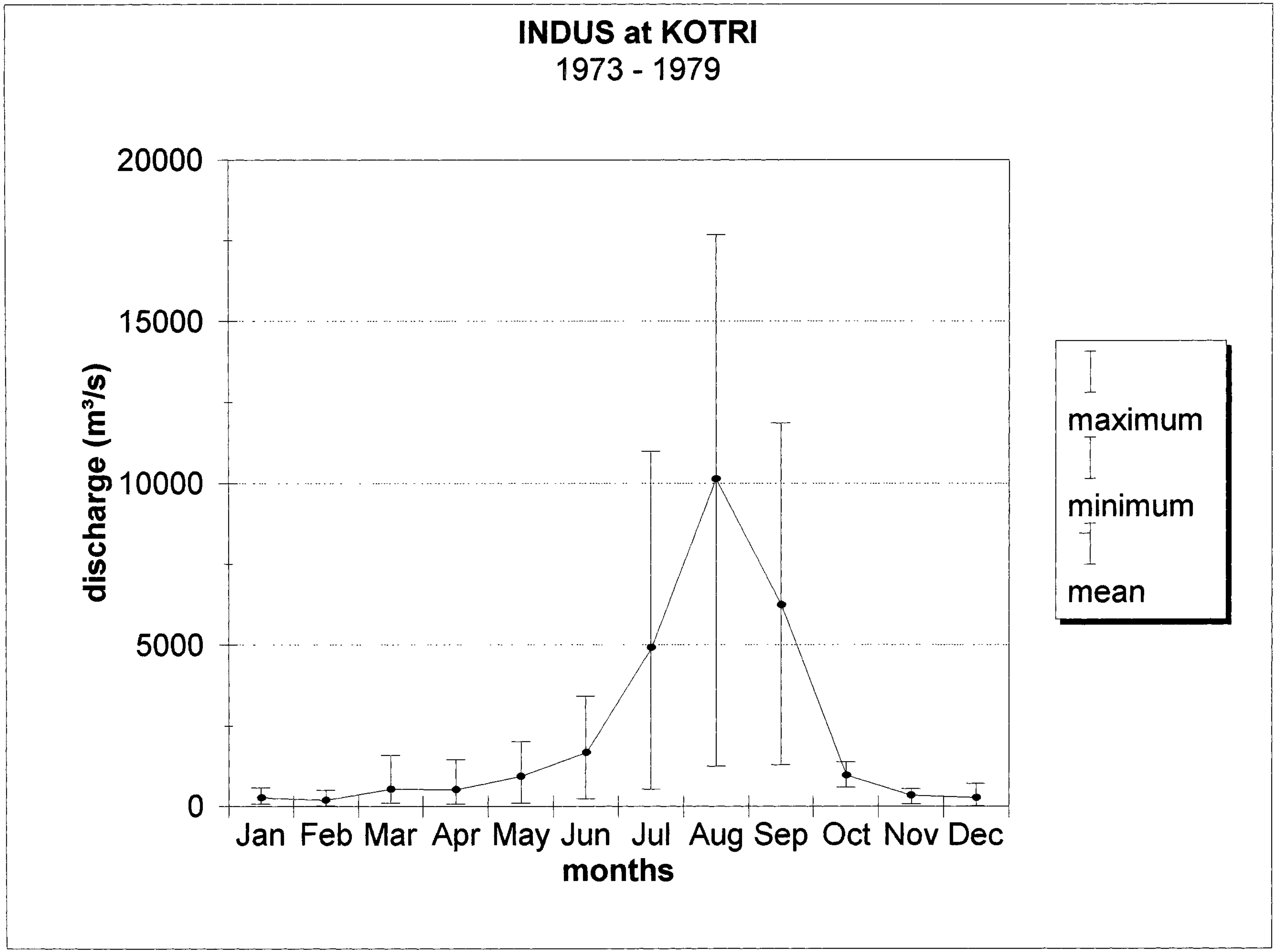


Figure 2.36

GLOBAL RUNOFF DATA CENTRE (GRDC)

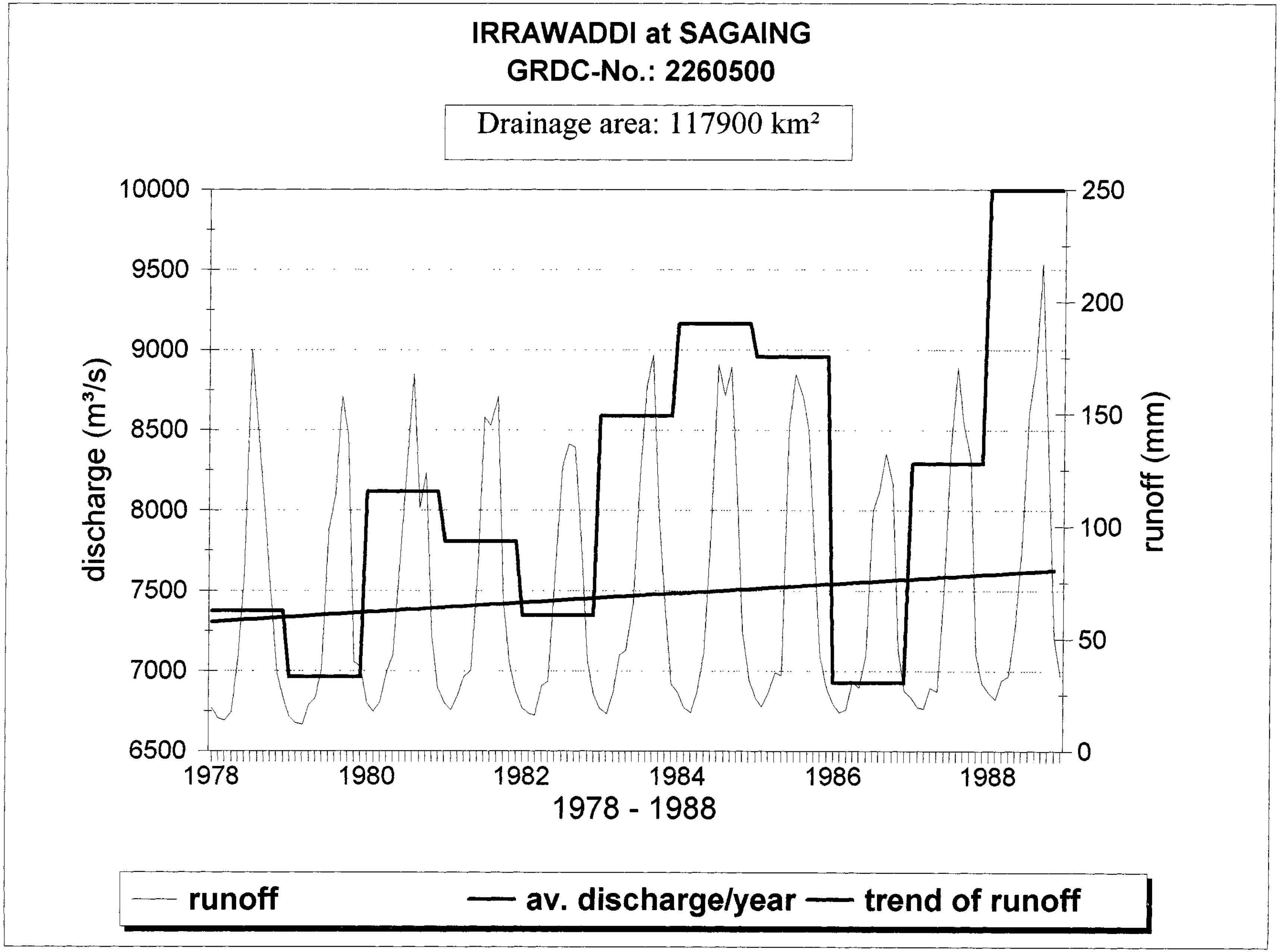


Figure 2.37

GLOBAL RUNOFF DATA CENTRE (GRDC)

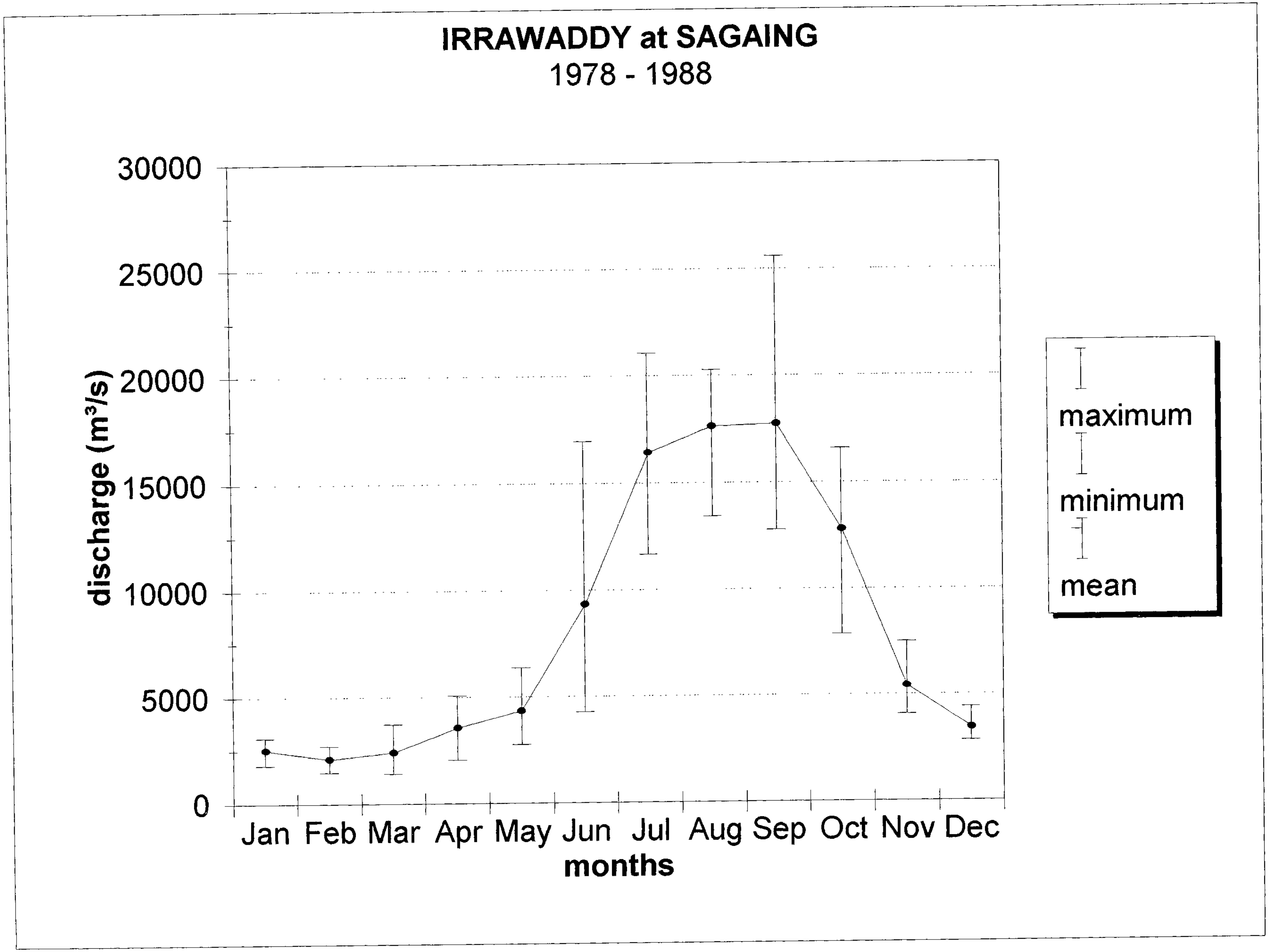


Figure 2.38

GLOBAL RUNOFF DATA CENTRE (GRDC)

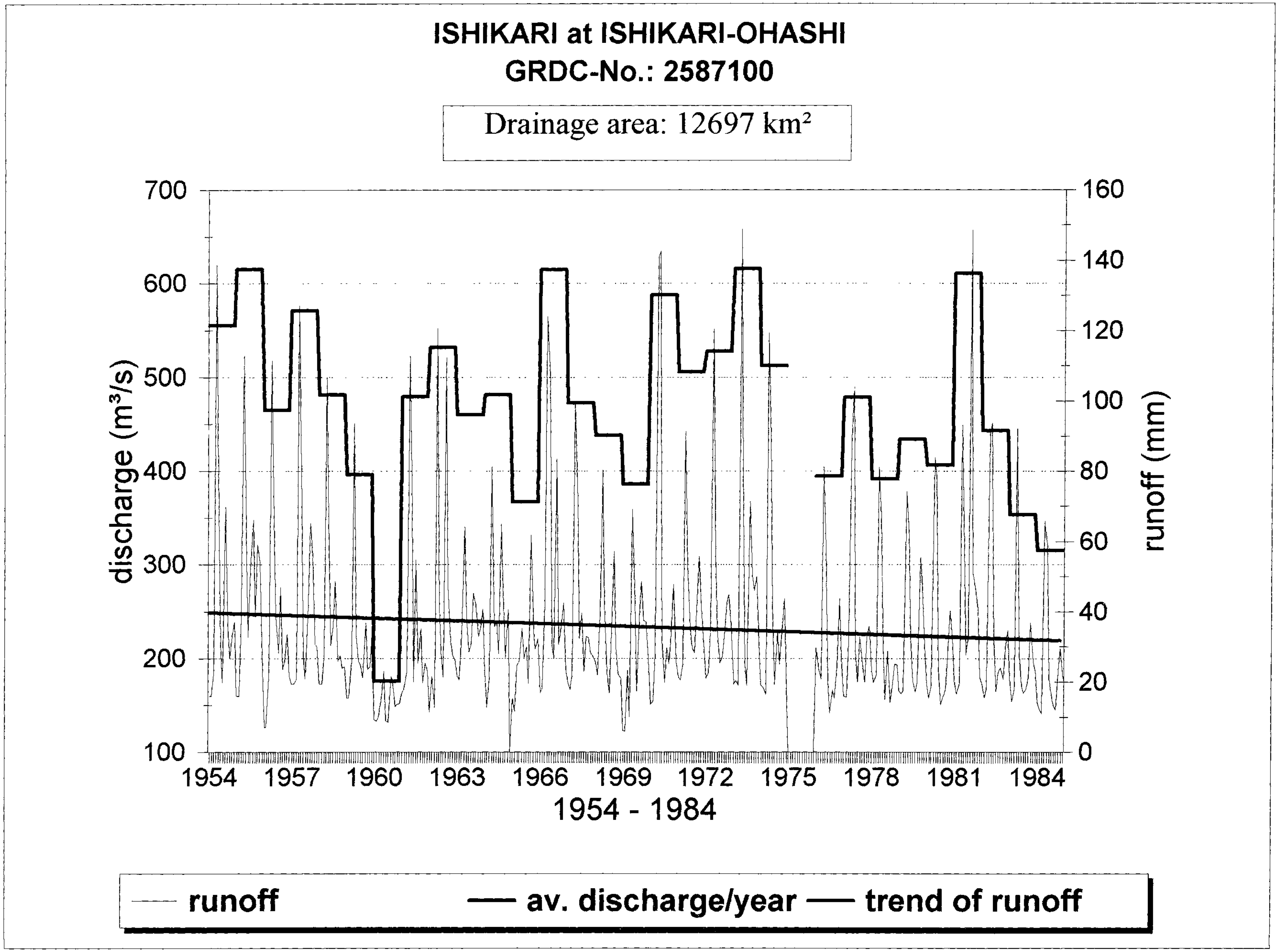


Figure 2.39

GLOBAL RUNOFF DATA CENTRE (GRDC)

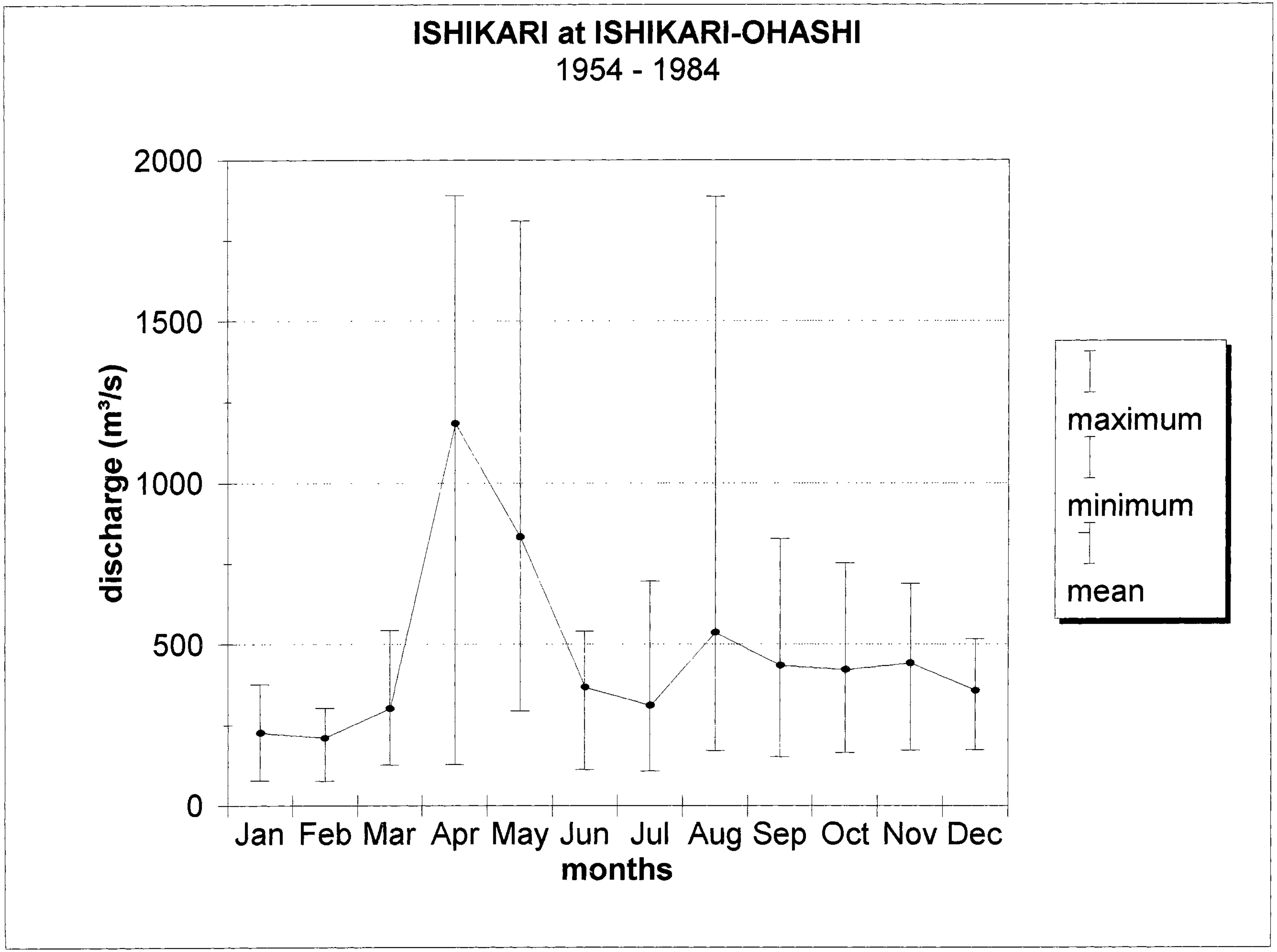


Figure 2.40

GLOBAL RUNOFF DATA CENTRE (GRDC)

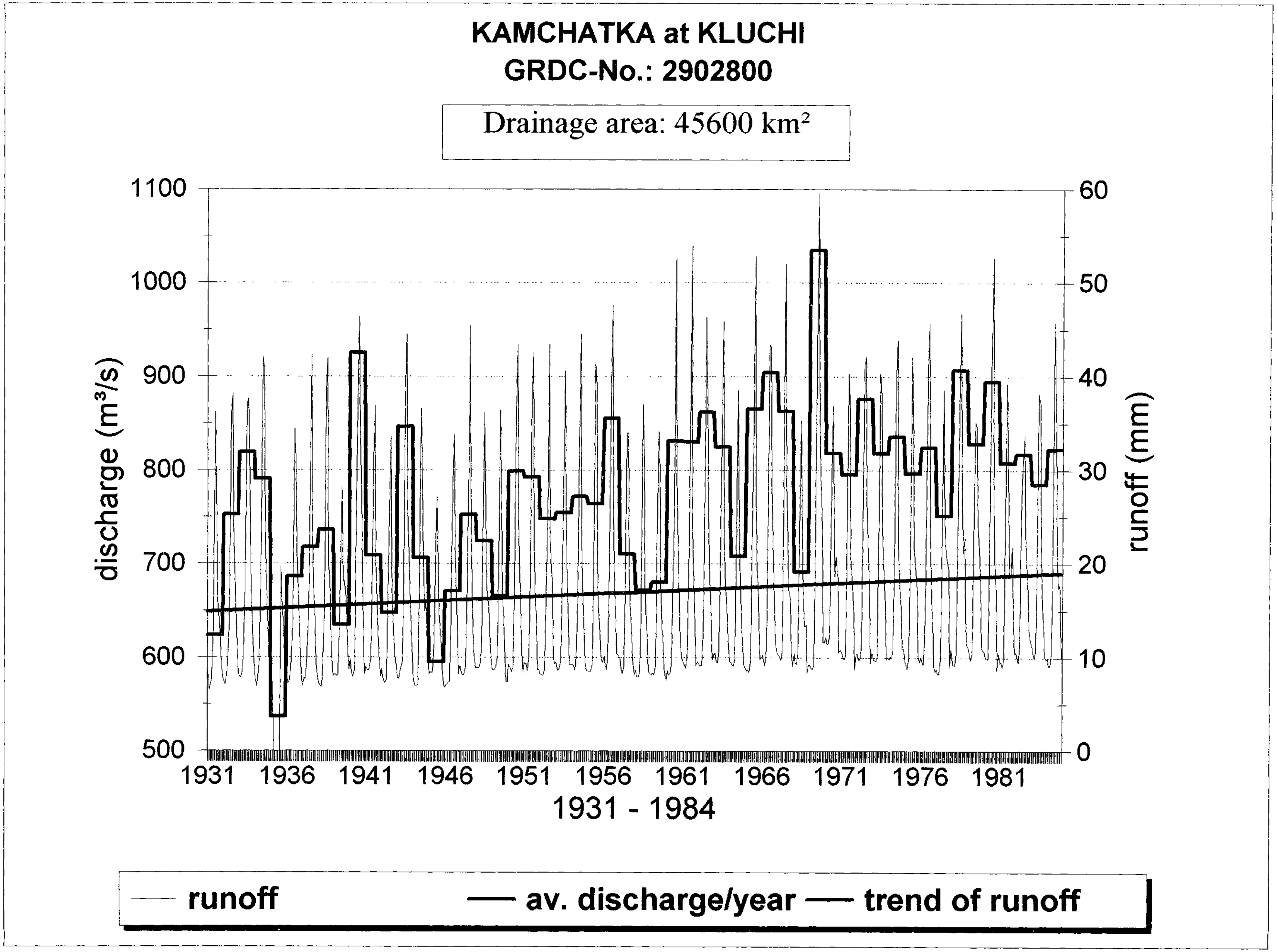


Figure 2.41

GLOBAL RUNOFF DATA CENTRE (GRDC)

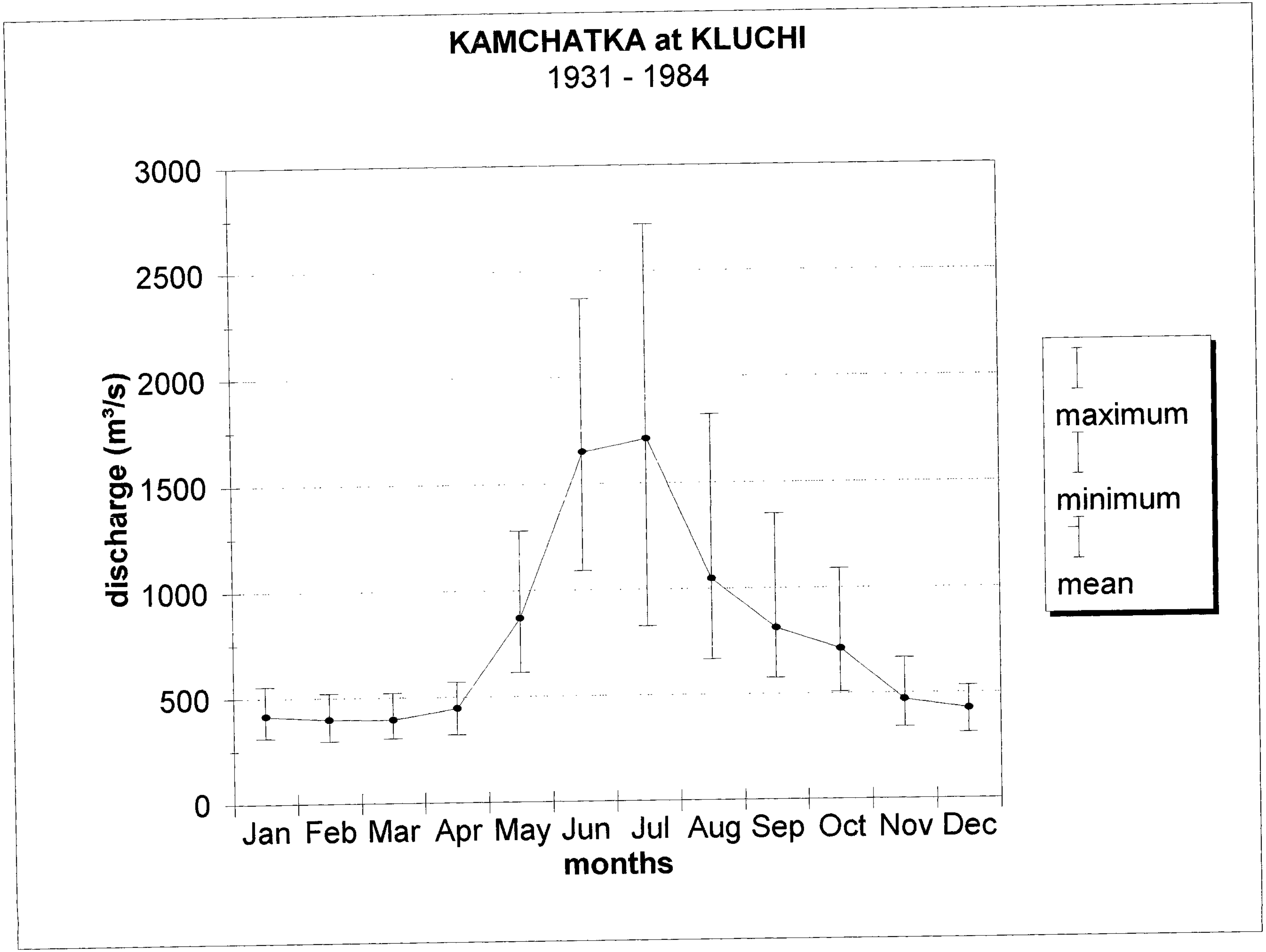


Figure 2.42

GLOBAL RUNOFF DATA CENTRE (GRDC)

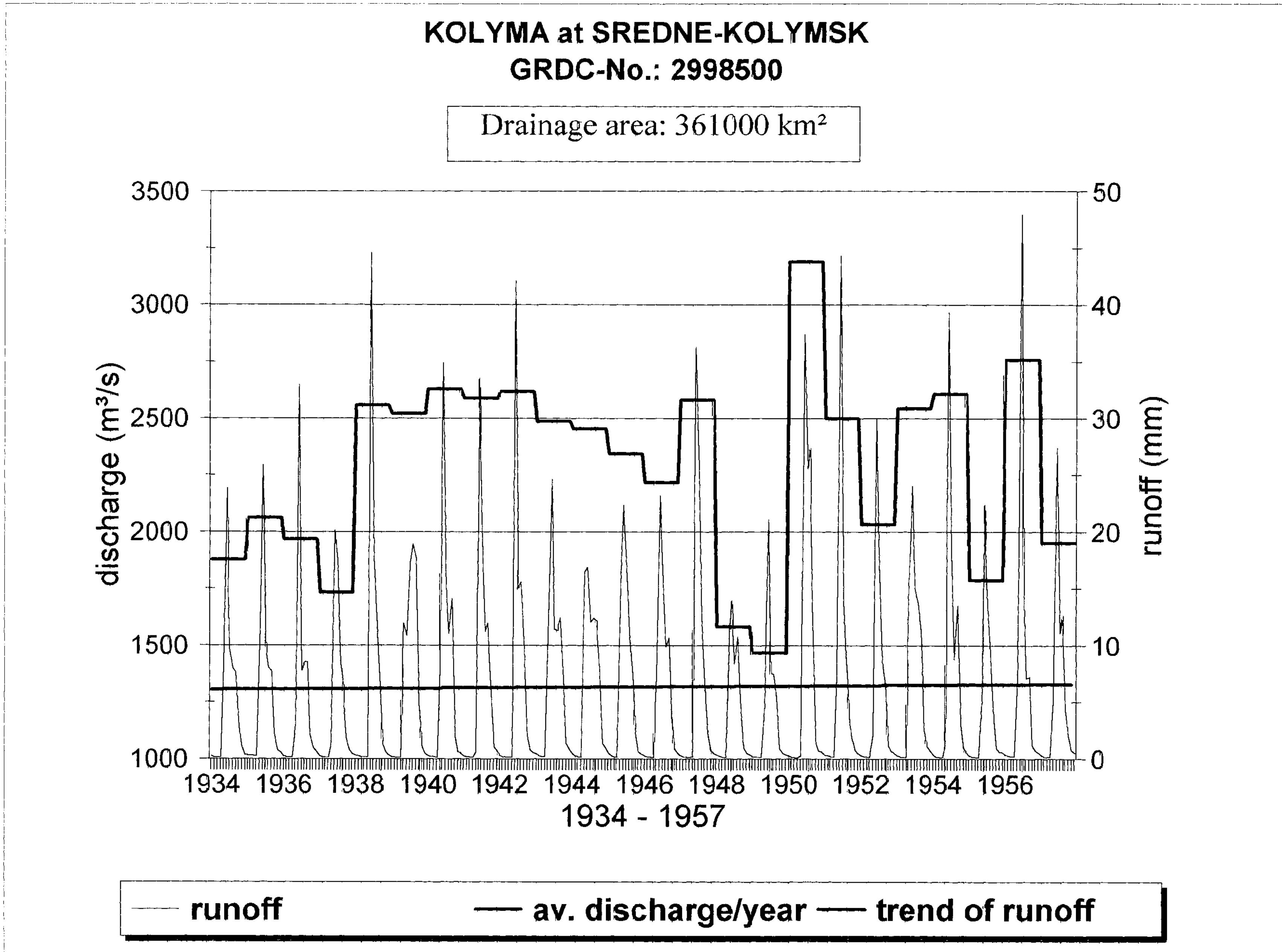


Figure 2.43

GLOBAL RUNOFF DATA CENTRE (GRDC)

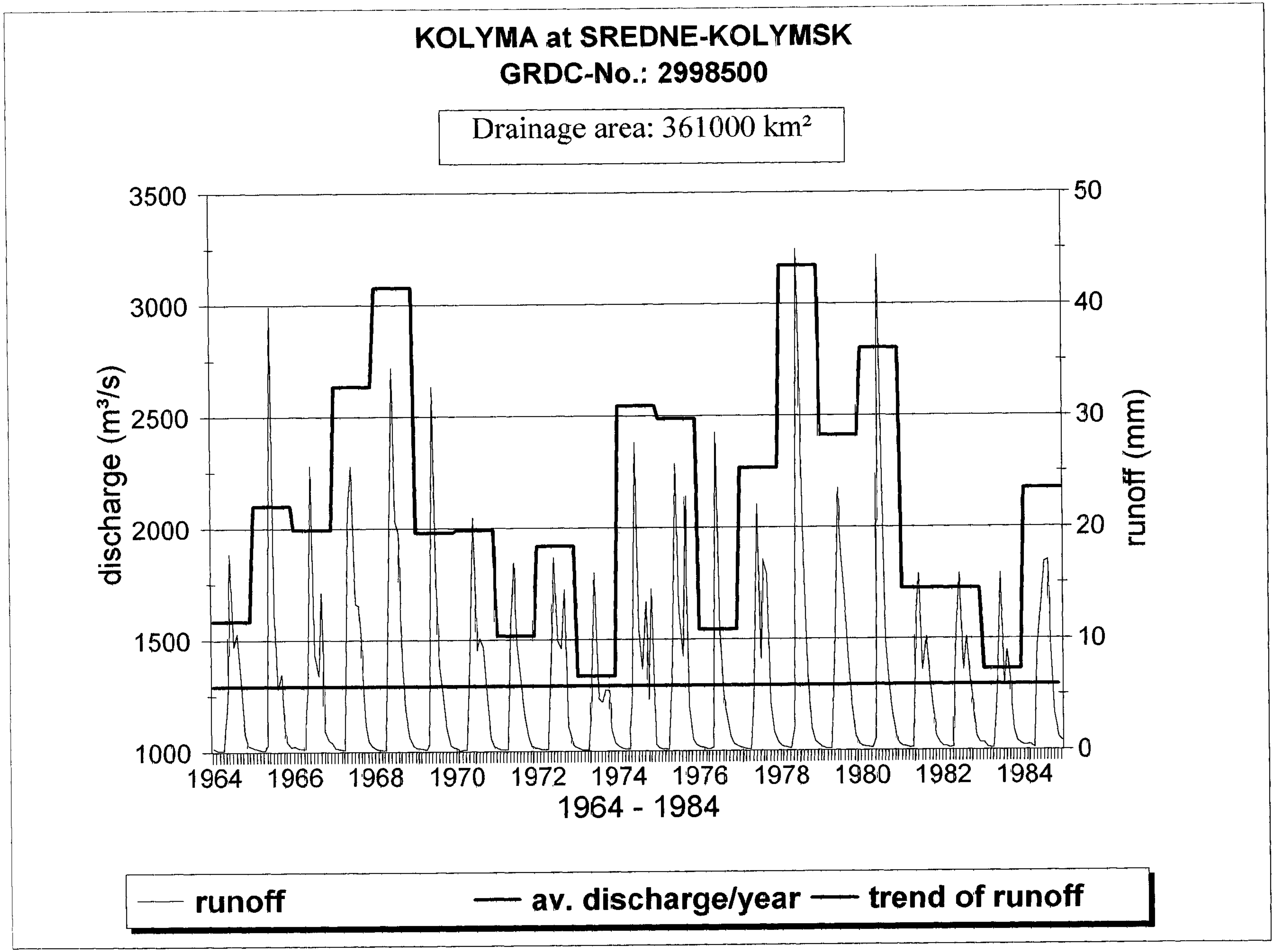


Figure 2.44

GLOBAL RUNOFF DATA CENTRE (GRDC)

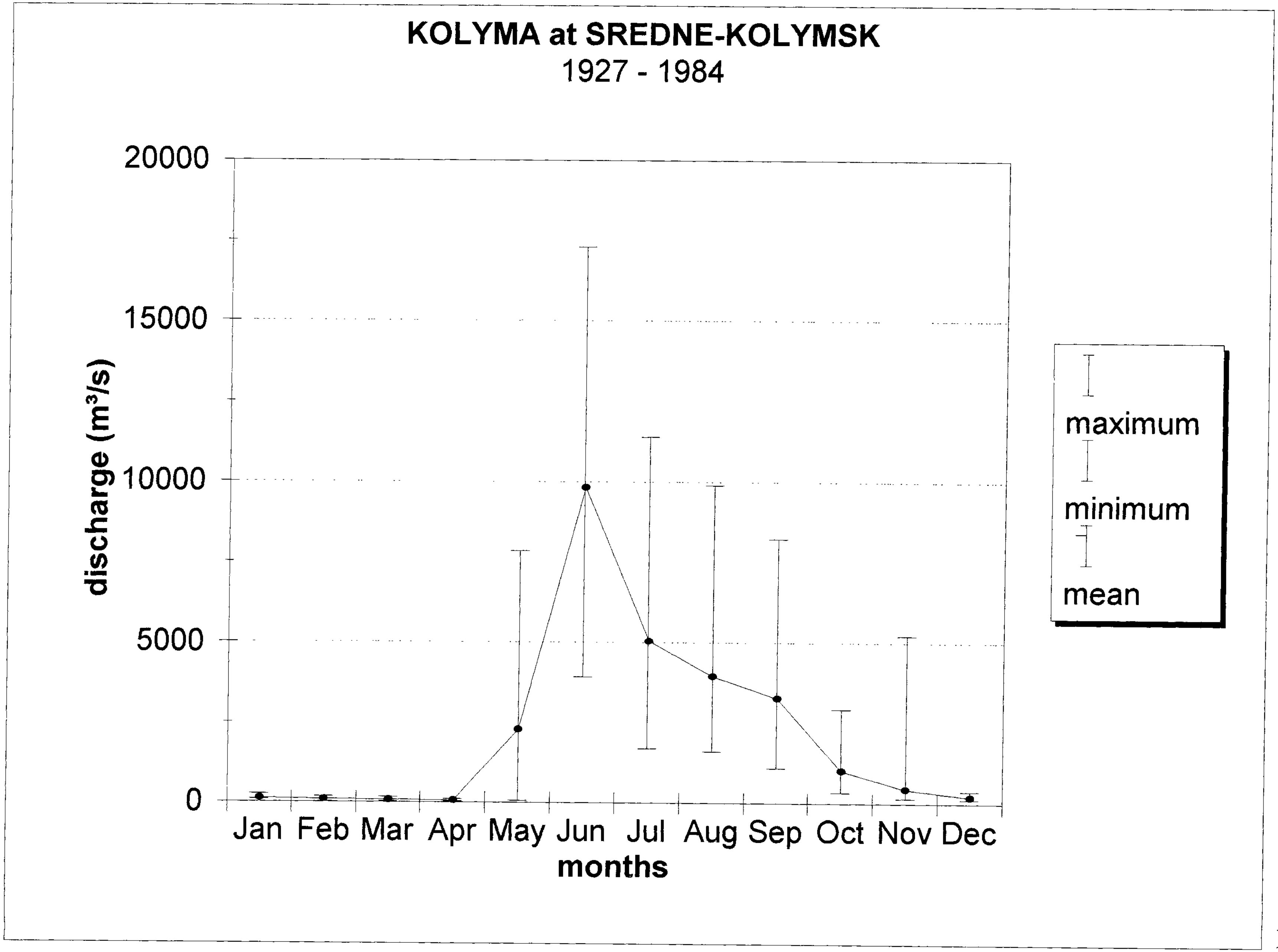


Figure 2.45

GLOBAL RUNOFF DATA CENTRE (GRDC)

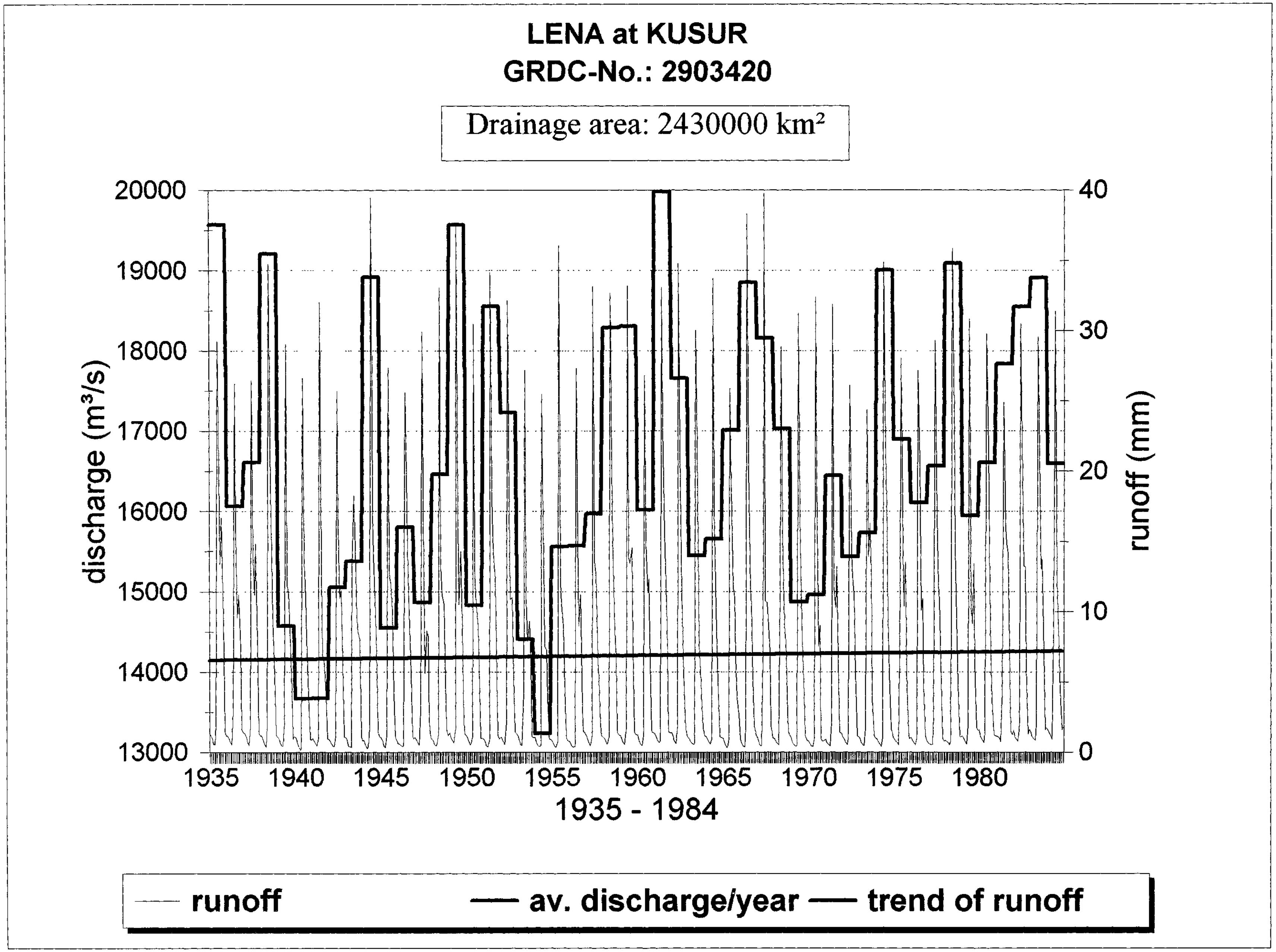


Figure 2.46

GLOBAL RUNOFF DATA CENTRE (GRDC)

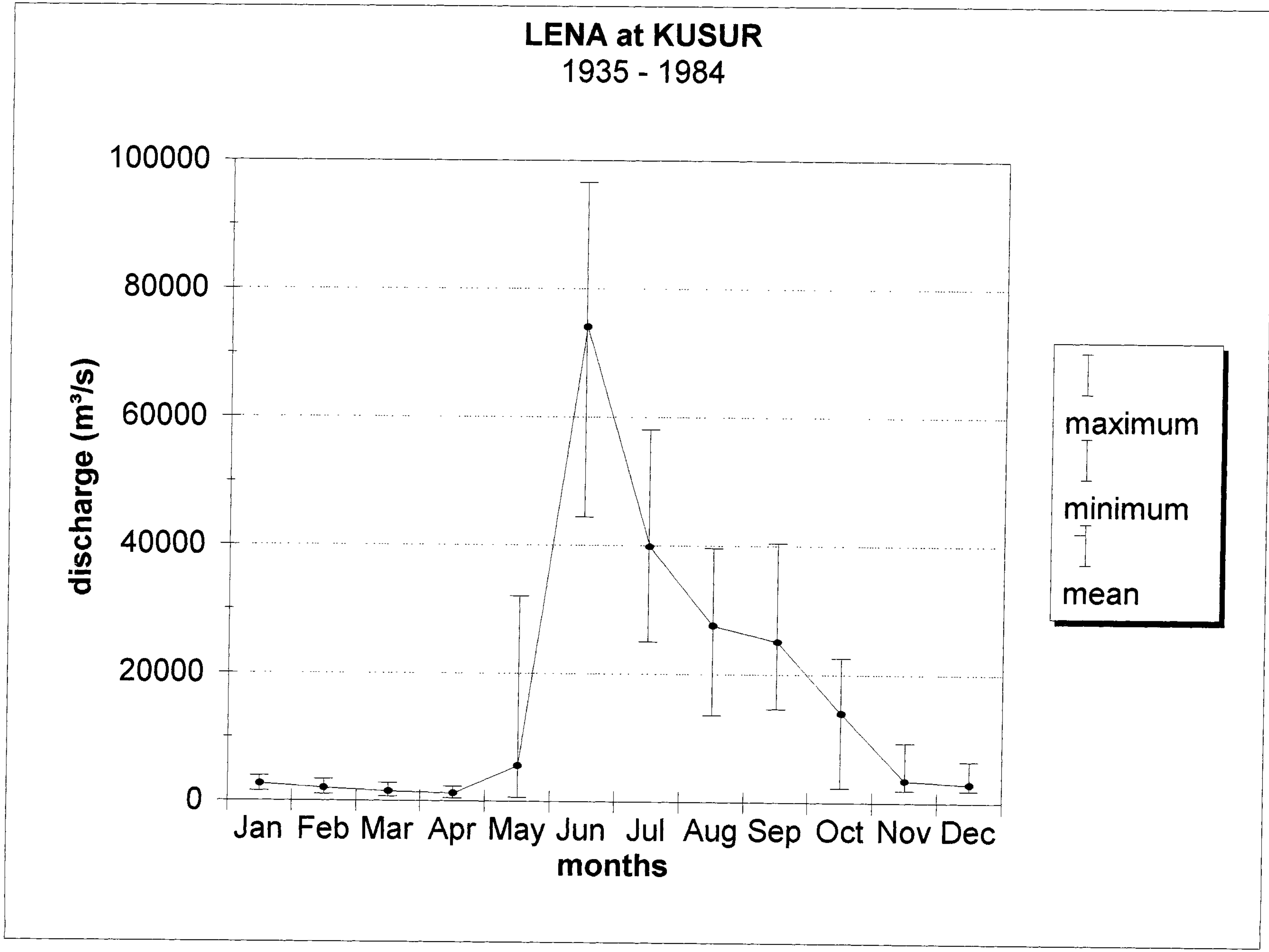


Figure 2.47

GLOBAL RUNOFF DATA CENTRE (GRDC)

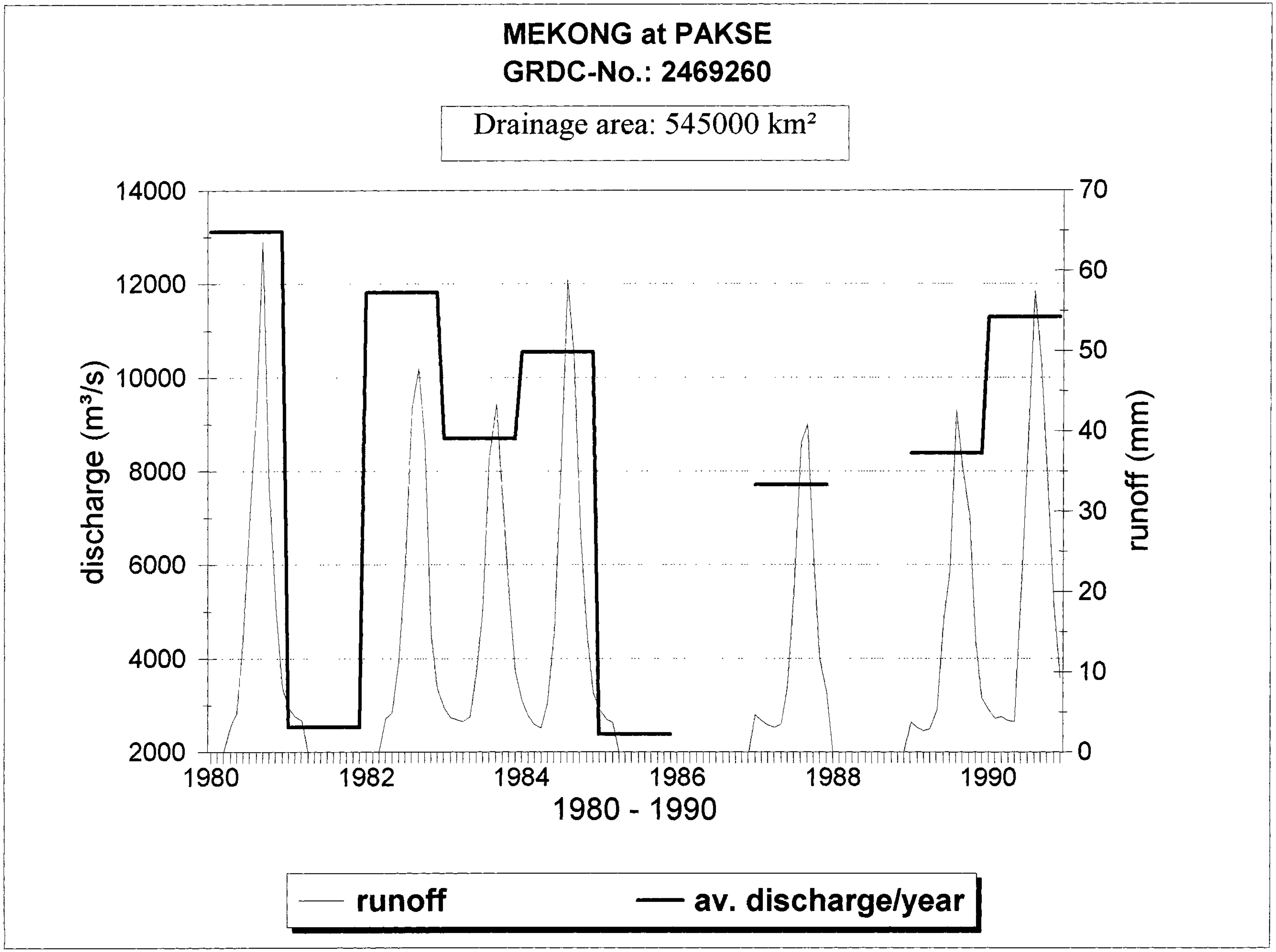


Figure 2.48

GLOBAL RUNOFF DATA CENTRE (GRDC)

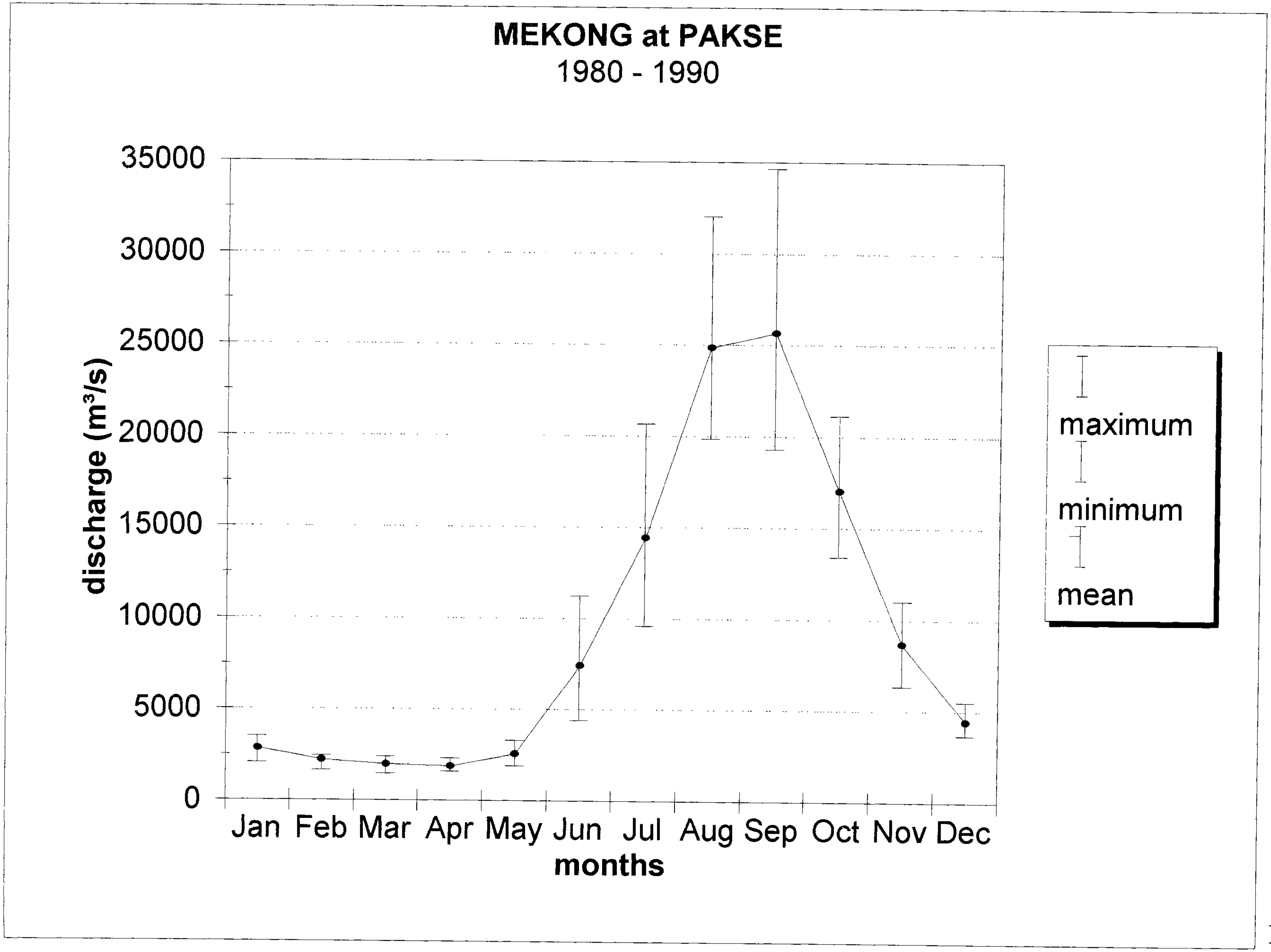


Figure 2.49

GLOBAL RUNOFF DATA CENTRE (GRDC)

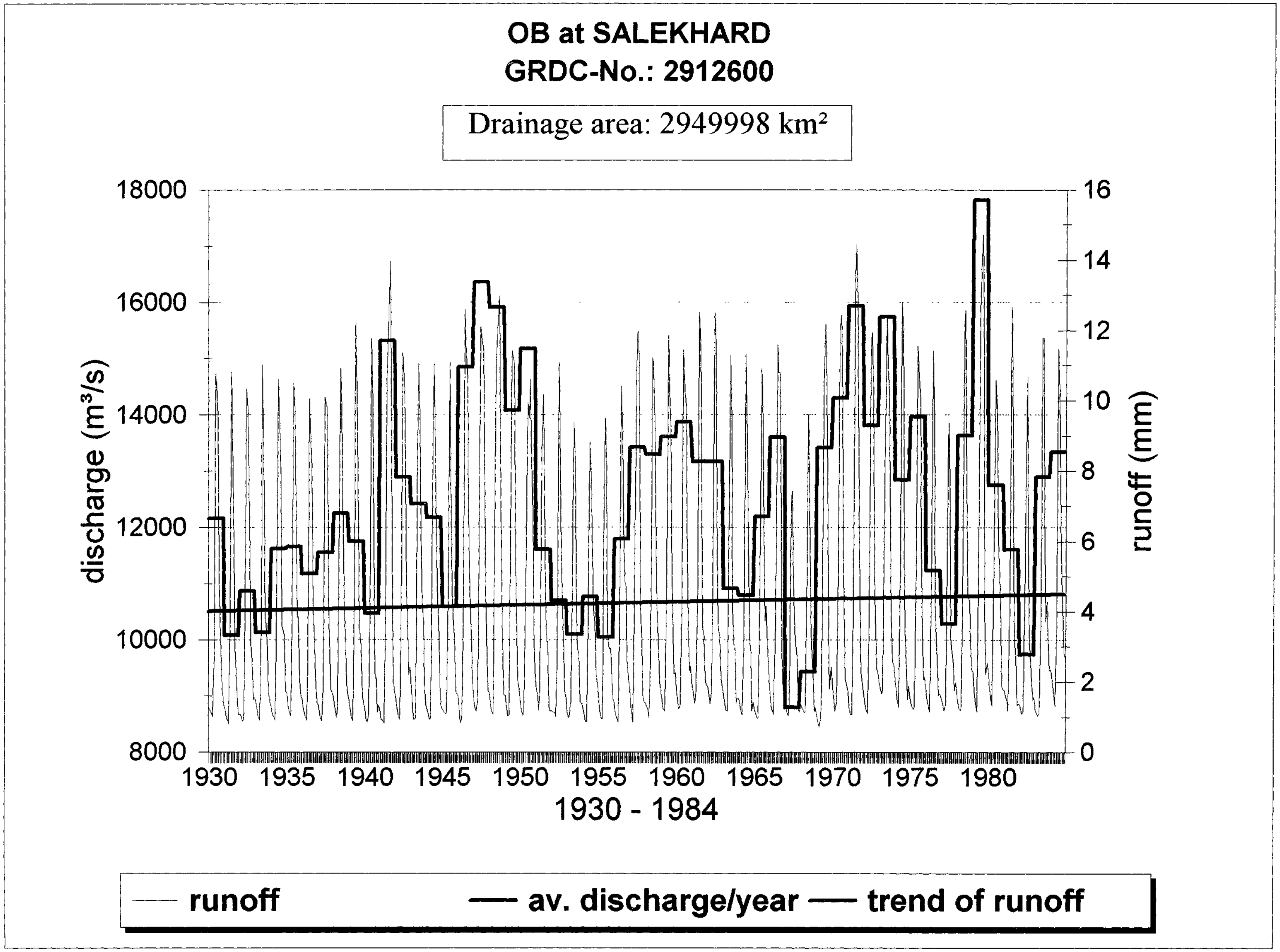


Figure 2.50

GLOBAL RUNOFF DATA CENTRE (GRDC)

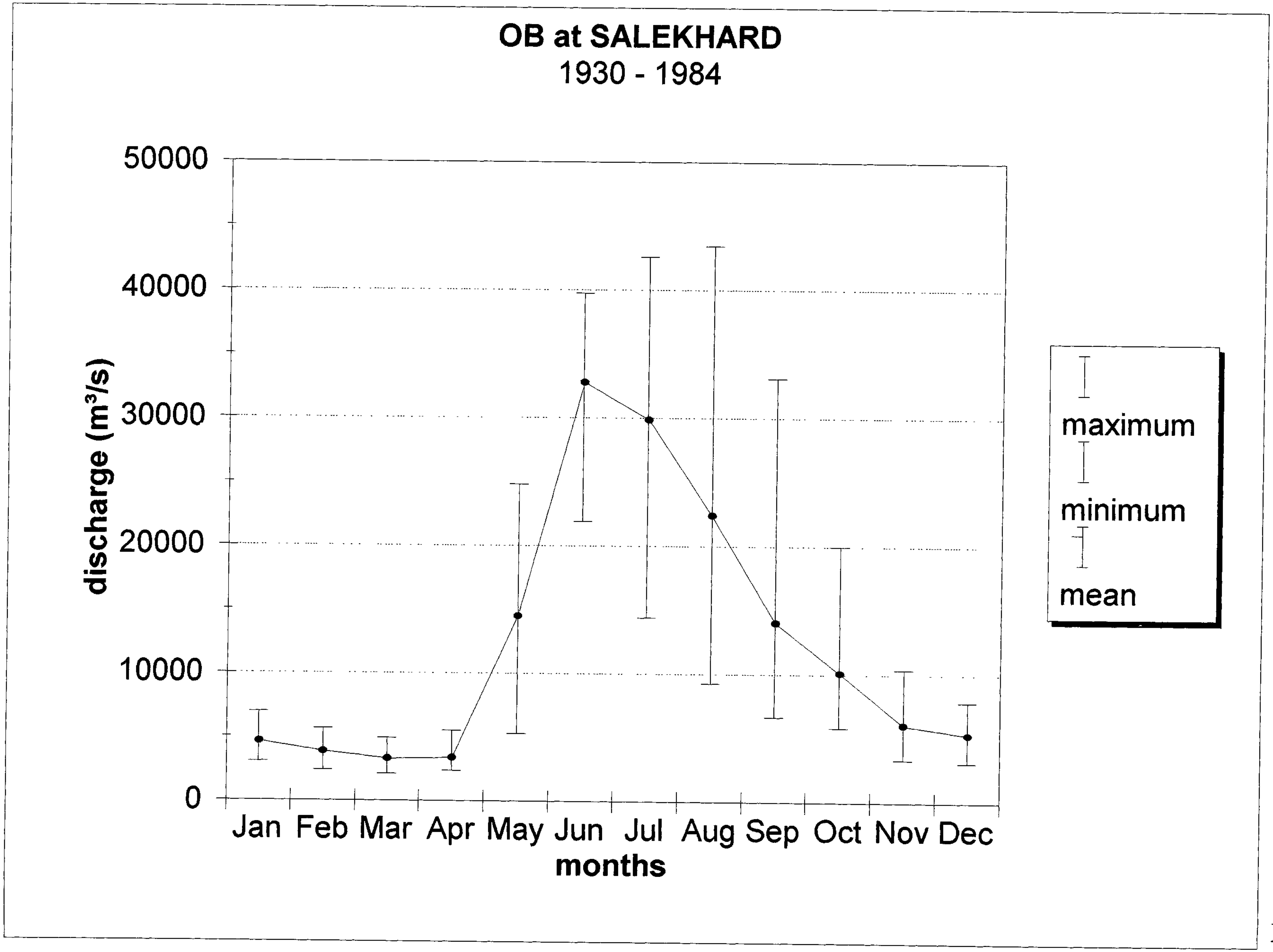


Figure 2.51

GLOBAL RUNOFF DATA CENTRE (GRDC)

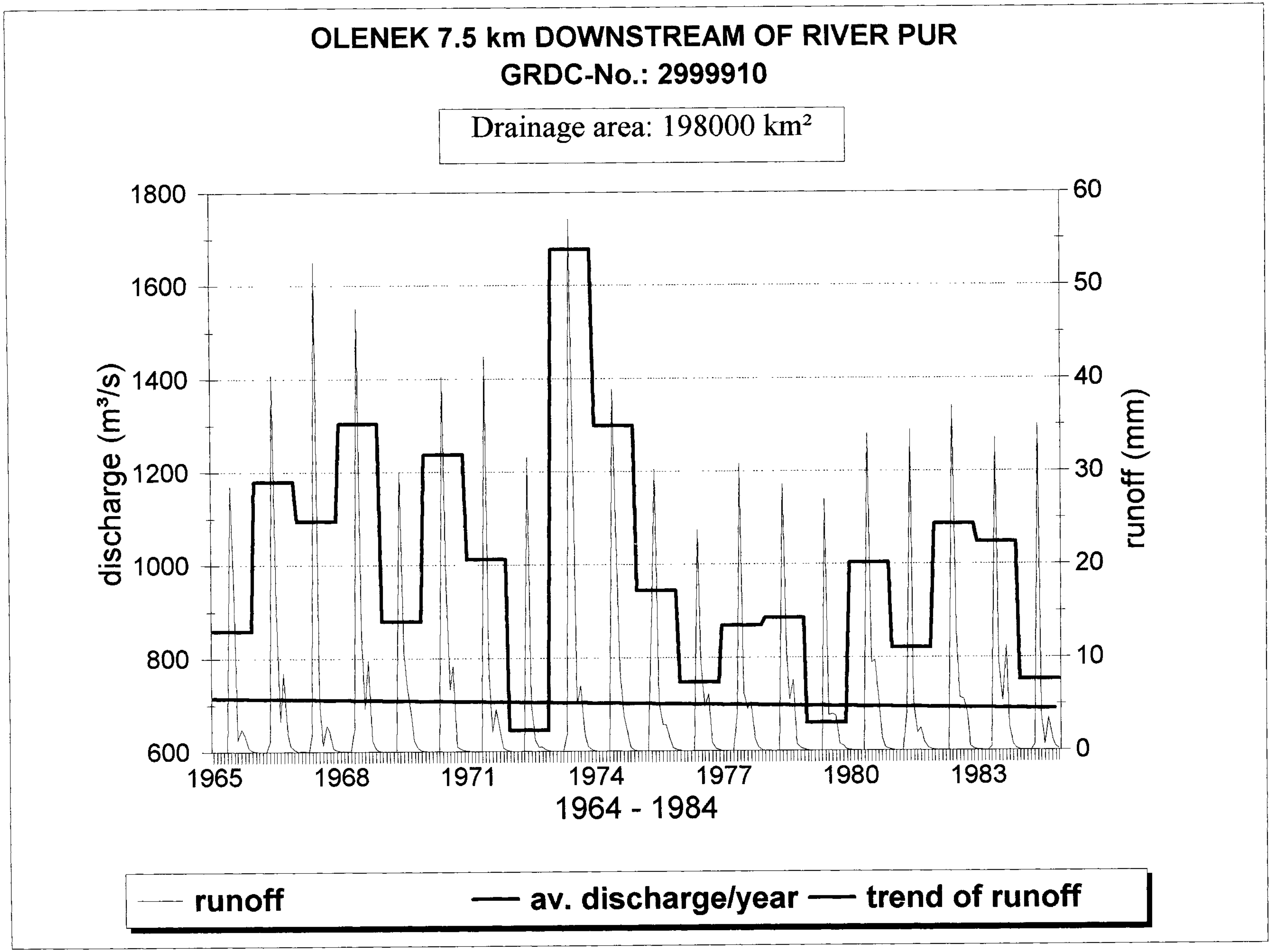


Figure 2.52

GLOBAL RUNOFF DATA CENTRE (GRDC)

OLENEK 7.5 km downstream of RIVER PUR
1965 - 1984

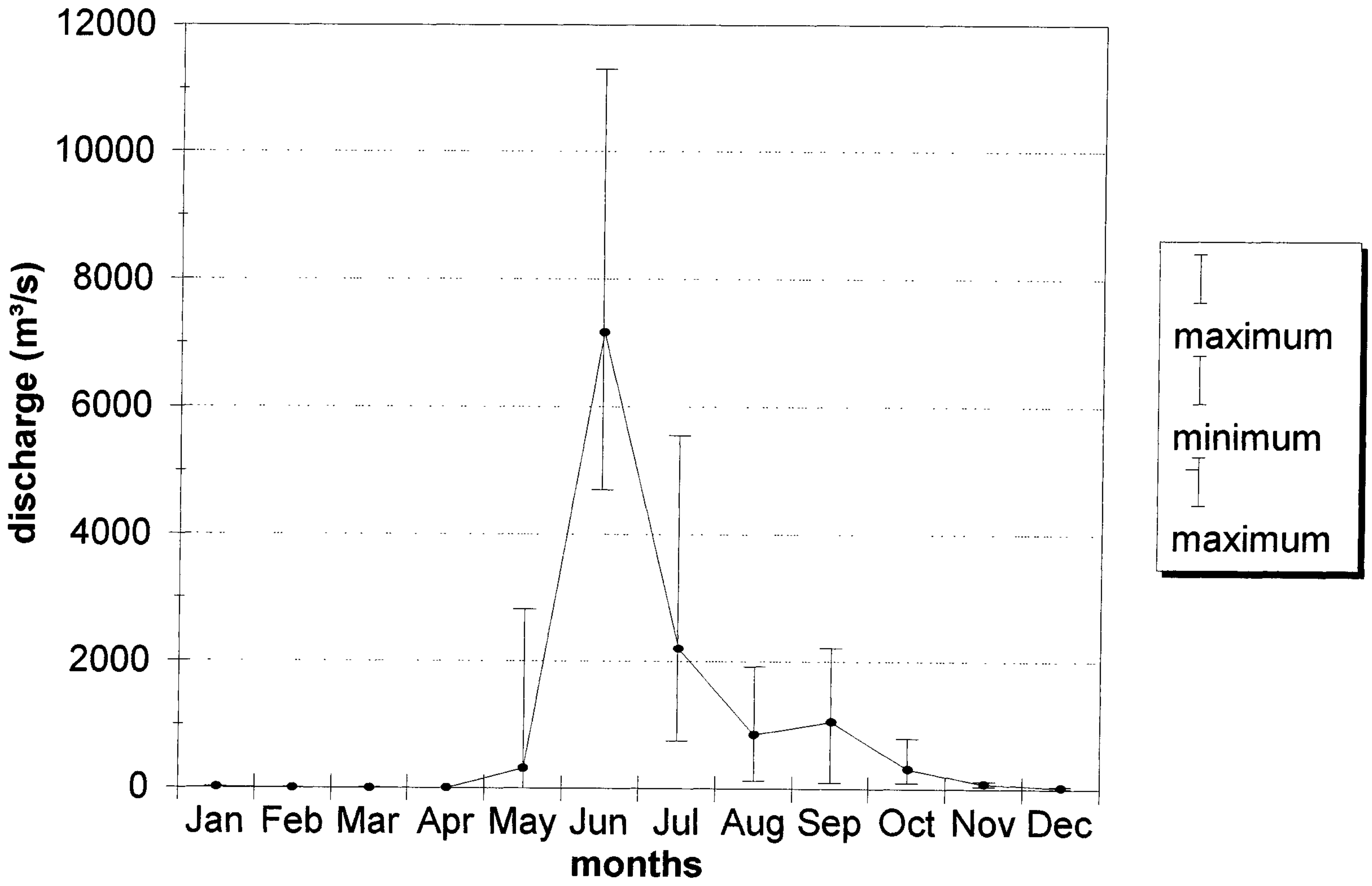


Figure 2.53

GLOBAL RUNOFF DATA CENTRE (GRDC)

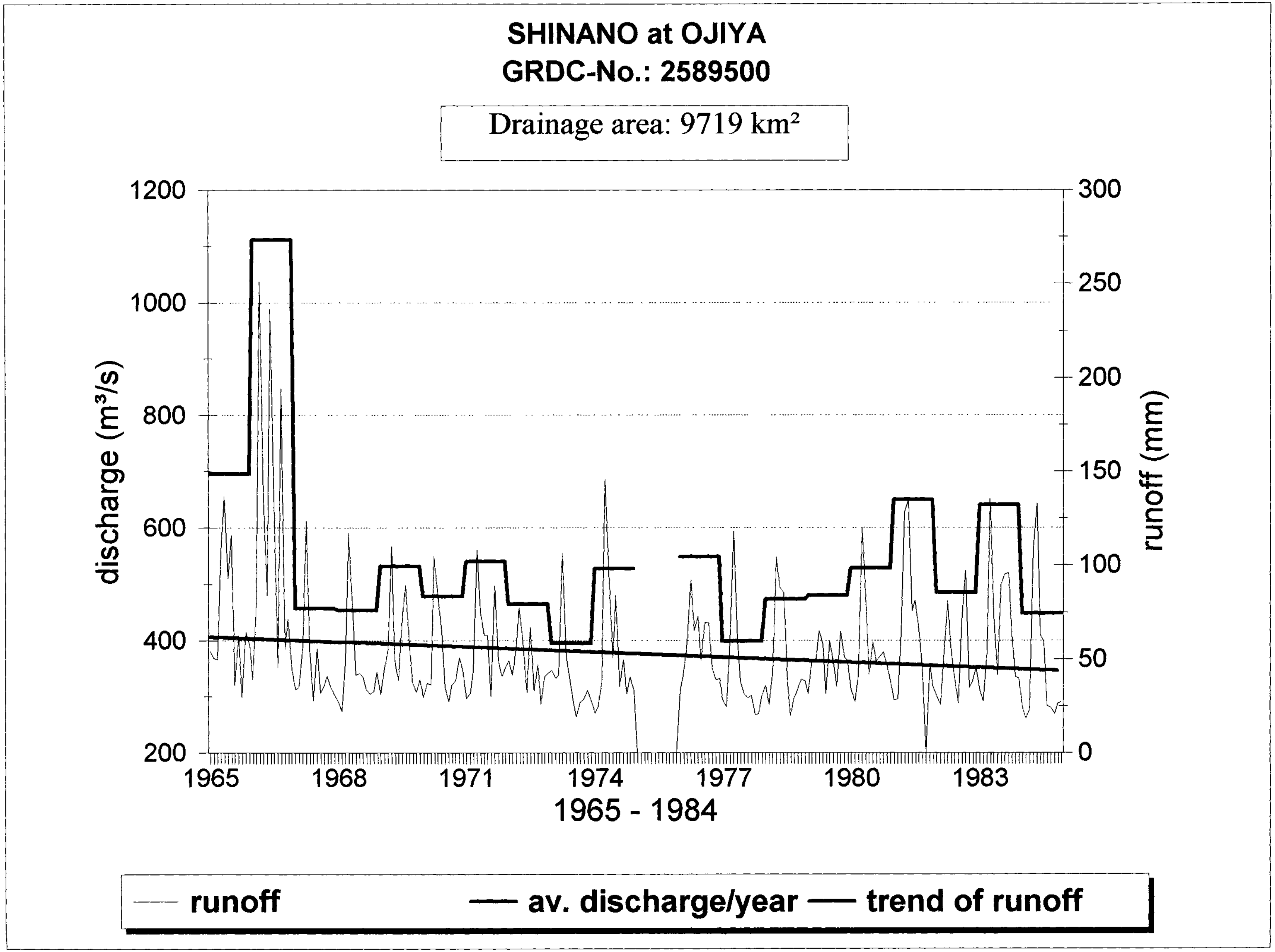


Figure 2.54

GLOBAL RUNOFF DATA CENTRE (GRDC)

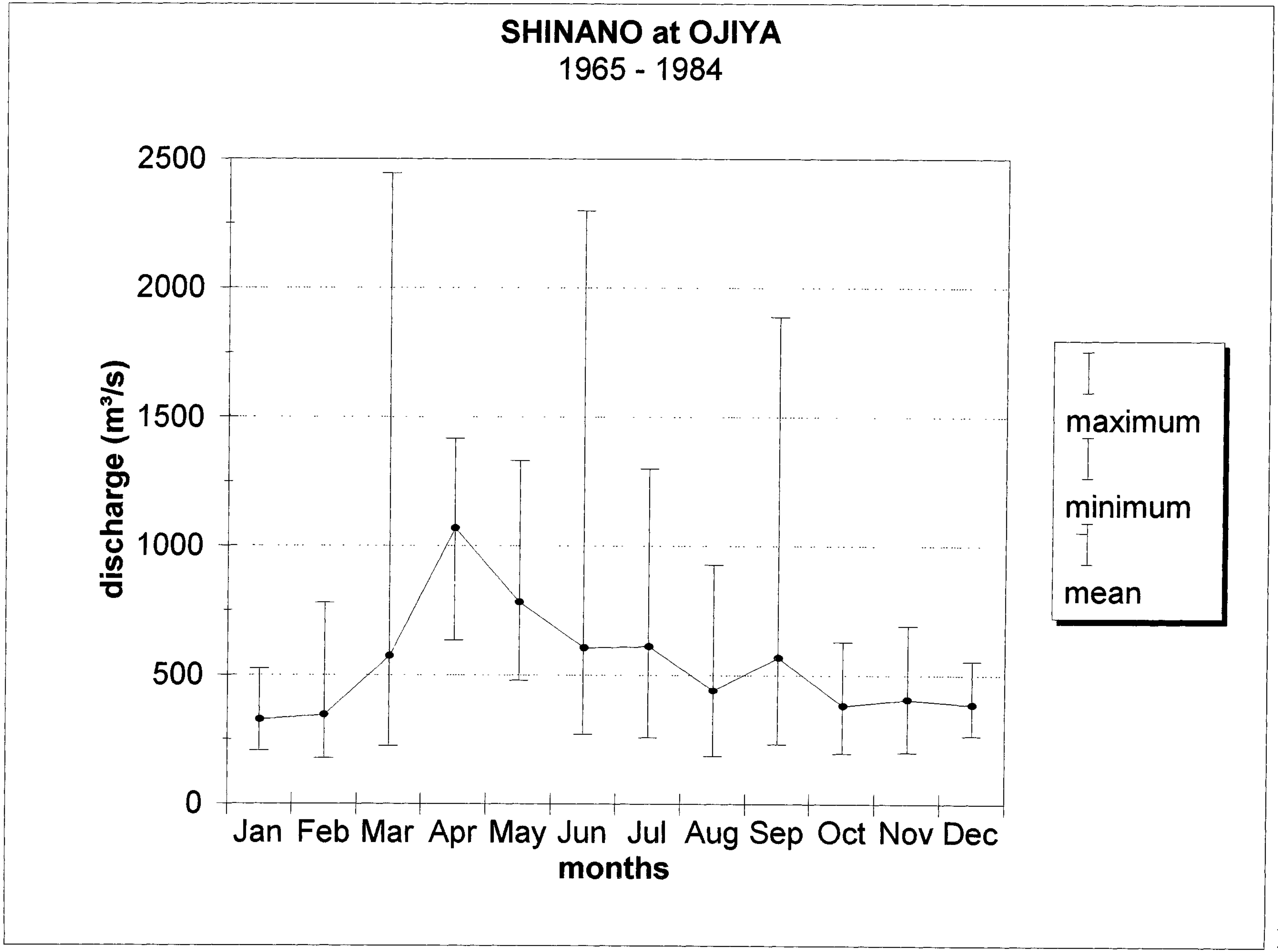


Figure 2.55

GLOBAL RUNOFF DATA CENTRE (GRDC)

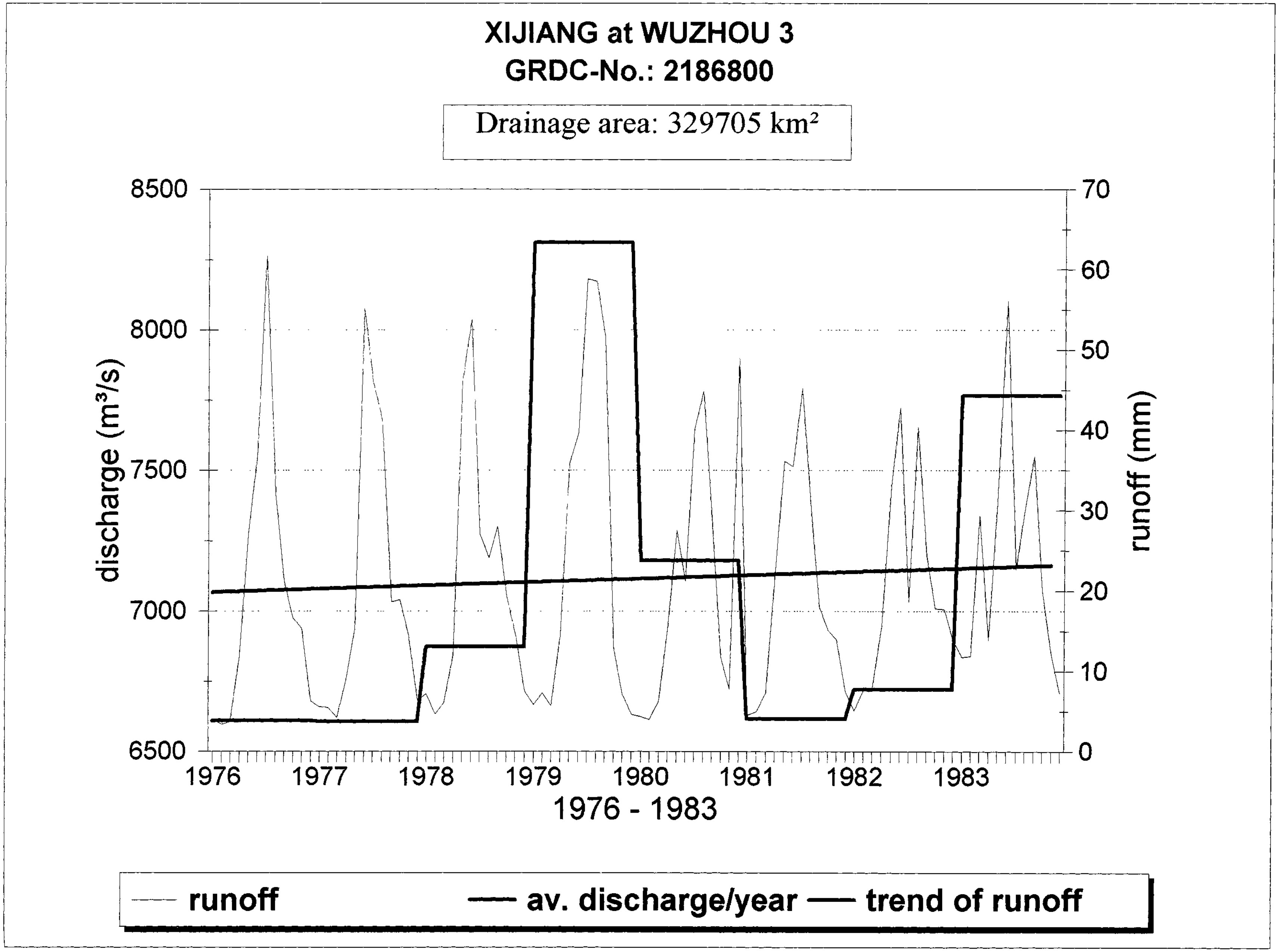


Figure 2.56

GLOBAL RUNOFF DATA CENTRE (GRDC)

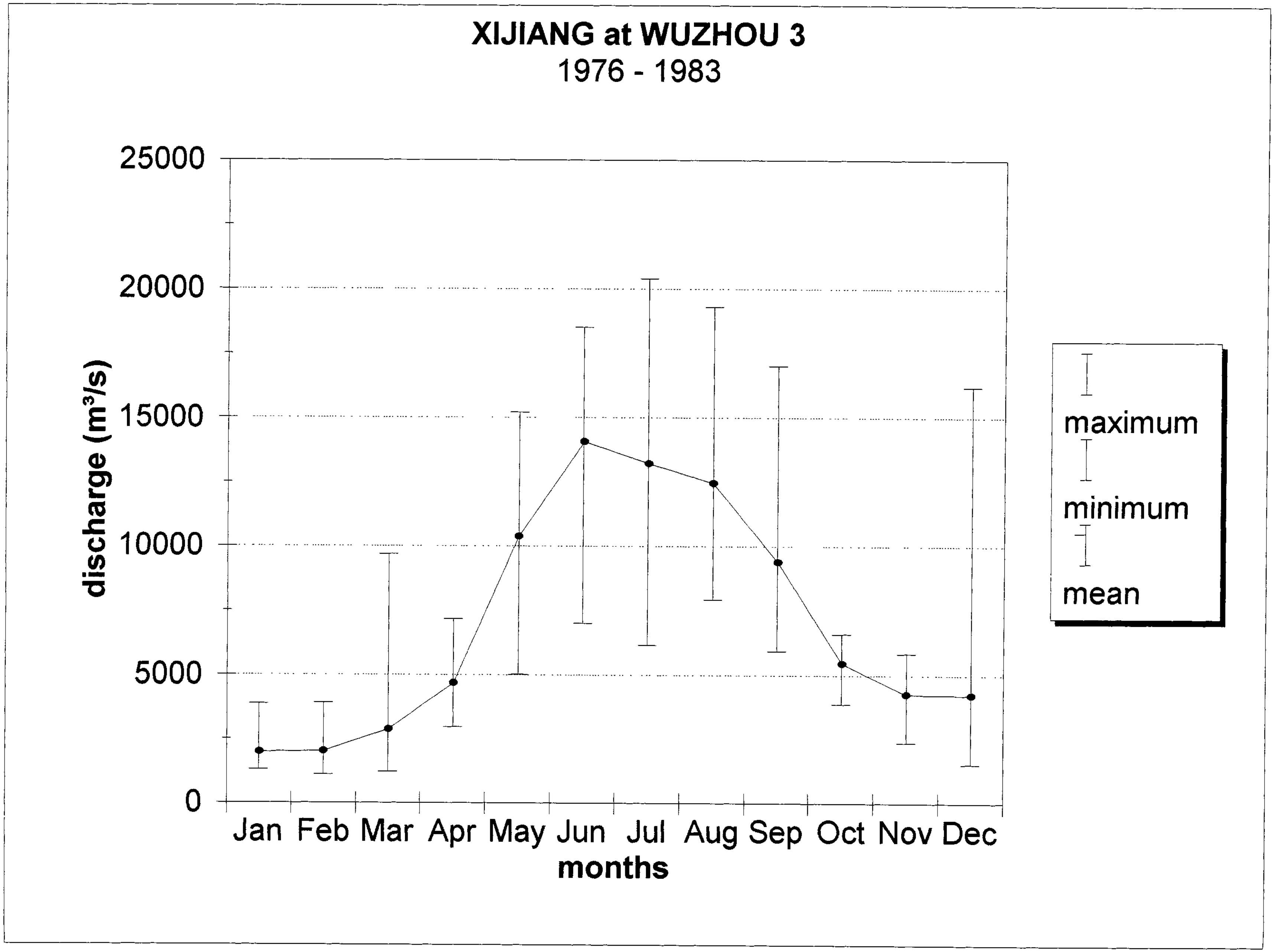


Figure 2.57

GLOBAL RUNOFF DATA CENTRE (GRDC)

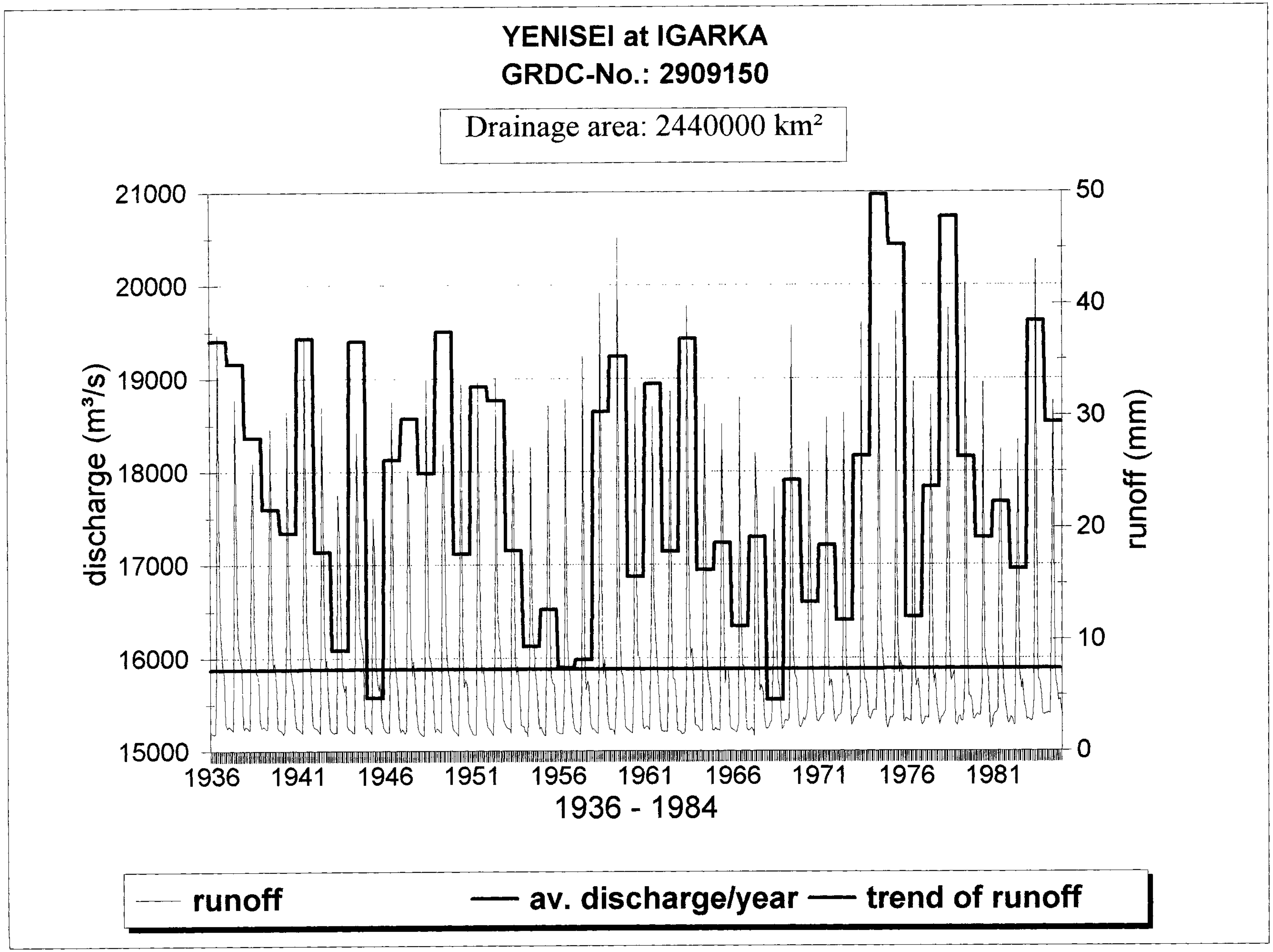


Figure 2.58

GLOBAL RUNOFF DATA CENTRE (GRDC)

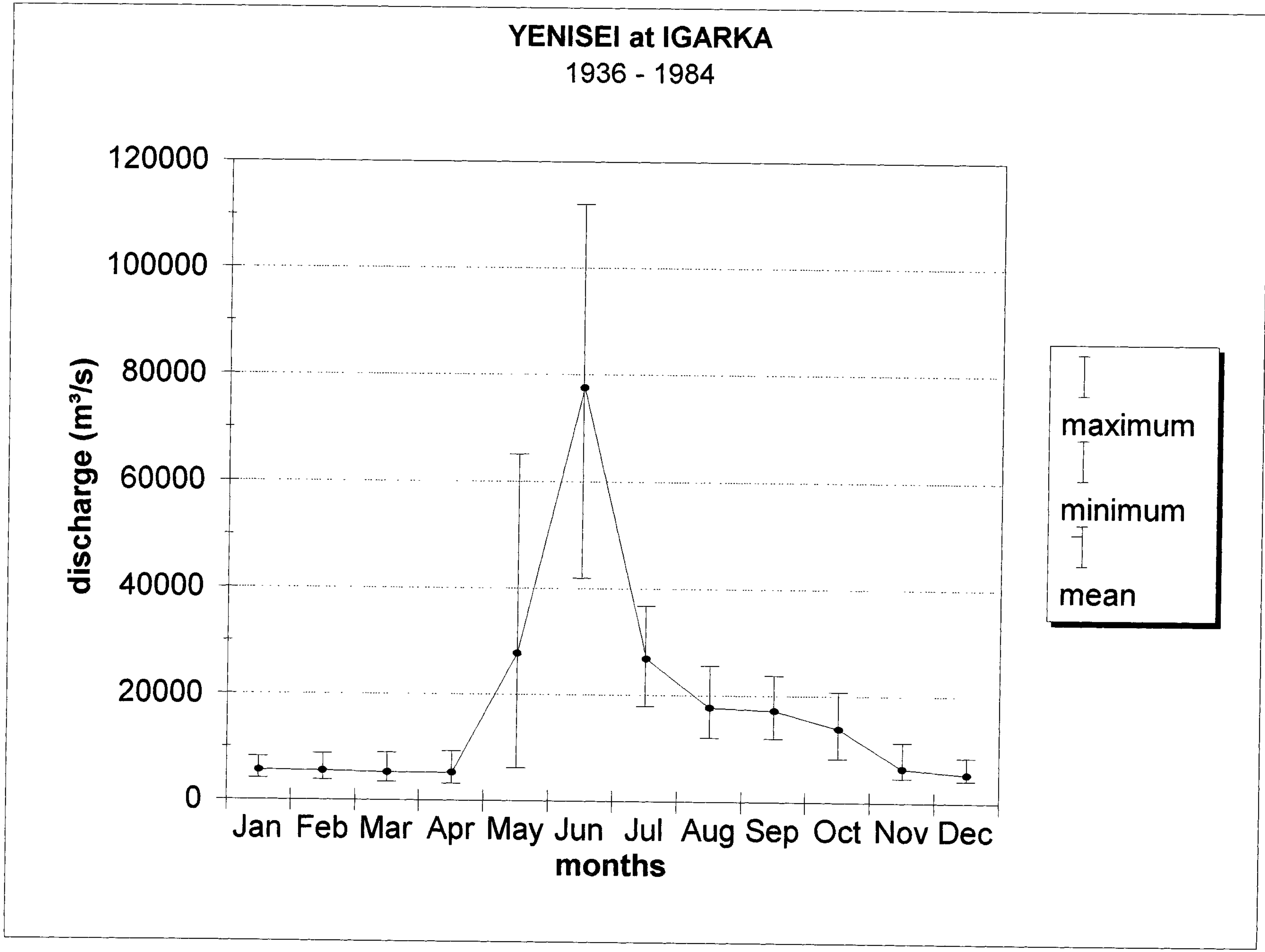


Figure 2.59

Australia and Oceania

GLOBAL RUNOFF DATA CENTRE (GRDC)

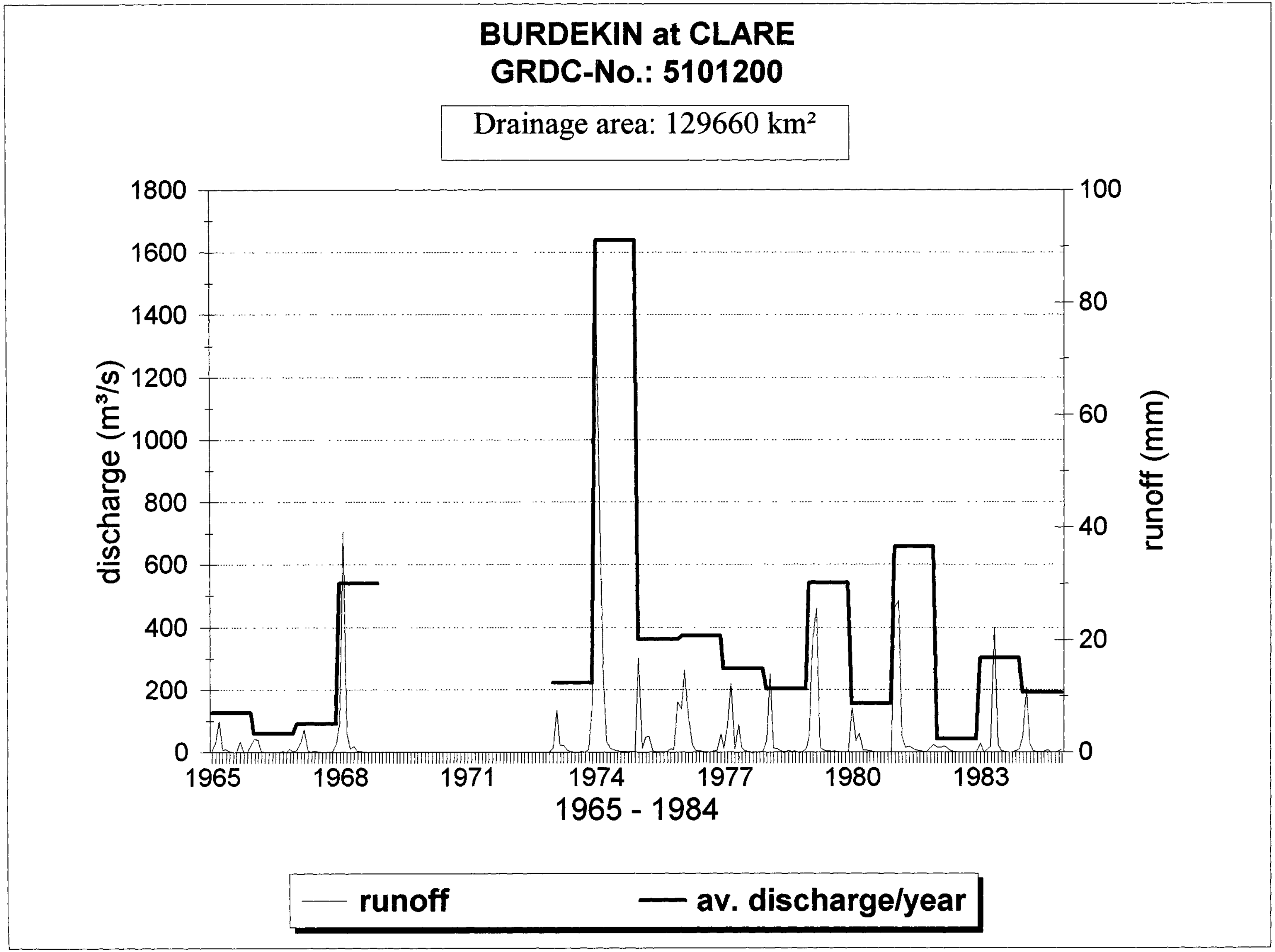


Figure 2.60

GLOBAL RUNOFF DATA CENTRE (GRDC)

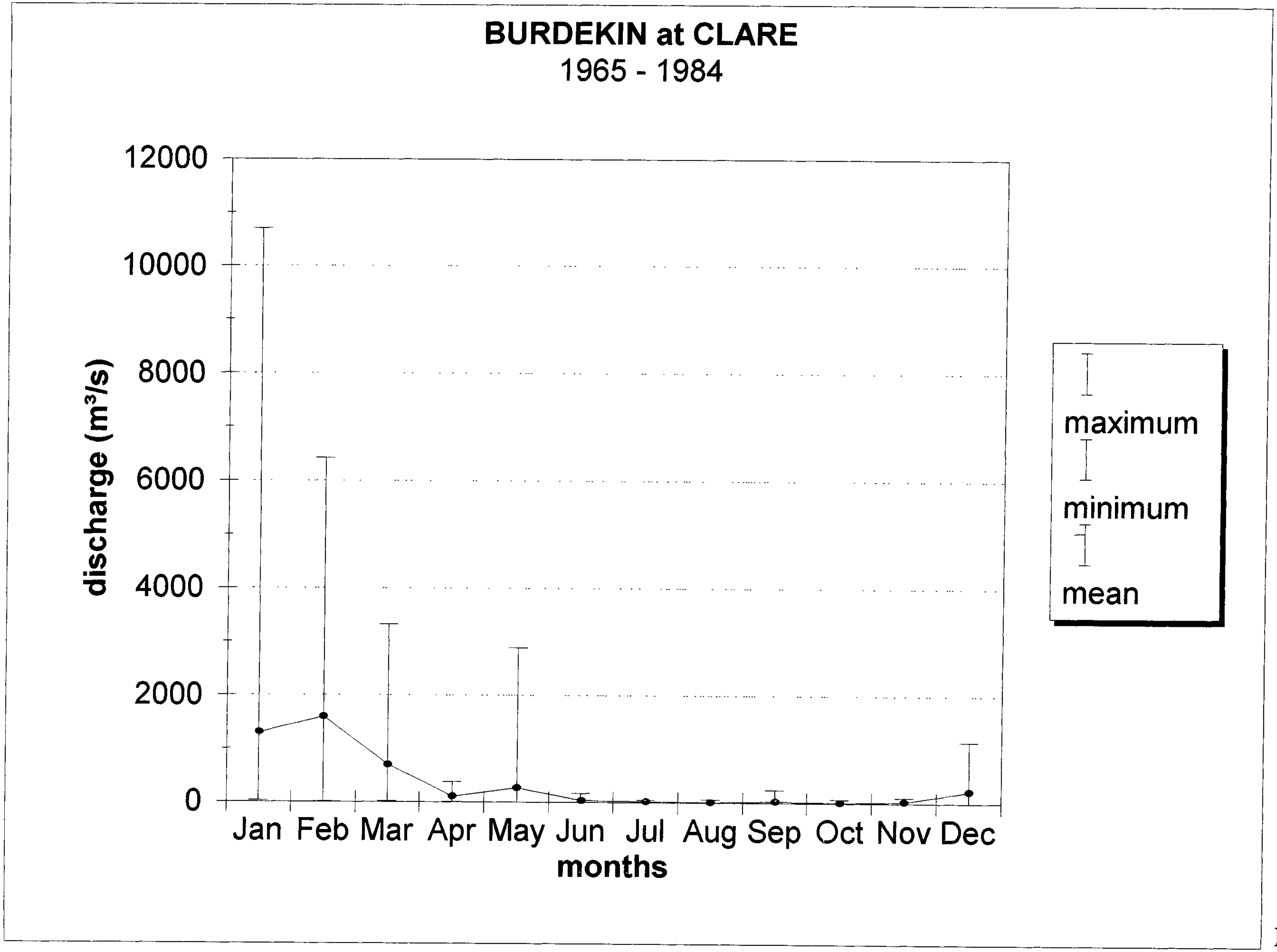


Figure 2.61

GLOBAL RUNOFF DATA CENTRE (GRDC)

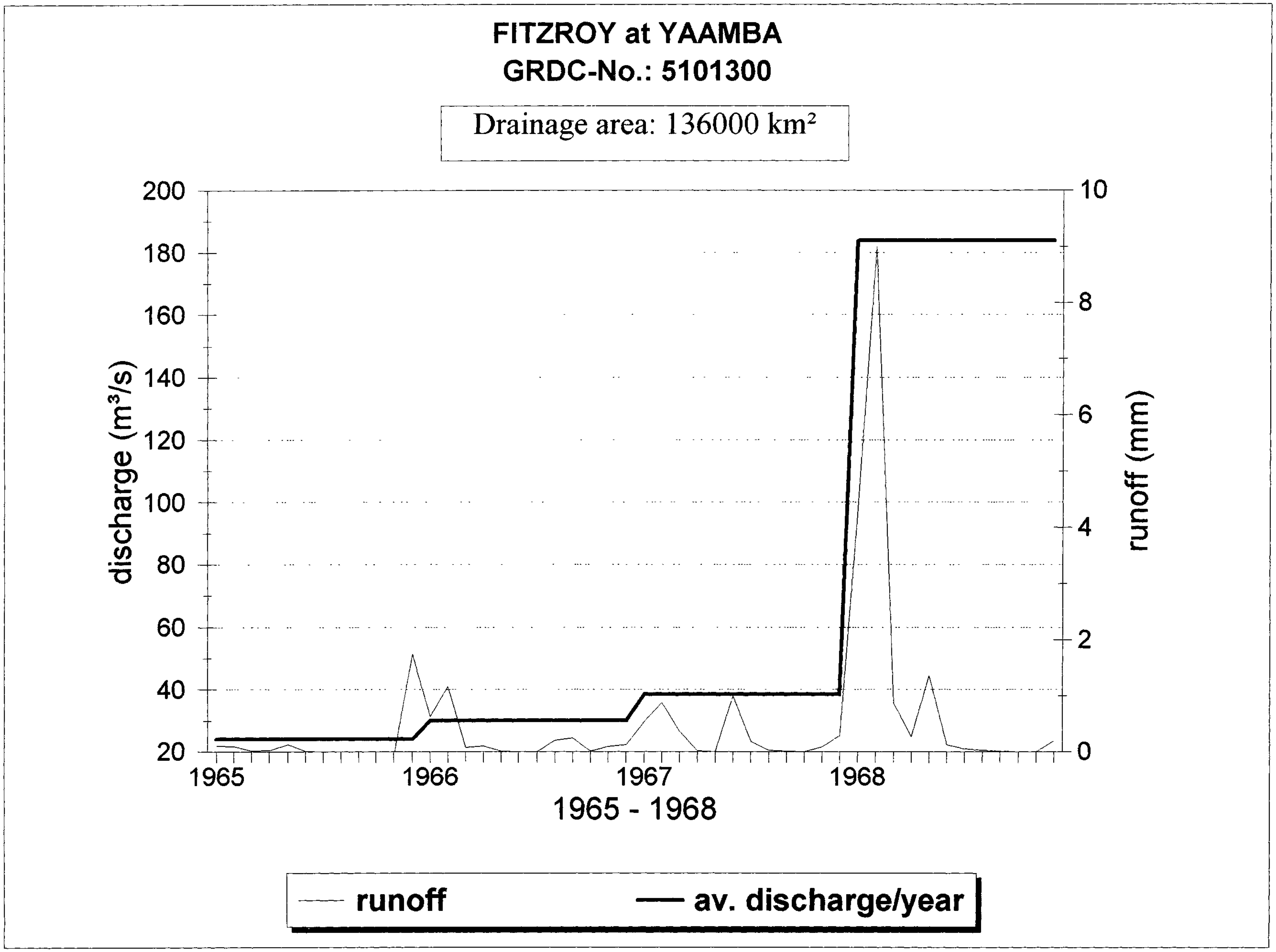


Figure 2.62

GLOBAL RUNOFF DATA CENTRE (GRDC)

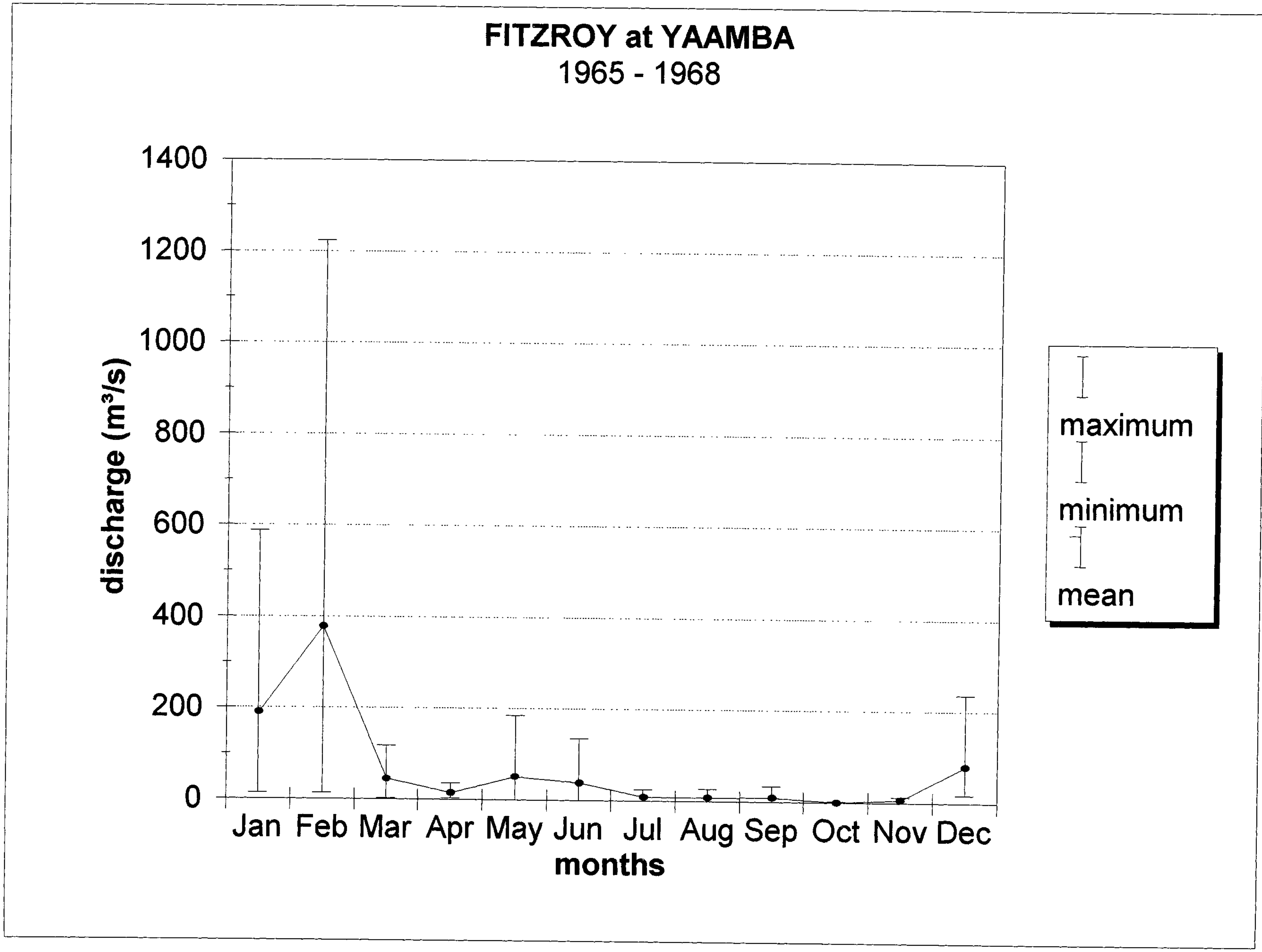


Figure 2.63

GLOBAL RUNOFF DATA CENTRE (GRDC)

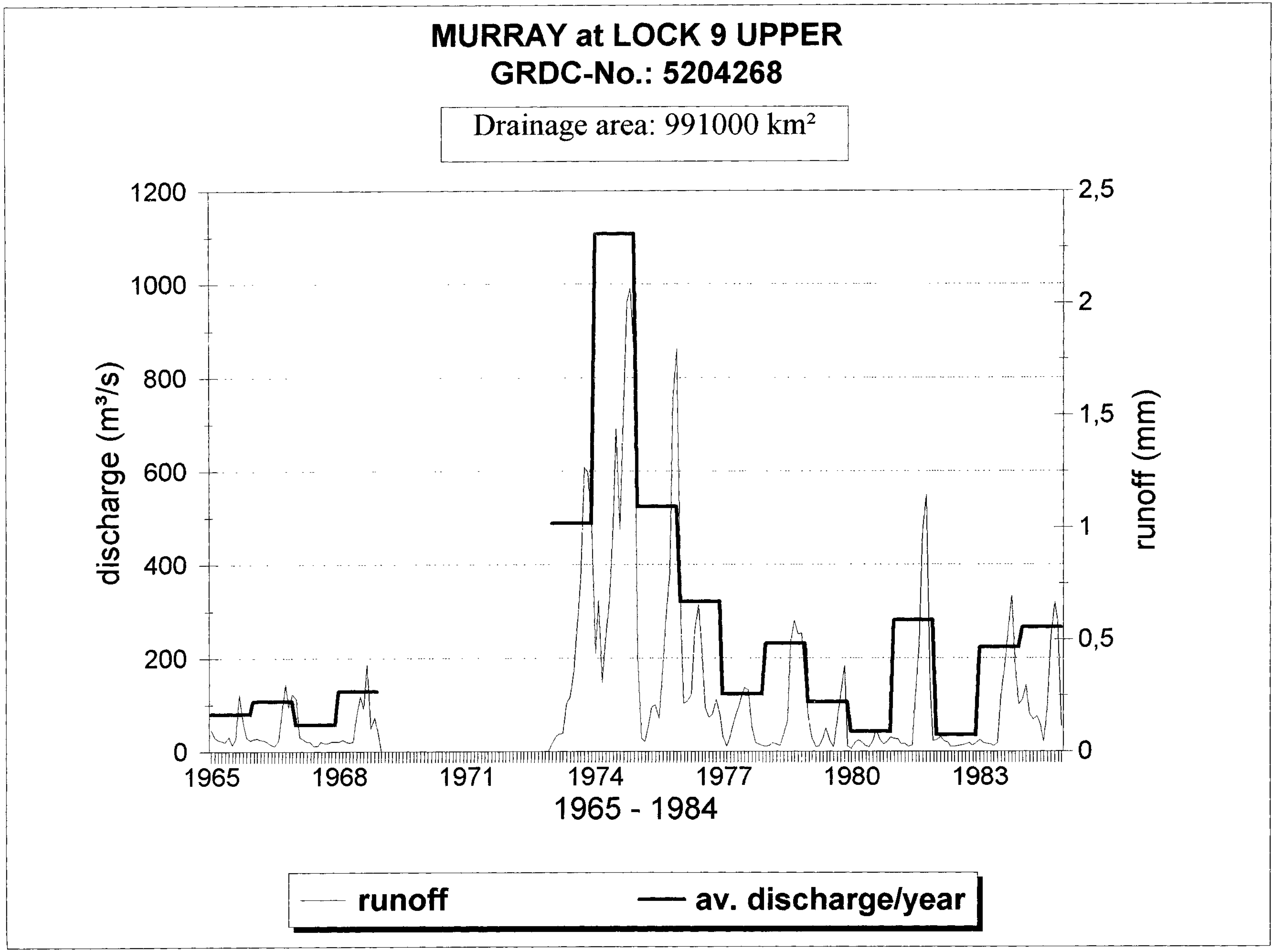


Figure 2.64

GLOBAL RUNOFF DATA CENTRE (GRDC)

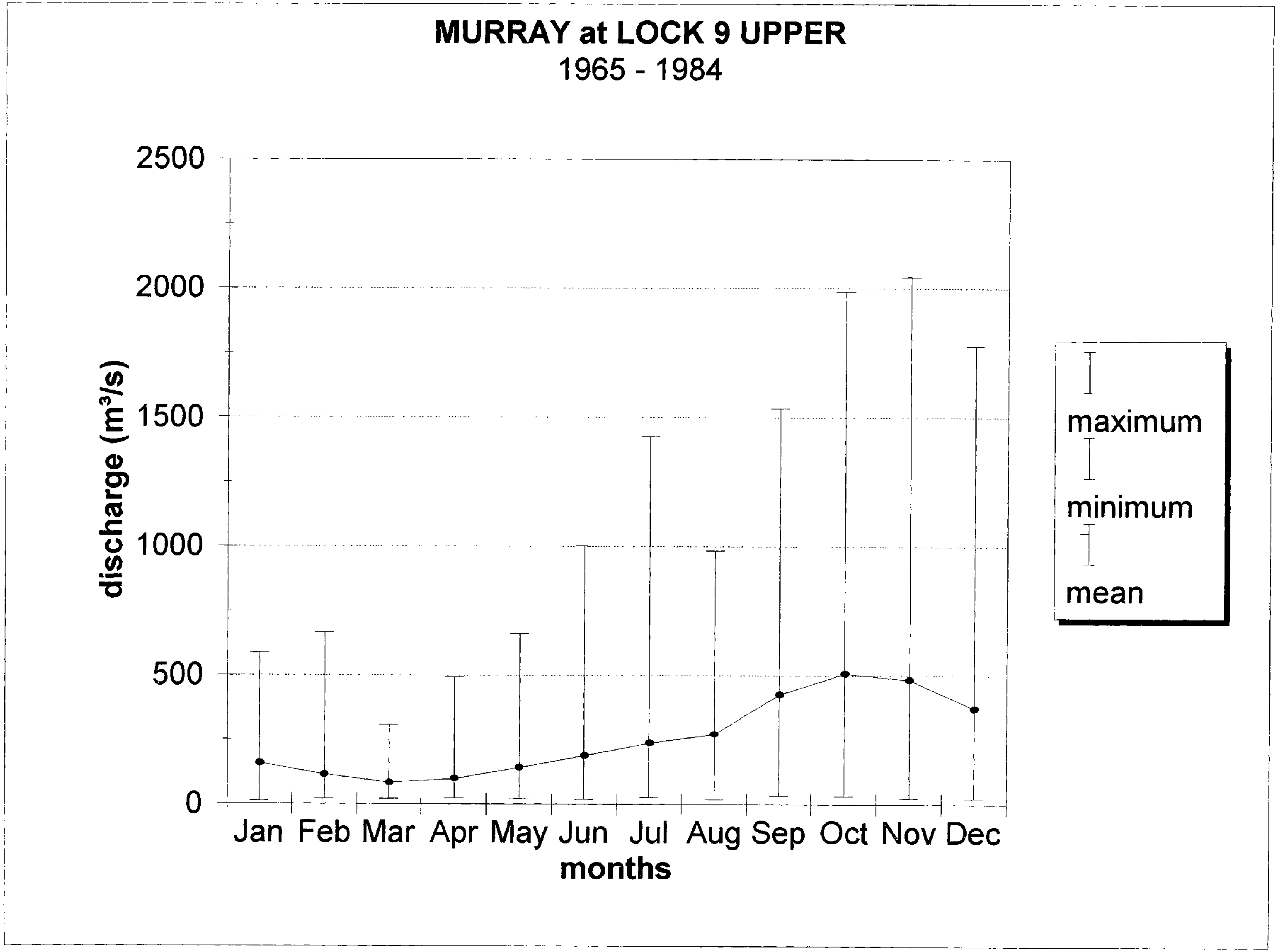


Figure 2.65

GLOBAL RUNOFF DATA CENTRE (GRDC)

SEPIK at AMBUNTI
GRDC-No.: 5550500

Drainage area: 40922 km²

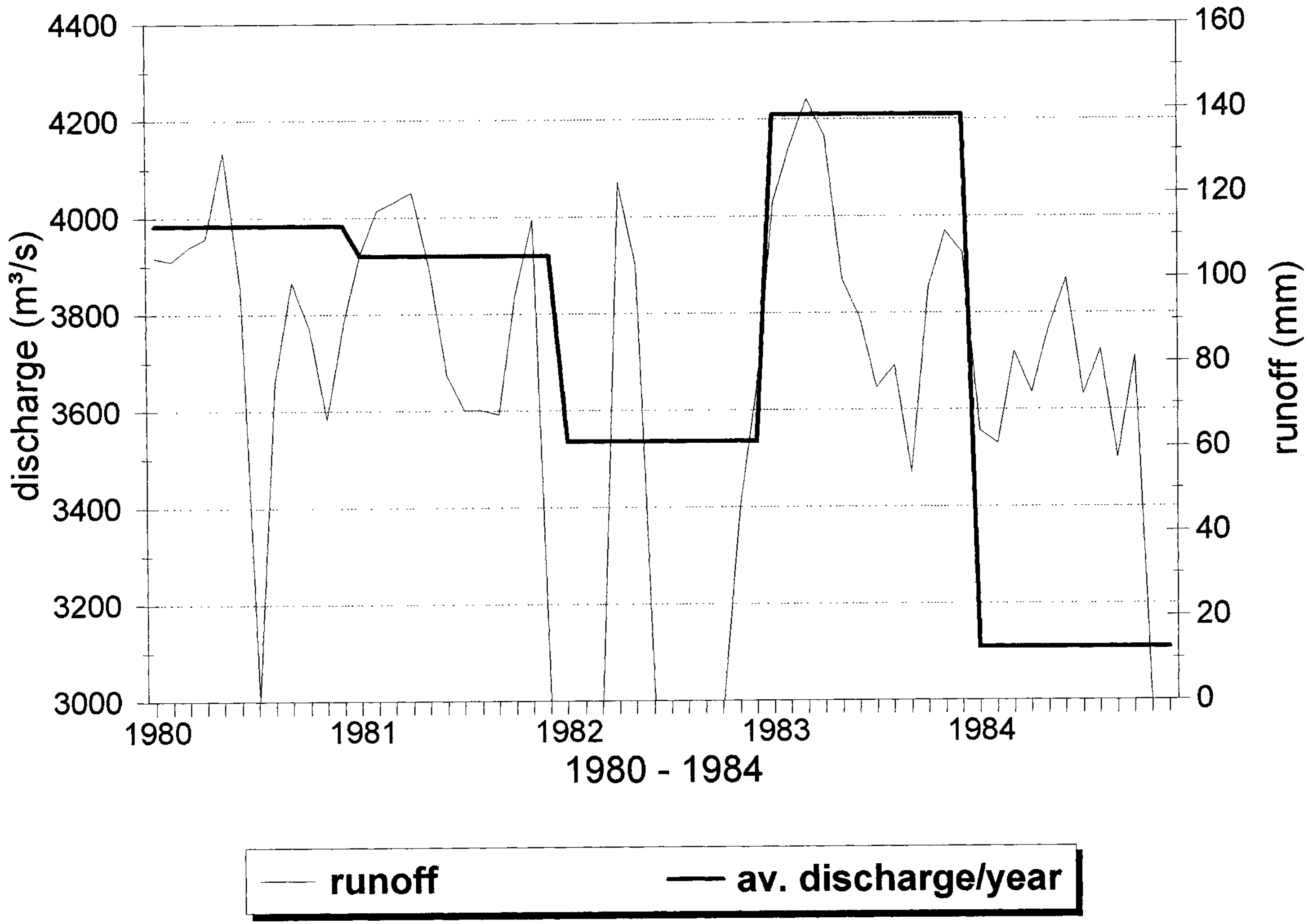


Figure 2.66

GLOBAL RUNOFF DATA CENTRE (GRDC)

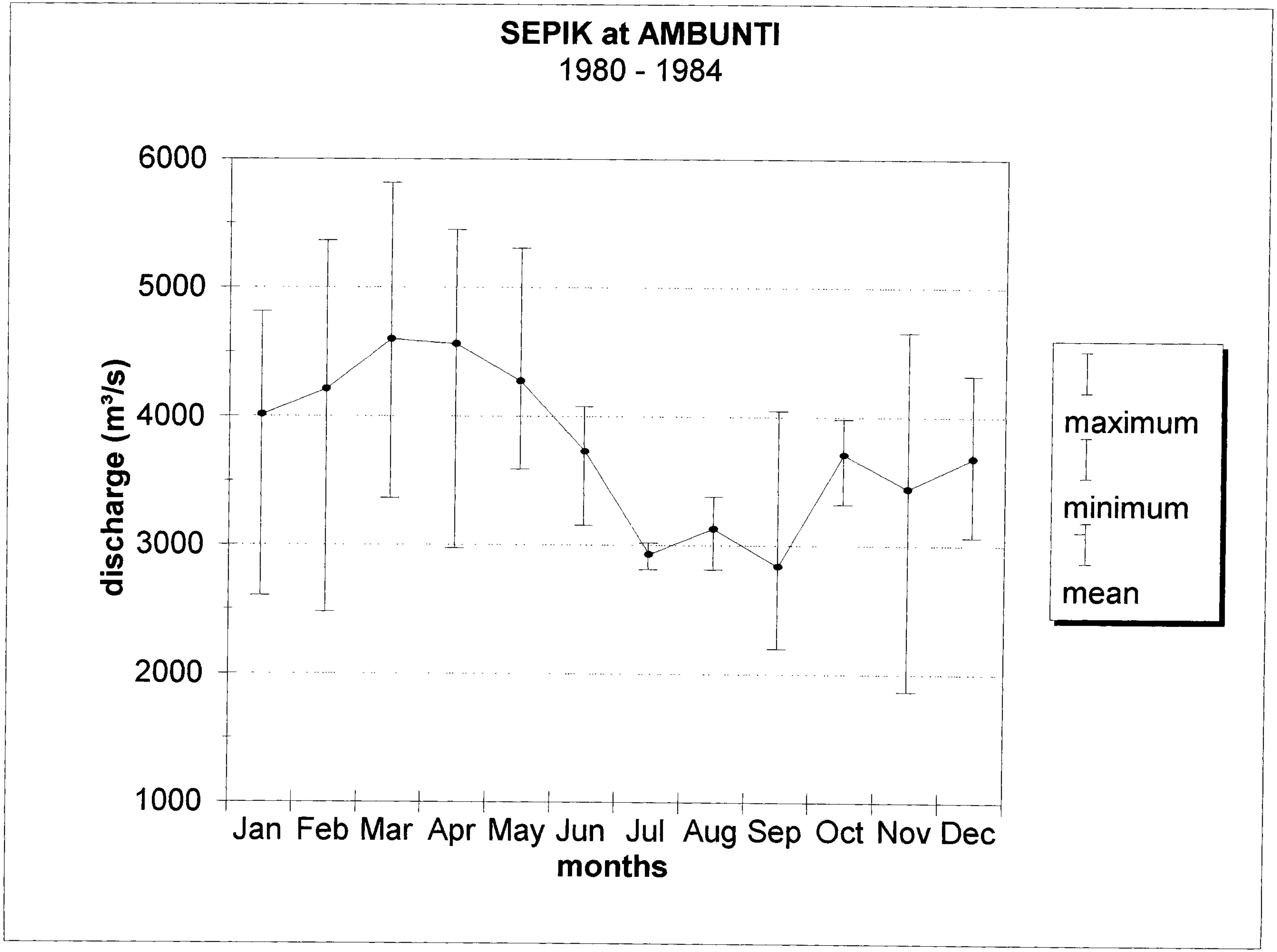


Figure 2.67

Europe

GLOBAL RUNOFF DATA CENTRE (GRDC)

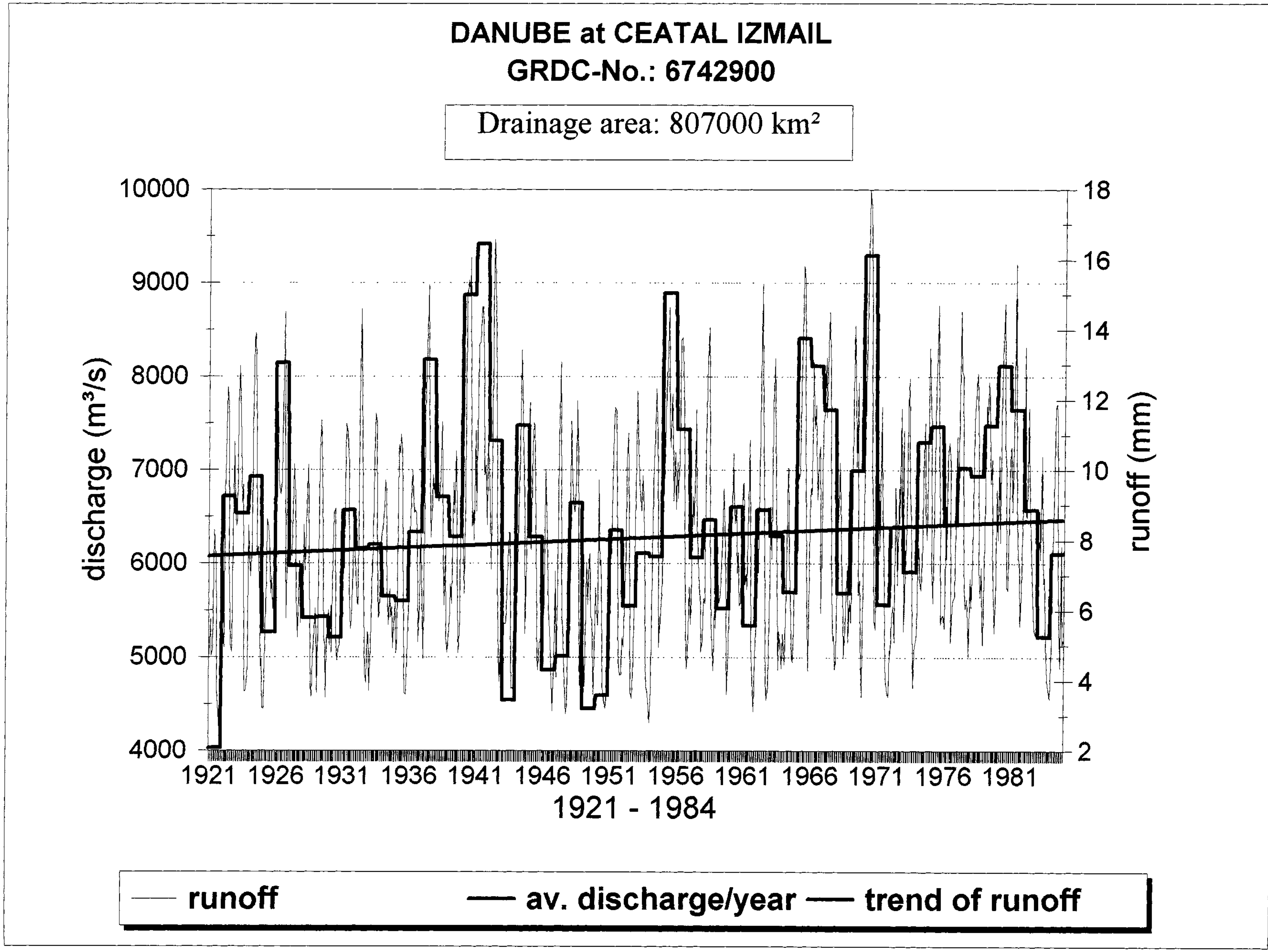


Figure 2.68

GLOBAL RUNOFF DATA CENTRE (GRDC)

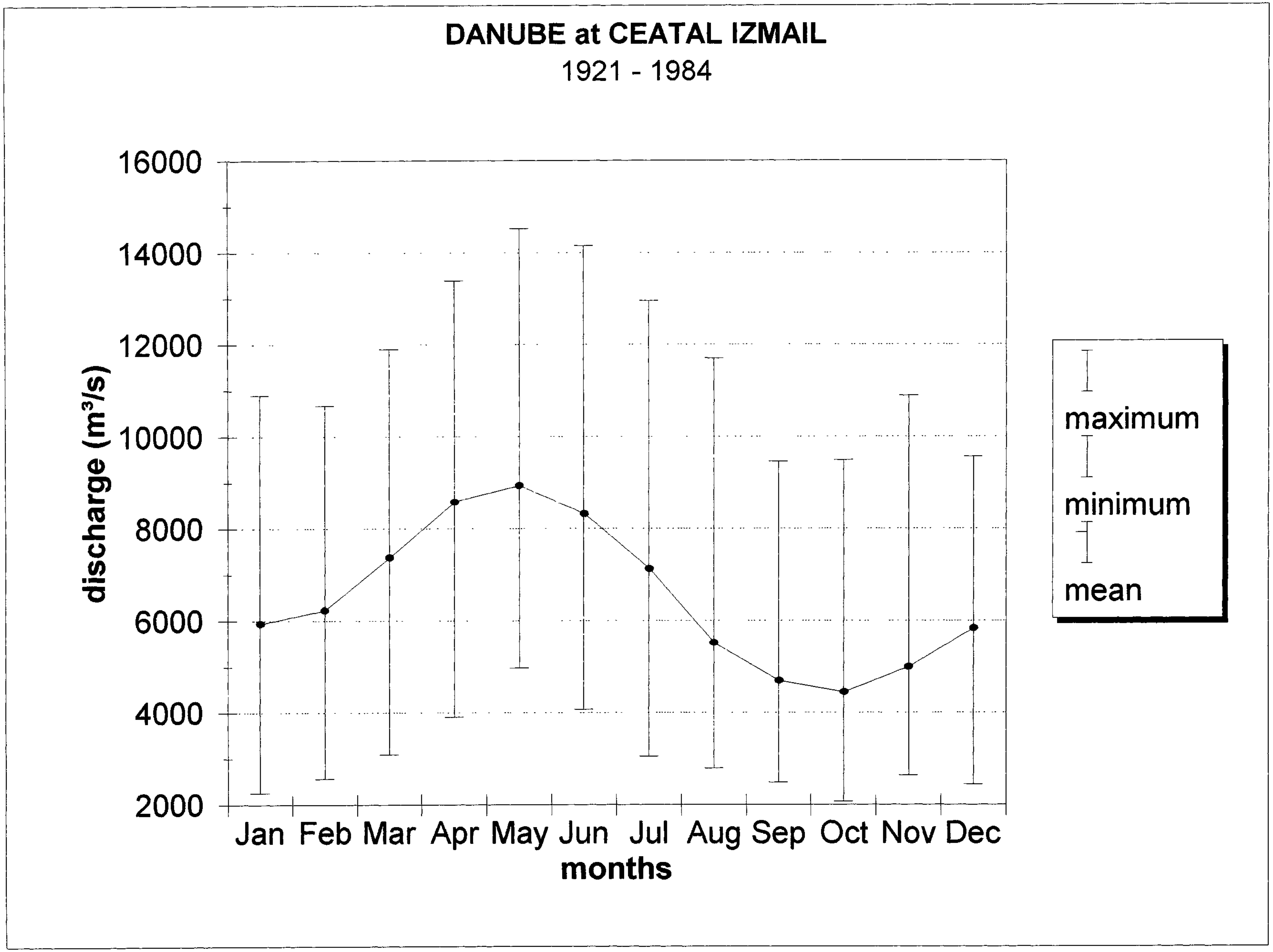


Figure 2.69

GLOBAL RUNOFF DATA CENTRE (GRDC)

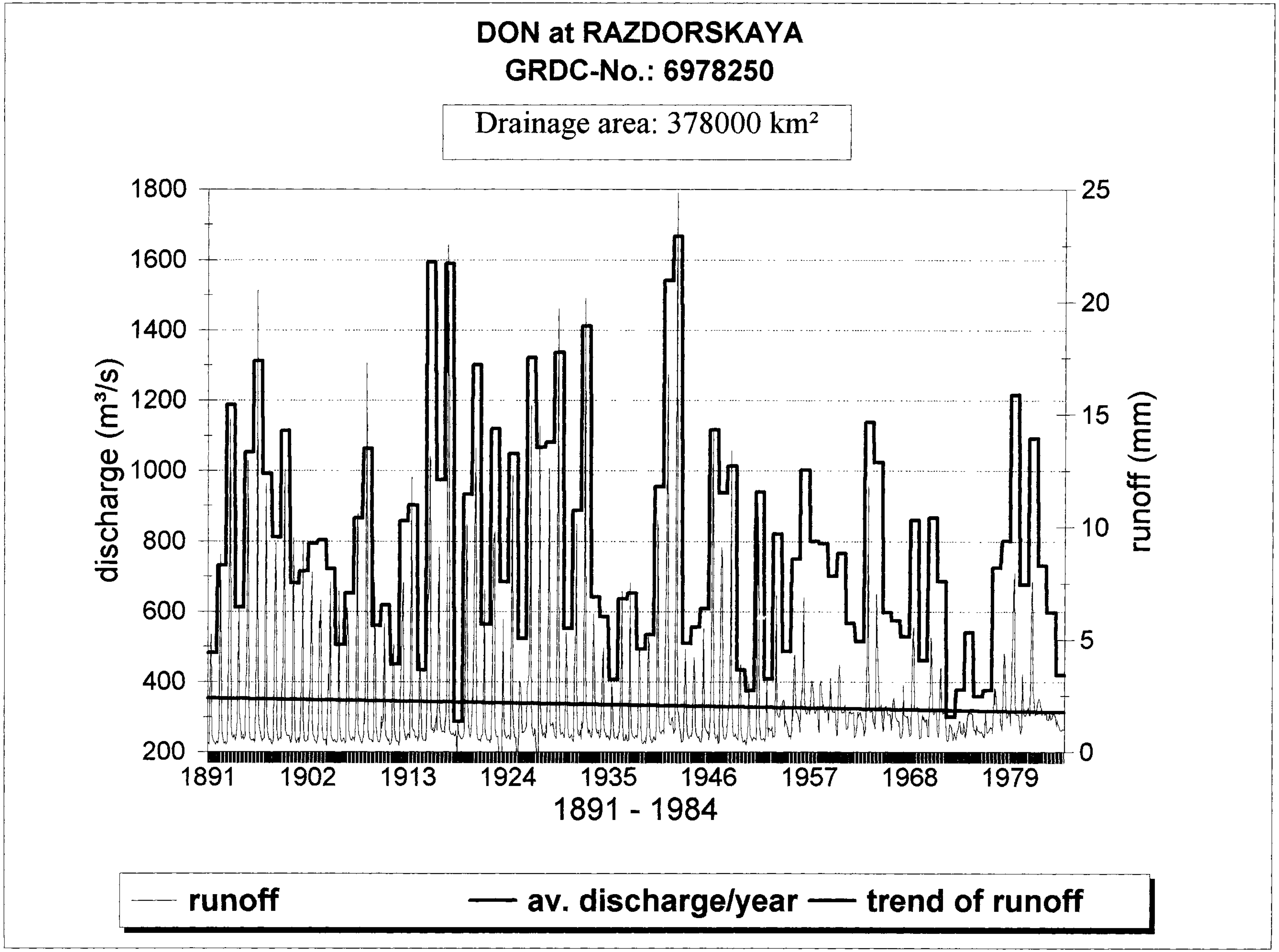


Figure 2.70

GLOBAL RUNOFF DATA CENTRE (GRDC)

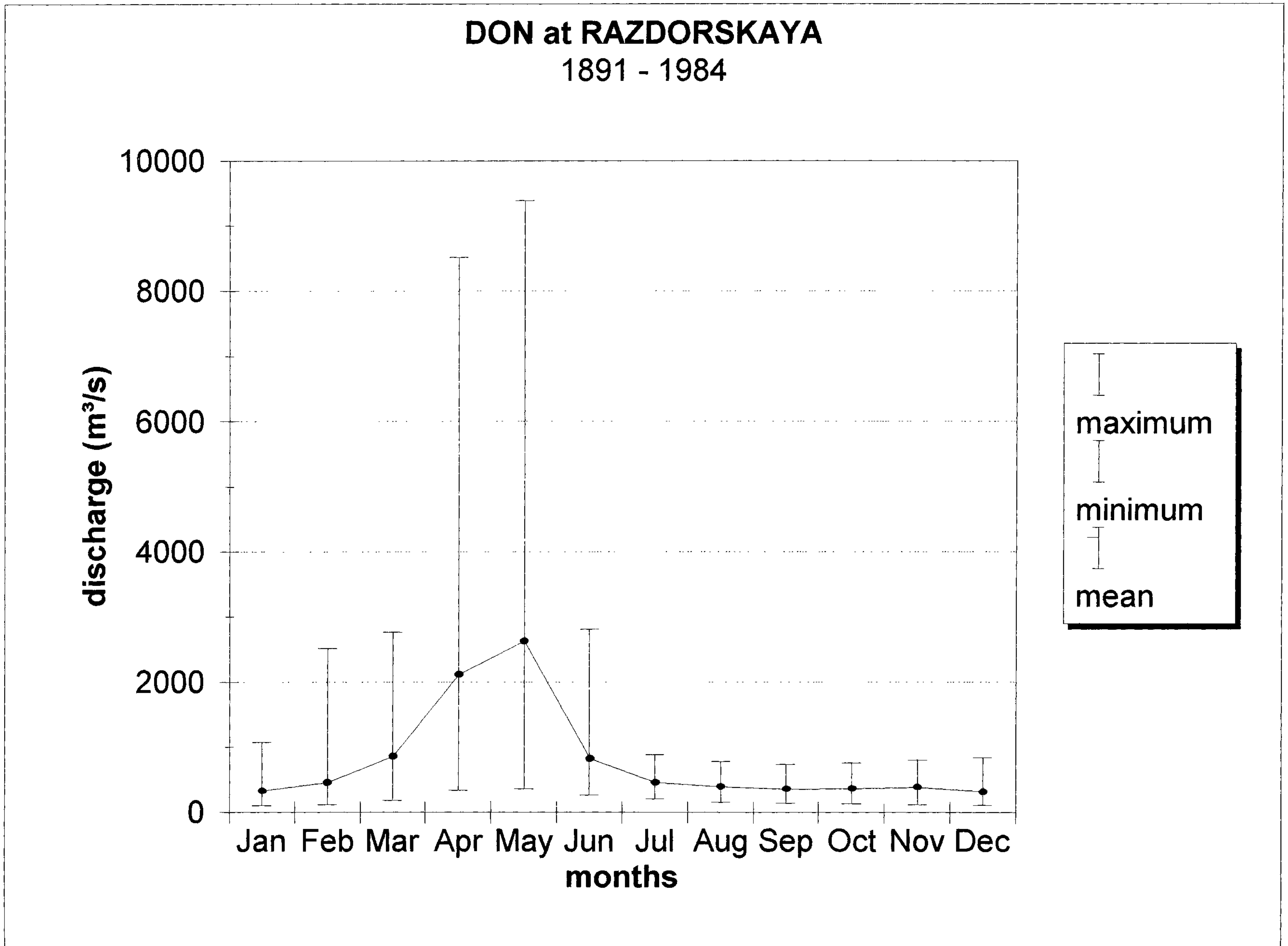


Figure 2.71

GLOBAL RUNOFF DATA CENTRE (GRDC)

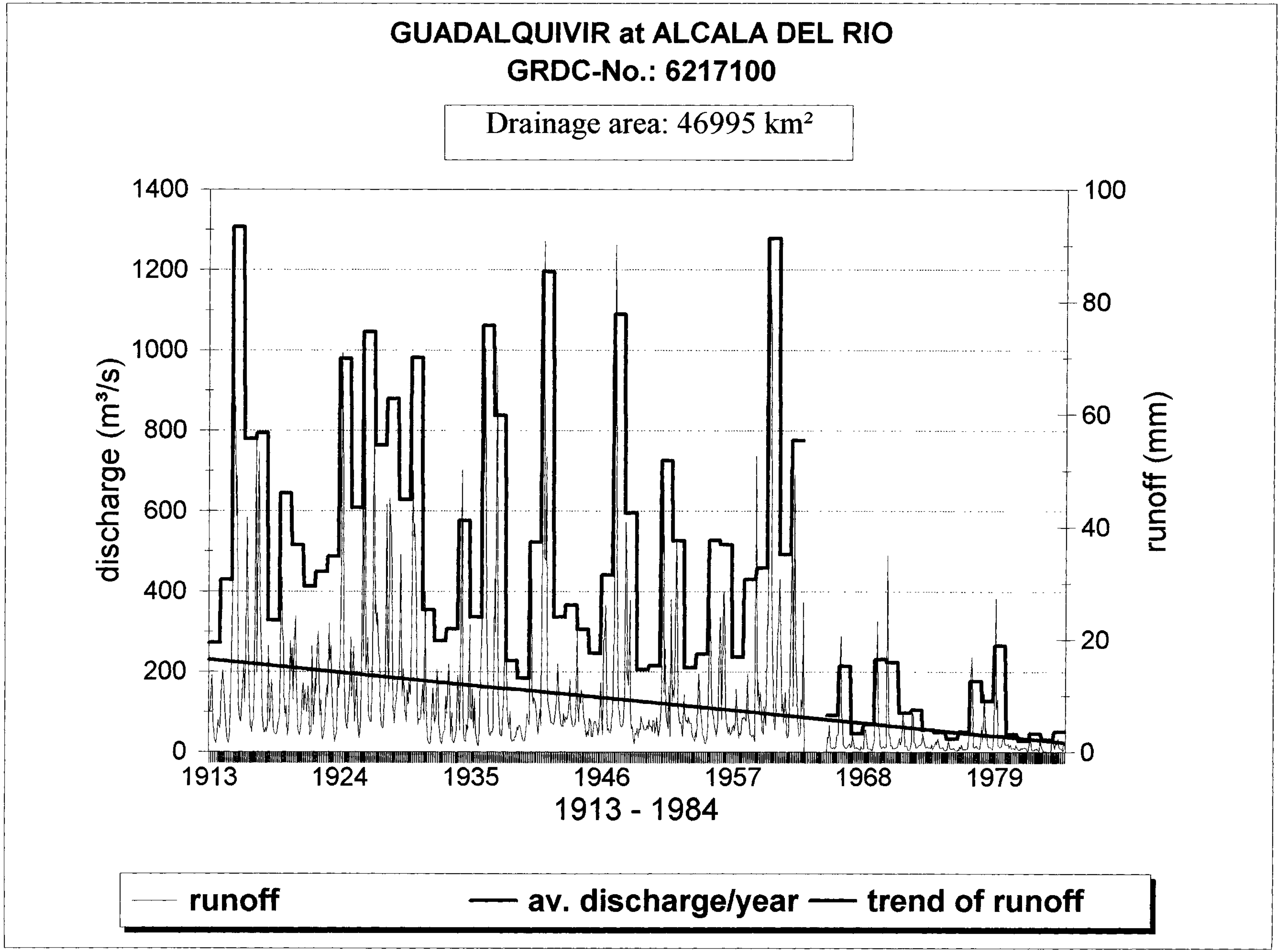


Figure 2.72

GLOBAL RUNOFF DATA CENTRE (GRDC)

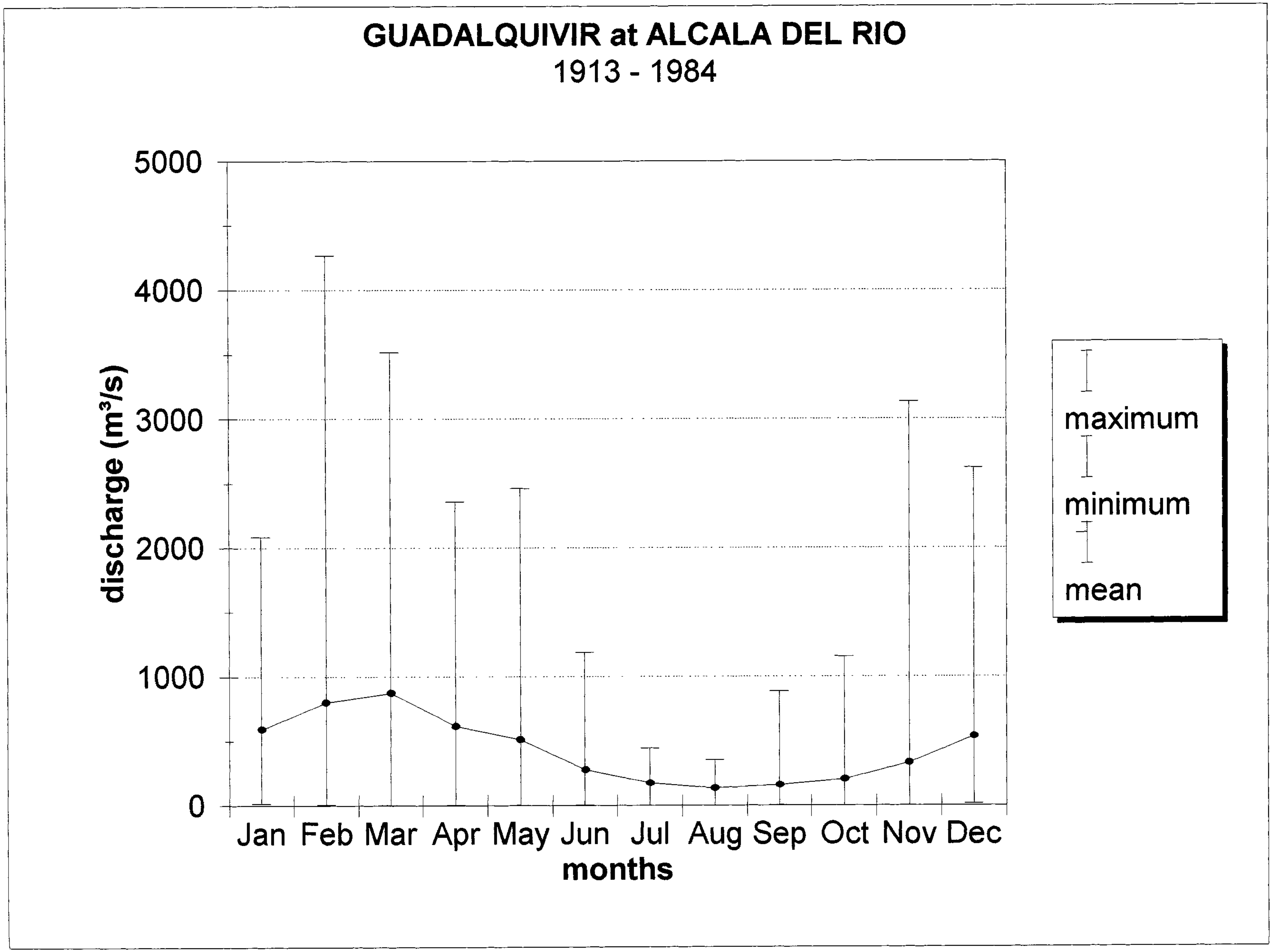


Figure 2.73

GLOBAL RUNOFF DATA CENTRE (GRDC)

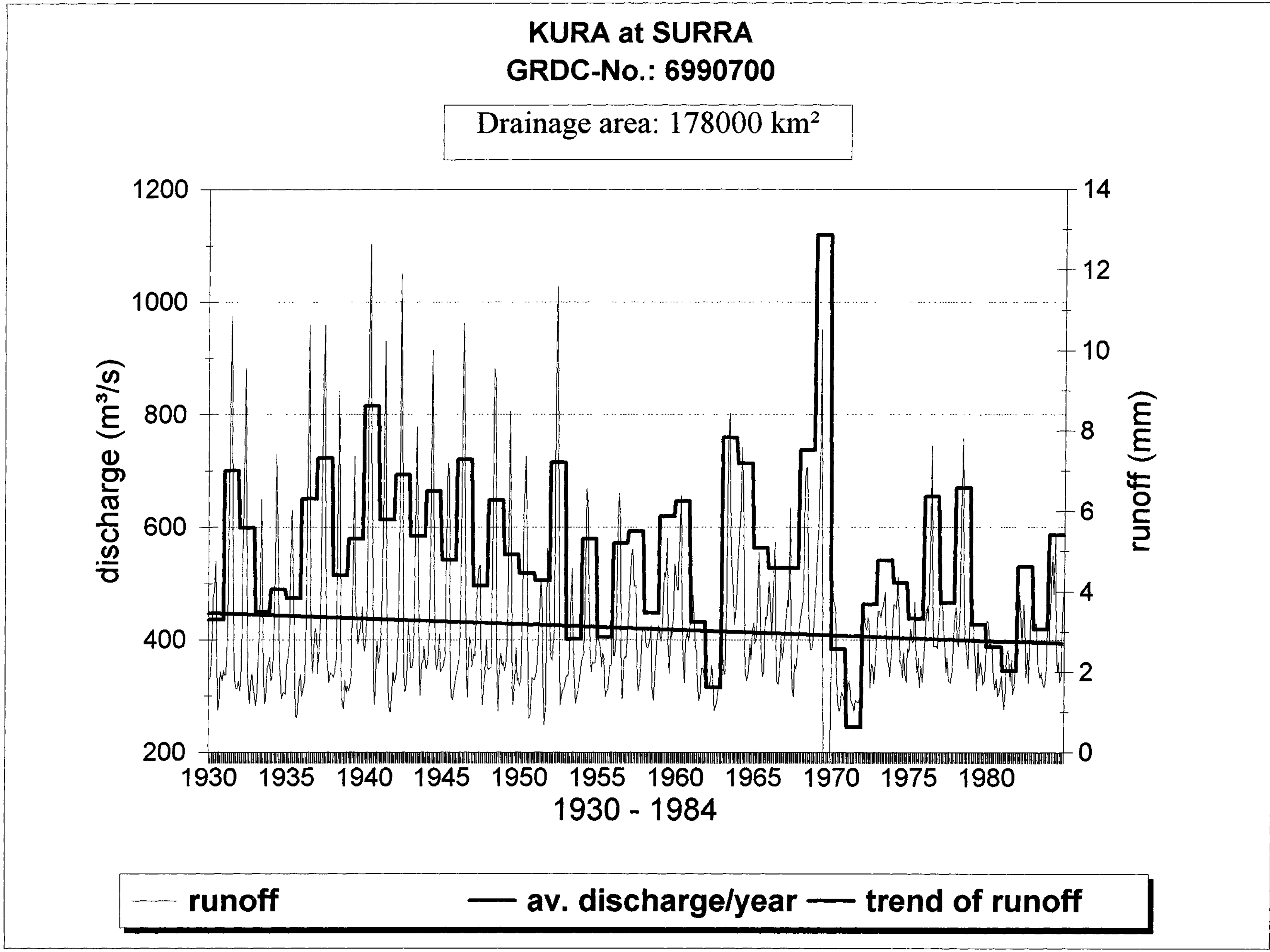


Figure 2.74

GLOBAL RUNOFF DATA CENTRE (GRDC)

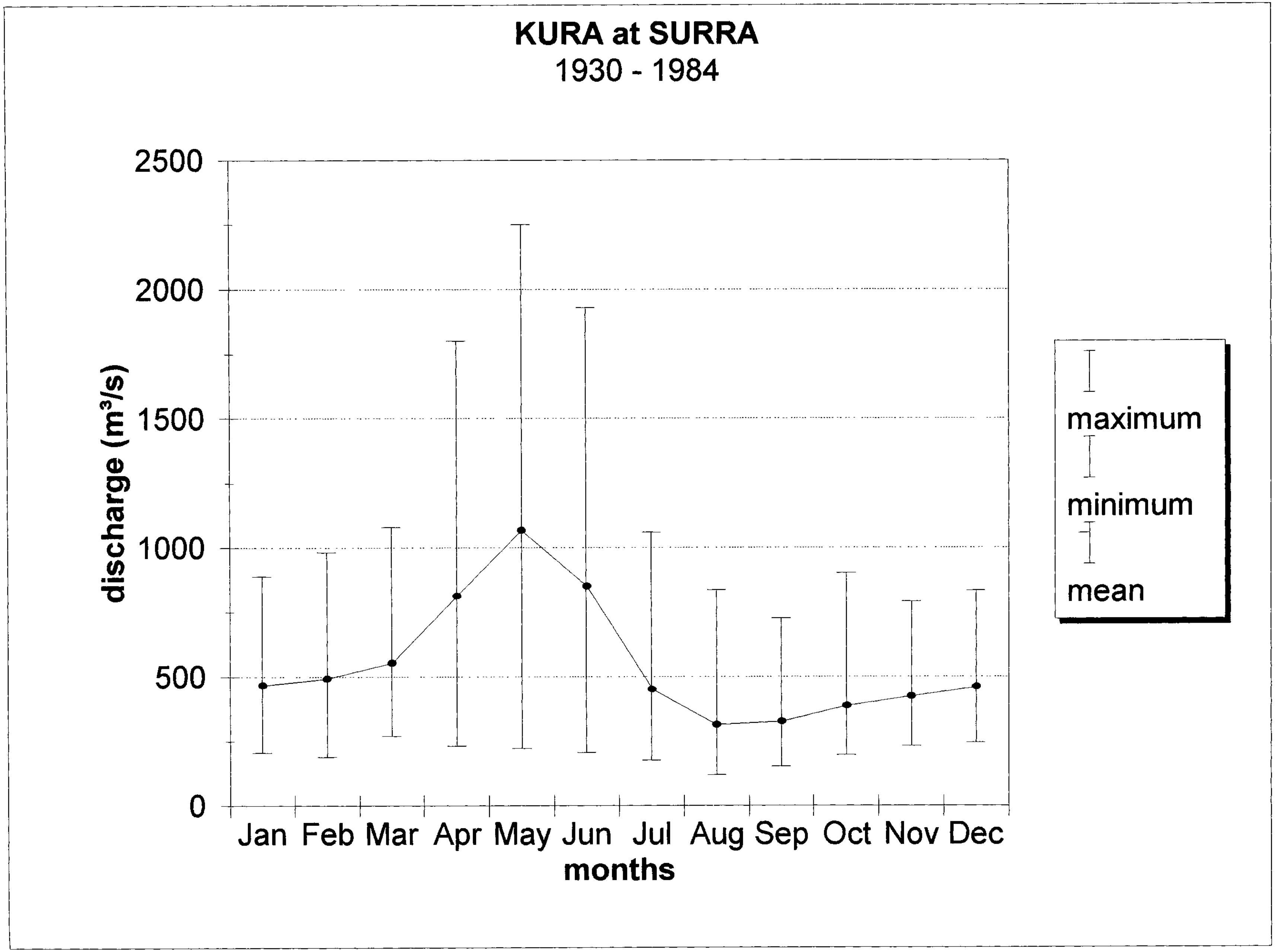


Figure 2.75

GLOBAL RUNOFF DATA CENTRE (GRDC)

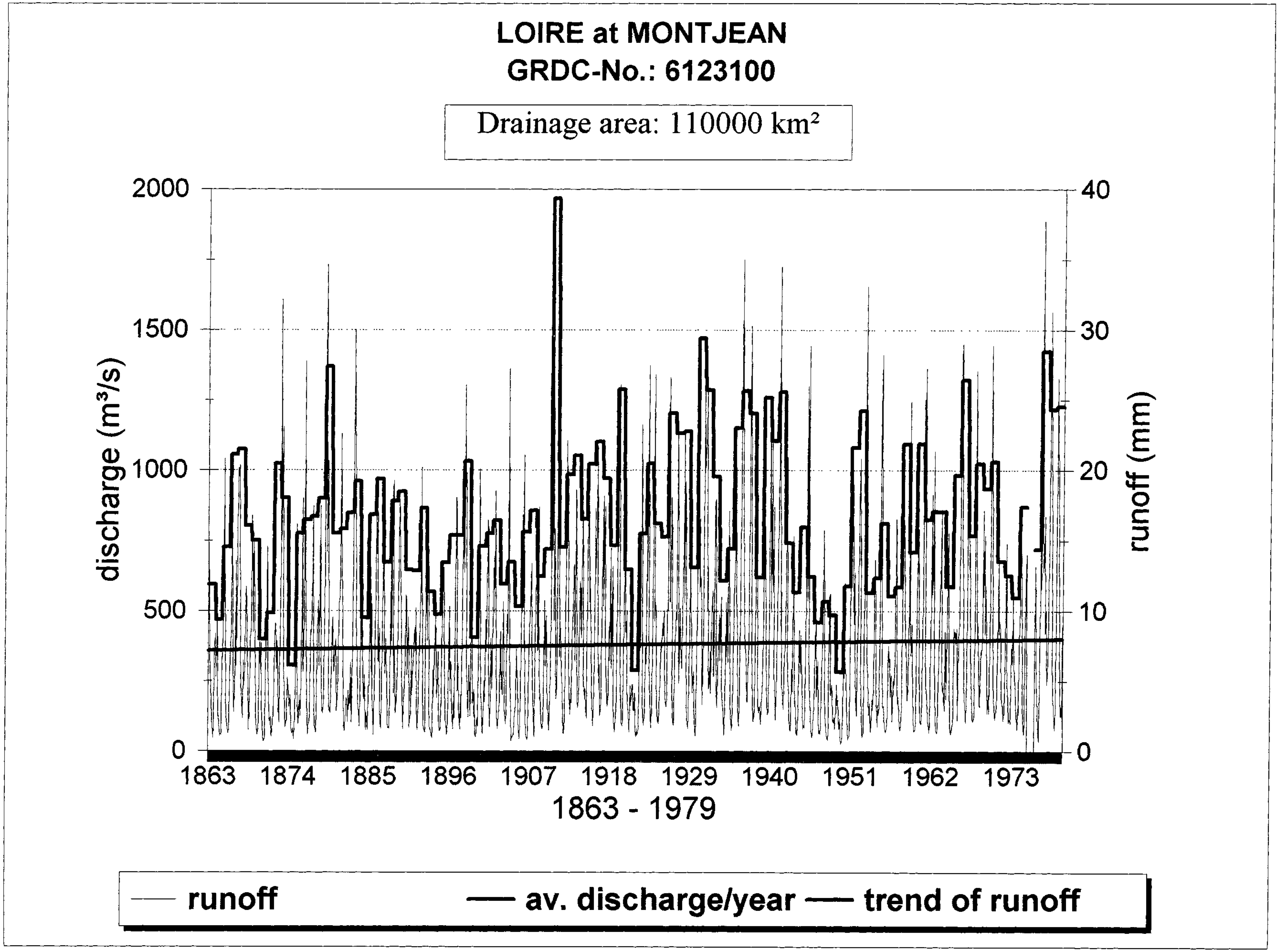


Figure 2.76

GLOBAL RUNOFF DATA CENTRE (GRDC)

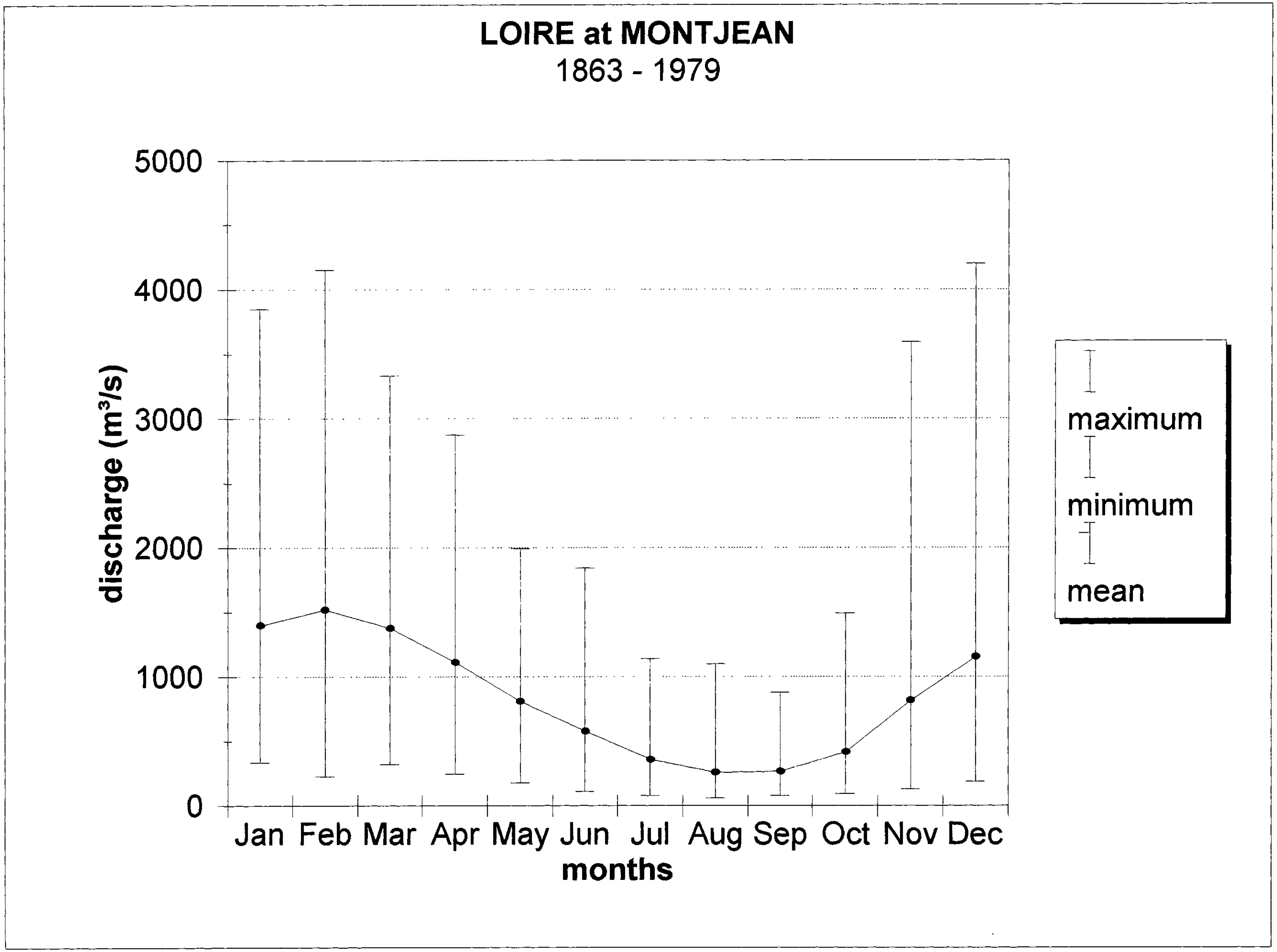


Figure 2.77

GLOBAL RUNOFF DATA CENTRE (GRDC)

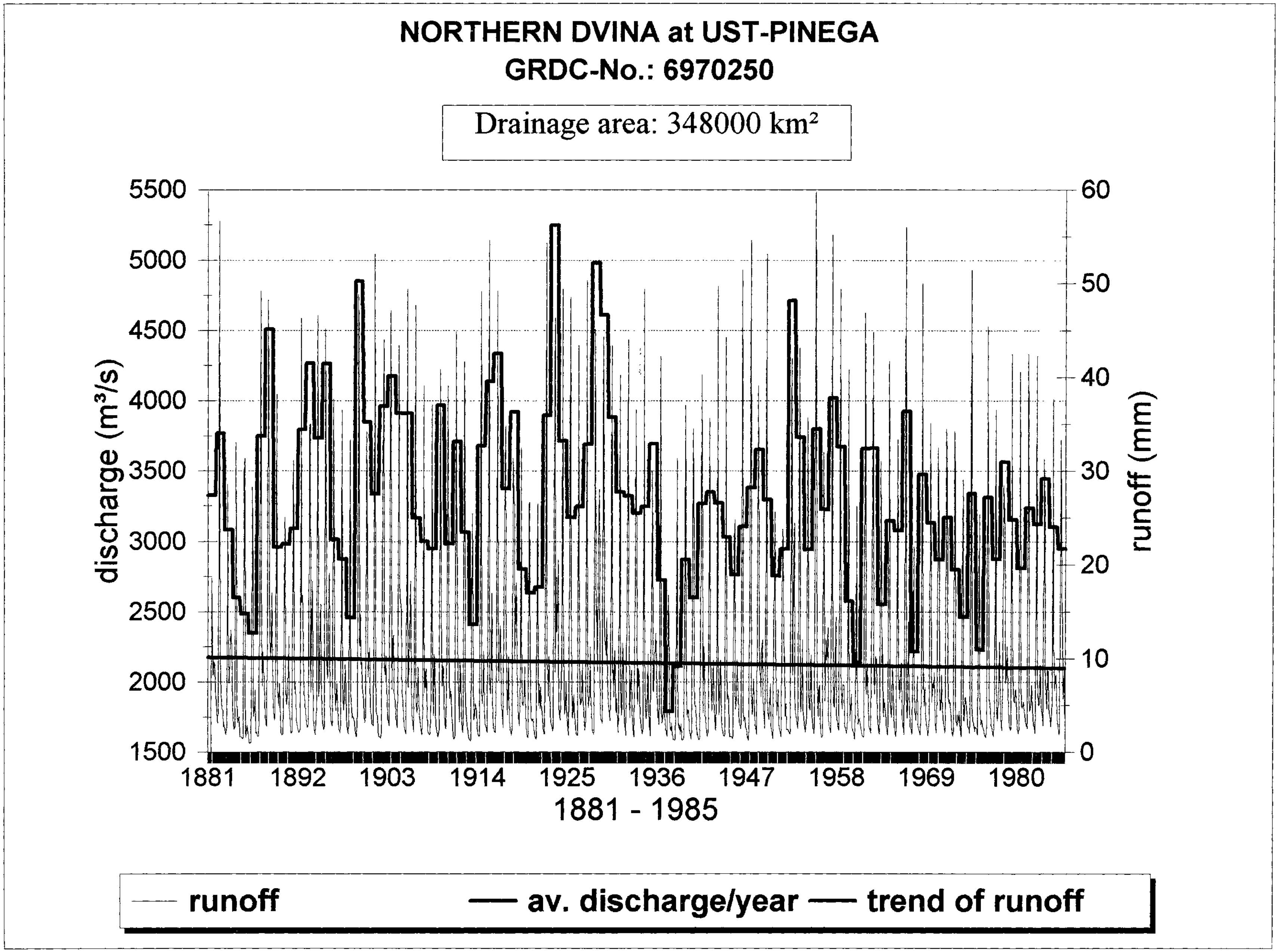


Figure 2.78

GLOBAL RUNOFF DATA CENTRE (GRDC)

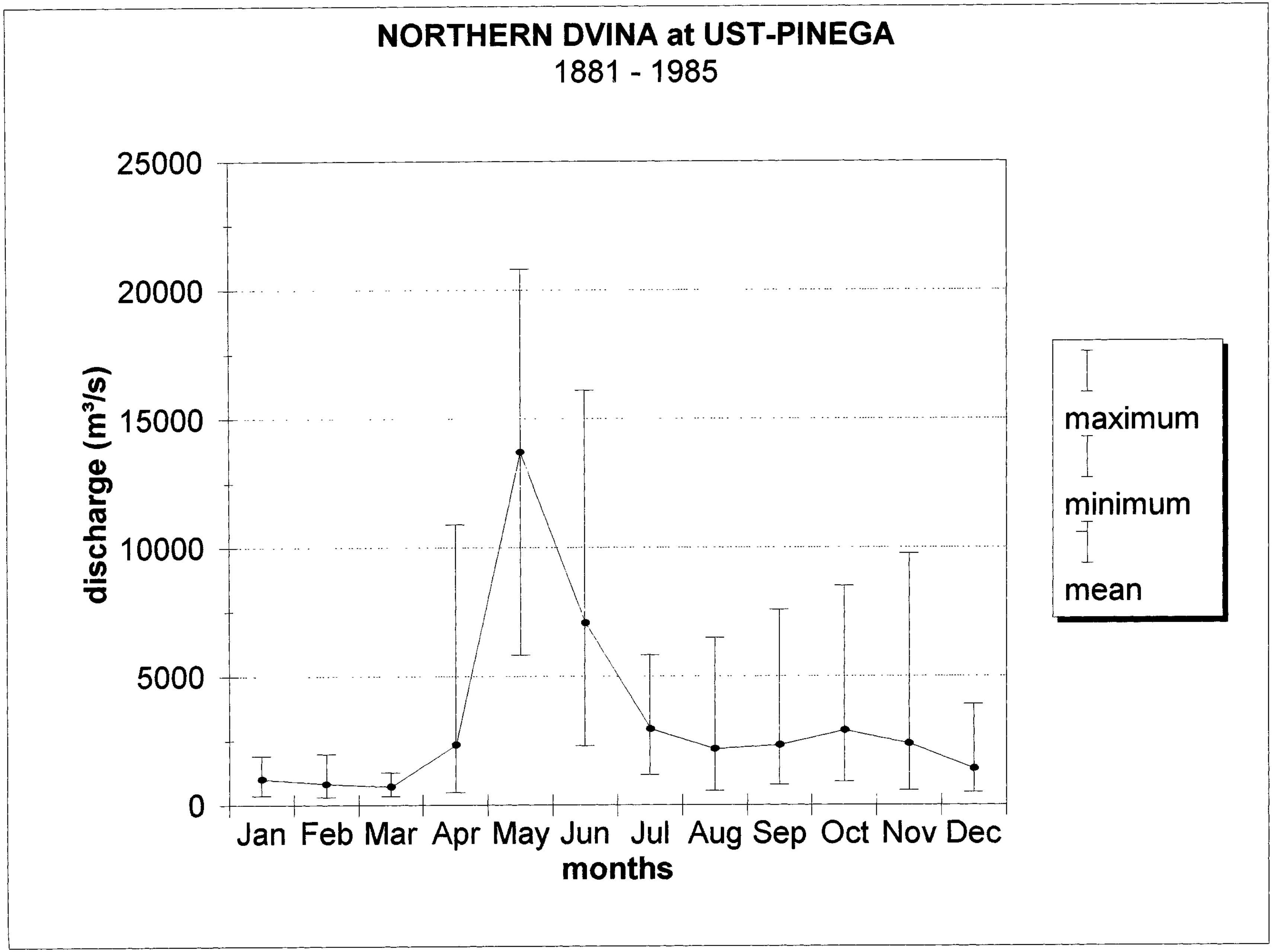


Figure 2.79

GLOBAL RUNOFF DATA CENTRE (GRDC)

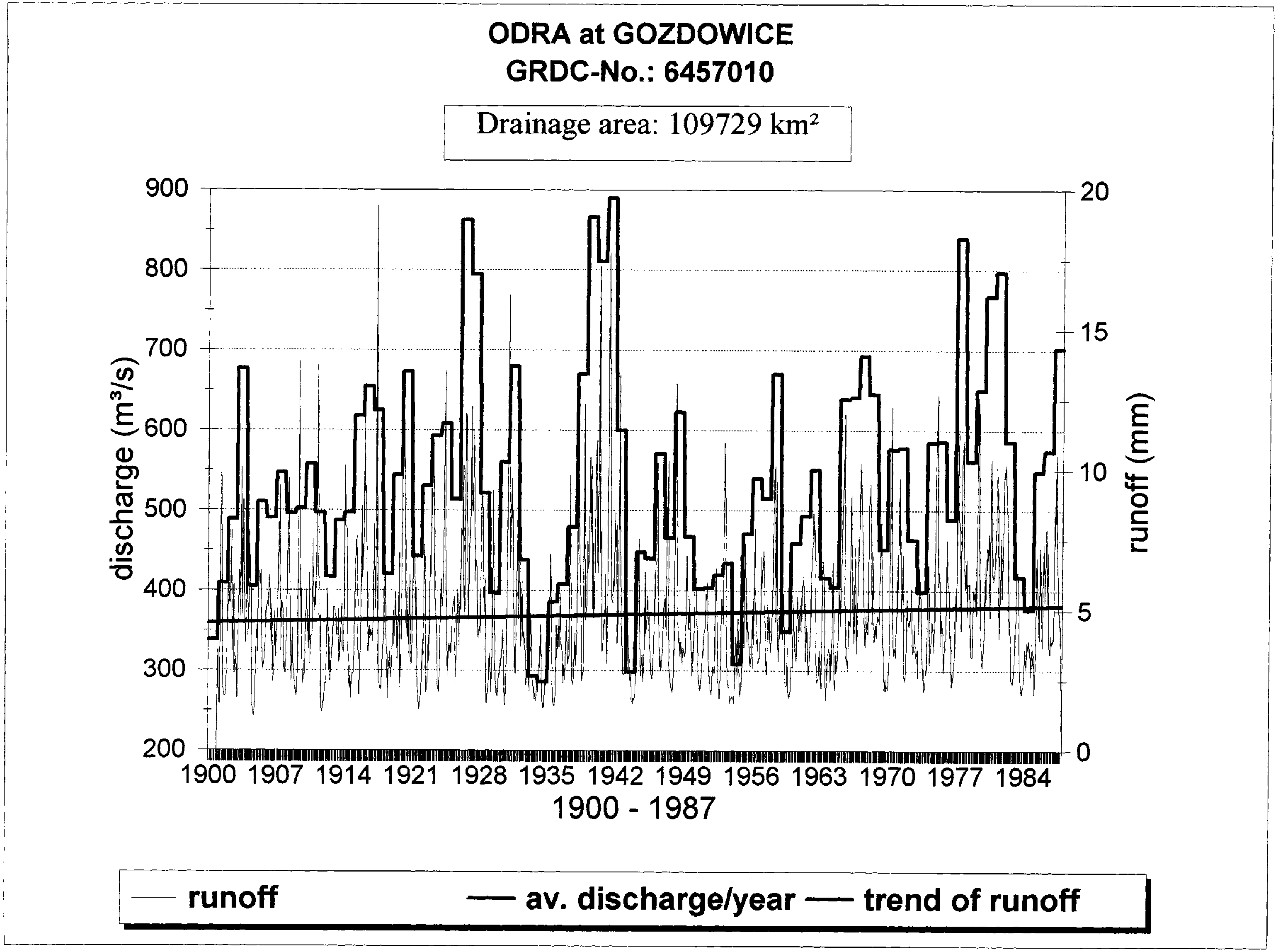


Figure 2.80

GLOBAL RUNOFF DATA CENTRE (GRDC)

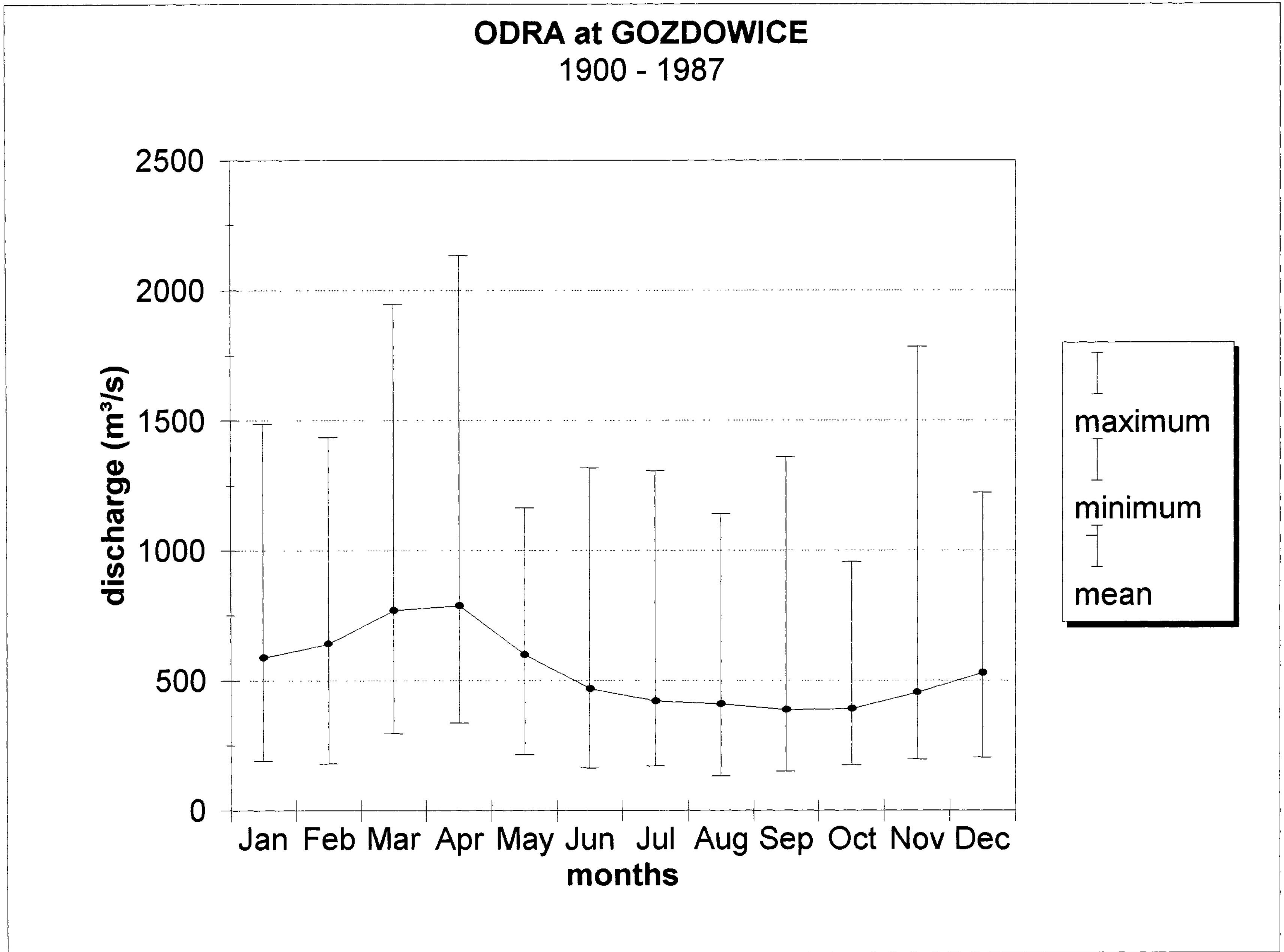


Figure 2.81

GLOBAL RUNOFF DATA CENTRE (GRDC)

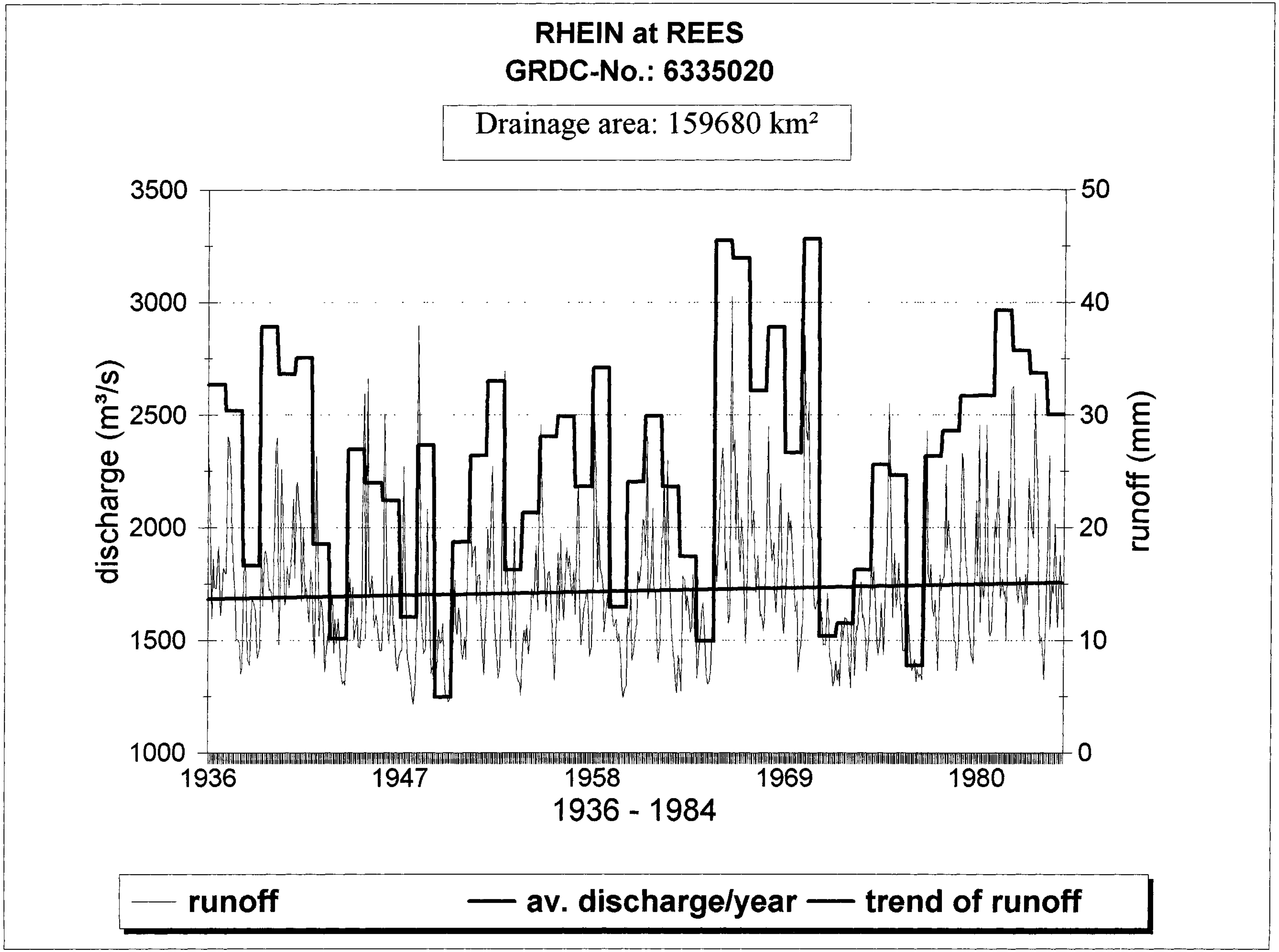


Figure 2.82

GLOBAL RUNOFF DATA CENTRE (GRDC)

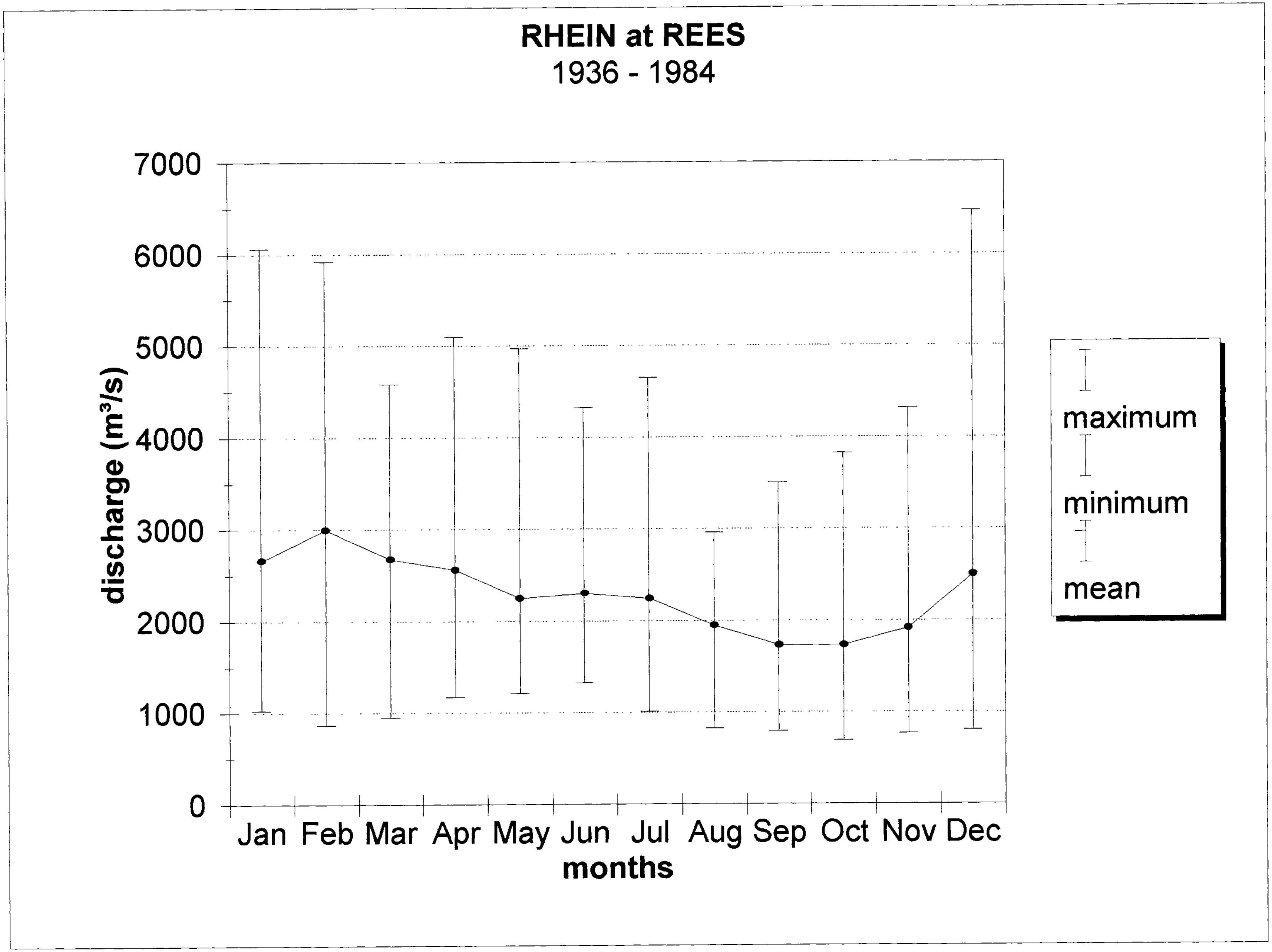


Figure 2.83

GLOBAL RUNOFF DATA CENTRE (GRDC)

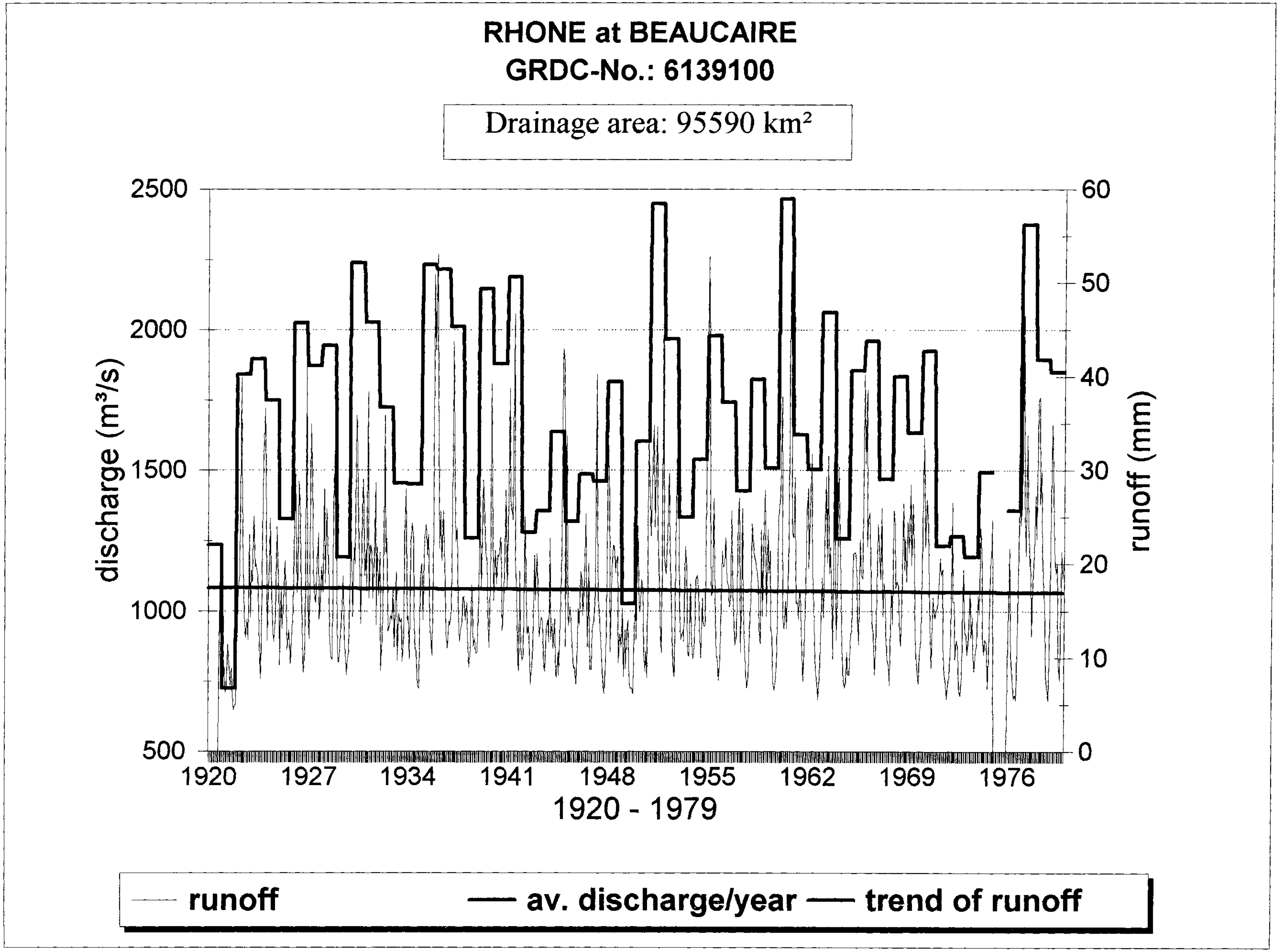


Figure 2.84

GLOBAL RUNOFF DATA CENTRE (GRDC)

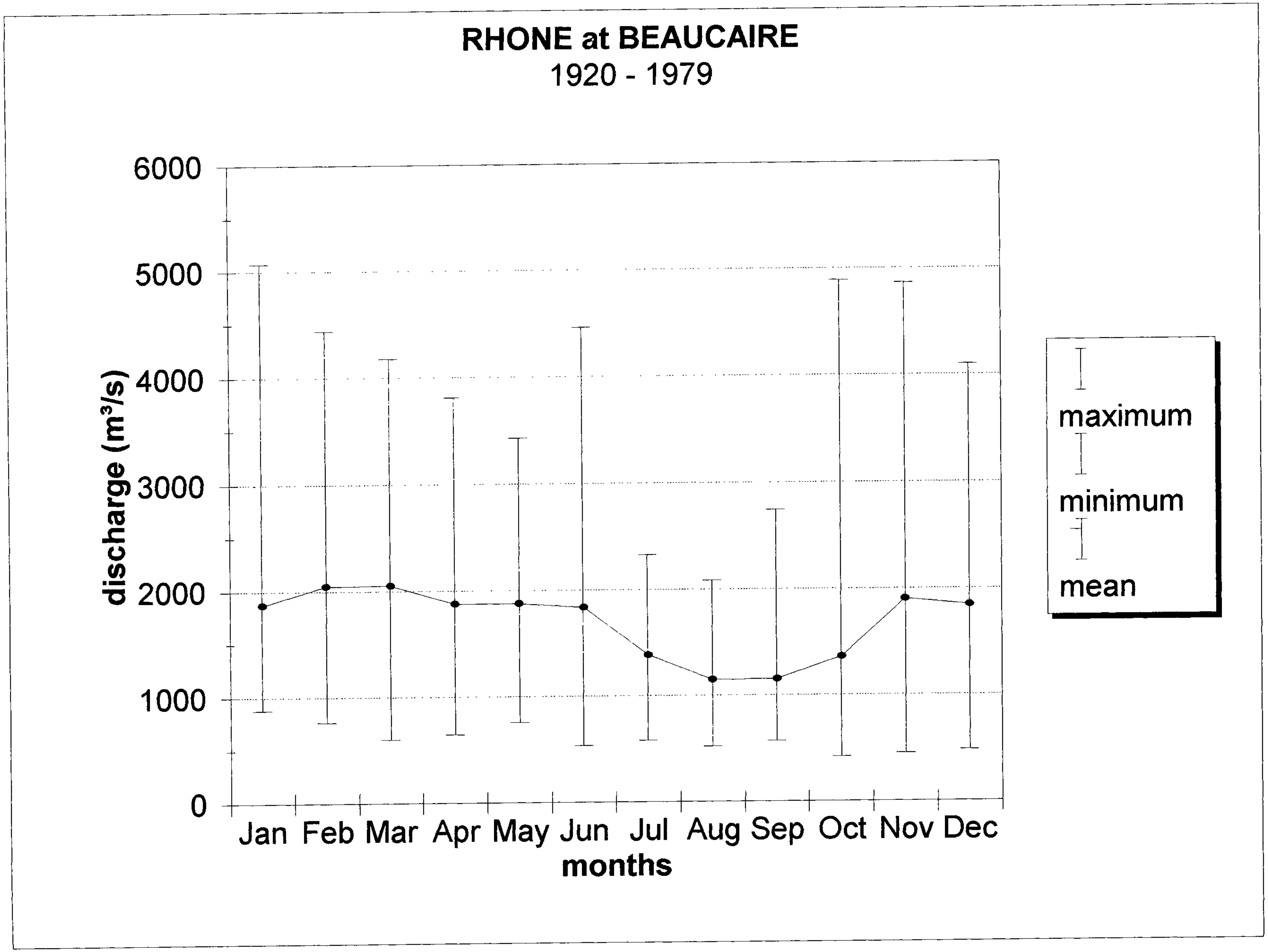


Figure 2.85

GLOBAL RUNOFF DATA CENTRE (GRDC)

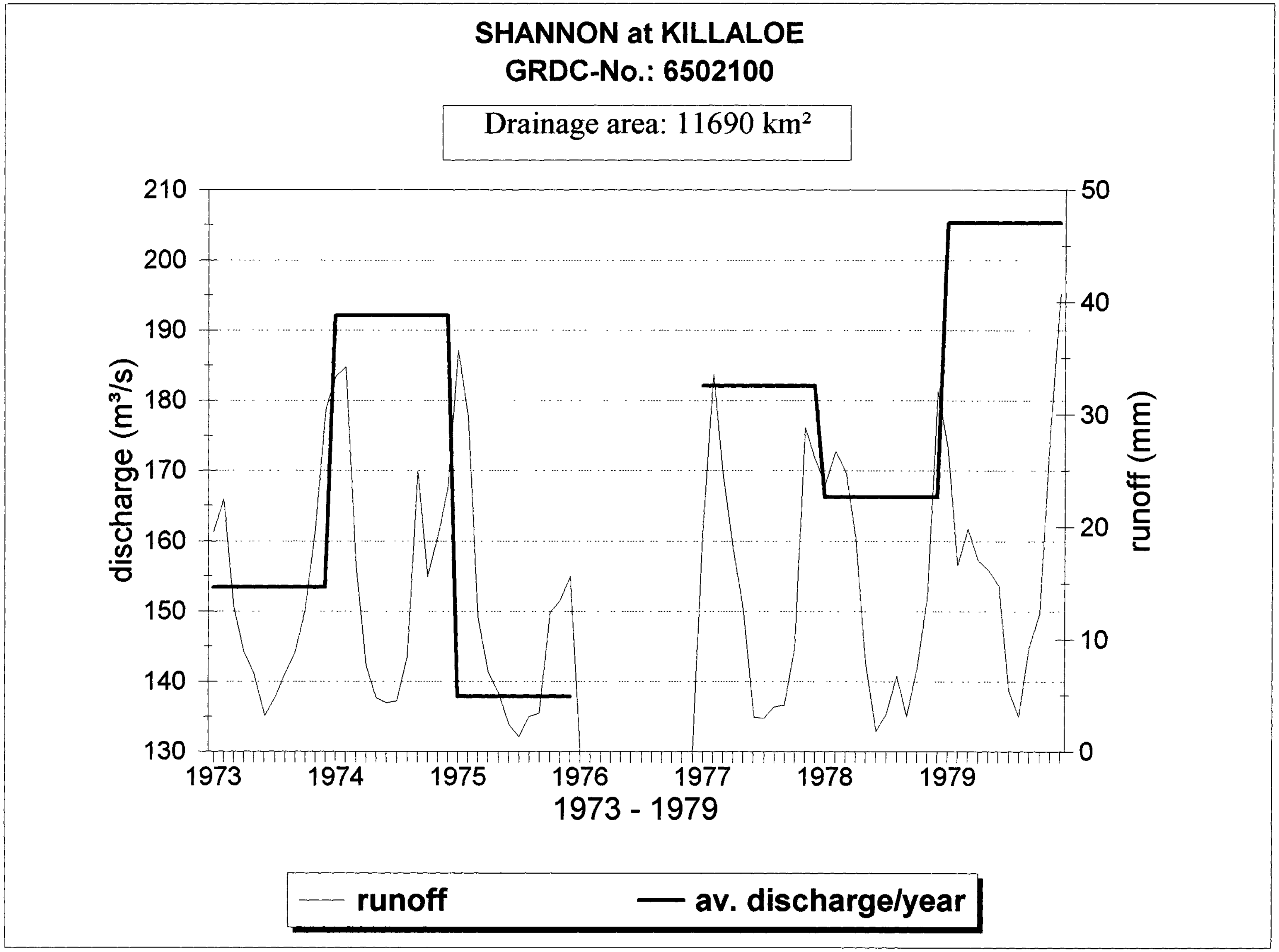


Figure 2.86

GLOBAL RUNOFF DATA CENTRE (GRDC)

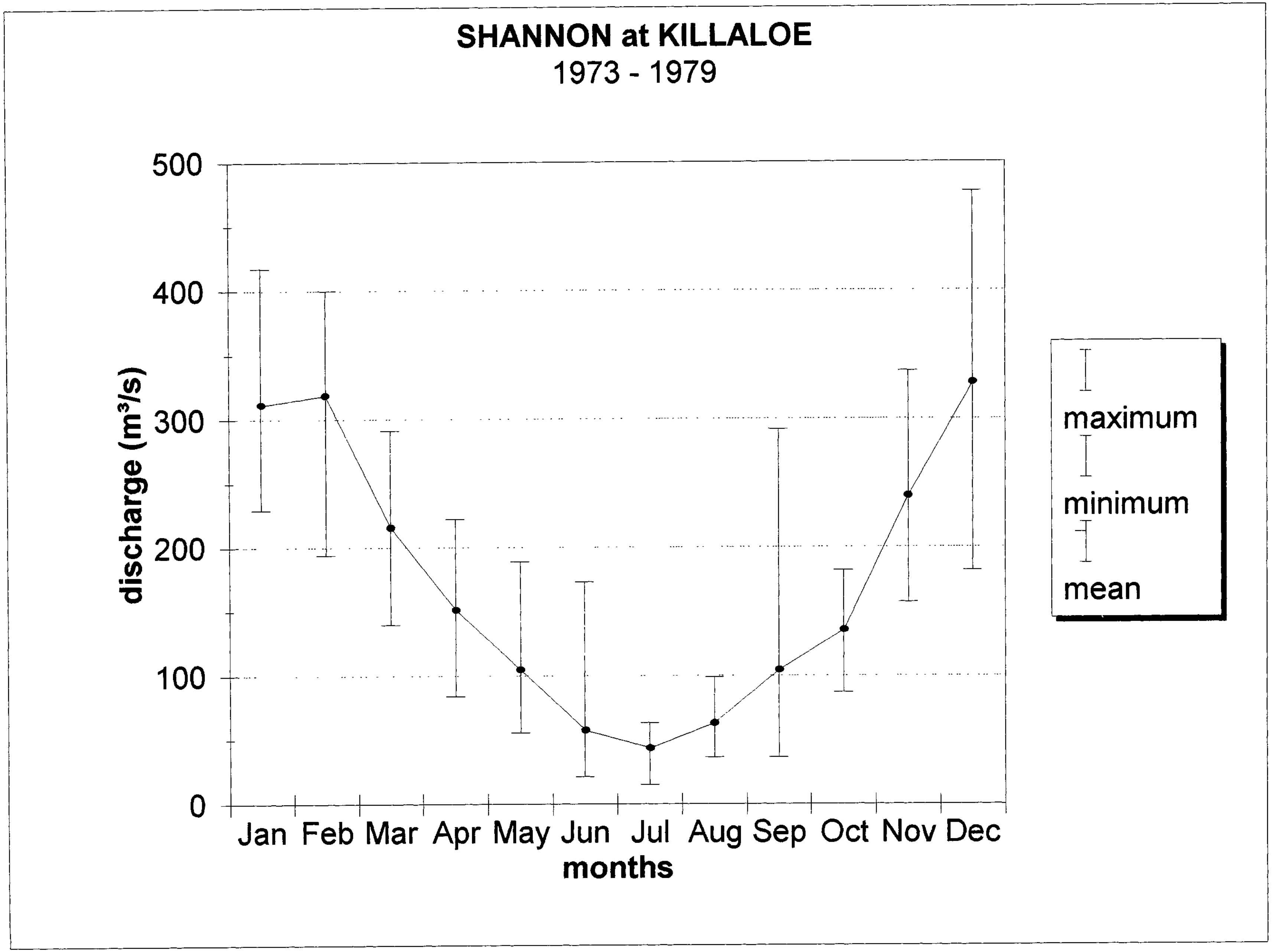


Figure 2.87

GLOBAL RUNOFF DATA CENTRE (GRDC)

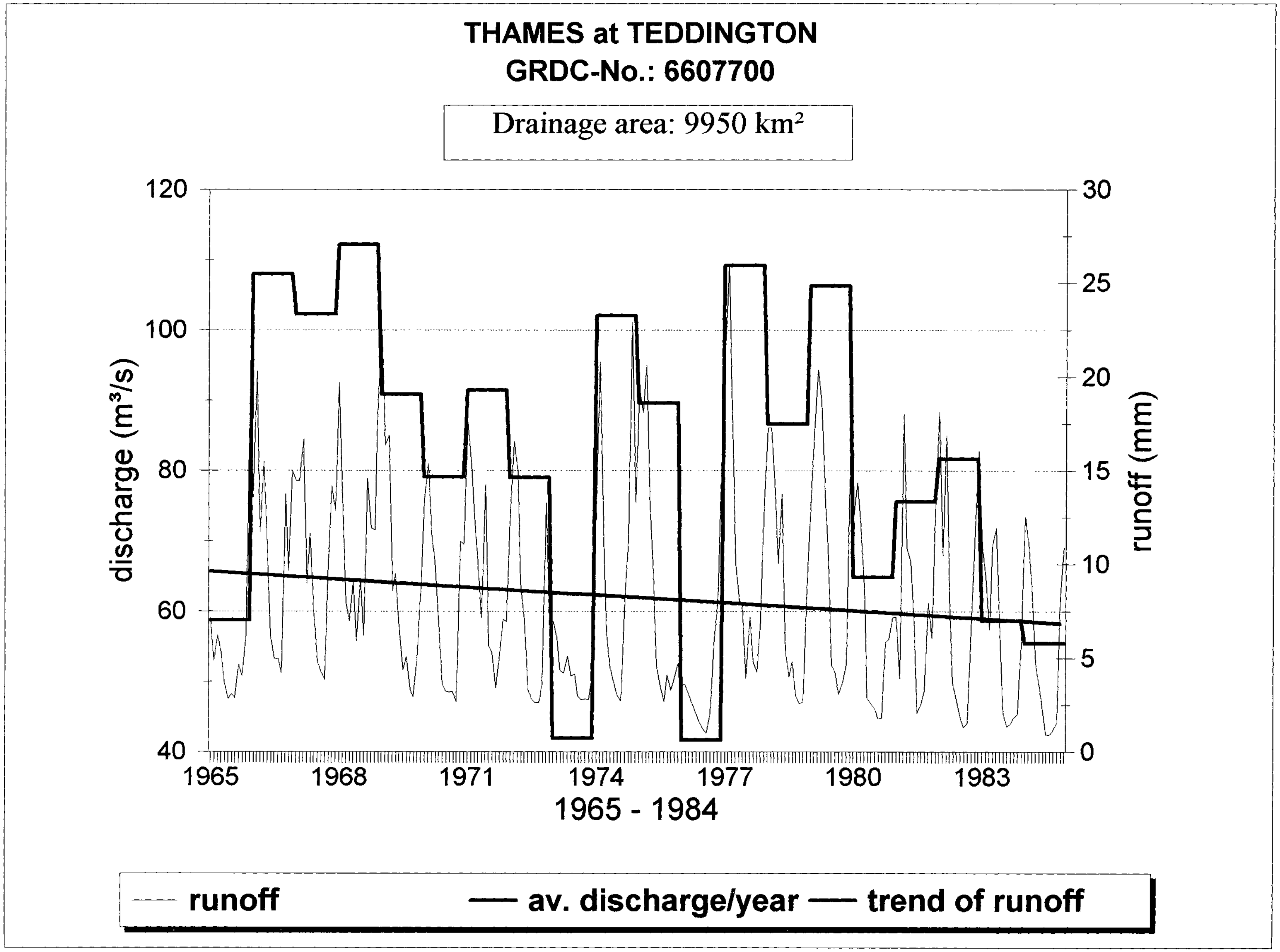


Figure 2.88

GLOBAL RUNOFF DATA CENTRE (GRDC)

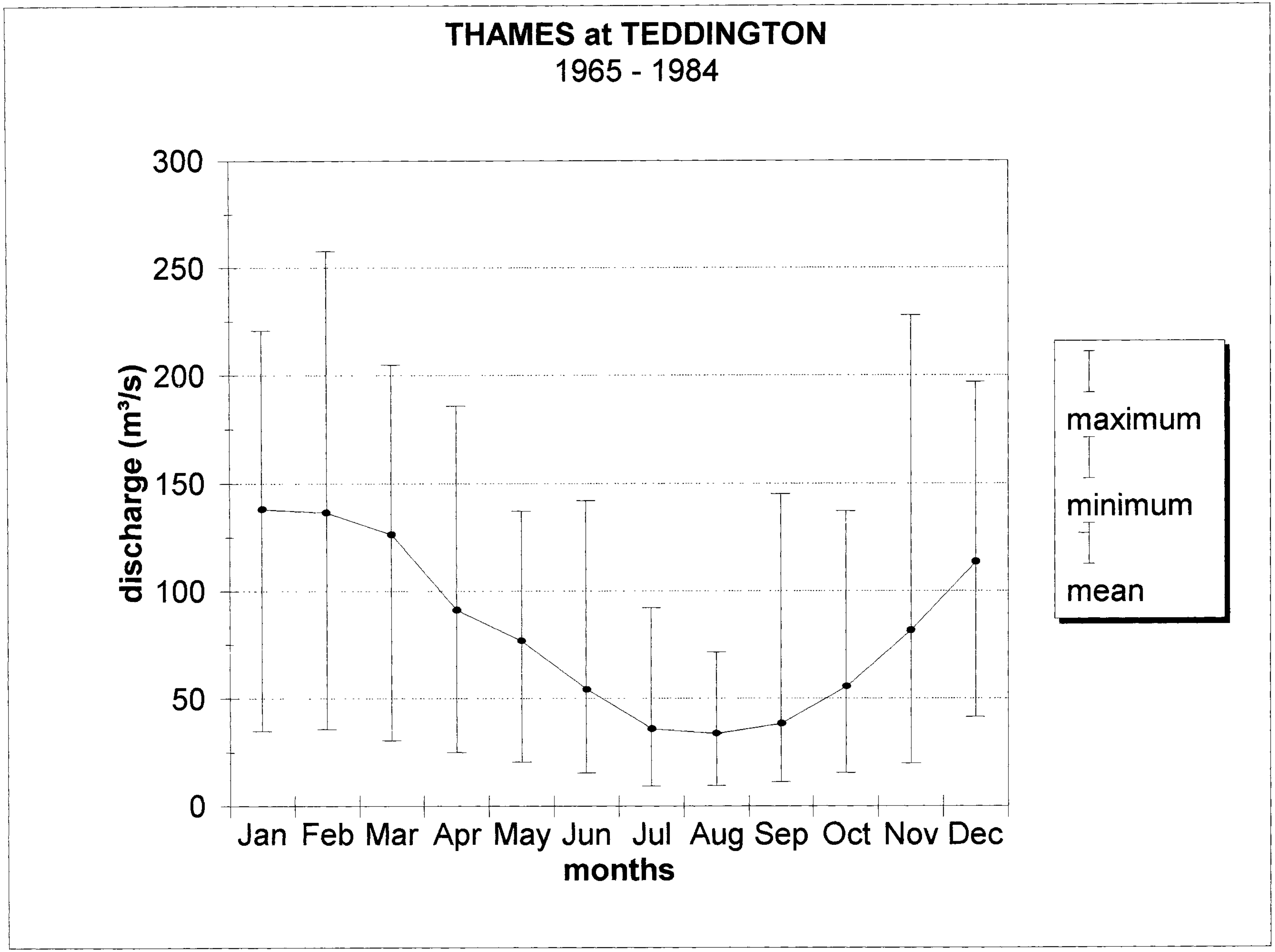


Figure 2.89

GLOBAL RUNOFF DATA CENTRE (GRDC)

WESER at INTSCHEDE
GRDC-No.: 6337200

Drainage area: 37788 km²

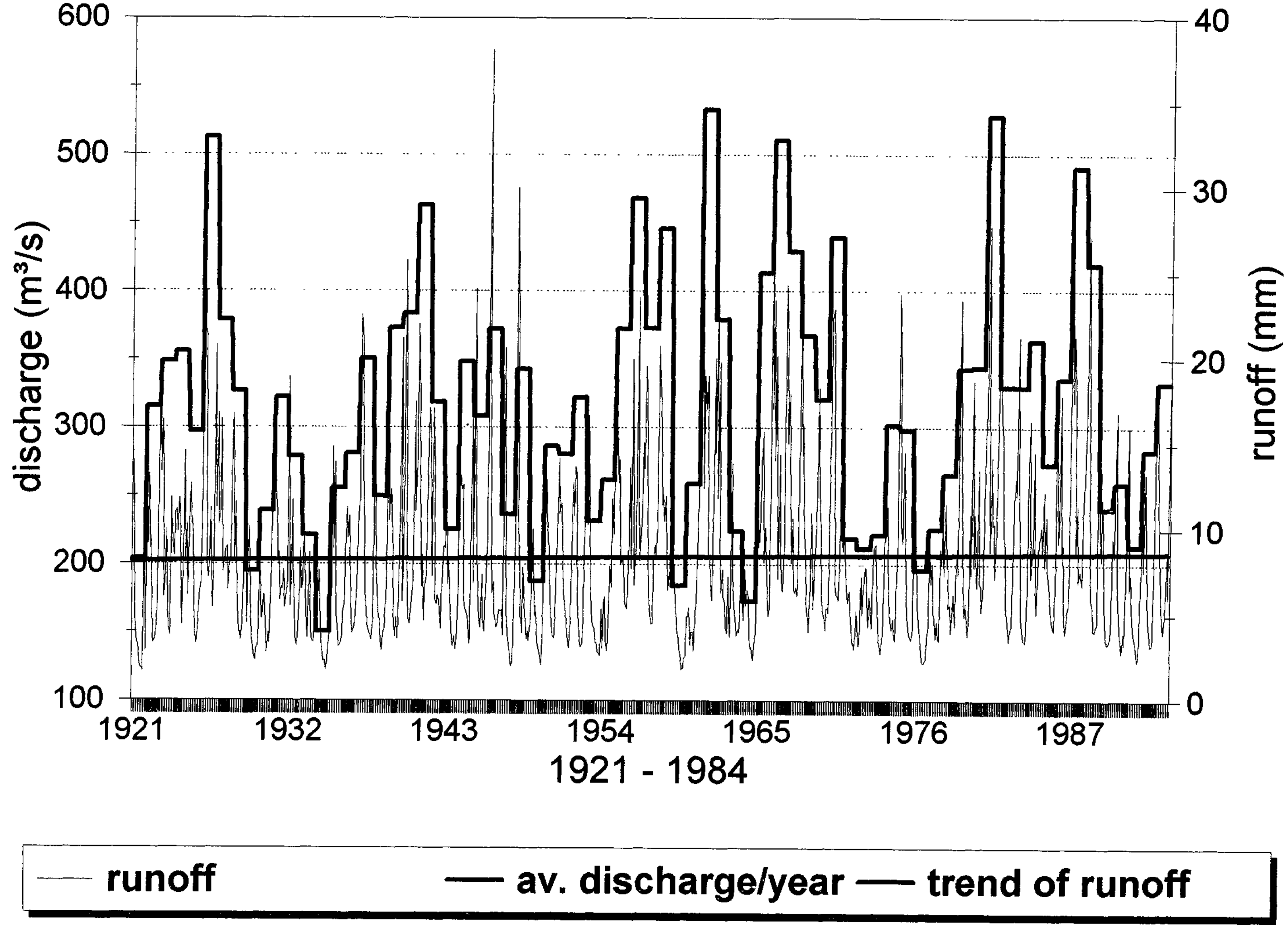


Figure 2.90

GLOBAL RUNOFF DATA CENTRE (GRDC)

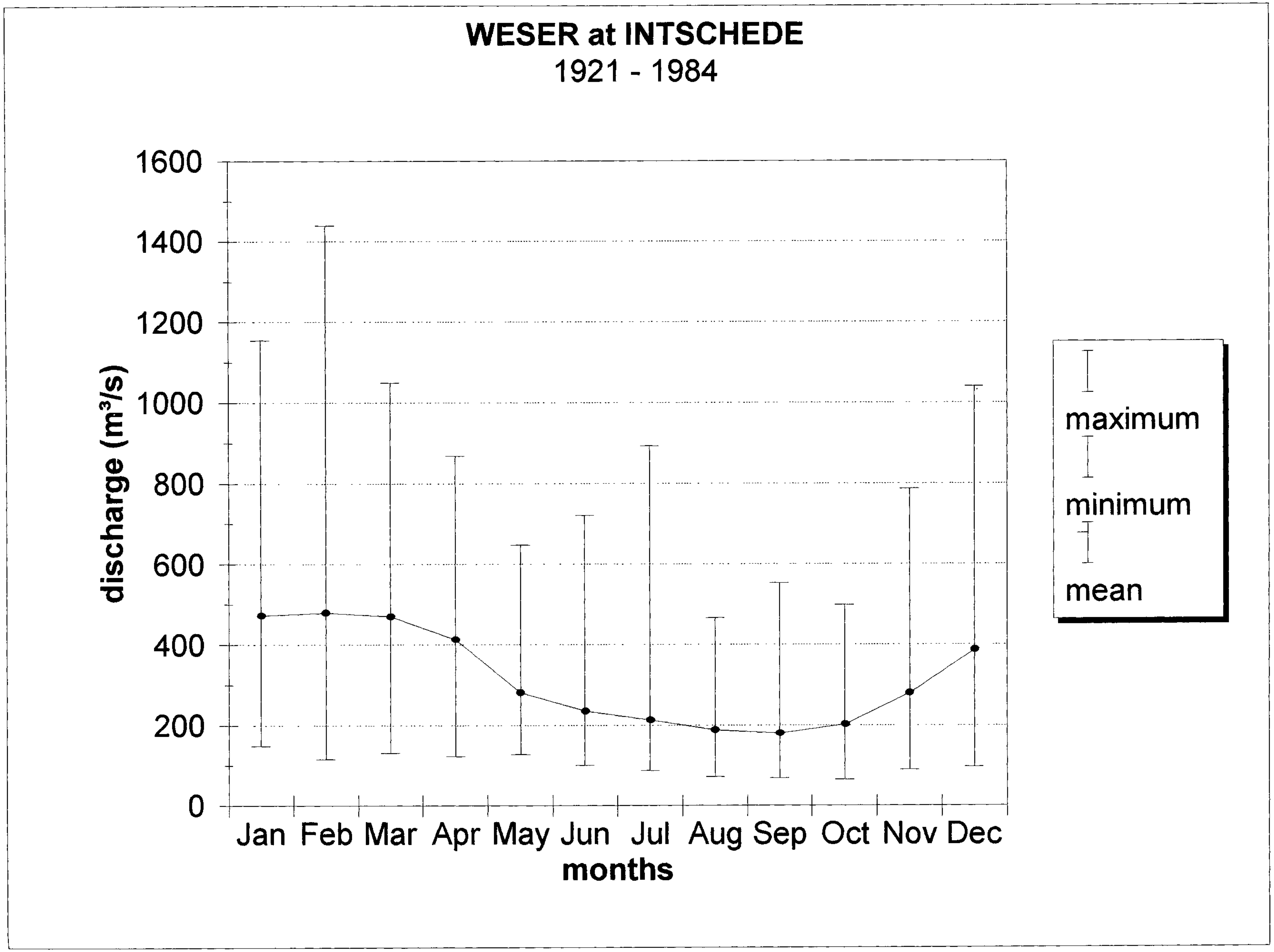


Figure 2.91

GLOBAL RUNOFF DATA CENTRE (GRDC)

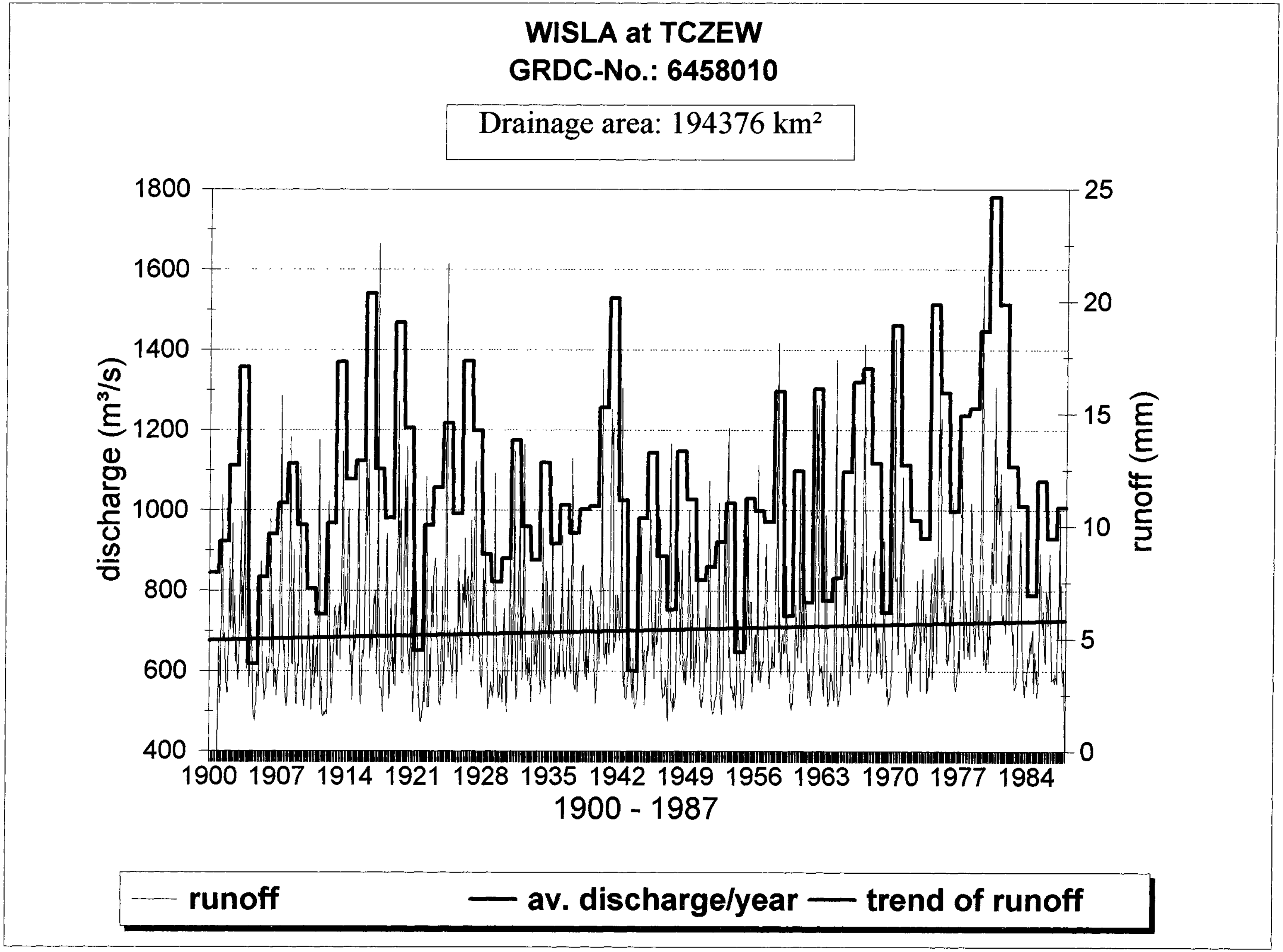


Figure 2.92

GLOBAL RUNOFF DATA CENTRE (GRDC)

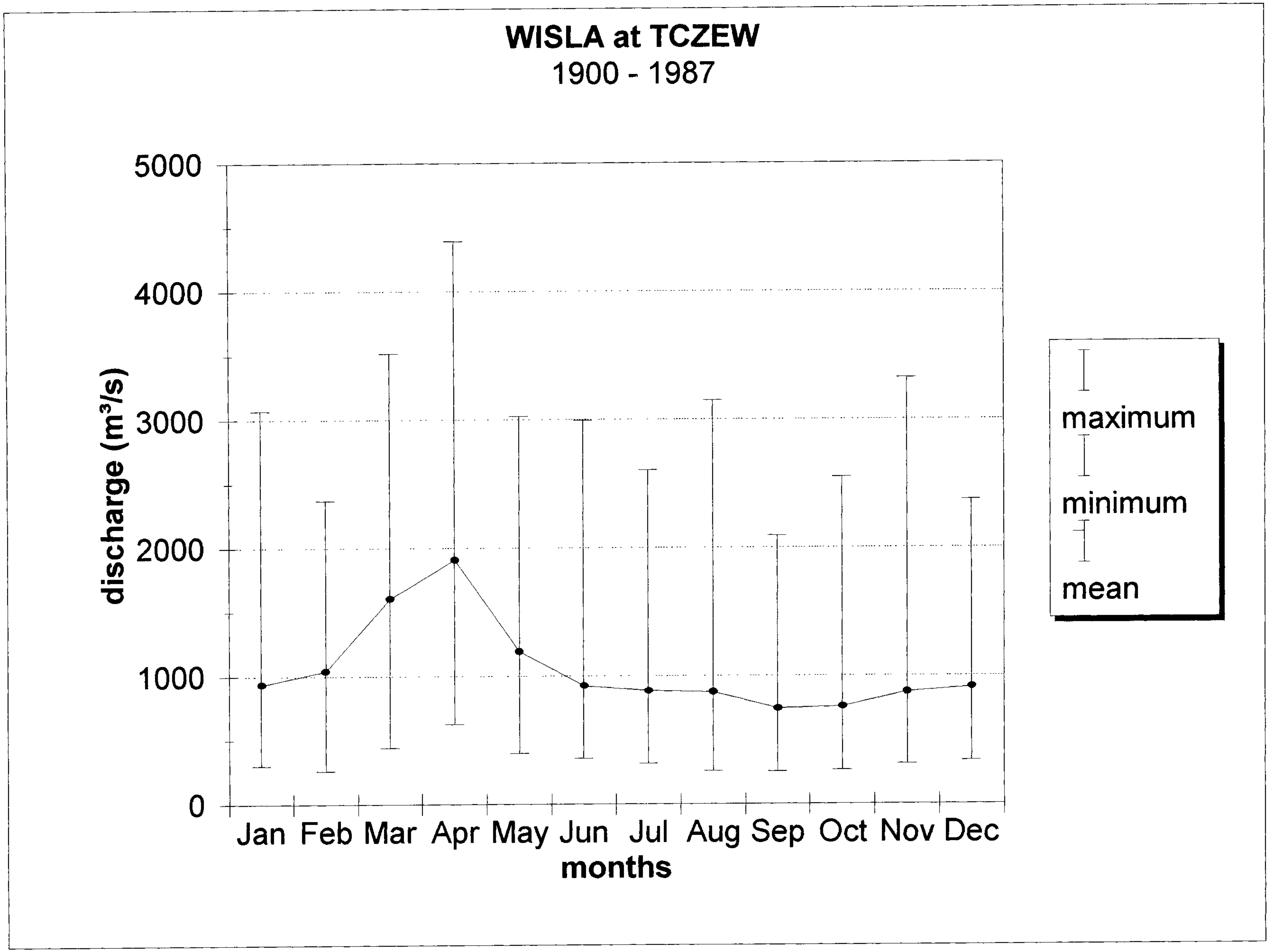


Figure 2.93

North and Central America

GLOBAL RUNOFF DATA CENTRE (GRDC)

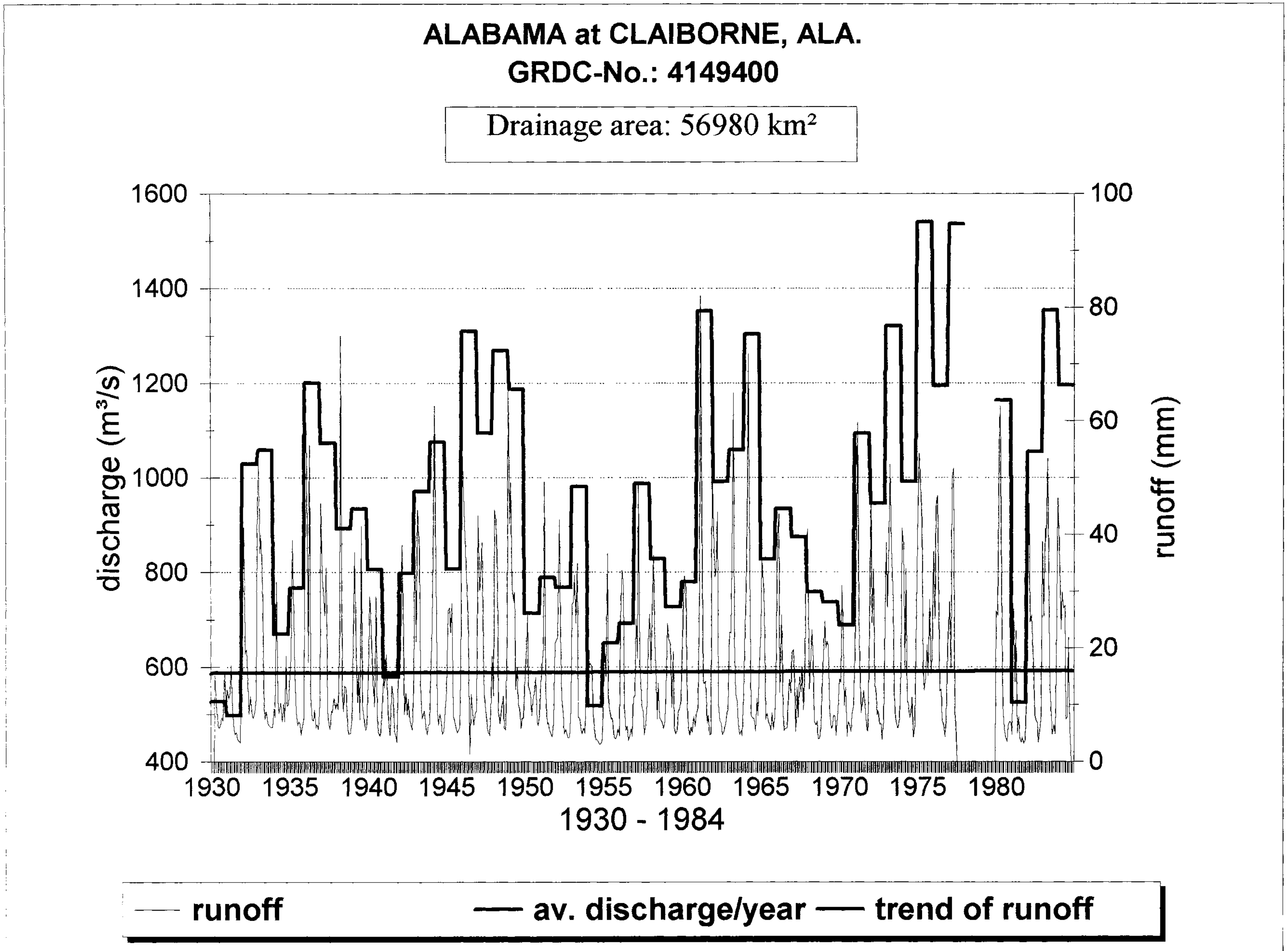


Figure 2.94

GLOBAL RUNOFF DATA CENTRE (GRDC)

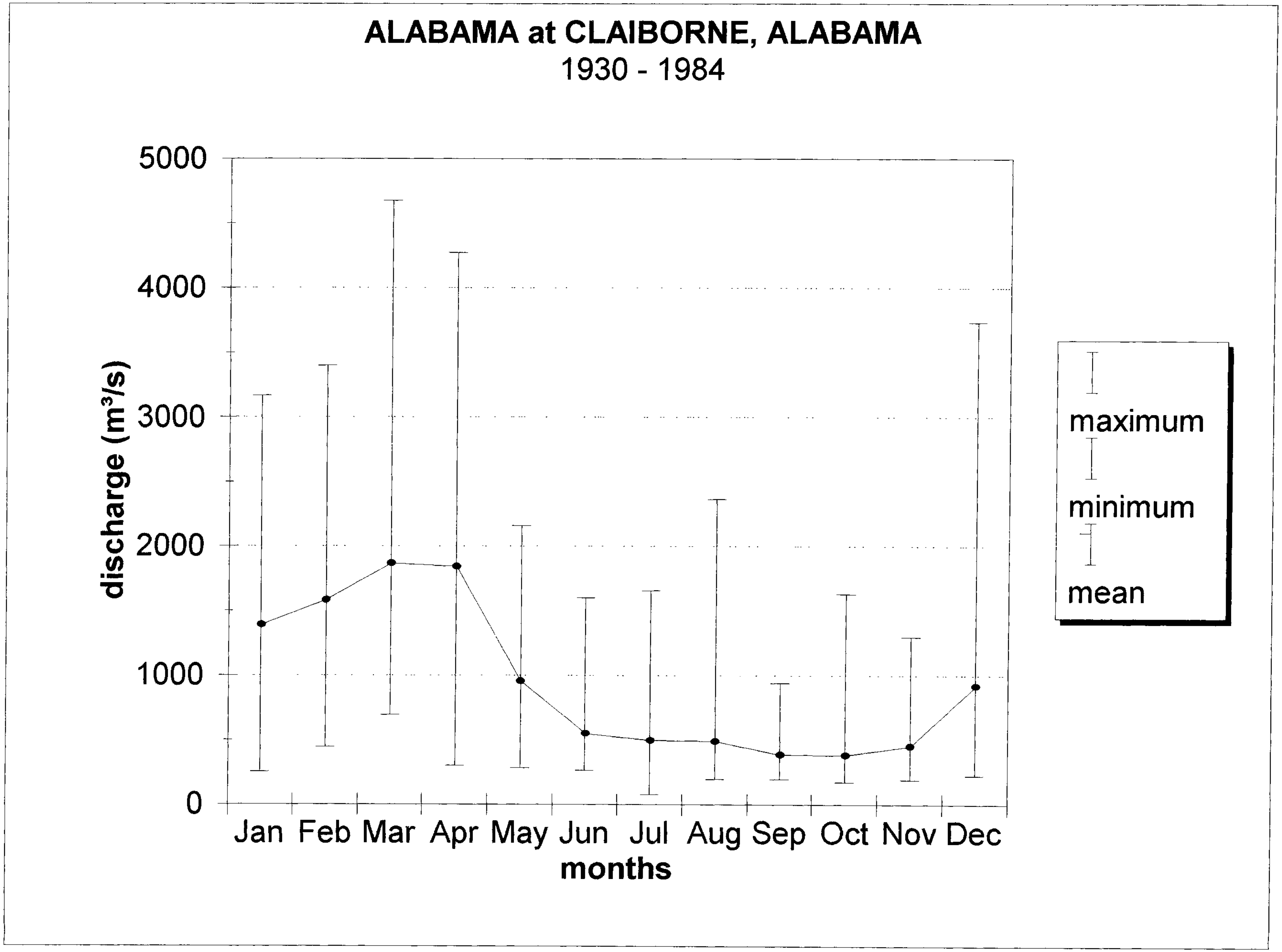


Figure 2.95

GLOBAL RUNOFF DATA CENTRE (GRDC)

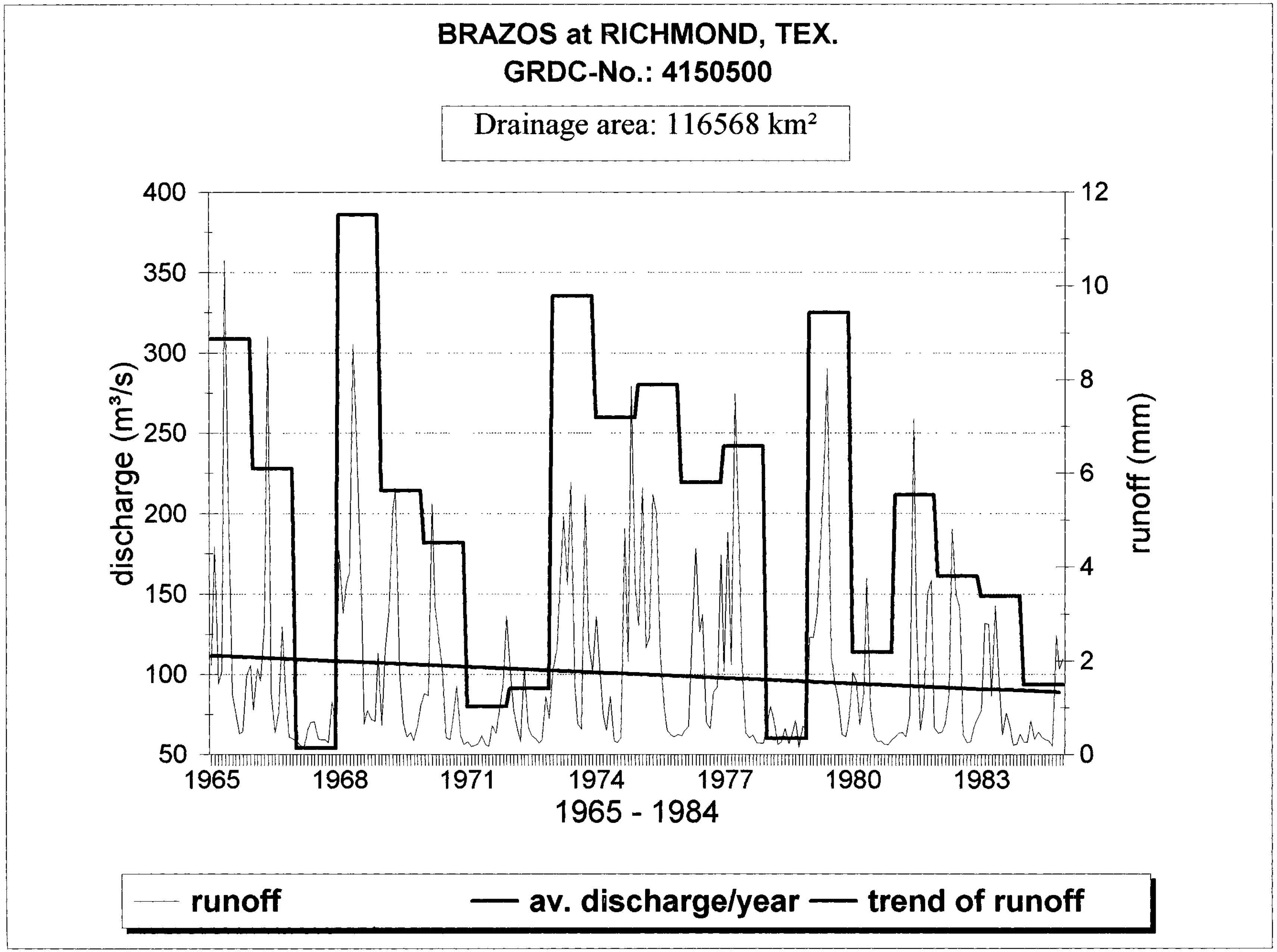


Figure 2.96

GLOBAL RUNOFF DATA CENTRE (GRDC)

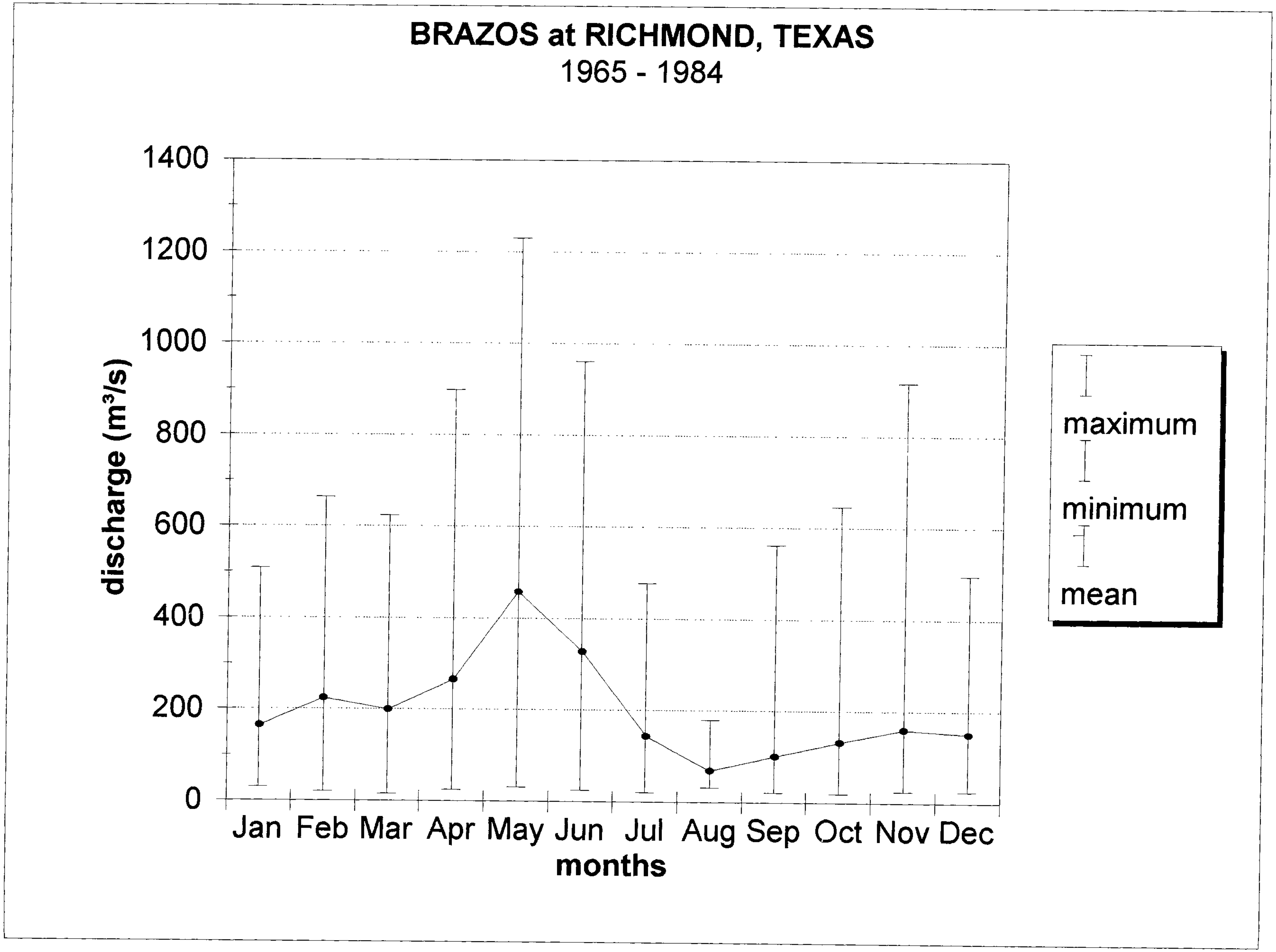


Figure 2.97

GLOBAL RUNOFF DATA CENTRE (GRDC)

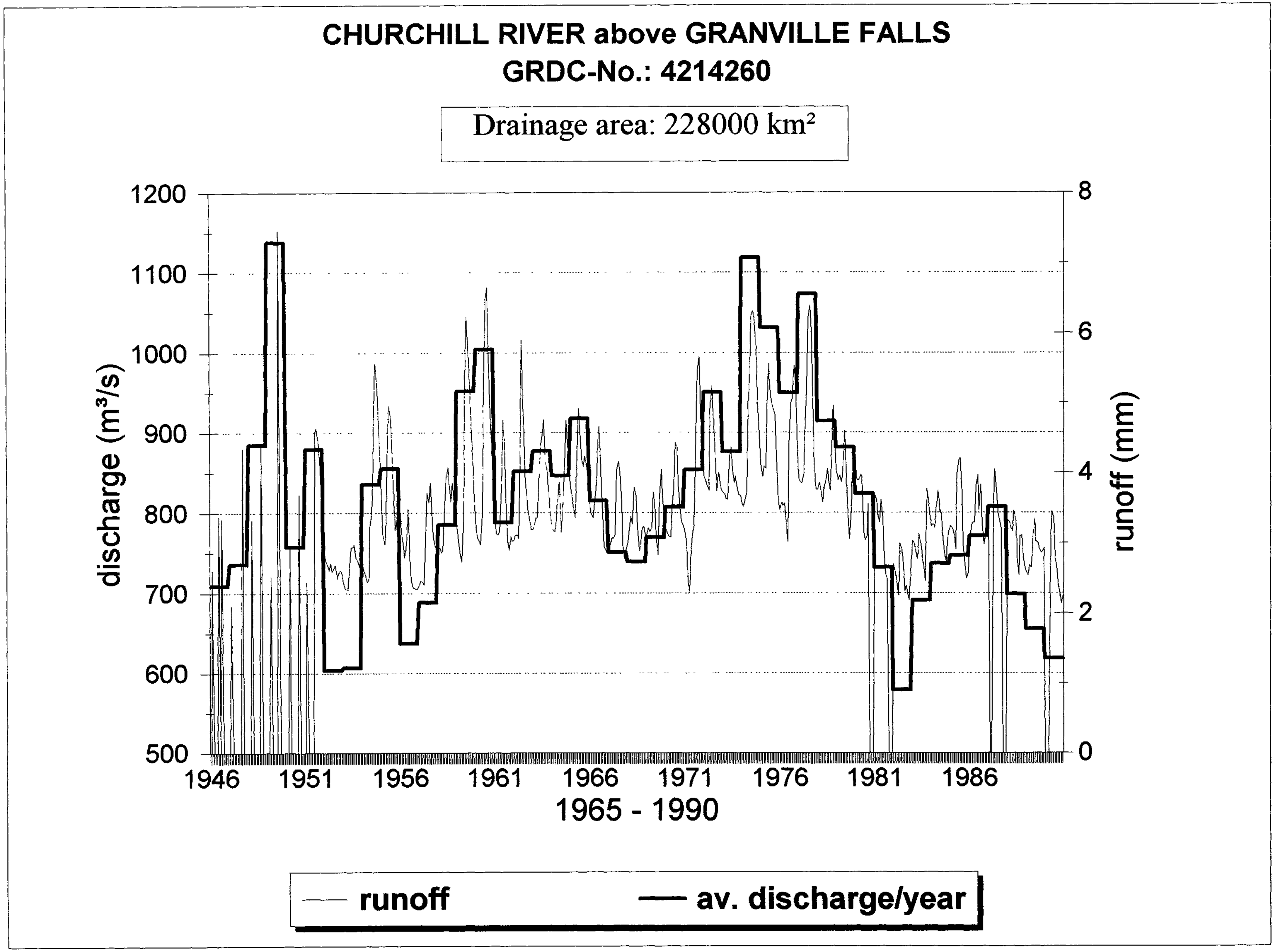


Figure 2.98

GLOBAL RUNOFF DATA CENTRE (GRDC)

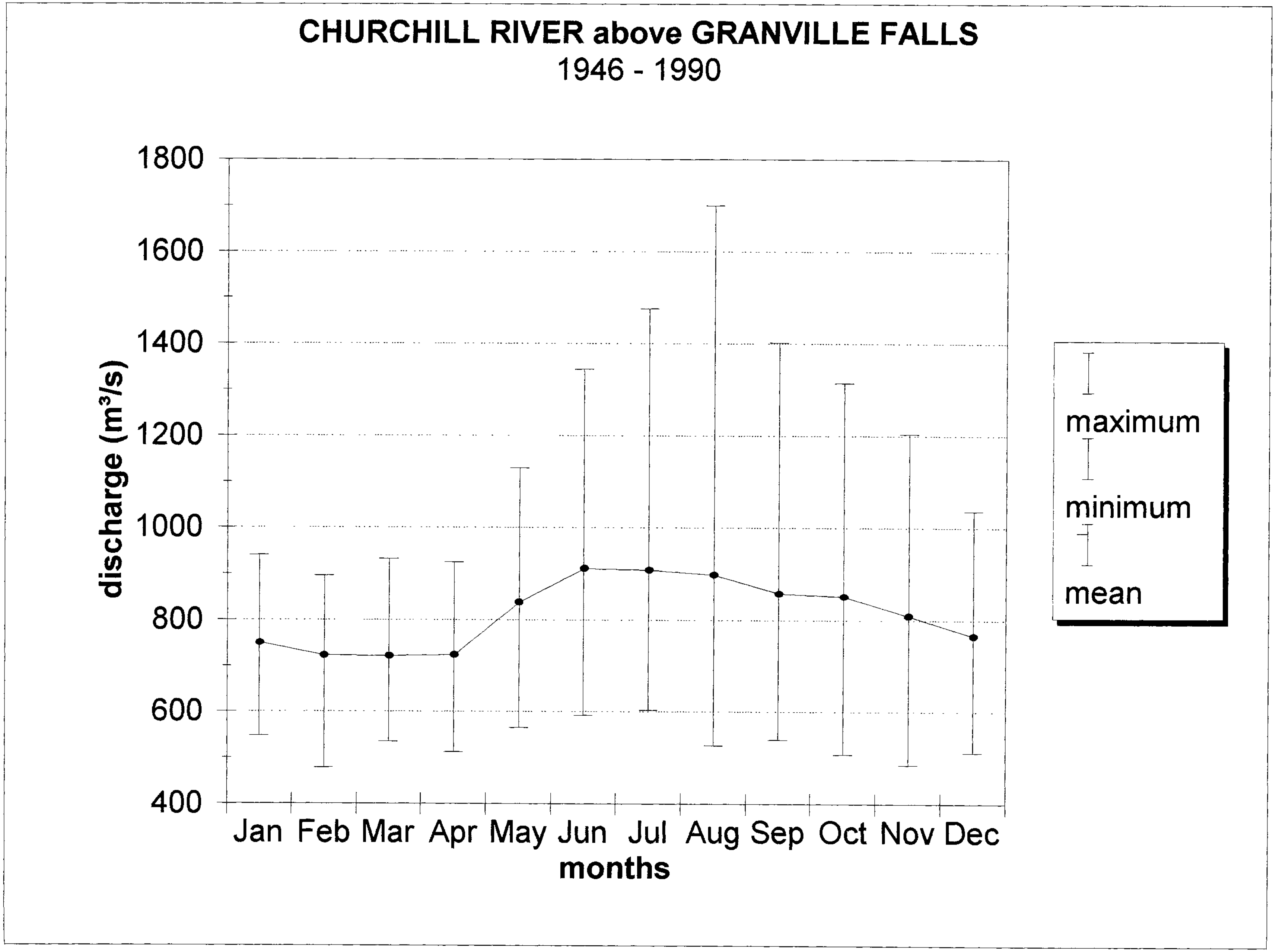


Figure 2.99

GLOBAL RUNOFF DATA CENTRE (GRDC)

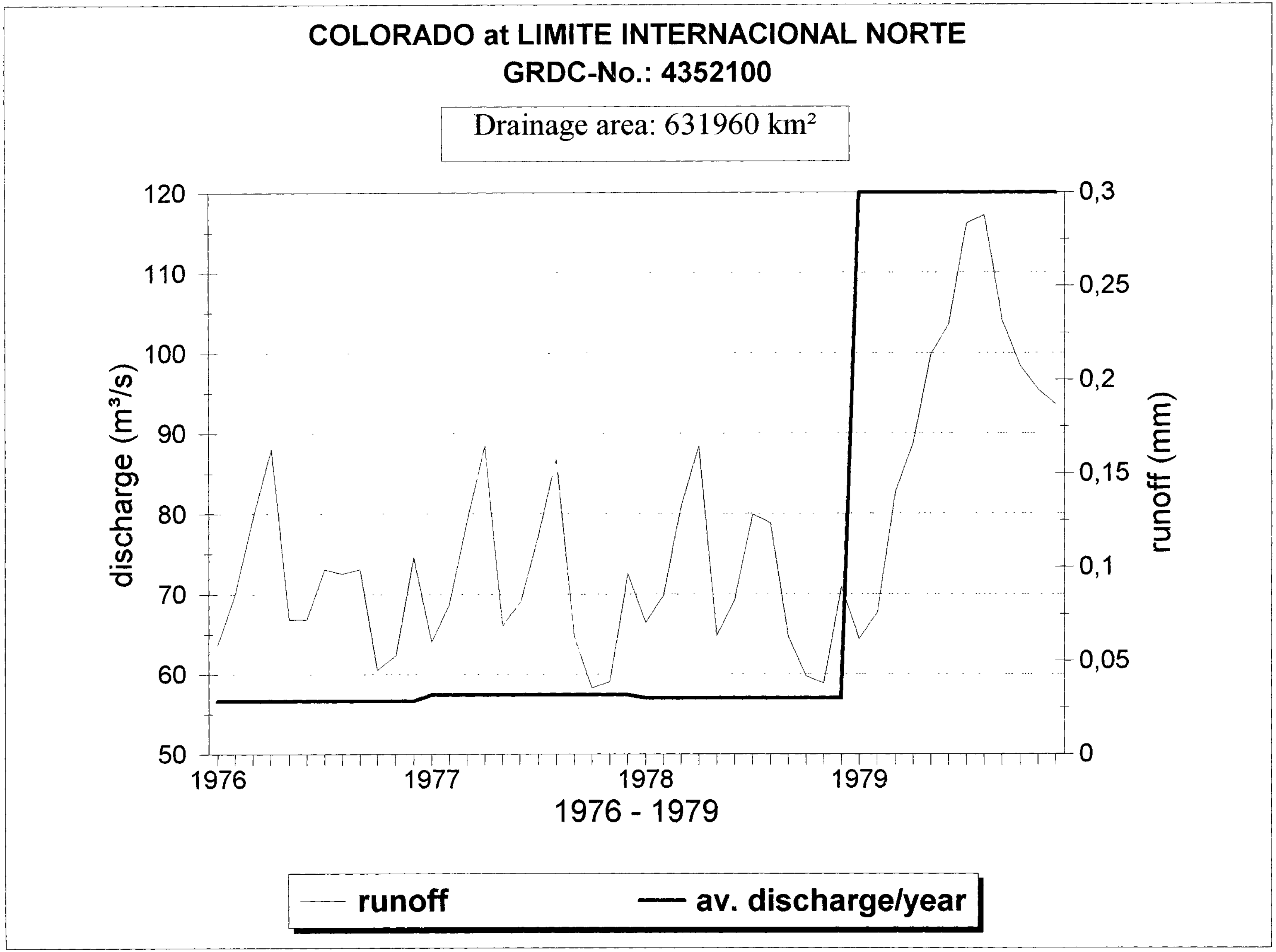


Figure 2.100

GLOBAL RUNOFF DATA CENTRE (GRDC)

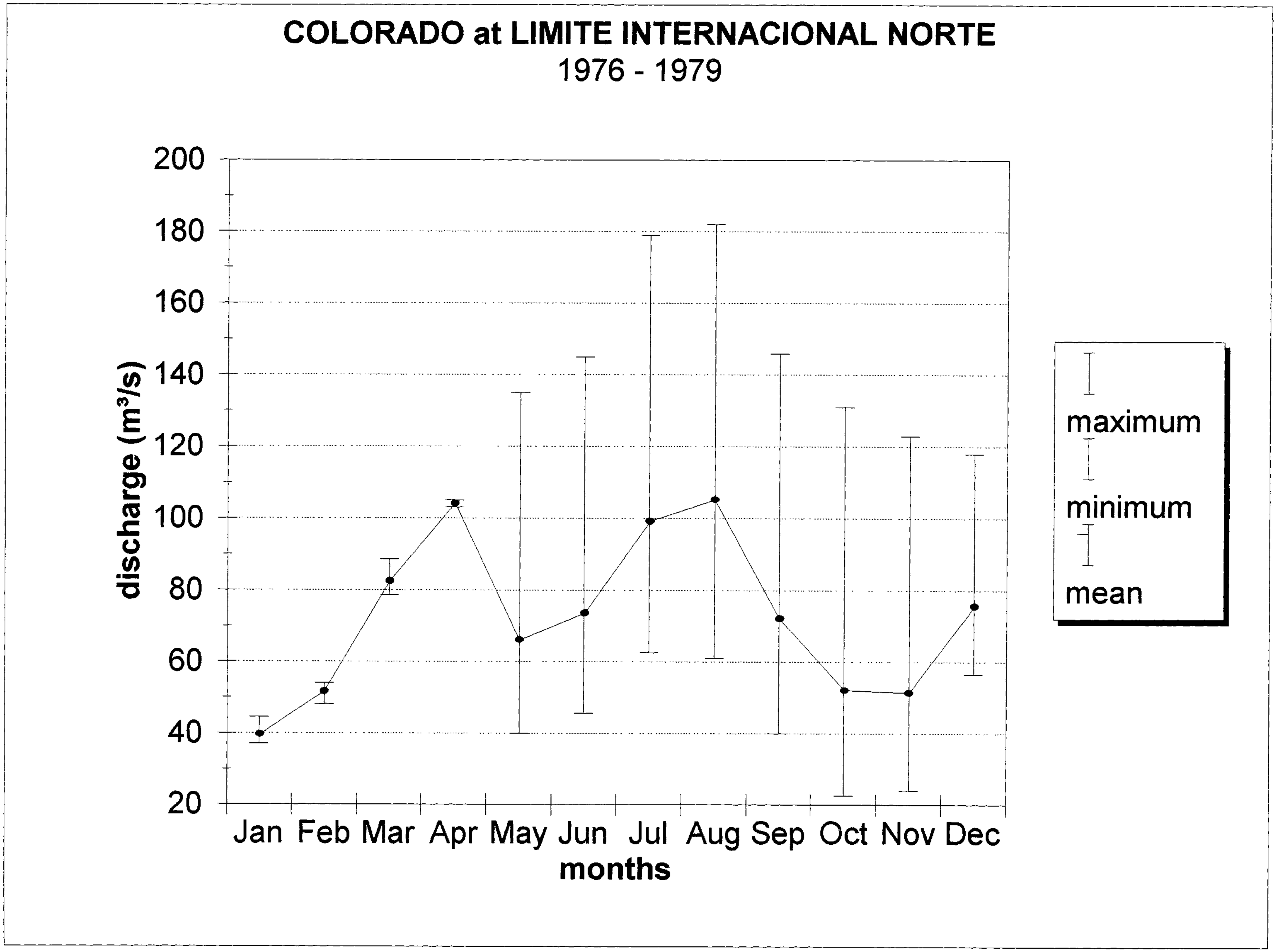


Figure 2.101

GLOBAL RUNOFF DATA CENTRE (GRDC)

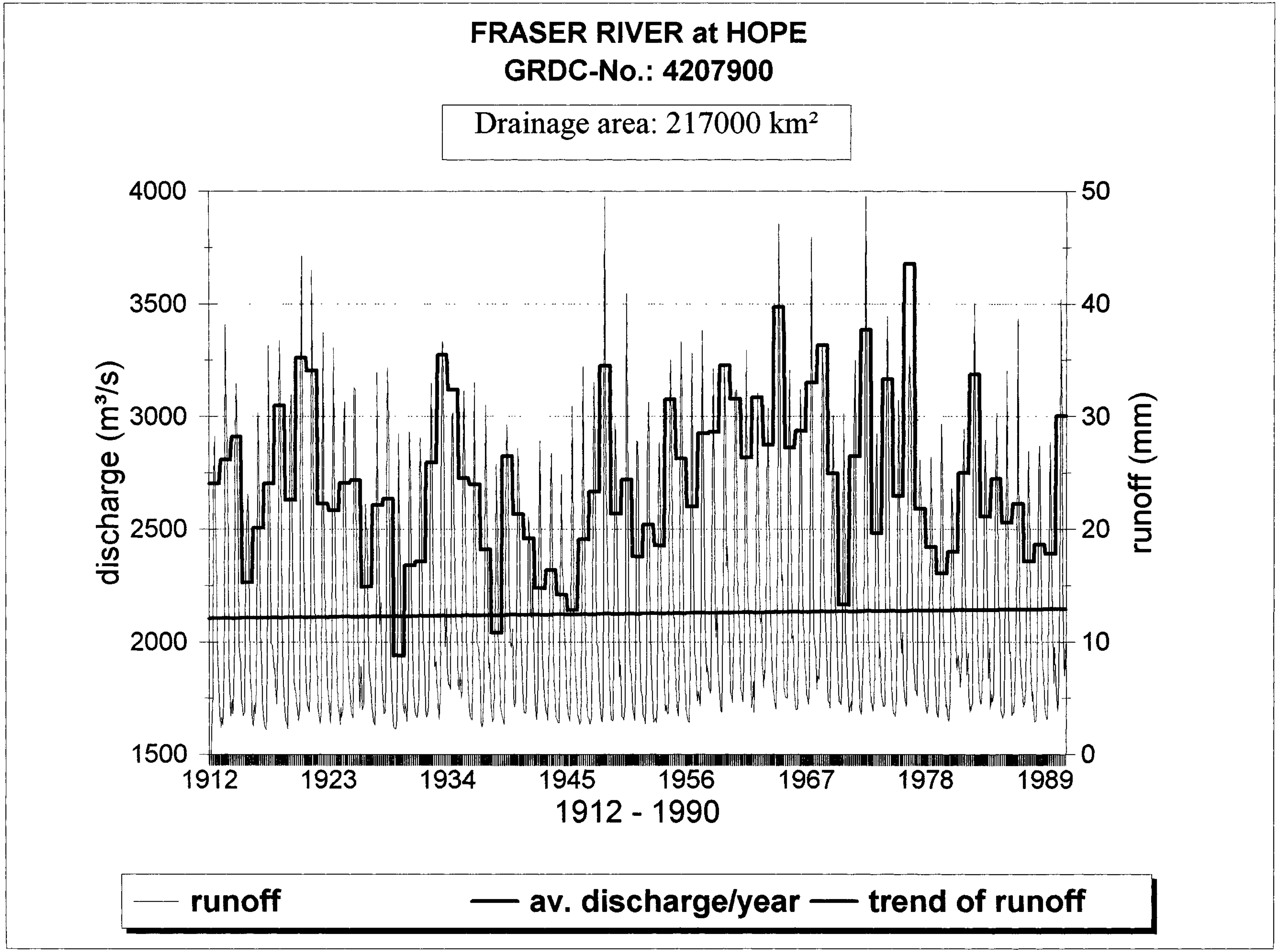


Figure 2.102

GLOBAL RUNOFF DATA CENTRE (GRDC)

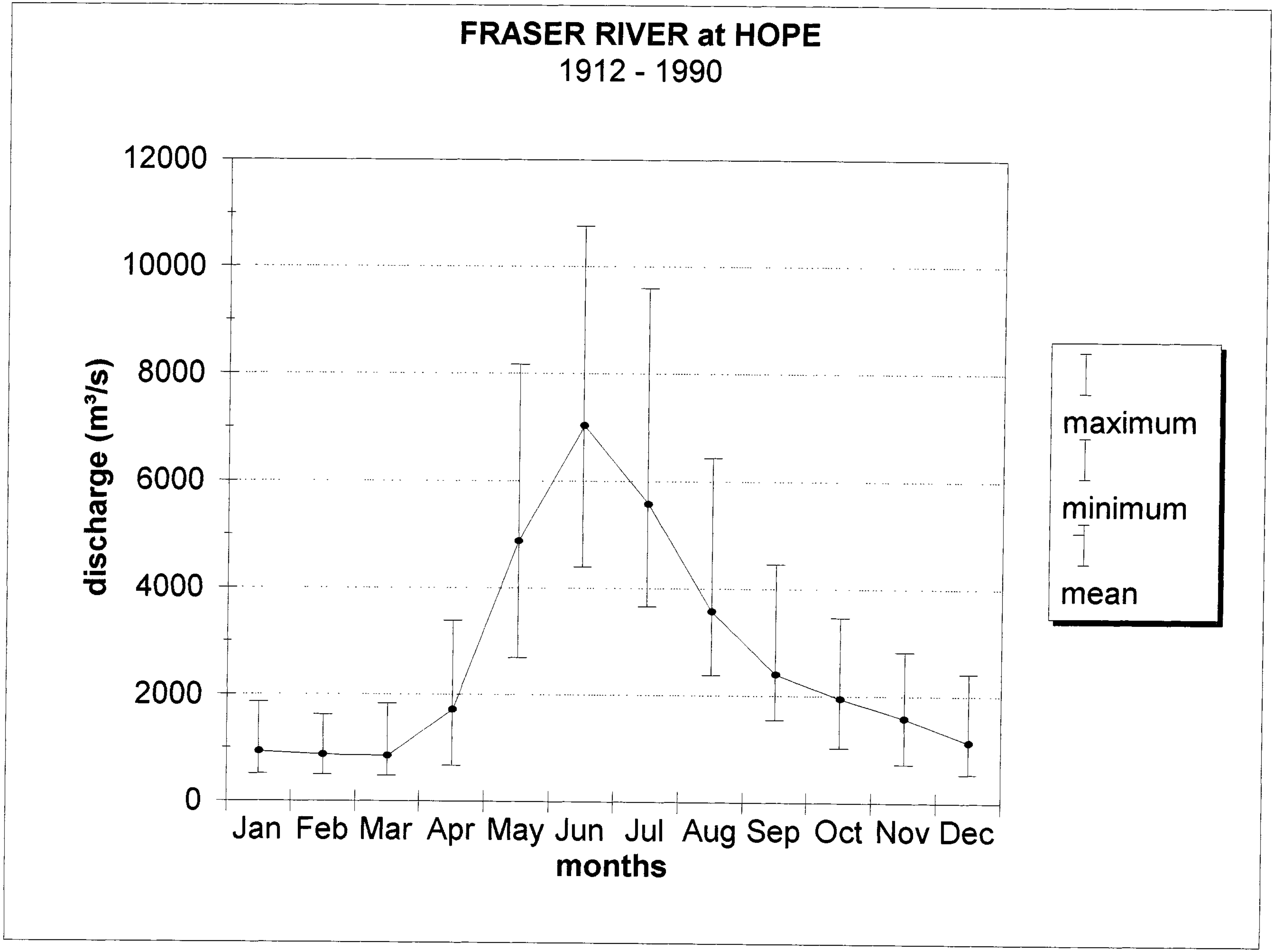


Figure 2.103

GLOBAL RUNOFF DATA CENTRE (GRDC)

MACKENZIE RIVER at NORMAN WELLS
GRDC-No.: 4208150

Drainage area: 1570000 km²

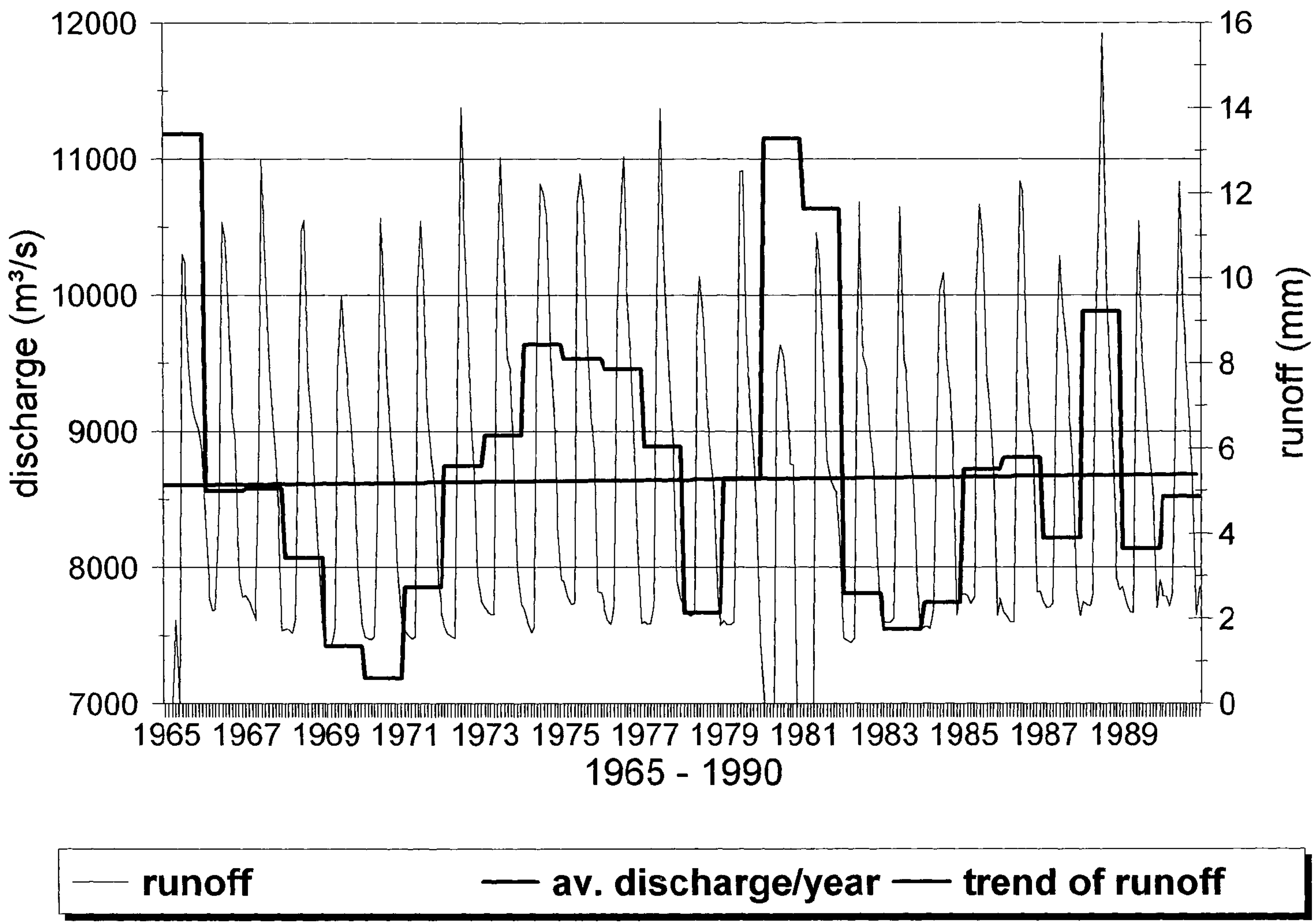


Figure 2.104

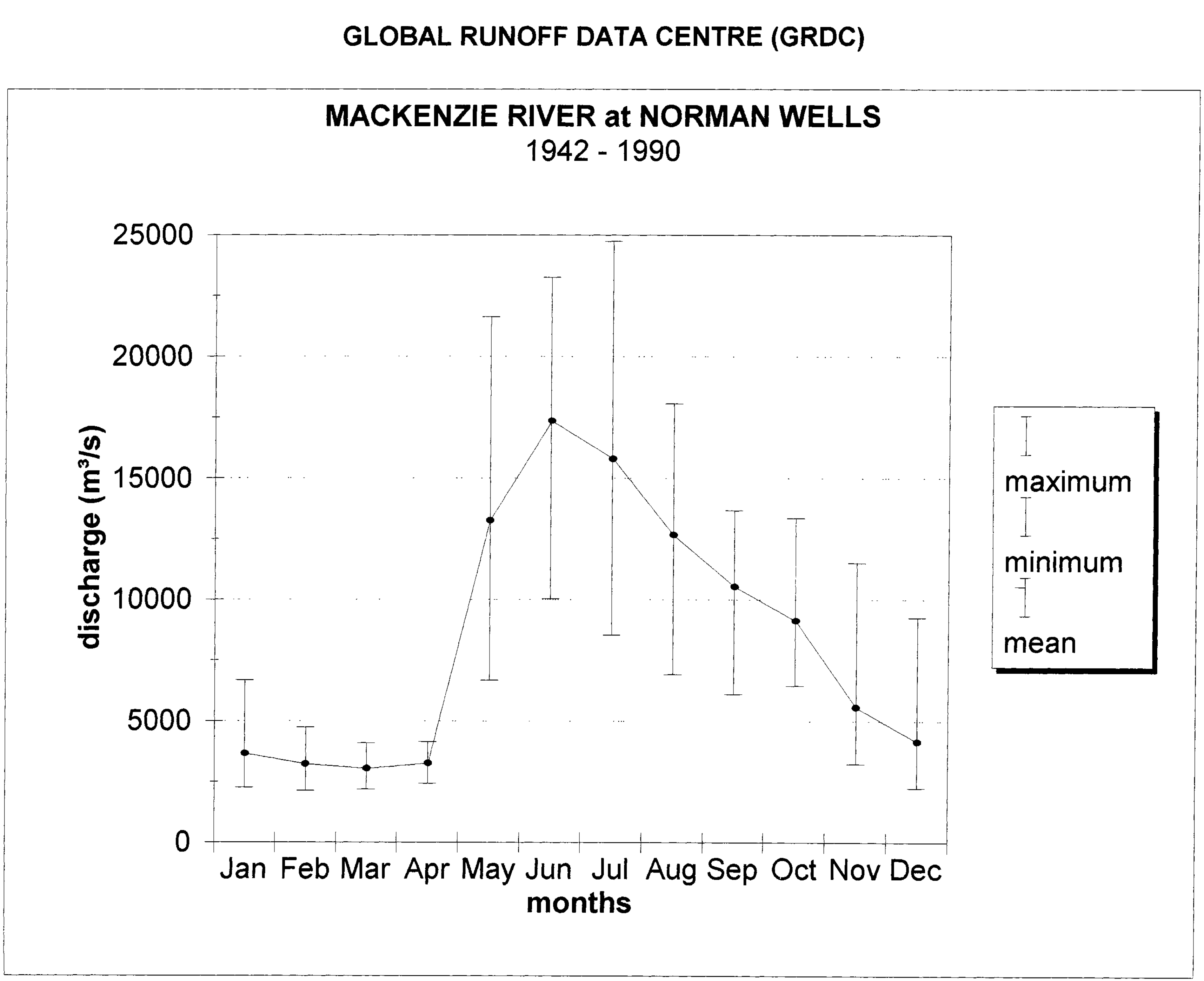

GLOBAL RUNOFF DATA CENTRE (GRDC)
MACKENZIE RIVER at NORMAN WELLS
1942 - 1990
25000
20000
15000
10000
5000
0
discharge (m^3/s)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
months
maximum
minimum
mean

Figure 2.105

GLOBAL RUNOFF DATA CENTRE (GRDC)

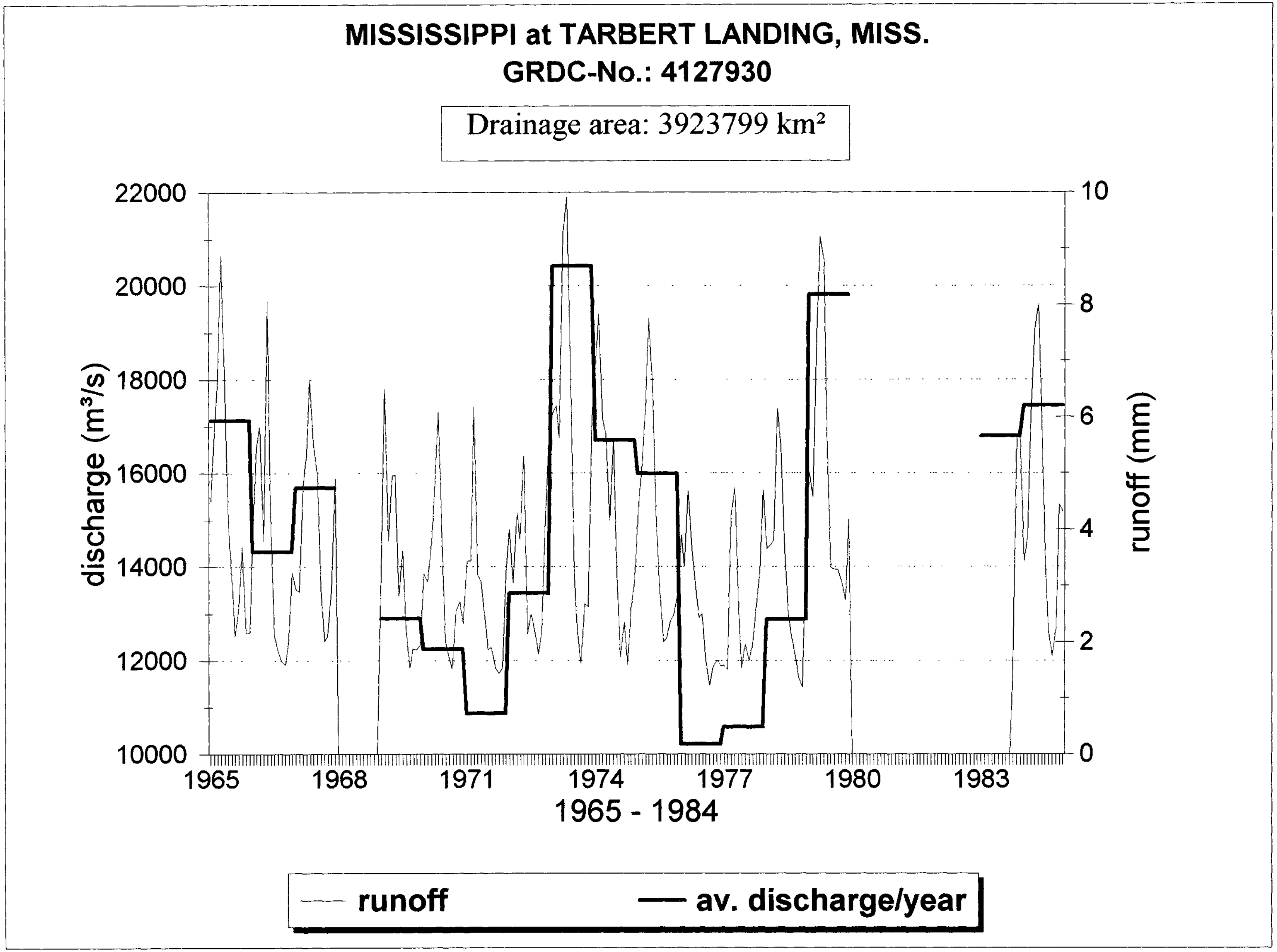


Figure 2.106

GLOBAL RUNOFF DATA CENTRE (GRDC)

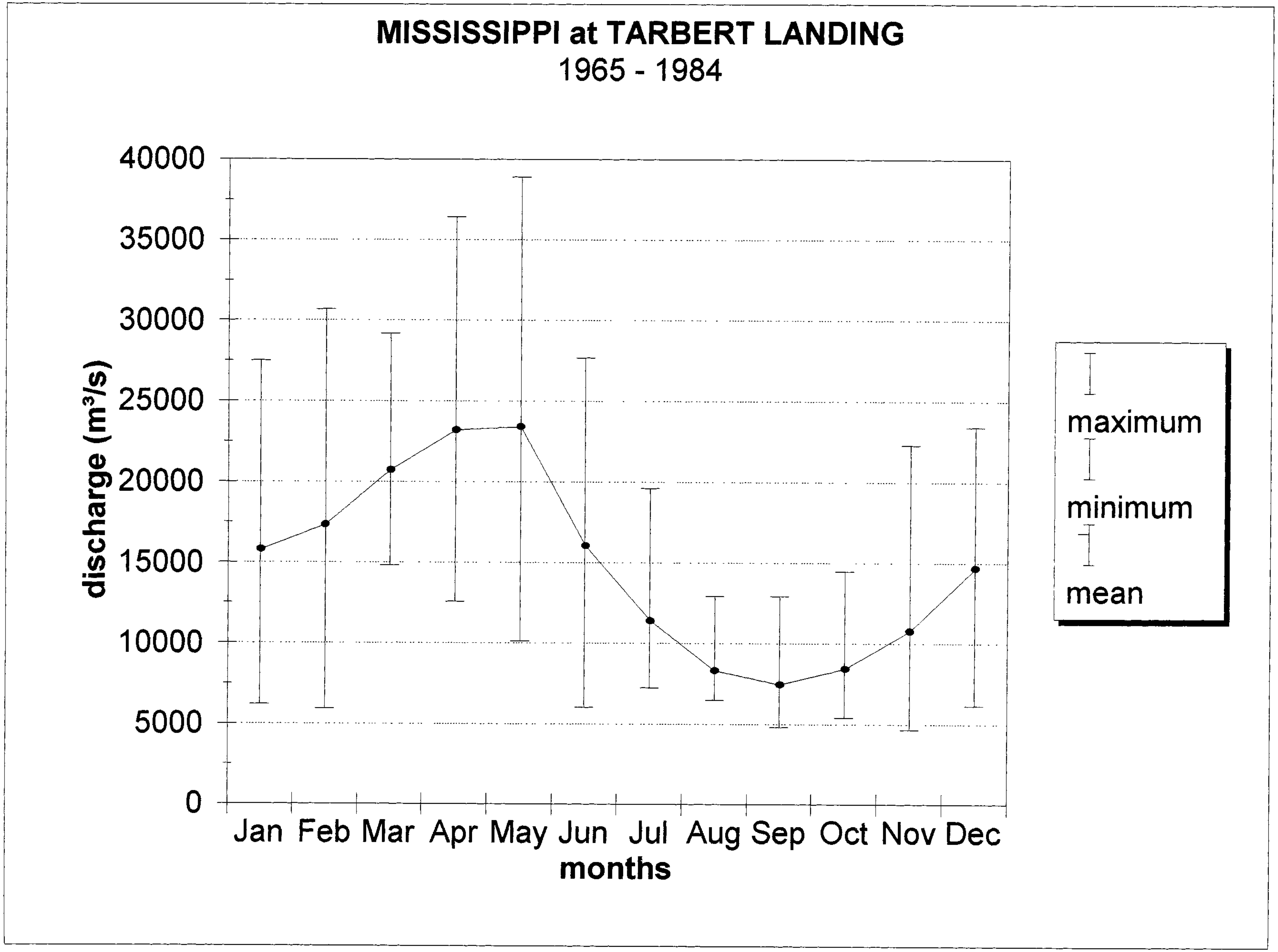


Figure 2.107

GLOBAL RUNOFF DATA CENTRE (GRDC)

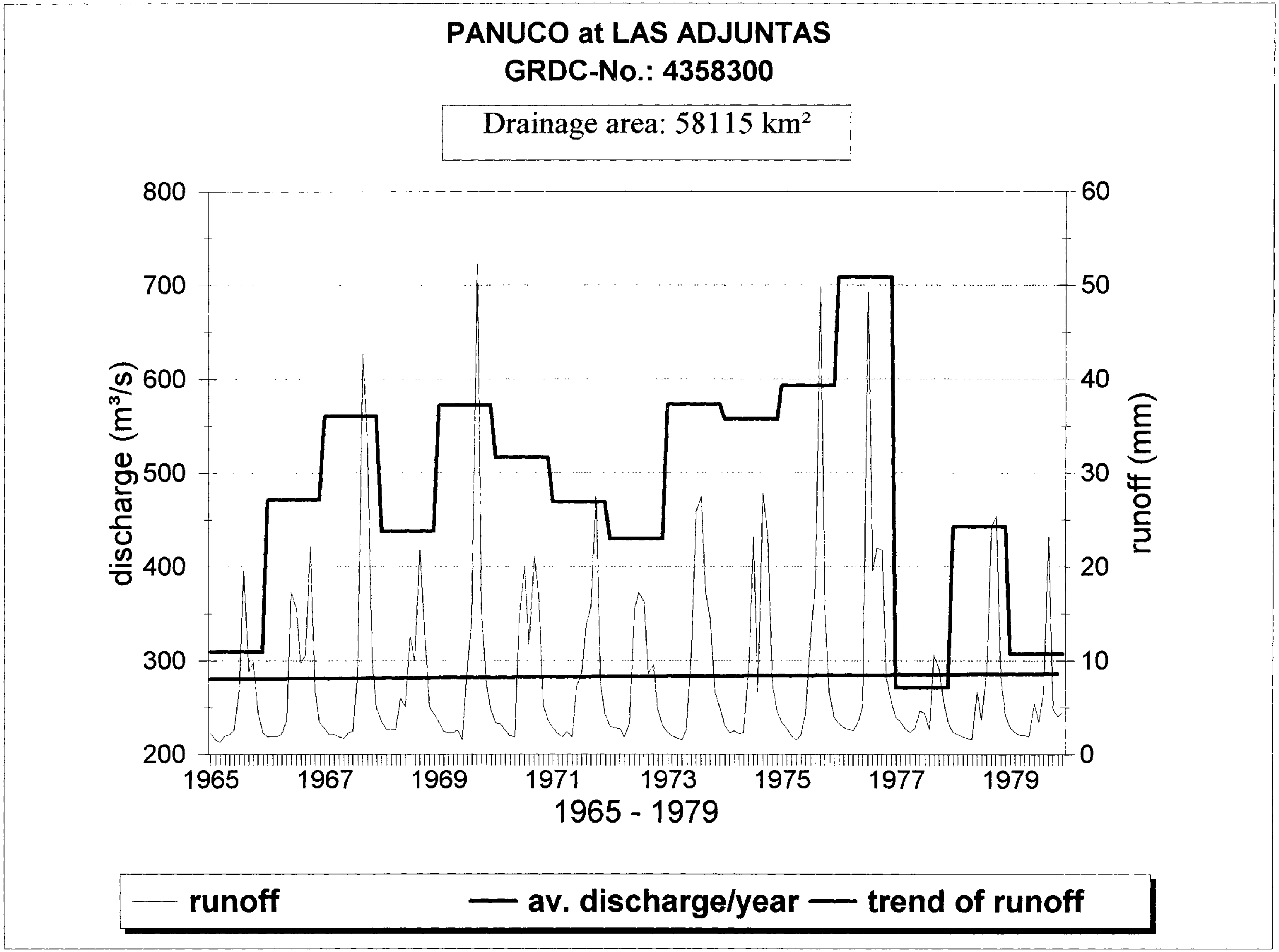


Figure 2.108

GLOBAL RUNOFF DATA CENTRE (GRDC)

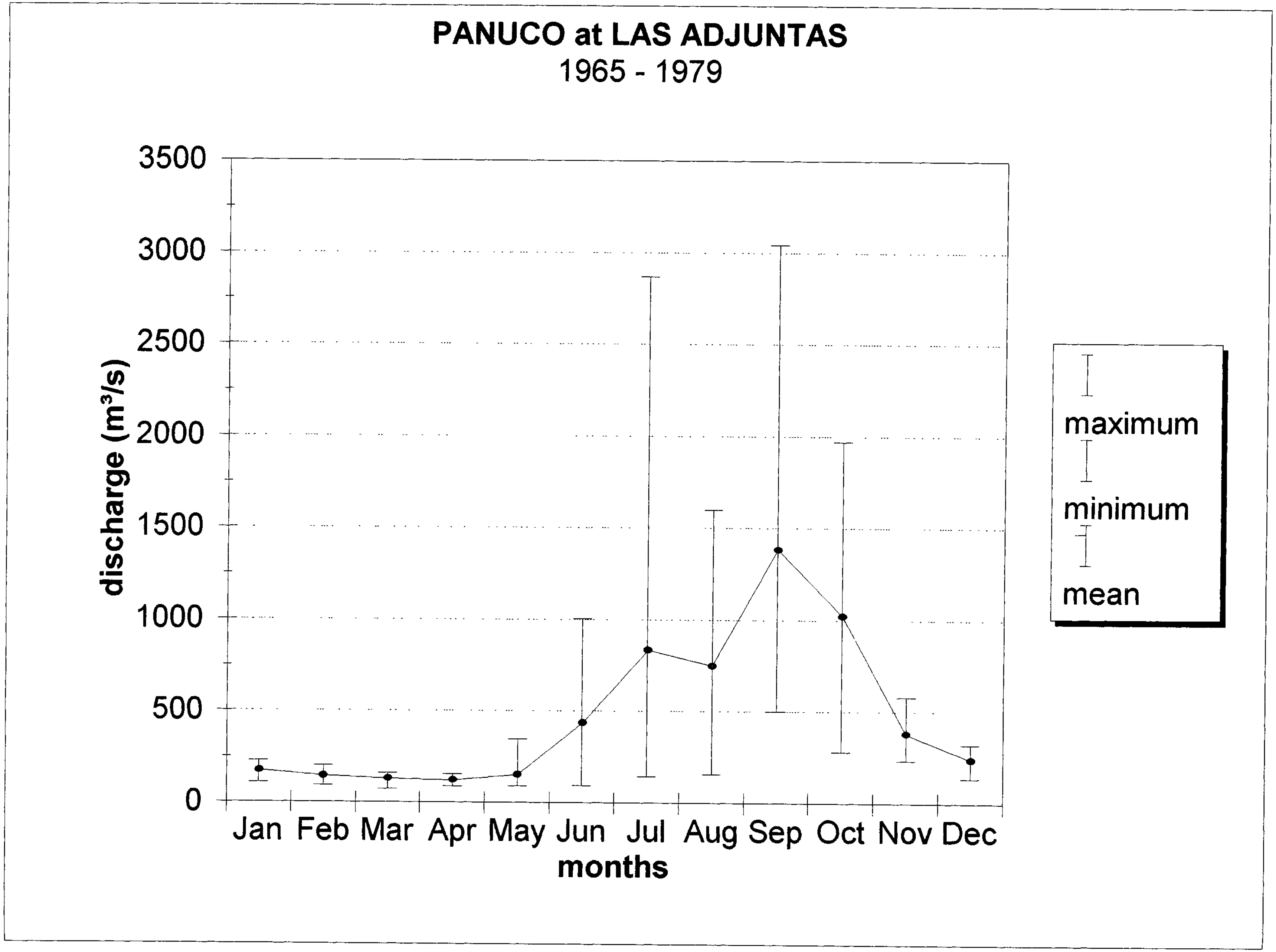


Figure 2.109

GLOBAL RUNOFF DATA CENTRE (GRDC)

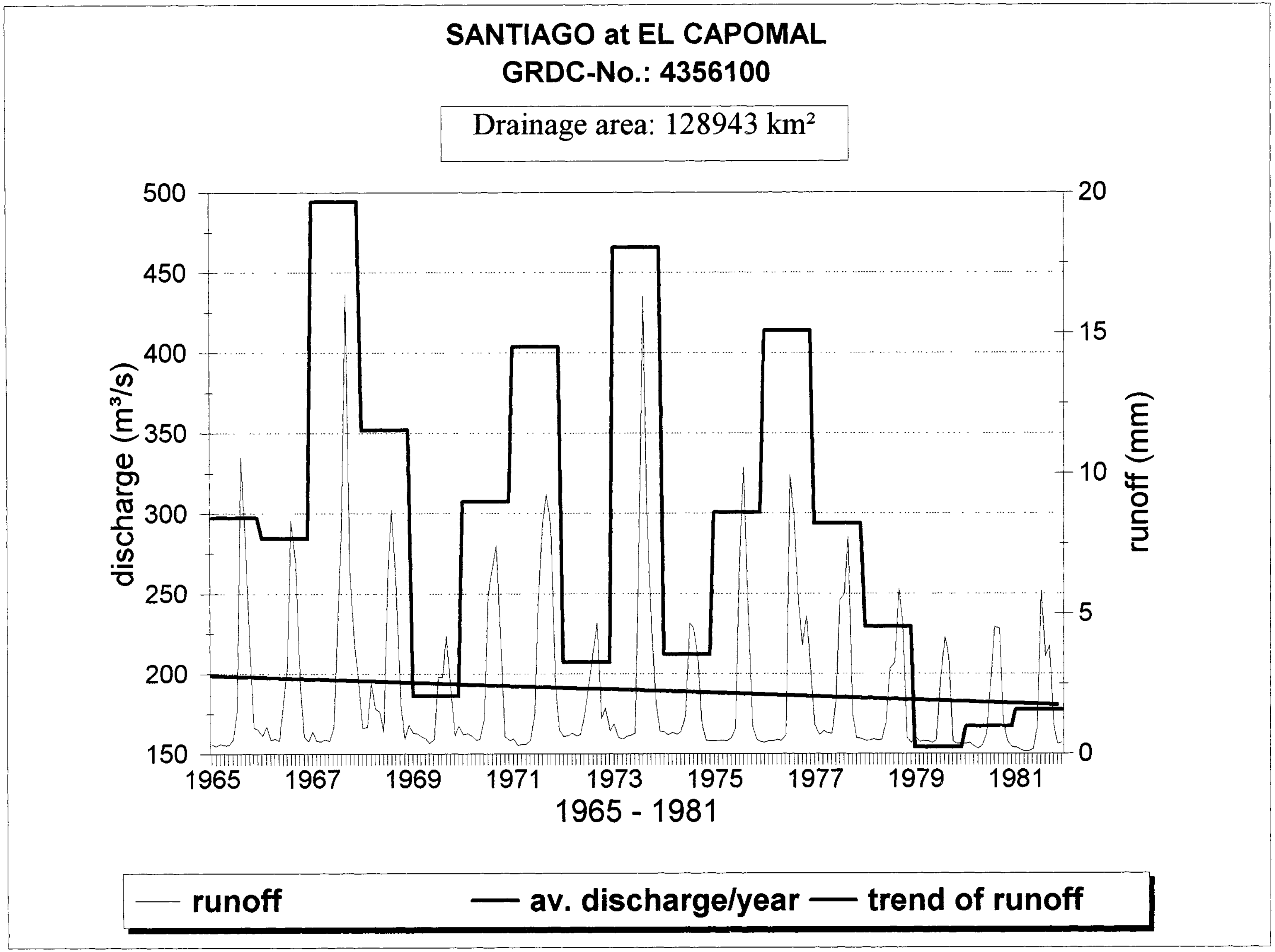


Figure 2.110

GLOBAL RUNOFF DATA CENTRE (GRDC)

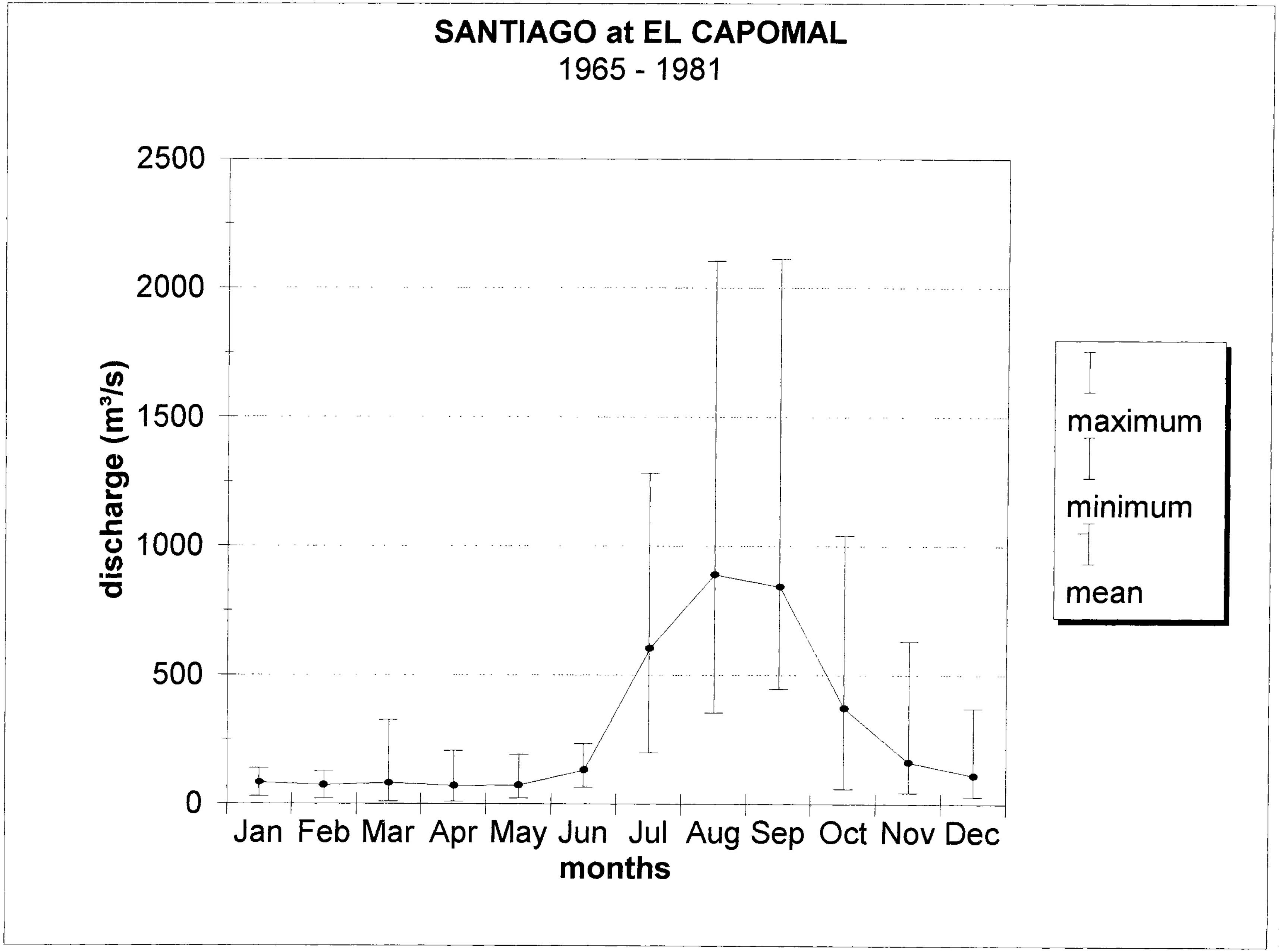


Figure 2.111

GLOBAL RUNOFF DATA CENTRE (GRDC)

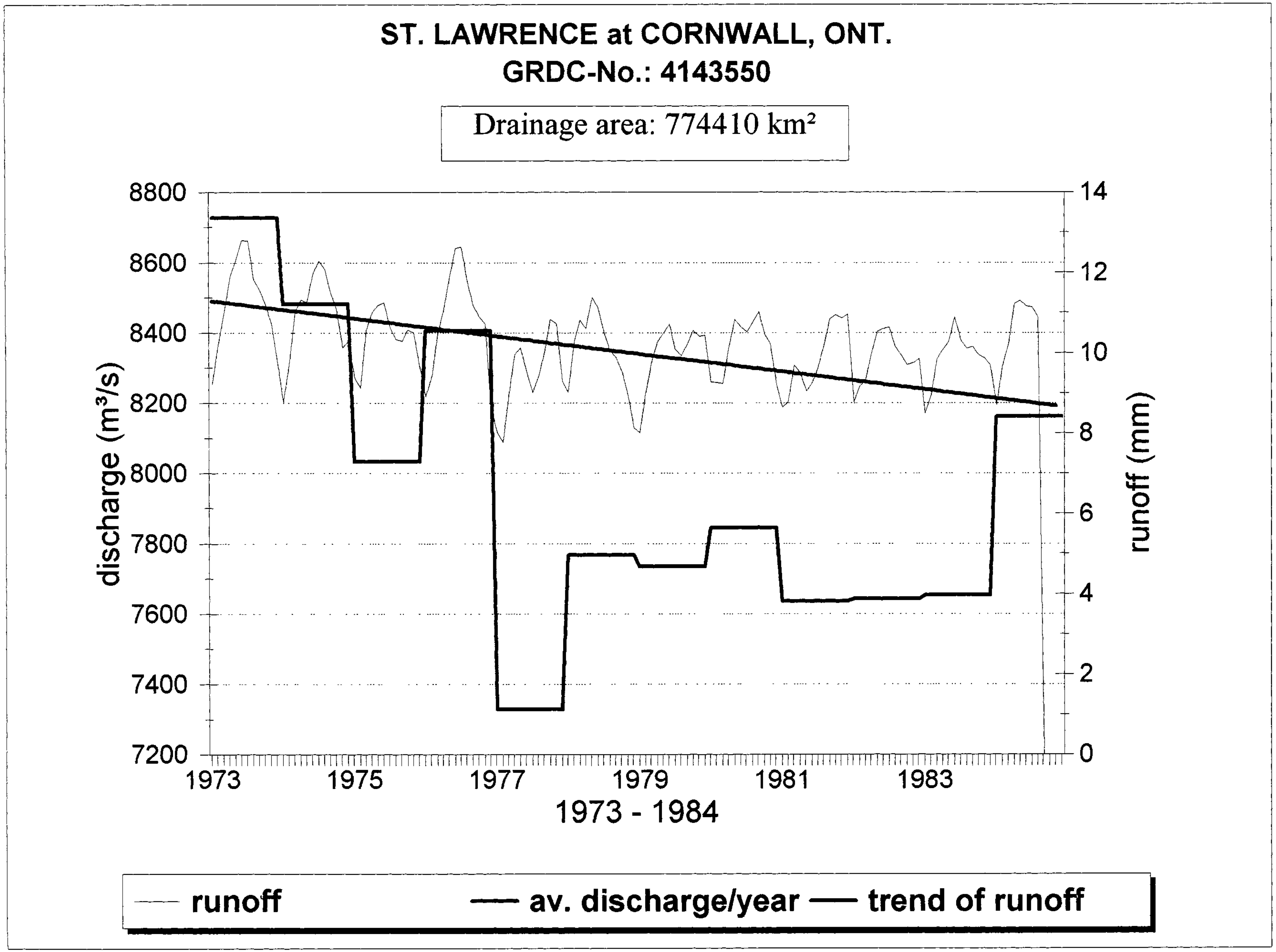


Figure 2.112

GLOBAL RUNOFF DATA CENTRE (GRDC)

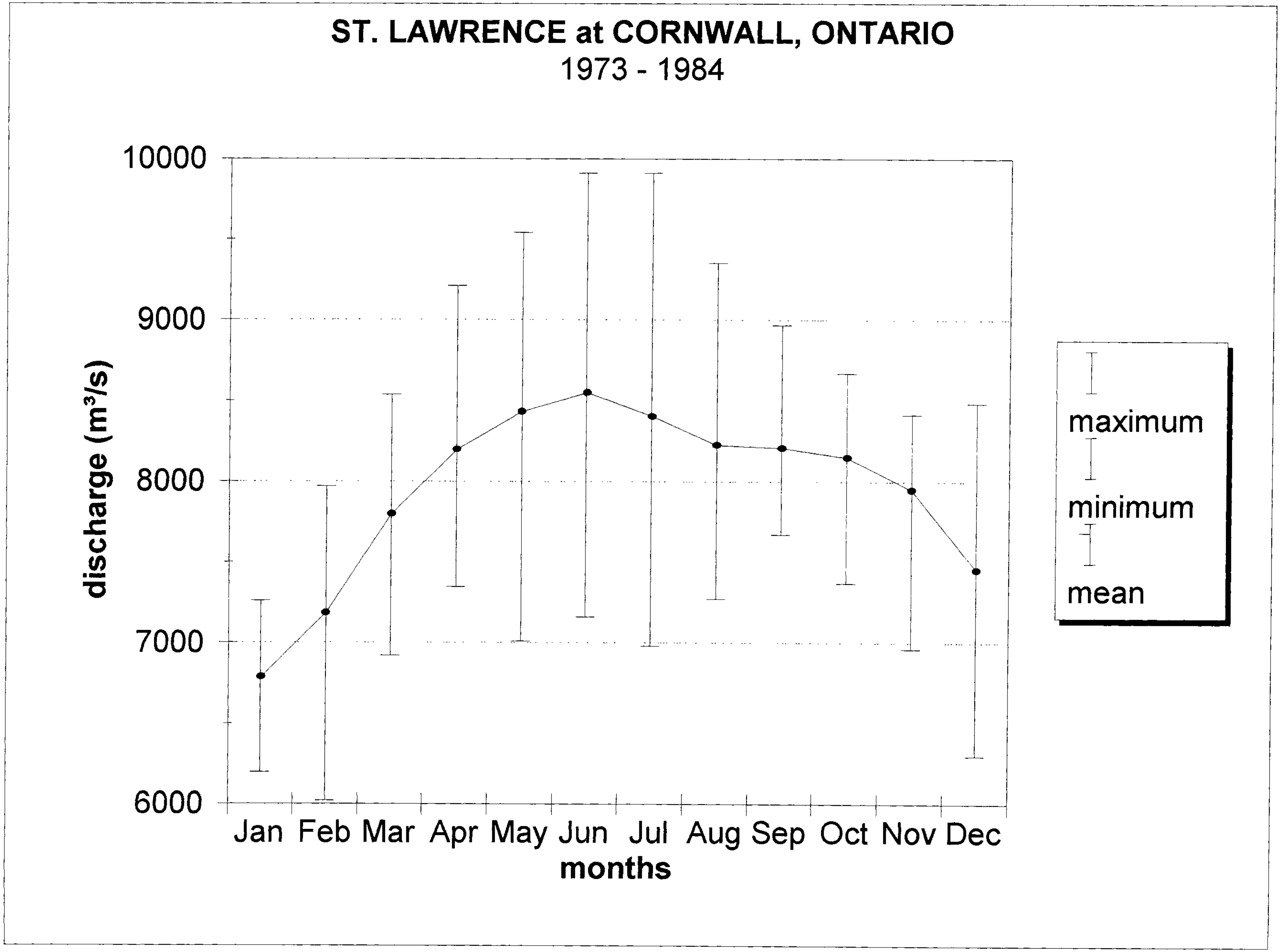


Figure 2.113

GLOBAL RUNOFF DATA CENTRE (GRDC)

YUKON at PILOT STATION
GRDC-No.: 4103200

Drainage area: 831390 km²

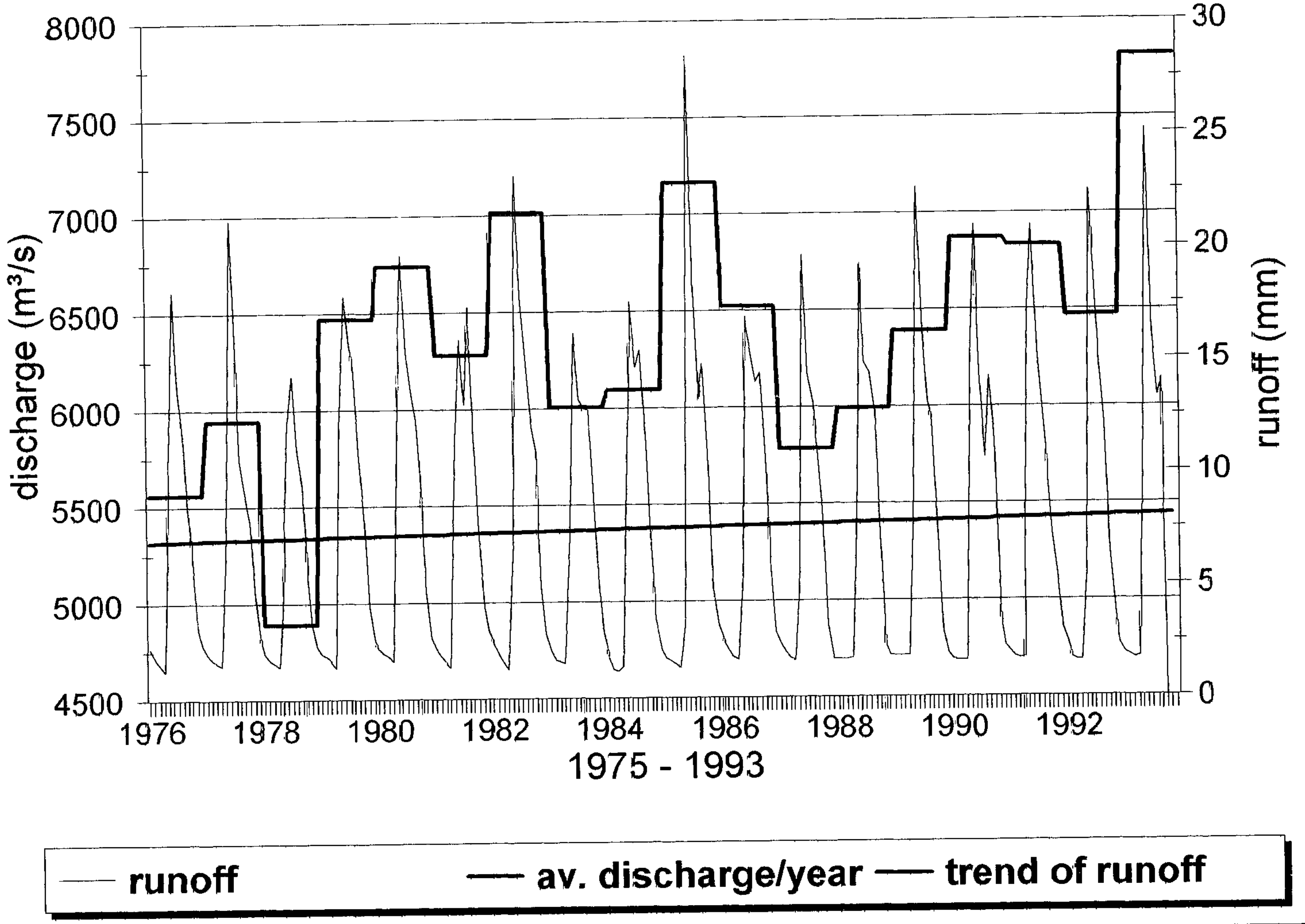


Figure 2.114

GLOBAL RUNOFF DATA CENTRE (GRDC)

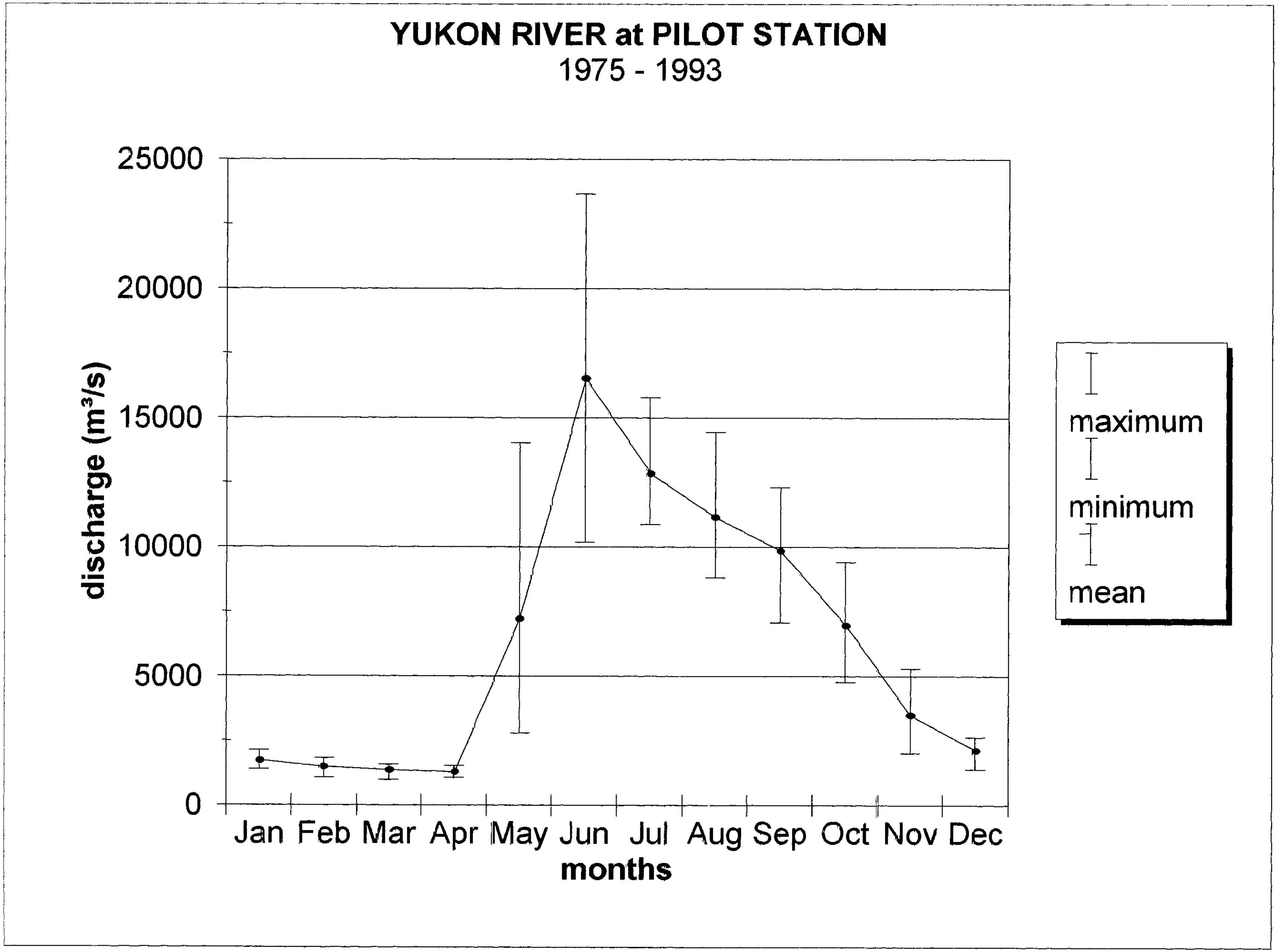


Figure 2.115

South America

GLOBAL RUNOFF DATA CENTRE (GRDC)

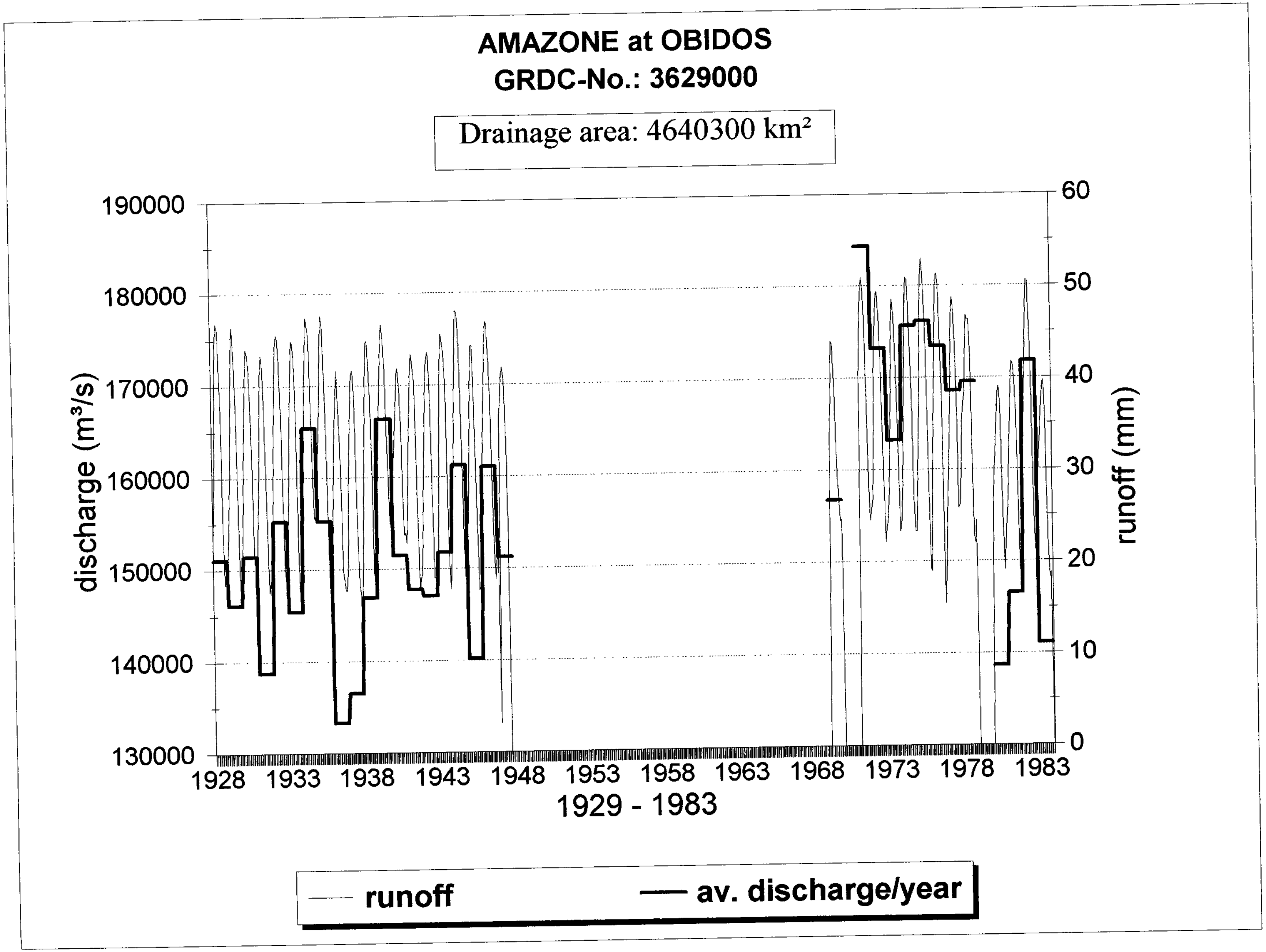


Figure 2.116

GLOBAL RUNOFF DATA CENTRE (GRDC)

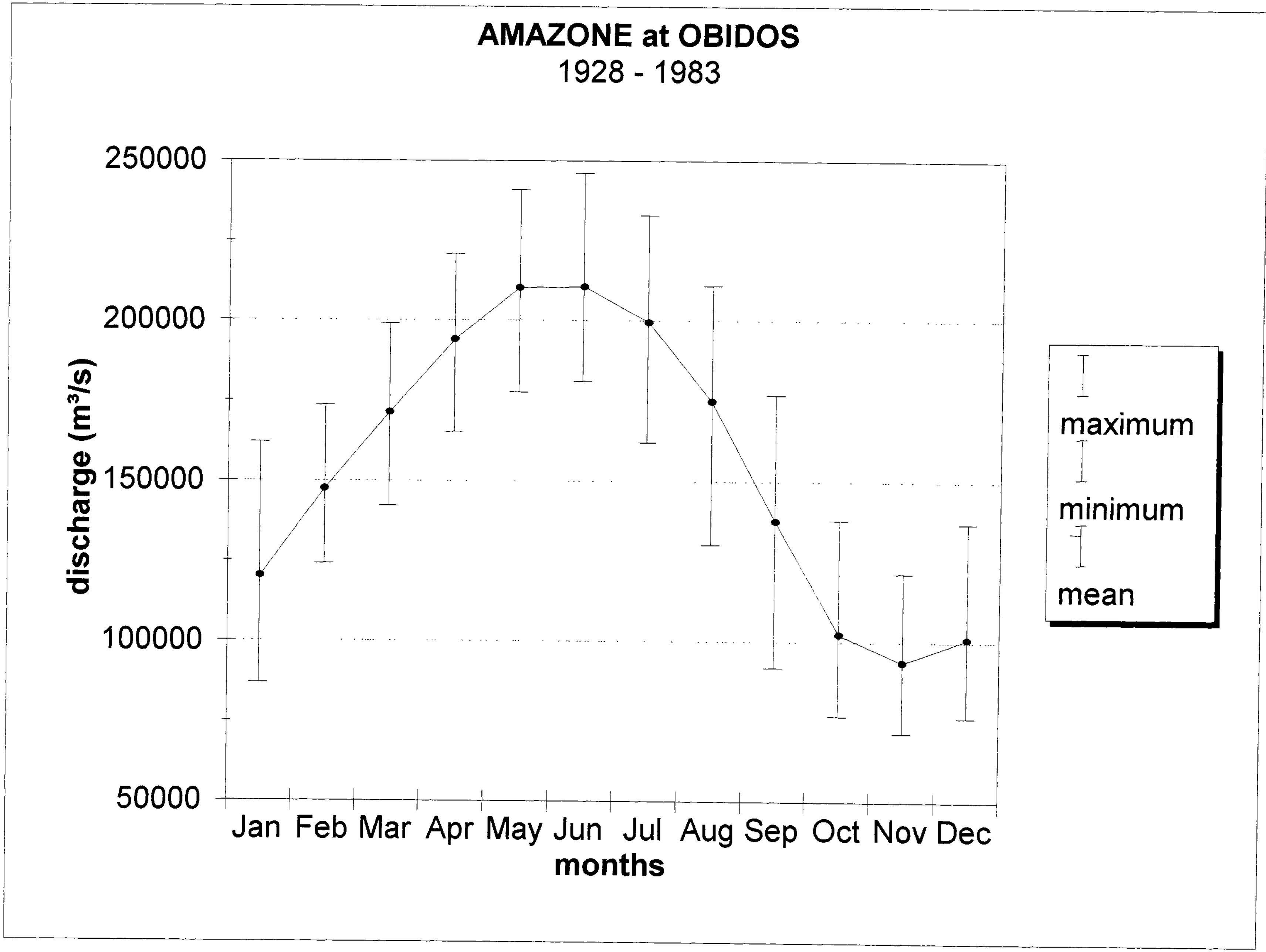


Figure 2.117

GLOBAL RUNOFF DATA CENTRE (GRDC)

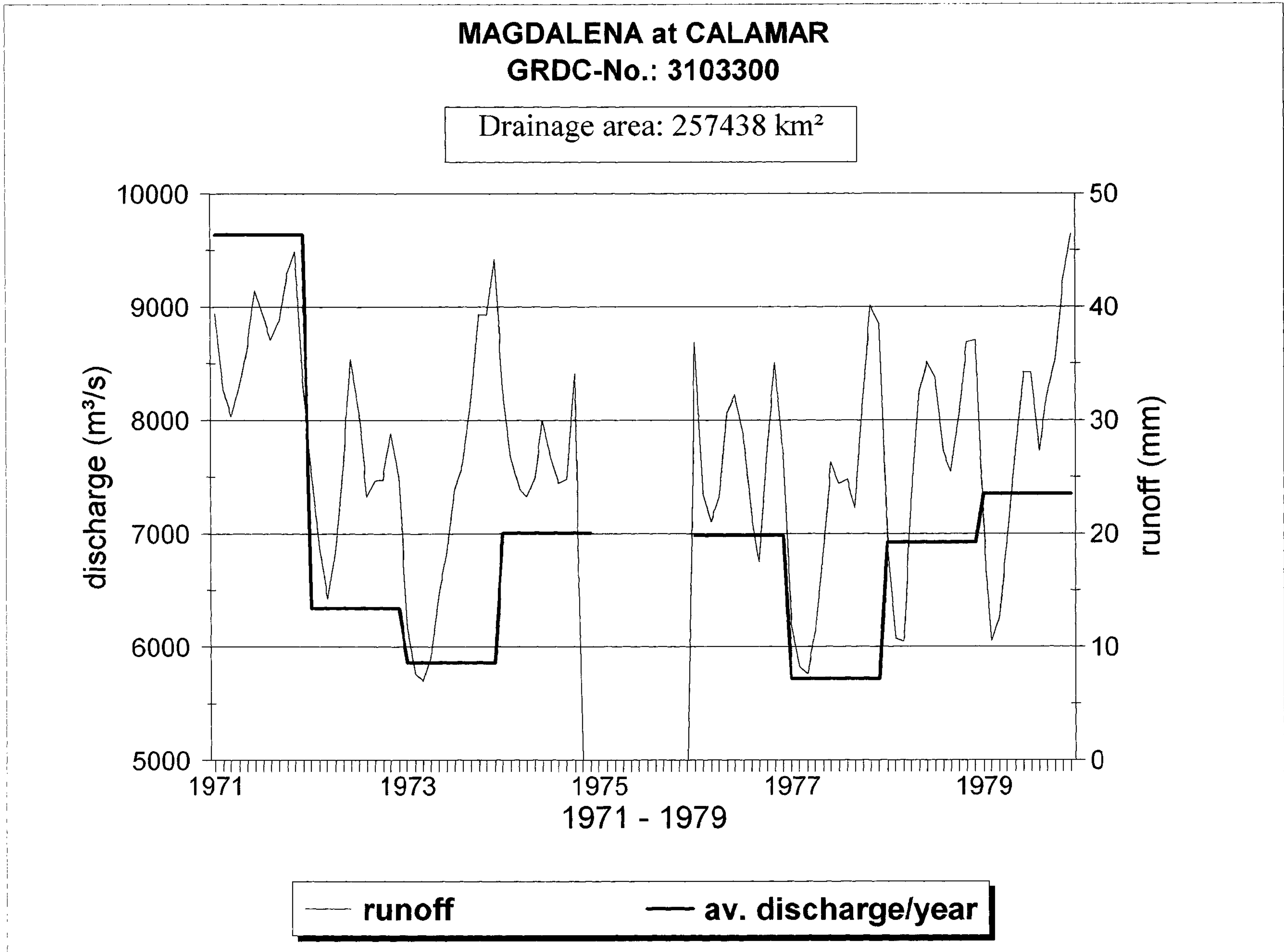


Figure 2.118

GLOBAL RUNOFF DATA CENTRE (GRDC)

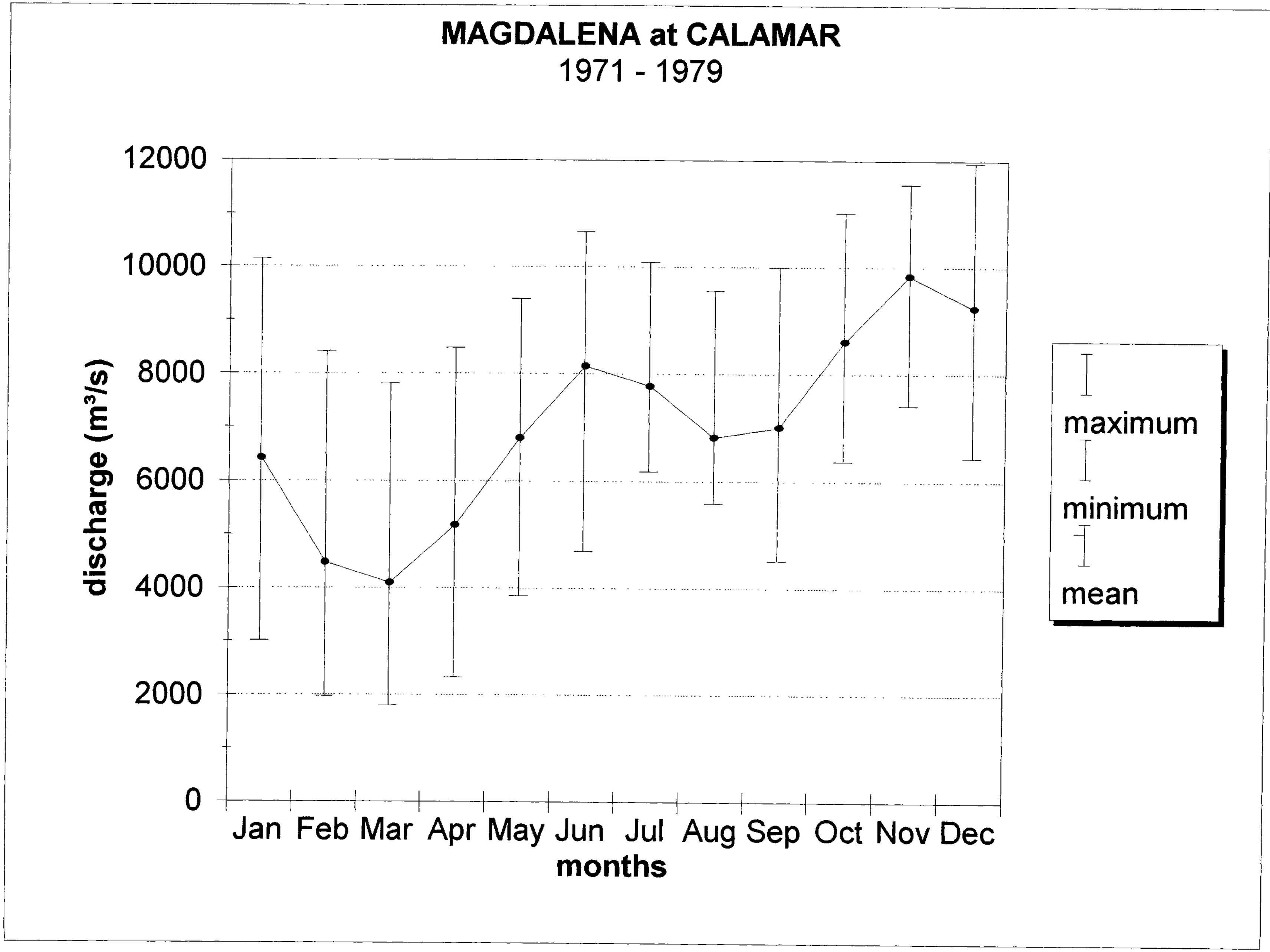


Figure 2.119

GLOBAL RUNOFF DATA CENTRE (GRDC)

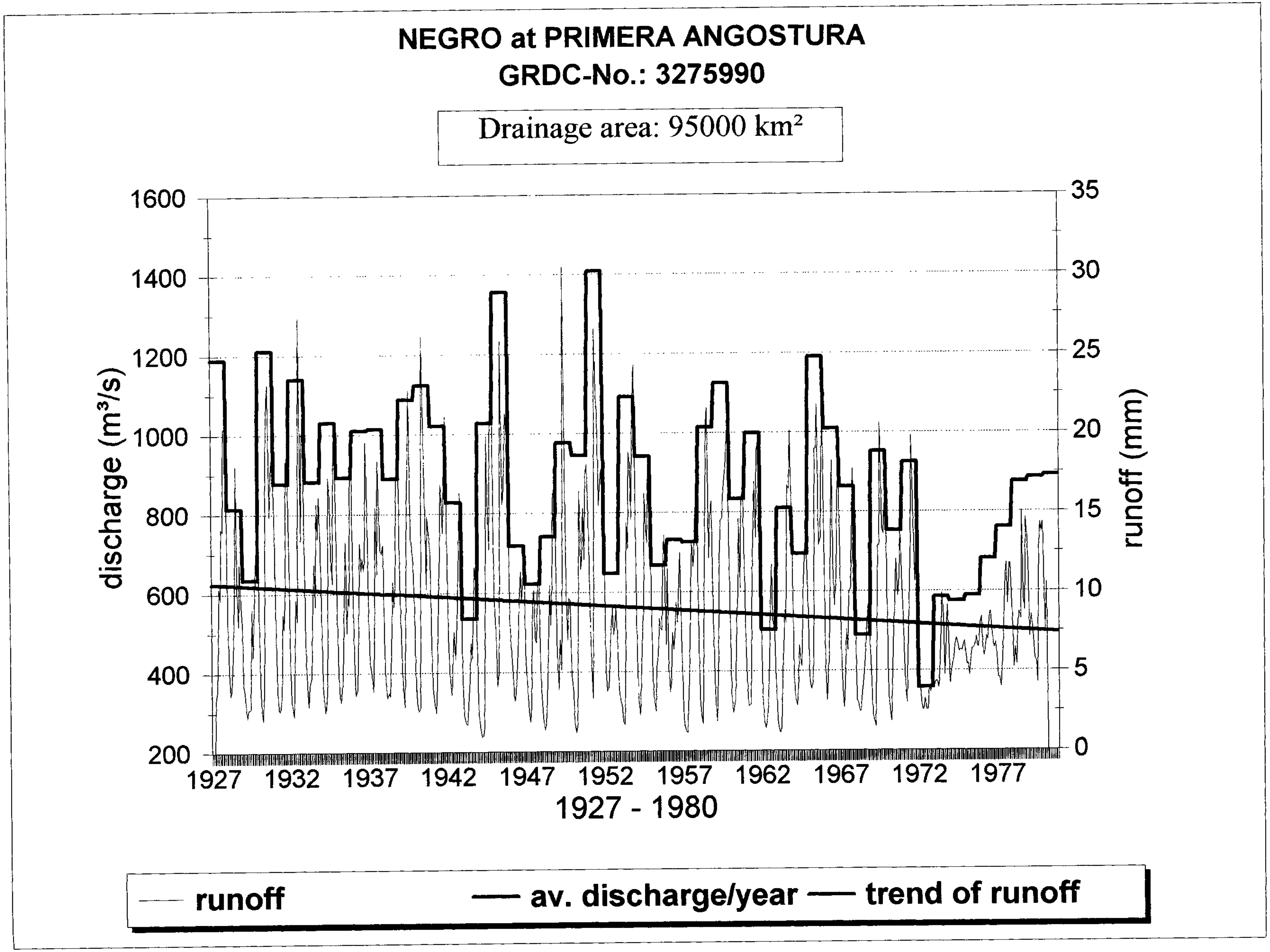


Figure 2.120

GLOBAL RUNOFF DATA CENTRE (GRDC)

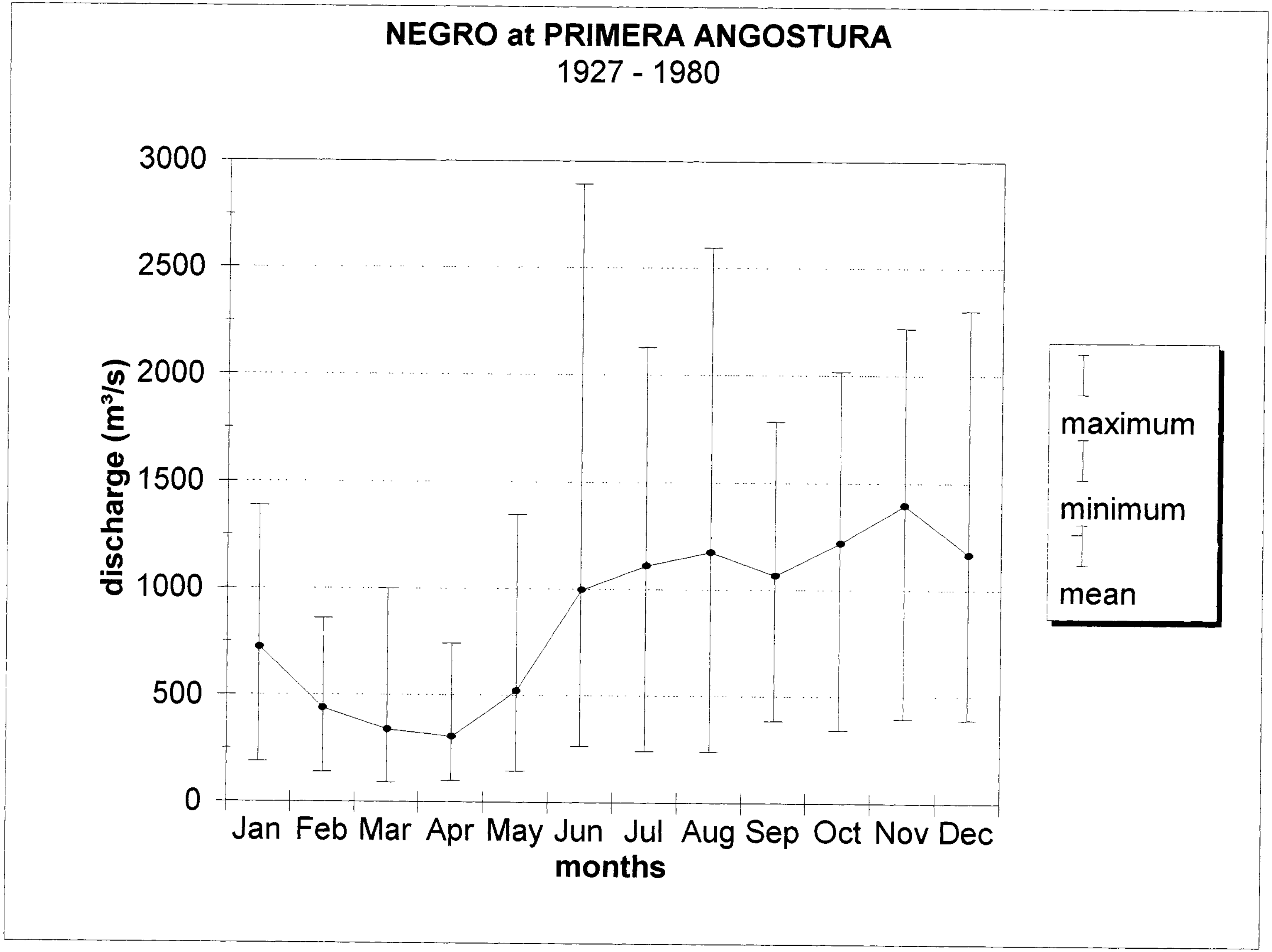


Figure 2.121

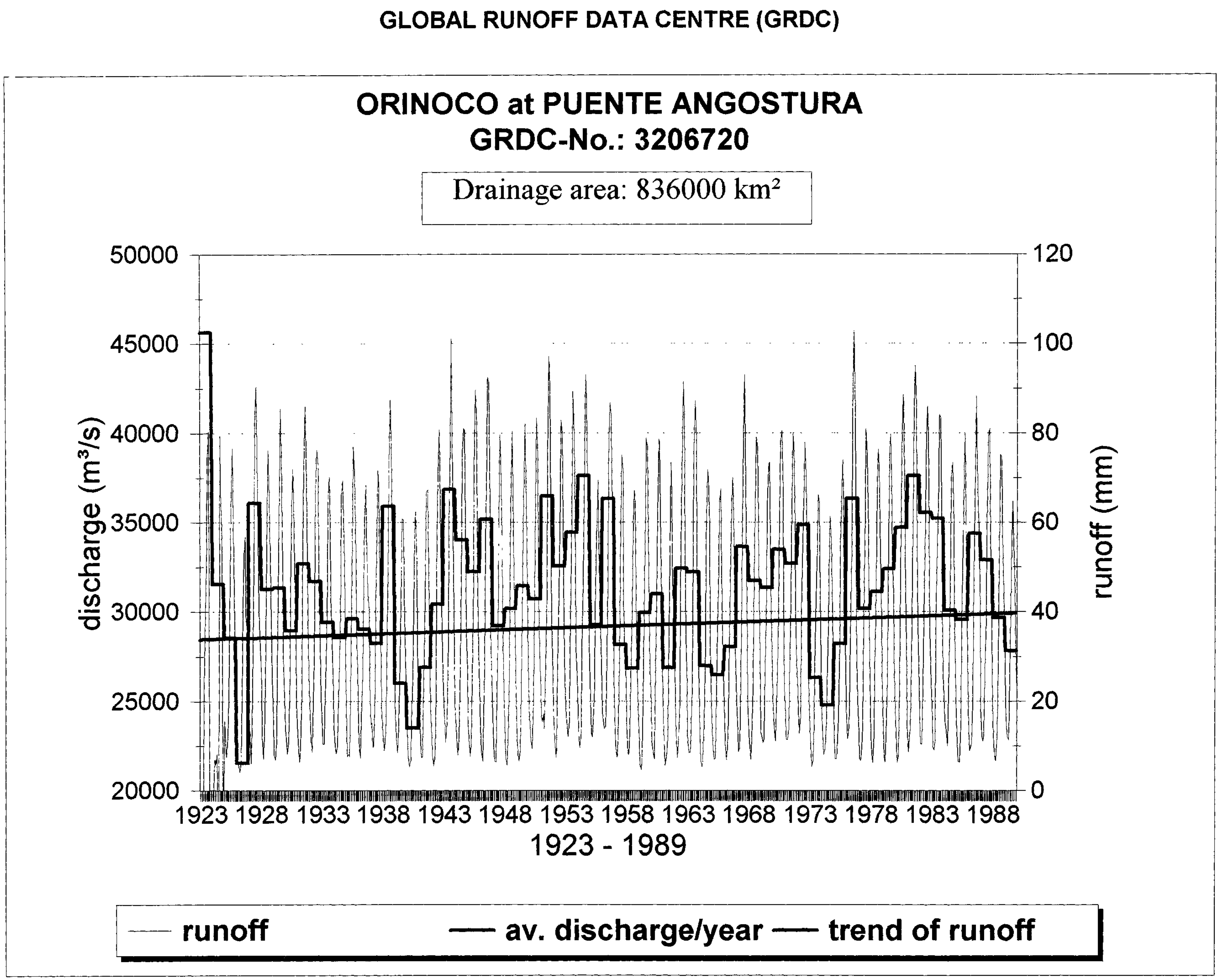

GLOBAL RUNOFF DATA CENTRE (GRDC)
ORINOCO at PUENTE ANGOSTURA
GRDC-No.: 3206720
Drainage area: 836000 km²
50000
45000
40000
35000
30000
25000
20000
discharge (m³/s)
120
100
80
60
40
20
0
runoff (mm)
1923 1928 1933 1938 1943 1948 1953 1958 1963 1968 1973 1978 1983 1988
1923 - 1989
runoff
av. discharge/year
trend of runoff

Figure 2.122

GLOBAL RUNOFF DATA CENTRE (GRDC)

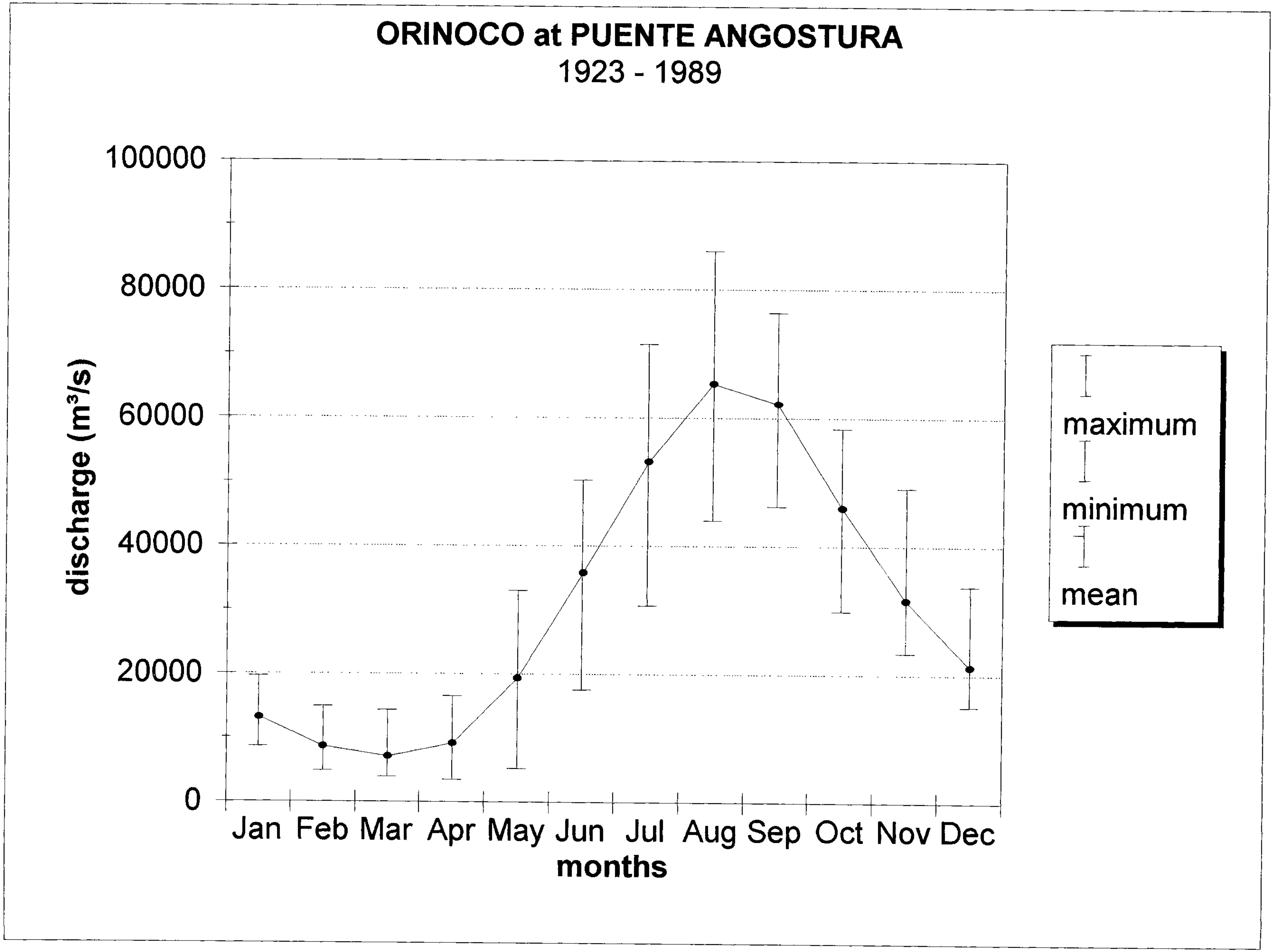


Figure 2.123

GLOBAL RUNOFF DATA CENTRE (GRDC)

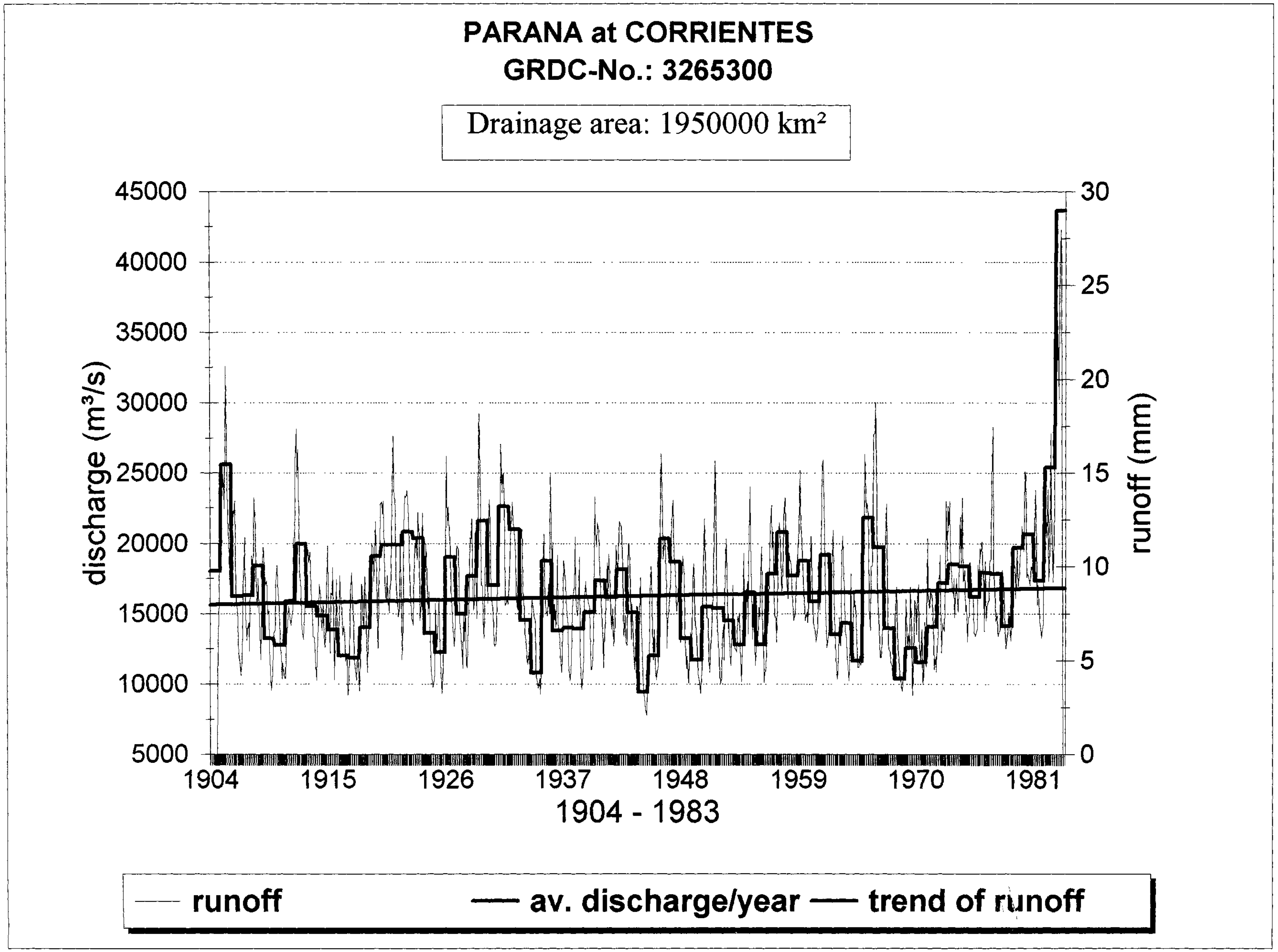


Figure 2.124

GLOBAL RUNOFF DATA CENTRE (GRDC)

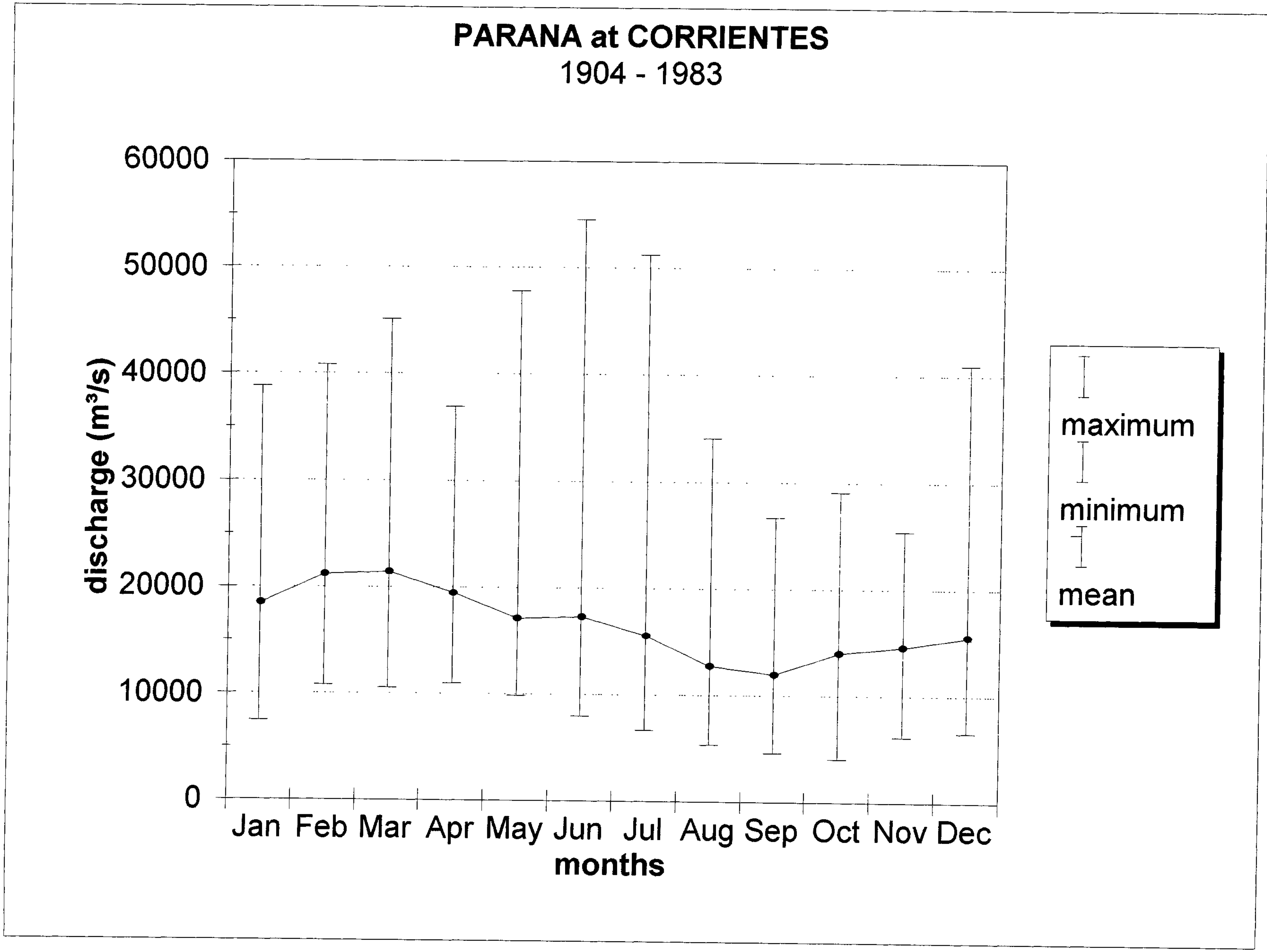


Figure 2.125

GLOBAL RUNOFF DATA CENTRE (GRDC)

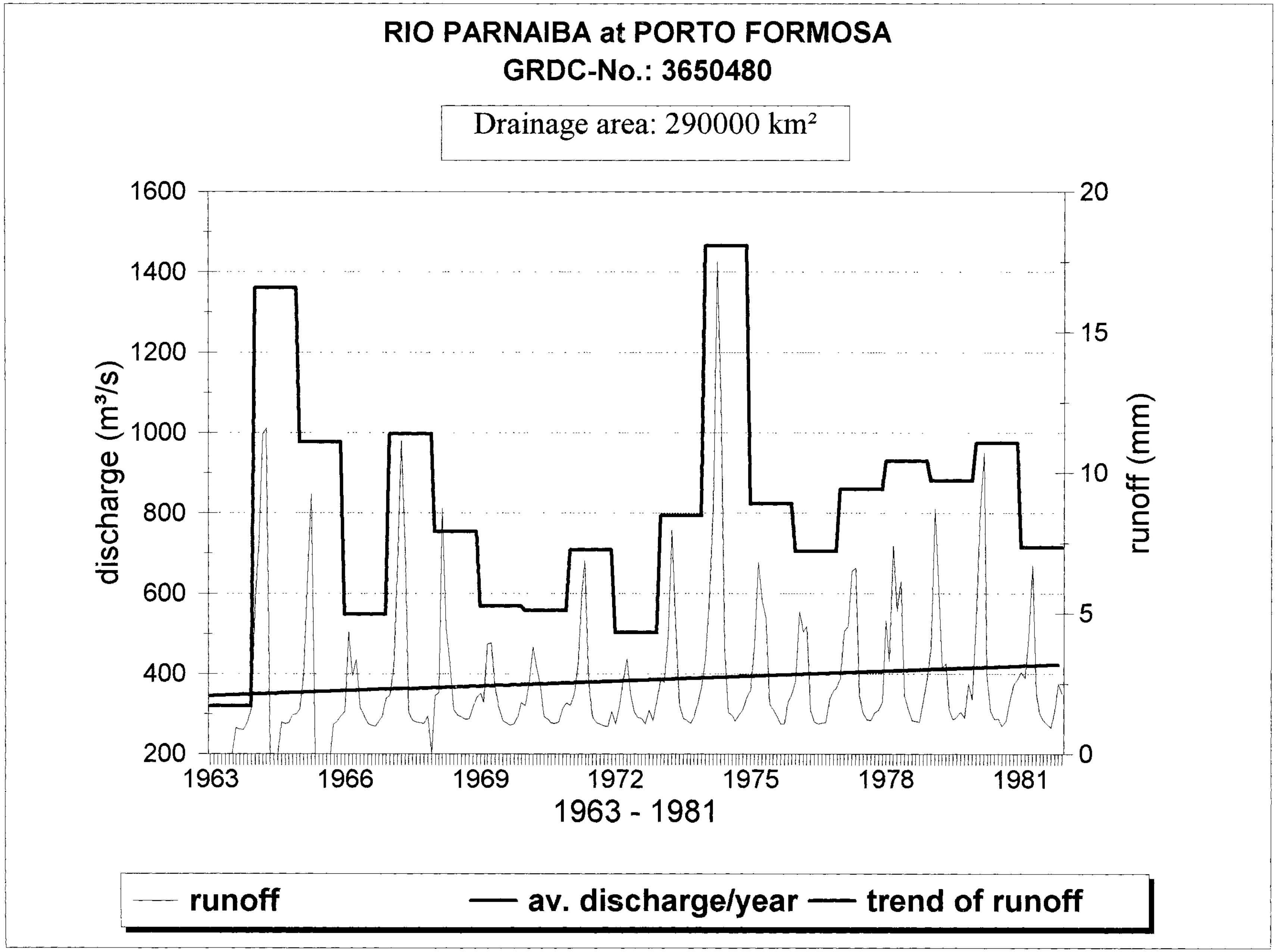


Figure 2.126

GLOBAL RUNOFF DATA CENTRE (GRDC)

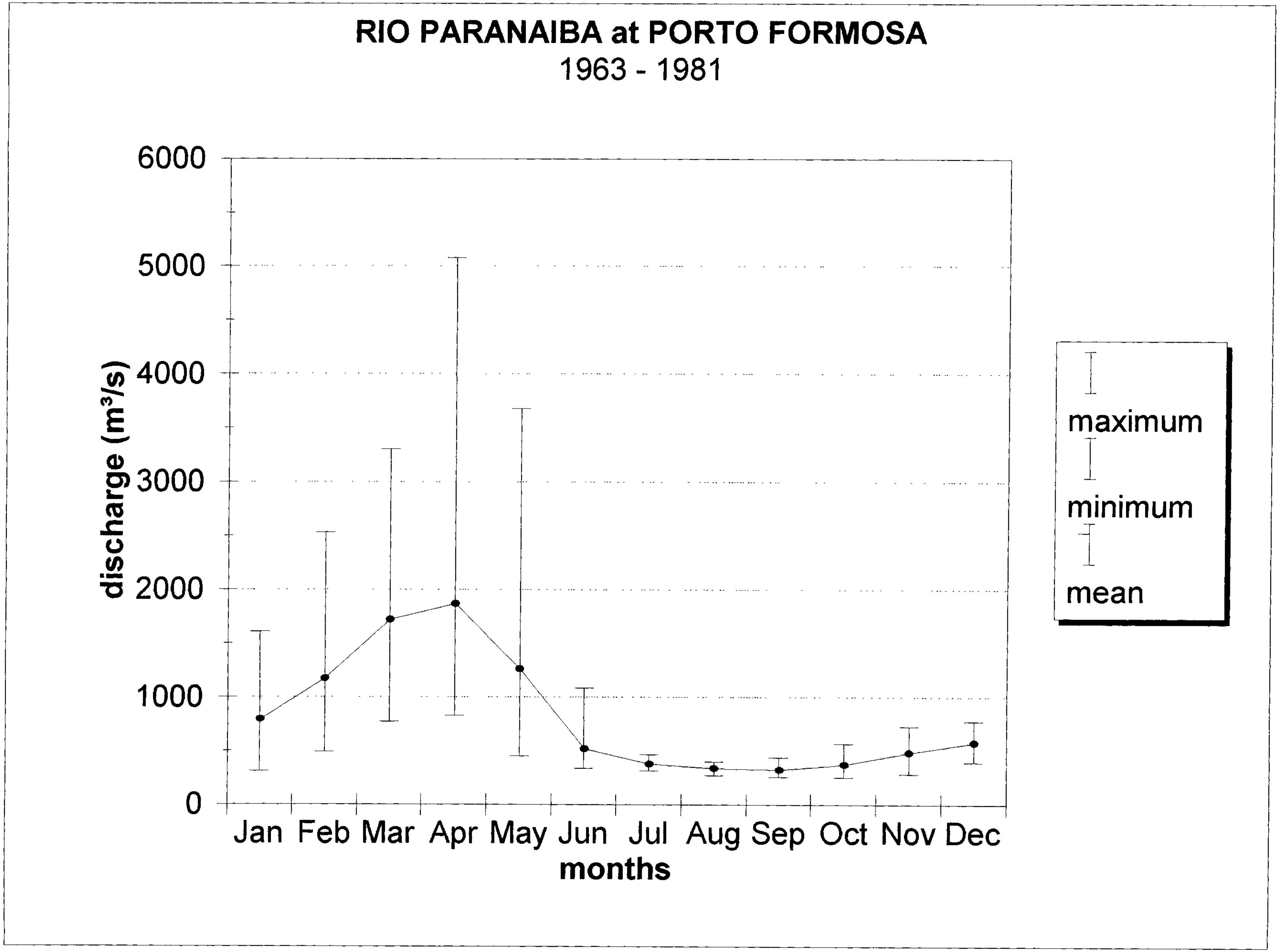


Figure 2.127

GLOBAL RUNOFF DATA CENTRE (GRDC)

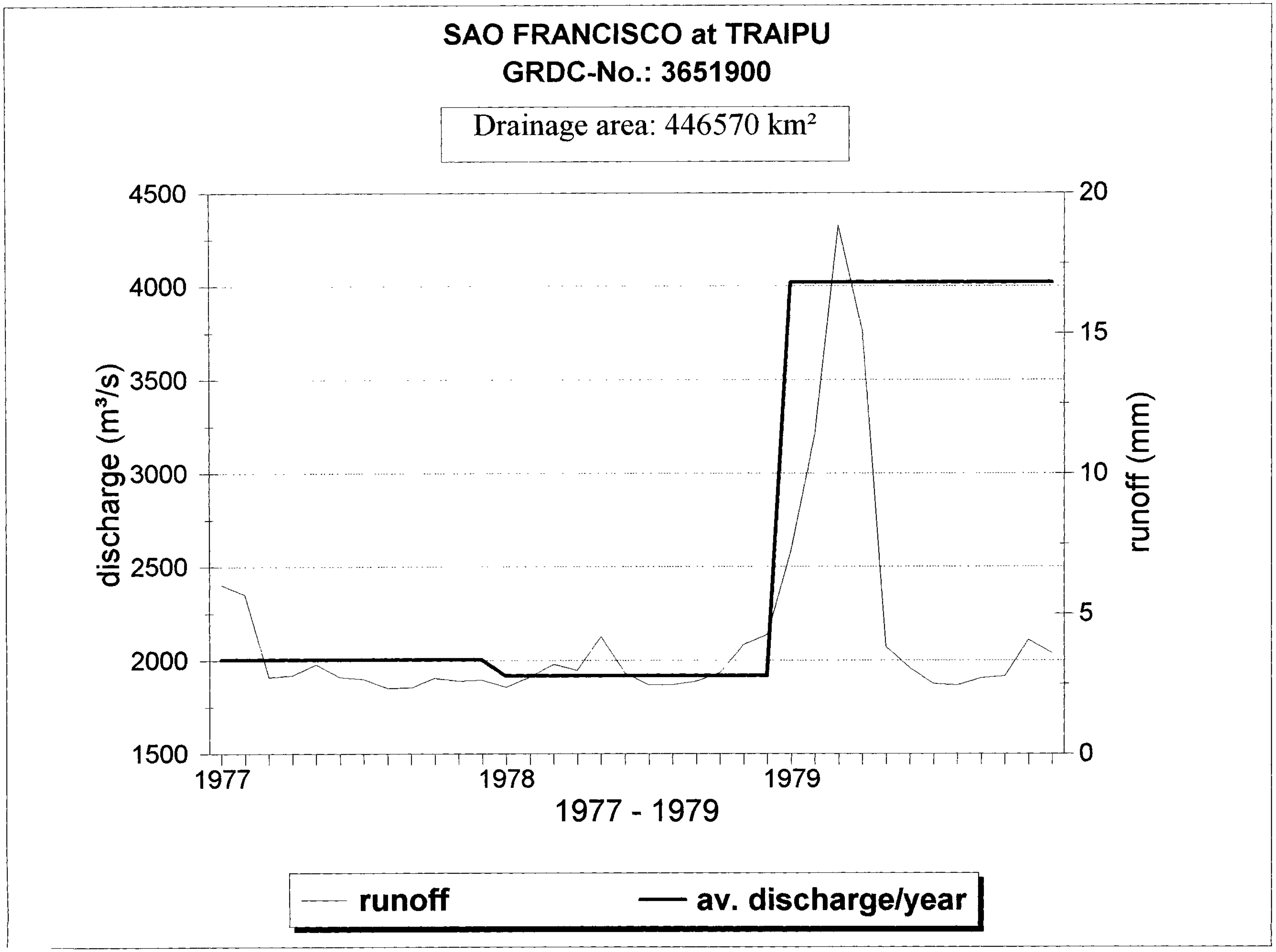


Figure 2.128

GLOBAL RUNOFF DATA CENTRE (GRDC)

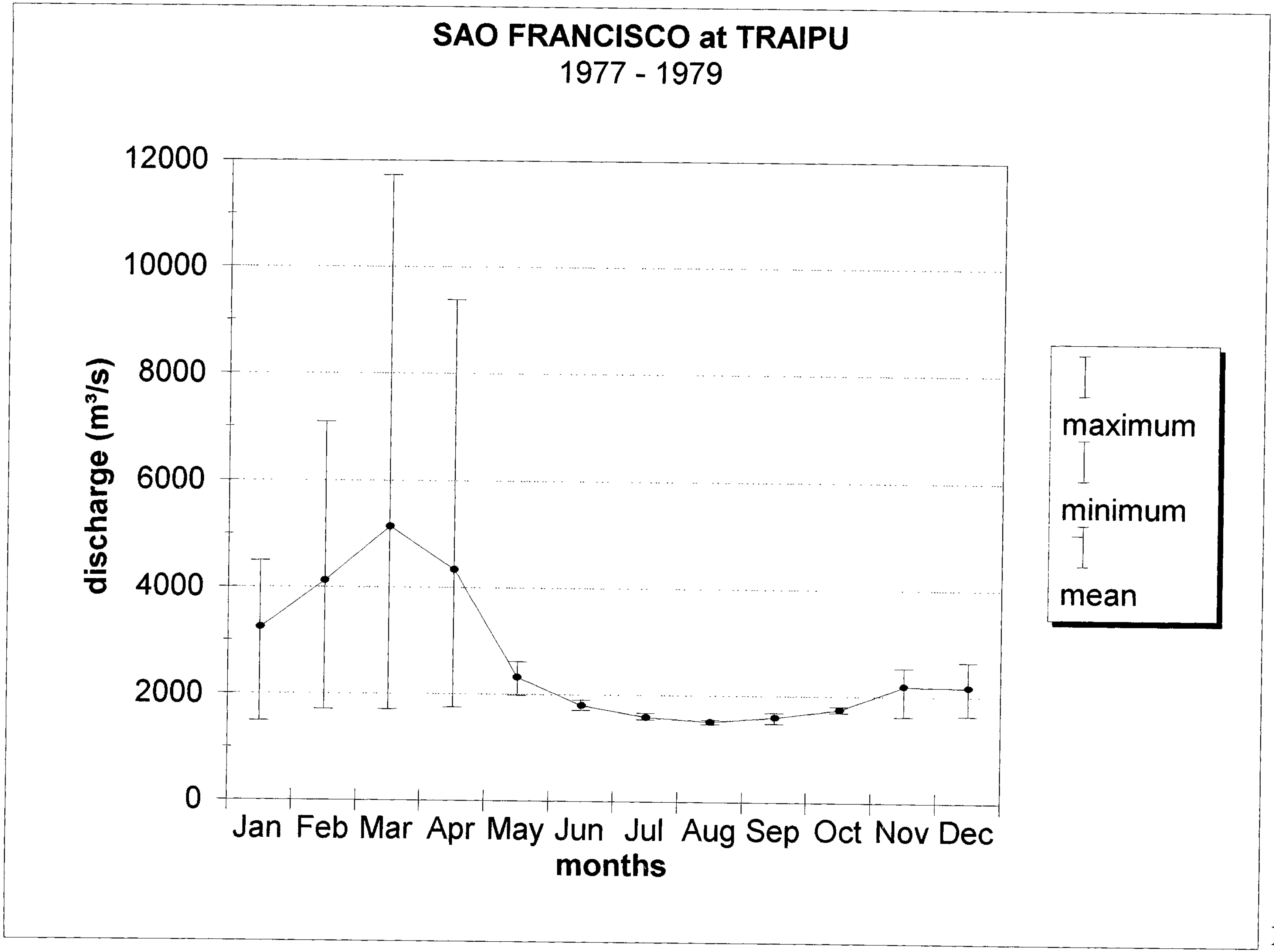


Figure 2.129

GLOBAL RUNOFF DATA CENTRE (GRDC)

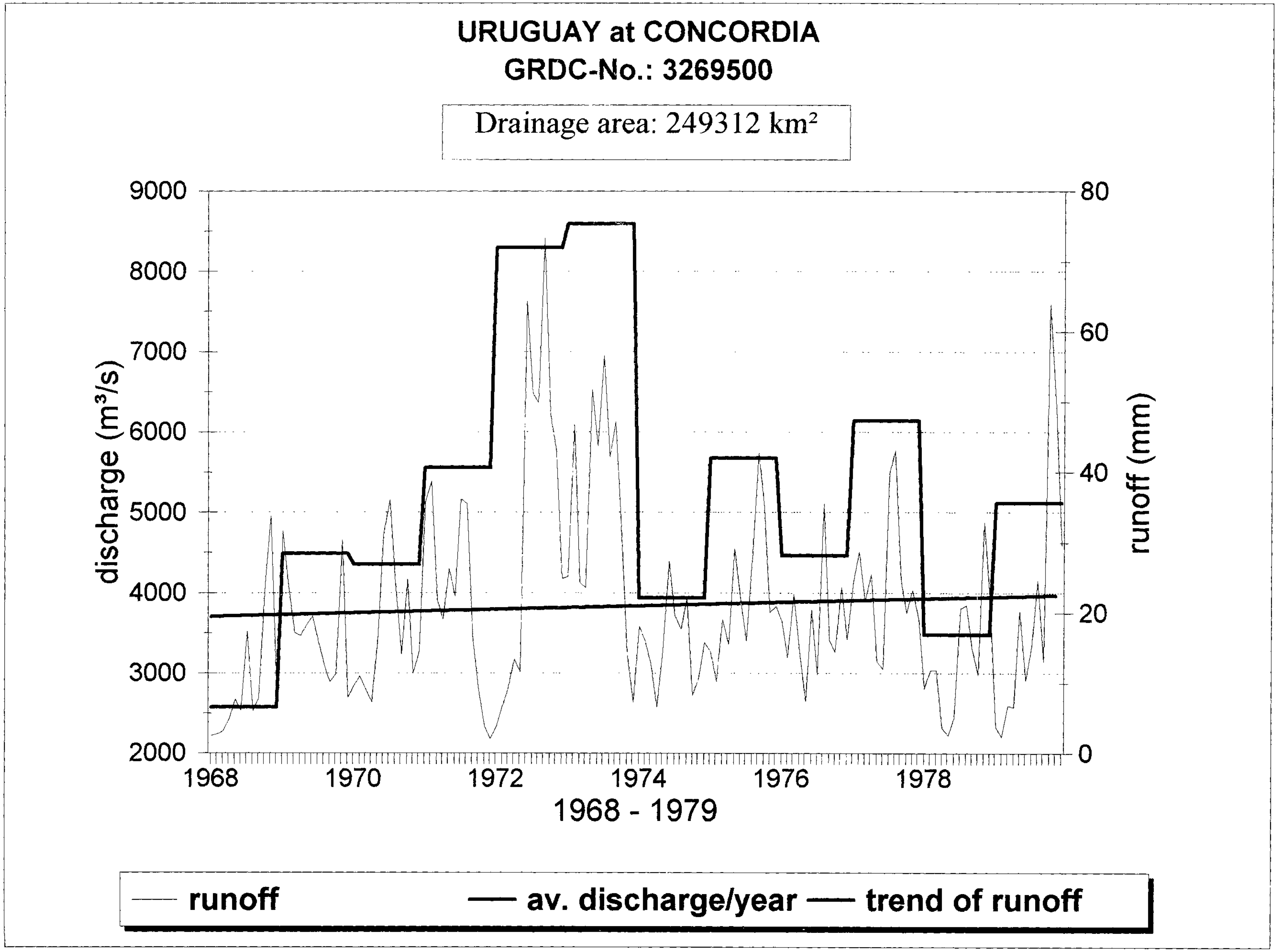


Figure 2.130

GLOBAL RUNOFF DATA CENTRE (GRDC)

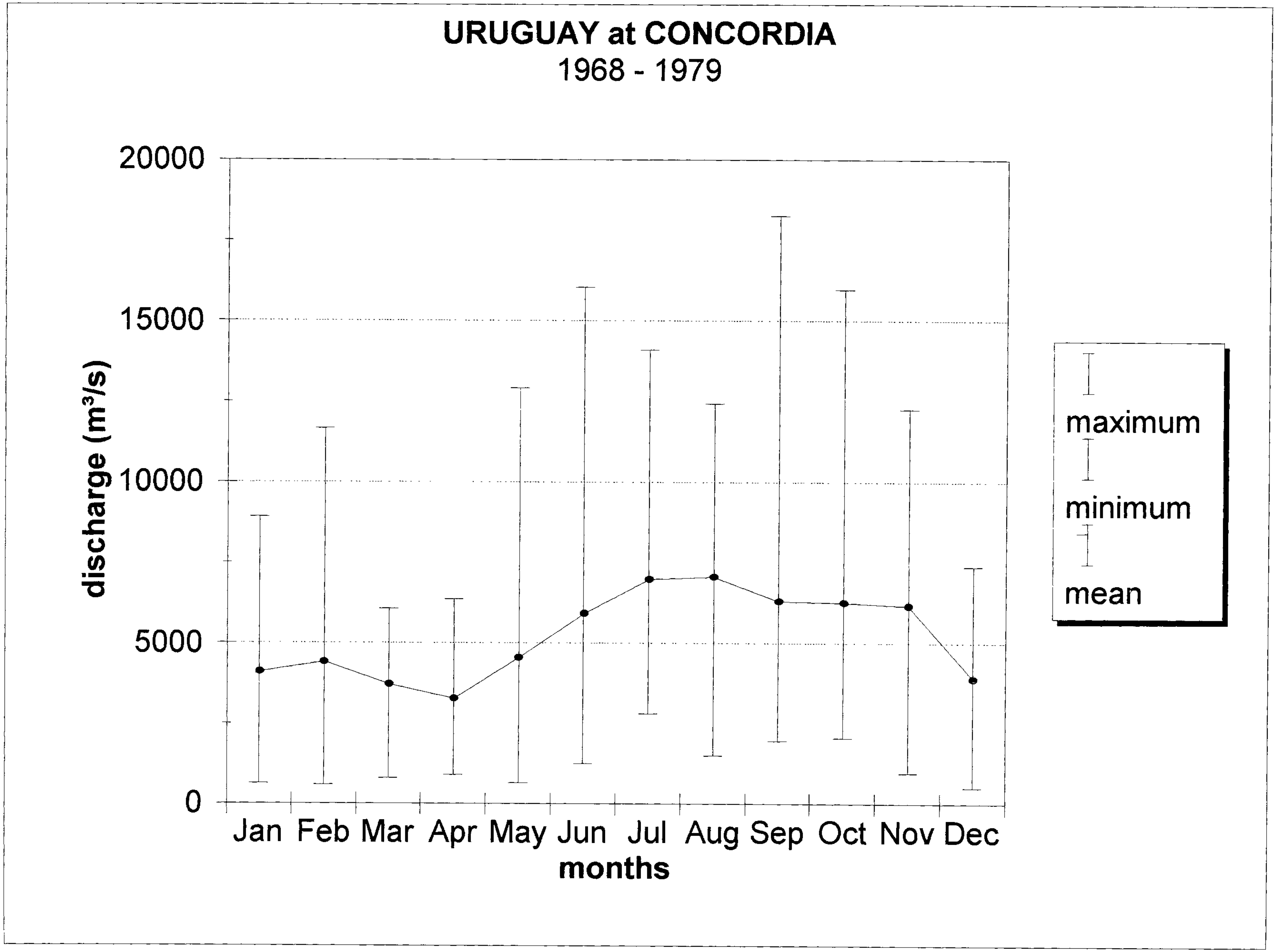


Figure 2.131

GLOBAL RUNOFF DATA CENTRE (GRDC)

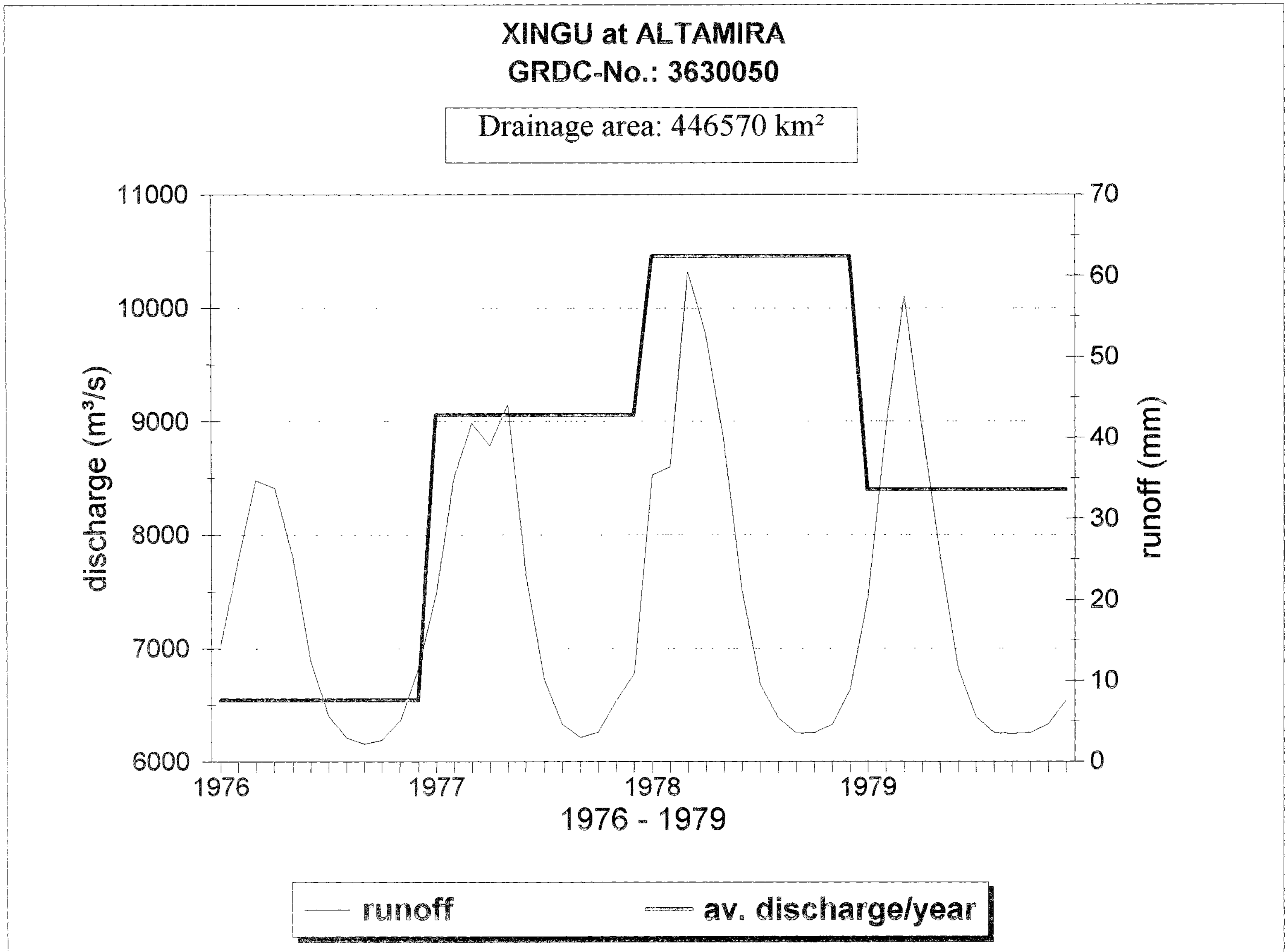


Figure 2.132

GLOBAL RUNOFF DATA CENTRE (GRDC)

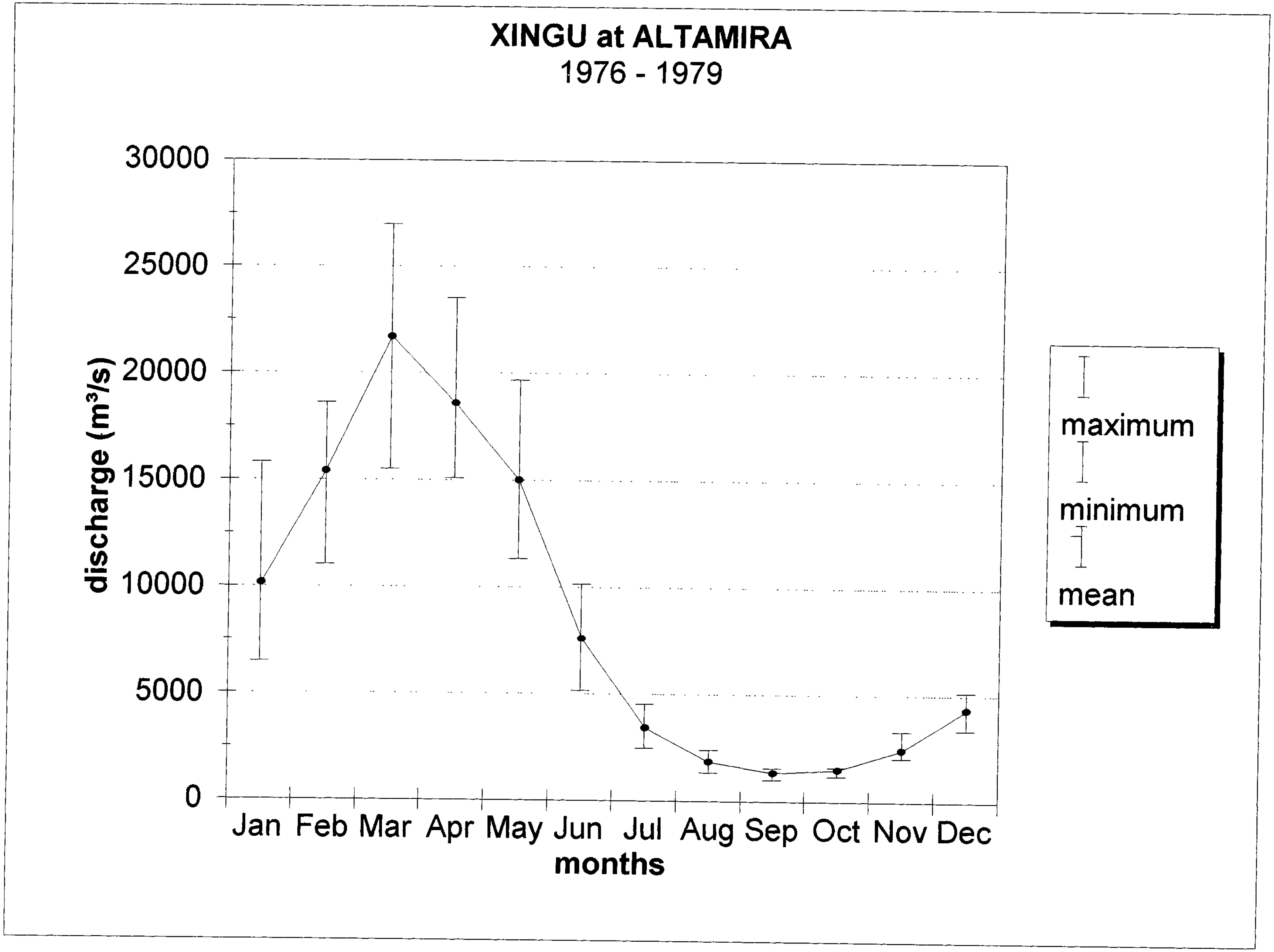


Figure 2.133

Annex 3

List of country codes used in tables 8 - 13 (Representative gauging stations)

INDEX 3

GRDC-COUNTRYCODES			
NAME	code	region	code-nr
AFGHANISTAN	AH	2	2
ALBANIA	AB	6	6
ALGERIA	AL	1	1
AMERICAN SAMOA	SH	5	9
ARGENTINA	AG	3	2
ARMENIA	AX	6	9
AUSTRALIA	AU	5	2
AUSTRALIA	AU	5	7
AUSTRALIA	AU	5	1
AUSTRALIA	AU	5	4
AUSTRALIA	AU	5	8
AUSTRALIA	AU	5	3
AUSTRALIA	AU	5	6
AUSTRIA	OS	6	2
AZERBEIDZHAN	AD	6	9
BANGLADESH	BW	2	6
BELGIUM	BX	6	2
BENIN	BJ	1	7
BOLIVIA	BO	3	7
BRAZIL	BZ	3	6
BULGARIA	BU	6	8
BURKINA FASO	HV	1	9
BYELORUSSIA	BY	6	9
CAMEROON	CM	1	3
CANADA	CN	4	2
CENTRAL AFRICAN REP	CE	1	7
CHAD	CD	1	5
CHILE	CH	3	1
CHINA	CI	2	1
COLUMBIA	CO	3	1
CONGO	CG	1	4
COSTA RICA	CS	4	8
COTE D'IVOIRE	IV	1	4
CUBA	CU	4	2
CYPRUS	CY	6	1
CZECHOSLOVAKIA	CZ	6	1
DEM.PEOPL.REP.KOREA	KR	2	8
DENMARK	DN	6	9
DOMINICAN REPUBLIC	DR	4	3
ECUADOR	EQ	3	8
EGYPT	EG	1	3
EL SALVADOR	ES	4	6
ESTONIA	EO	6	9
ETHIOPIA	ET	1	5
FIJI	FJ	5	1
FINLAND	FI	6	8
FRANCE	FR	6	1
FRENCH GUIANA	FG	3	5
FRENCH POLYNESIA	PF	5	4
GABON	GO	1	6
GEORGIA	GG	6	9
GERMANY	DL	6	3

INDEX 3

NAME	code	region	code-nr
GHANA	GH	1	5
GREECE	GR	6	2
GUADELOUPE	MF	4	5
GUAM	GM	5	9
GUATEMALA	GU	4	4
GUINEA	GN	1	6
GUYANA	GY	3	3
HONDURAS	HO	4	5
HONGKONG	HK	2	2
HUNGARY	HU	6	4
ICELAND	IL	6	4
INDIA	IN	2	8
IRAN	IR	2	4
IRAQ	IQ	2	5
IRELAND	IE	6	5
ISRAEL	IS	6	5
ITALY	IY	6	3
JAMAICA	JM	4	5
JAPAN	JP	2	5
JORDAN	JD	6	7
KAZAKHSTAN	KZ	2	9
KENYA	KN	1	7
KIRGHIZTAN	KG	2	9
LAOS	LA	2	4
LATVIA	LV	6	9
LESOTHO	LS	1	2
LIBERIA	LI	1	3
LITHUANIA	LT	6	9
LUXEMBOURG	LX	6	8
MADAGASCAR	MG	1	3
MALAWI	MW	1	9
MALAYSIA	MS	5	2
MALI	MI	1	1
MARTINIQUE	MR	4	7
MAURITANIA	MT	1	5
MAURITIUS	MA	1	6
MEXICO	MX	4	3
MICRONESIA	KA	5	9
MOLDAVIA	MK	6	9
MONGOLIA	MO	2	7
MOROCCO	MC	1	3
MOZAMBIQUE	MZ	1	8
MYANMAR	BM	2	2
NEPAL	NE	2	5
NETHERLANDS	NL	6	4
NEW CALEDONIA	NC	5	7
NEW ZEALAND	NZ	5	8
NICARAGUA	NK	4	7
NIGER	NR	1	2
NIGERIA	NI	1	8
NORWAY	NO	6	7
PAKISTAN	PK	2	3

INDEX 3

NAME	code	region	code-nr
PALAU	PB	5	9
PANAMA	PM	4	9
PAPUA NEW GUINEA	NG	5	5
PARAGUAY	PY	3	3
PERU	PR	3	9
PHILIPPINES	PH	5	6
POLAND	PL	6	4
PORTUGAL	PO	6	1
PUERTO RICO	PU	4	1
REP.KOREA	KO	2	6
REUNION	RE	1	9
ROMANIA	RO	6	7
RUSSIAN FEDERATION	RS	6	9
RUSSIAN FEDERATION	RS	2	9
RWANDA	RW	1	8
SAO TOME AND PRINCIPE	TP	1	9
SENEGAL	SG	1	8
SIERRA LEONE	SL	1	2
SINGAPORE	SR	5	7
SOMALIA	SI	1	8
SOUTH AFRICA	ZA	1	1
SPAIN	SP	6	2
SRI LANKA	SB	2	3
SUDAN	SU	1	6
SURINAM	SM	3	4
SWAZILAND	SV	1	5
SWEDEN	SN	6	2
SWITZERLAND	SW	6	9
SYRIA	SY	6	3
TADZHIKISTAN	TA	2	9
TAIWAN	TW	2	3
TANZANIA	TN	1	2
THAILAND	TH	2	9
TOGO	TG	1	6
TUNISIA	TS	1	2
TURKEY	TU	6	6
UGANDA	UG	1	4
UKRAINE	UR	6	9
UNITED KINGDOM	UK	6	6
URUGUAY	UY	3	4
USA	US	4	1
USA	US	5	1
UZBEKISTAN	UZ	2	9
VENEZUELA	VN	3	2
VIETNAM	VS	2	3
YUGOSLAVIA	YG	6	5
ZAIRE	ZR	1	1
ZAMBIA	ZB	1	5
ZIMBABWE	ZW	1	4