River Discharge to the Coastal Ocean

A Global Synthesis

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River Discharge to the Coastal Ocean
A Global Synthesis

Rivers provide the primary link between land and sea, historically discharging annually about $36\,000\,km^3$ of freshwater and more than 20 billion tons of solid and dissolved sediments to the global ocean. Together with tides, winds, waves, currents, and geology, rivers play a major role in determining the estuarine and coastal environment. The movement of freshwater and the distribution of river-derived sediments to the ocean have fundamental impacts on a wide variety of coastal environments, ranging from the Mississippi and Nile deltas, to coastal Siberia, to the Indonesian archipelago.

Utilizing the world's largest database – 1534 rivers that drain more than 85% of the landmass discharging into the global ocean – this book presents a detailed analysis and synthesis of the processes affecting the fluvial discharge of water, sediment, and dissolved solids. The ways in which climatic variation, episodic events, and anthropogenic activities – past, present, and future – affect the quantity and quality of river discharge are discussed in the final two chapters. The book contains more than 165 figures – many in full color – including global and regional maps. An extensive appendix presents the 1534-river database as a series of 44 tables that provide quantitative data regarding the discharge of water, sediment and dissolved solids. The appendix's 140 maps portray the morphologic, geologic, and climatic character of the watersheds. The complete database is also presented within a GIS-based package available online at www.cambridge.org/milliman.

River Discharge to the Coastal Ocean: A Global Synthesis provides an invaluable resource for researchers, professionals, and graduate students in hydrology, oceanography, geology, geomorphology, and environmental policy.

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Katherine L. Farnsworth is an Assistant Professor in the Department of Geoscience at the Indiana University of Pennsylvania. Her research examines the interaction between fluvial and marine systems including the flux and fate of sediments to the coastal oceans.

Contents

Table 4.3. *Examples of decreased sediment loads of global rivers resulting from dam construction and irrigation. Changes in Mediterranean river sediment discharge are shown in Table 4.4. Data from appendix.*

River	Country	Basin area (×10³ km²)	Previous load (Mt/yr)	Present load (Mt/yr)	% Decrease
Colorado	Mexico	640	120	0.1	100
Yisil Irmak	Turkey	65	19	19	99
Kizil Irmak	Turkey	79	17	0.44	97
Krishna	India	250	64	4	95
Liaohe	China	220	39	2.7	95
Rio Grande	USA	870	20	0.6	95
Grijalva	Mexico	50	24	1.3	95
Indus	Pakistan	980	250	<20	>90
Huanghe	China	750	1000	100	90
Chao Phraya	Thailand	160	30	3	90
Volta	Ghana	400	19	1.6	90
Limpopo	Mozambique	410	33	6	80
Orange	South Africa	1000	89	17	80
Song Hong	Vietnam	490	80	25	70
Yenisei	Russia	2600	13	4.1	70
Zhujiang	China	490	80	25	70
Mississippi	USA	3300	470	145	70
Changjiang	China	1800	470	180	60
Narmada	India	99	70	30	60
Danube	Romania	820	67	42	35
Totals		**15 473**	**2974**	**607**	**80**

Partly as a result, about half of the coastal sites adjacent to the Red River's mouth are eroding at 5–10 m/yr (Thanh *et al.*, 2004). As dam construction continues throughout Africa and southern Asia – the latter area responsible for 60–70% of the global sediment flux – the amount of sediment and water trapped by dams will continue to increase.

The amount of fluvial sediment trapped behind dams and deposited in and along irrigation ditches is difficult to quantify, and even for those rivers for which we have "before" and "after" discharges, the numbers are hazy. Syvitski *et al.* (2005) calculated that retention within reservoirs has reduced the global river-sediment flux by 3.6 Bt/yr. However, the 34 rivers shown in Tables 4.3 (global) and 4.4 (Mediterranean Sea), which collectively drain 19 million km² of land area, show a 2.5 Bt/yr decline in sediment discharge over the past 50 years, a 75% reduction. The four major rivers in China (Huanghe, Changjiang, Zhujiang, and Liaohe) alone account for nearly 1.3 Bt/yr reduction in sediment discharge, an 80% reduction. The 78 rivers in our database for which we list post-dam values show a total reduction of sediment discharge of nearly 3.5 Bt/yr. Since these rivers account for less than half the total pre-dam sediment discharge calculated in Chapter 2, and many rivers remain undocumented in terms of pre- and/or post-dam values, we assume that global decreased sediment discharge attributable to reservoir retention may exceed 5 Bt/yr.

Box 4.2 Mediterranean Sea and its rivers

Few regions are as diverse in climate and landscape, or have been impacted by so many human activities, as the watershed surrounding the Mediterranean Sea. Climate ranges from cold moist alpine to hot arid desert, precipitation from <100 to >3500 mm/yr, and river runoff from <10 (Libya) to >1000 mm/yr (Greece, Albania) (Fig. 4.23). Records of human occupation date back into the Paleolithic, and the impact of human activities and their environmental impacts are found as early as the Early Bronze Age (see McNeill, 1992, and Wainwright and Thornes, 2004, for thorough discussions). By the Greco-Roman period, much of Mediterranean landscape had been deforested and

Figure 4.23. Mediterranean Basin, illustrating the stark difference between humid to moderate- to high-runoff regions in the north and arid regions in the south. Note the green, ribbon-like lower Nile River in the southeast. NASA image.

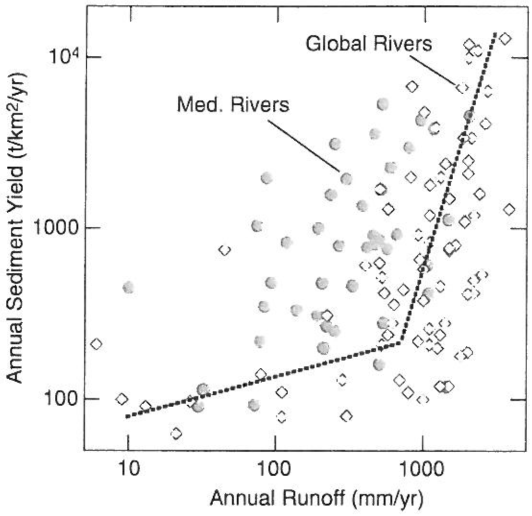


Figure 4.24. Sediment yield vs. annual runoff for small young mountainous rivers (drainage basins 1000–10 000 km^2) in the Mediterranean basin (red dots) compared to sediment yields from similar-sized rivers in western North America, Japan, Taiwan, Indonesia, Philippines, and New Zealand (open diamonds).

farmed as well as (locally) mined (reviewed by Wainwright and Thornes, 2004). Anthropogenic impacts, particularly in the northern Mediterranean watersheds, appear to have lessened somewhat during the Middle Ages, only to accelerate again in the seventeenth century.

One rather obvious impact of this long history can be seen in the high sediment yields of small rivers that drain young mountains compared to small mountainous rivers from other parts of the world (Woodward, 1995; Hooke, 2006, and references therein). Mediterranean rivers with runoffs between 200 mm/yr and 300 mm/yr (e.g., Arno, Goksu, Reno, Simeto, Ombrone, and Mazufran), for example, had pre-dam sediment yields of 270, 250, 790, 1900, 3100, and 1600 t/km^2/yr, respectively, whereas rivers in other parts of the world with similar runoffs (Wairua and Awatare rivers in New Zealand, Diego River in Mexico) have or had (pre-dam) yields of 310, 130, and 80 t/km^2/yr (Fig. 4.24). Woodward (1995) estimated that about 75% of the sediment yields in the upper watersheds of Mediterranean rivers (which are generally the most susceptible to high rates of erosion) result from human activities, perhaps the highest of any global climatic zone (see also Dedkov and Mozzherin, 1992). But the anthropogenic influence on erosion is uneven throughout the Mediterranean. Soil loss in the Pindus (Greece), Lucanian Appenines (Italy) watersheds is much greater than in the western Taurus Mountains (Turkey). Erosion is particularly high in the Rif Mountains (Morocco), where soil loss exceeds soil formation by an order of magnitude (McNeill, 1992).

In recent years the damming of many Mediterranean rivers as well as climate change has resulted in dramatic declines in the discharge of both water and sediment. Most obvious is the Nile River following construction of the Aswan Dam in the mid 1960s (see p. 143), but the discharge from many other rivers also declined during the second half of the twentieth century. Of the 20 long-term discharge trends that we have for Mediterranean rivers, only two (Segura and Rhone) show a statistically significant increase in discharge between 1951 and 2000, whereas 14 show decreased discharges of 30% or more (Fig. 4.25a). A 2003 UNEP report estimates that, since the beginning of the twentieth century, freshwater discharge to the Mediterranean has dropped by half. Declining precipitation explains decreased discharge of some rivers (e.g. Var and Llobregat), but in many rivers the decrease seems to be related primarily to dams and irrigation (see Milliman *et al.*, 2008) (Fig. 4.25b). A similar explanation applies to several Black Sea rivers, although, again, the available database is incomplete (Milliman *et al.*, 2010).

Decreased water discharge, combined with changing land-use practices, has resulted in reduced erosion rates in many watersheds, which in turn has led to dramatic declines in sediment discharge (Liquete *et al.*, 2009). The 14 rivers (exclusive of the Nile) in Table 4.4, which drain a total area of 445 000 km^2, have experienced a collective 75% drop in their sediment discharge; decreases range from 13% (Ceyhan River) to >95% (Ebro and Asi rivers) (UNEP/MAP, 2003). Added to this is the 98% decrease of sediment discharge from the Nile River in response to the Aswan Dam (Table 4.4). The impacts of these decreased sediment loads include deepening river channels (aided by river-sand mining), eroding shoreline, and (in the case of the Nile, Ebro, and Rhone rivers) eroding deltas.

Table 4.4. *Pre- and post-dam changes in annual water discharge (Q) and sediment discharge (Q_s) in Mediterranean rivers. Data from appendix.*

River	Basin area (km^2)	Country	Pre-dam Q (km^3/yr)	Post-dam Q (km^3/yr)	Pre-dam Q_s (Mt/yr)	Post-dam Q_s (Mt/yr)	% Q_s loss
Ebro	87 000	Spain	50	17	18	0.15	99
Rhone	96 000	France	54		59	6.2	89
Ombrone	3200	Italy	0.8		10	1.9	81
Tiber	17 000	Italy	7.4		1.3	0.3	77
Tronto	1200	Italy	0.3		1.2	0.6	50
Pescara	3300	Italy	1.7	0.9	2.2	1.2	45
Po	74 000	Italy	46		15	10	33
Semani	5300	Albania	5.6		30	16	47
Drini	13 000	Albania	12		16	2.1	87
Vijose	6700	Albania	6.4		29	8.3	71
Asi	23 000	Turkey	2.7		19	0.36	98
Ceyhan	21 000	Turkey	7		5.5	4.8	13
Cheliff	44 000	Algeria	1.3		8	4	50
Moulouya	51 000	Morocco	1.3	0.2	13	1	92
Totals (w/o Nile)	**262 700**				**227**	**57**	**75**
Nile	2 900 000	Egypt	80	<<30	120	2	98
Totals (w/ Nile)	**3 162 700**				**347**	**59**	**83**

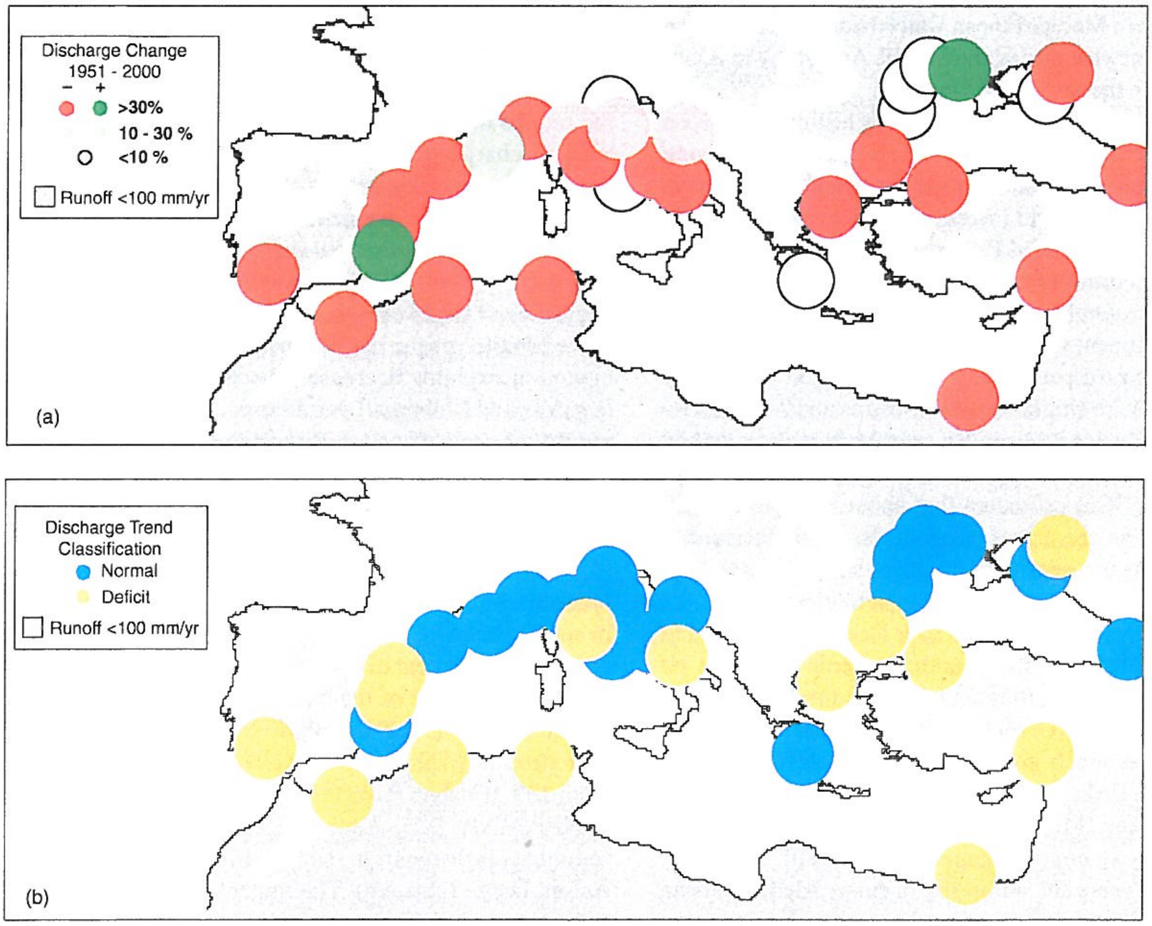


Figure 4.25. Change in water discharge (a) and distribution of normal and deficit rivers (b, as defined by Milliman *et al.*, 2008) based on a comparison of 50-yr discharge and precipitation trends for rivers draining into the Mediterranean and Black seas, 1951–2000. For those rivers not represented by a complete set of discharge data, the trend was extrapolated for the full 50 years (see Milliman *et al.*, 2008).

Appendices. Global river data base

Introduction

This appendix contains our global database for which we have divided the globe into seven broad regions, North America (along with Central America), South America, Africa, Europe, Eurasia, Asia (including, for ease of graphical presentation, Russia), and Oceania (Appendix Figure A.1). The broad regions are subdivided into even smaller areas (44 in total), each represented by a series of three maps and, in tabular form, the characteristics of rivers within each region; all 1534 rivers that empty into the coastal ocean.

Some of the 44 areas encompass a single country (e.g. Mexico, Australia); others encompass a number of smaller countries (e.g. Nicaragua, Costa Rica, and Panama; Ivory Coast, Ghana, Togo, and Benin). North and Central America are represented by eight areas (Canada; USA conterminous; USA Alaska; Hawaii and Fiji; Mexico; Belize, Guatemala, El Salvador, and Honduras; Nicaragua, Costa Rica, and Panama; Cuba, Jamaica, Hispaniola, and Puerto Rico), South America by five (Colombia and Venezuela; Ecuador and Peru; Chile and Argentina; Brazil; French Guiana, Suriname, and Guyana), Africa by eight (Egypt, Libya, and Sudan; Tunisia, Algeria, Morocco, and Western Sahara; Senegal, Gambia, Guinea Bissau, Guinea, Sierra Leone, and Liberia; Ivory Coast, Ghana, Togo, and Benin; Nigeria, Cameroon, Equatorial Guinea, Gabon, and Republic of the Congo; Democratic Republic of Congo and Angola; Namibia, South Africa, Mozambique, and Madagascar; Tanzania, Kenya, and Somalia), Europe by ten (Iceland; Scandinavia; Estonia, Latvia, Lithuania, and Poland; Germany, Belgium, and The Netherlands; United Kingdom; France; Portugal and Spain; Italy; Albania, Croatia, and Greece; Bulgaria, Romania, and Ukraine), Eurasia by three (Georgia and Turkey; Israel and Lebanon; Saudi Arabia, Yemen, Iraq, and Iran), Asia by six (Russia; Pakistan, India, Sri Lanka, and Bangladesh; Malaysia, Burma, Thailand, and Vietnam; China; Taiwan; Japan and Korea), and Oceania by four (Philippines; Indonesia and Papua New Guinea; Australia; New Zealand). The total number of countries represented in our database is 109.

For each of these 44 areas we present three maps, the first locating the rivers in the data base and their general drainage patterns. Regional morphology is also shown, based on the five categories used in the database and our river classification: coastal plain (<100 m), lowland (100–500 m), upland (500–1000 m), mountain (1000–3000 m), and high mountain (>3000 m) (see Chapter 2). A second map presents a simplified regional geology of the area (derived from Larsen and Pittman, 1985), showing the distribution of five types of rocks: Cenozoic Sedimentary/Metamorphic, Cenozoic Igneous, Mesozoic Sedimentary/Metamorphic, Mesozoic Igneous, and Pre-Mesozoic. The third map shows regional surface runoff (derived from Korzoun *et al.*, 1977) together with monthly flow histograms of some representative rivers within the area, mostly derived from RivDis (http://www.rivdis.sr.unh.edu).

Tables and data categories

For each area we present in tabular form the critical characteristics for the rivers shown in the preceding maps. Some of these entries can be found in other databases: e.g. basin area, mean annual water, sediment, and dissolve solid discharge. But we also show less commonly reported characteristics, such as basin morphology, climate, and geology of the headwaters, etc., as collectively they also help define the fluvial regime. Because of the limited space in the book itself, there are categories that we can only present in the digital database (www.cambridge.org/milliman); in the following sentences and paragraphs these are identified by italics.

River name

Many rivers are known by more than one name, the international name often being different from the local name. Most non-Chinese refer to the Yangtze and Yellow rivers, rather than the Changjiang and Huanghe. Similar problems can be found for the Rhine/Rhein and Danube/Donau. Indonesian rivers can be denoted by their Dutch or native spellings (e.g. Tjitarum vs. Citarum). Although many refer to the Ganges (Ganga to Indians) and Brahmaputra as separate rivers (or as a hyphenated name), Bangladeshis refer to the combined river system as the Padma. Rivers that drain more than one country or rivers that form the boundary between two countries also can have more than one name. Occasionally a river will have its name changed for political reasons, only to have it changed back again: the Congo River was the Zaire for

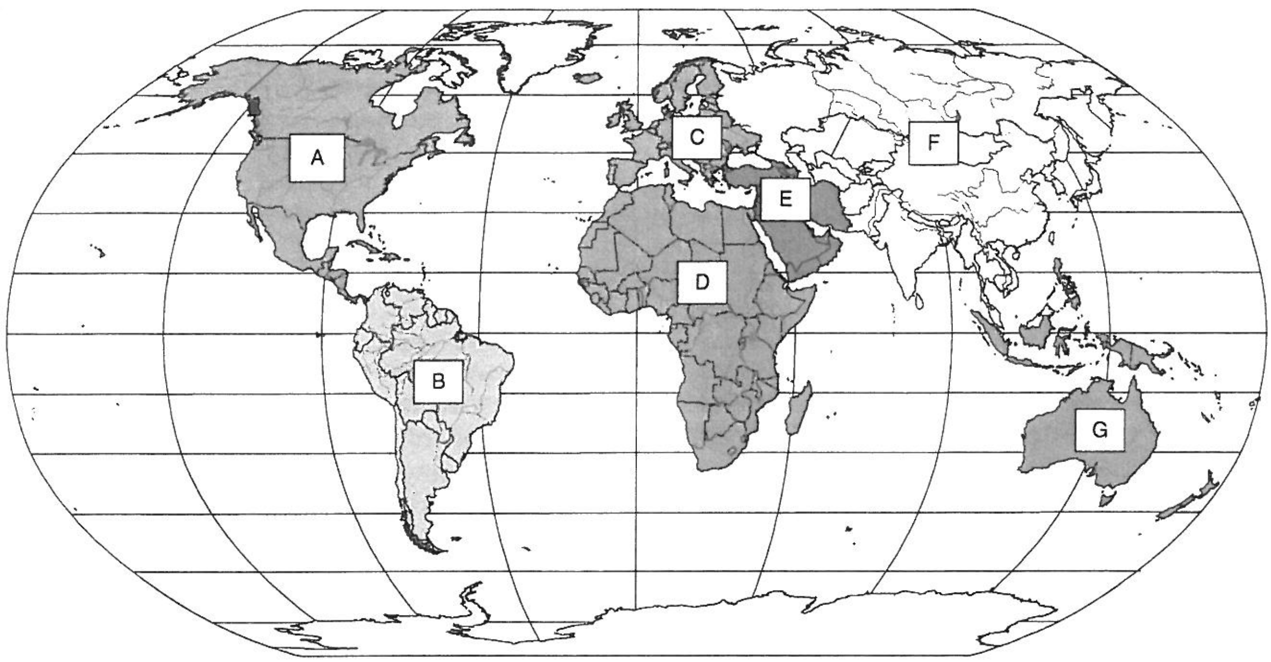


Figure A.1. Location map of the seven broadly defined regions of the database.

several decades, before reverting back to the Congo in the 1990s.

We have tried to maintain consistency in our reference to rivers, generally using the common name used in English-speaking countries. However, we admit to have succumbed to some personal biases, such as referring to the Changjiang and Huanghe rather than Yangtze and Yellow rivers – 1 billion Chinese cannot be wrong. *We include commonly used alternative names in the electronic version of this database;* Meybeck and Ragu (1996) also have listed many variations of river names in their Table II.

Country

By country, we refer to where the river exits to the coastal ocean (i.e. river's mouth) rather than the country of origin (i.e. headwaters), even though the river may mostly flow through another country. We therefore list the countries for the Rhine, Colorado, and the Ganges–Brahmaputra as The Netherlands, Mexico, and Bangladesh, respectively, rather than Germany, USA, and Nepal/India.

Ocean

In our original GLORI database (Milliman *et al.*, 1995) we listed the ocean into which the river emptied: Atlantic, Pacific, Indian, or Arctic. But as the list of rivers has increased, we have become more specific as to geographic location. Rather than listing the Arctic as the ocean into which a river drains, for example, we now list Beaufort Sea, Chukchi Sea, Kara Sea, White Sea, etc.

Basin area

The area of a river's drainage basin is assumed to refer to the entire area upstream of the river mouth. Although the total drainage basin areas of many large rivers are well-documented (although not consistent between various authorities – see Chapter 1), cited basin areas for other rivers may refer to the area upstream of a particular hydrologic station, which is smaller – sometimes much smaller – than the total drainage basin. Because we have taken some basin areas from the GRDC metadata list, the basin areas listed in our tables may be too small; the relative error may be greater in smaller drainage basins. Given the inexactitude of our numbers and in keeping with other numerical data listed in the database, we have rounded areas to the first two digits; a basin area of 127 500 km^2, for example, becomes 130 000 km^2.

River length

We consider river length to represent the distance from the farthest headwater to the river's mouth. As with basin area, however, lengths of some rivers are considered to end at the seaward-most gauging station. Others cited river lengths may begin at the confluence of certain tributaries, others at the mouth of a downstream lake. As such, rivers are often longer than their reported lengths would suggest.

Maximum elevation

As seen in Chapter 2, topography is an important controlling factor in determining the sediment load of a river (Ahnert, 1970; Pinet and Souriau, 1988; Milliman and Syvitski, 1992), in part because elevation can serve as a surrogate for a variety of physical factors that control erosion: tectonic activity, erosion by ice and glaciers, orographic precipitation, landslides, etc.

Some compendia (e.g. *Taiwan Hydrologic Yearbook*) list the maximum elevation of a river basin, but others refer to mean elevation or topographic relief of sub-basins. For many rivers we were forced to estimate maximum elevations from topographic maps. In our database we only report the first two digits of elevation – 1241 m, for instance, rounds to 1200 m.

Elevation categories (in digital database)

Based on maximum elevations, we divide river basins into five morphological classes.

Coastal plain *(<100 m)*
Lowland *(100–500 m)*
Upland *(500–1000 m)*
Mountain *(1000–3000 m)*
High mountain *(>3000 m)*

Table A.1. *Categories and abbreviations used in climate classification.*

Temperature	
	Tropical (**Tr**) – summer and winter >20°
	Subtropical (**STr**) – summer >20°; winter >10°
	Temperate (**Te**) – summer >10°; winter >0°
	Sub Arctic (**SAr**) – summer >10°; winter <0°
	Arctic (**Ar**) – summer >0°; winter <<0°
Runoff	
	Arid (**A**) – Runoff <100 mm/yr
	Subarid (**SA**) – Runoff 100–250 mm/yr
	Humid (**H**) – Runoff 250–750 mm/yr
	Wet (**W**) – Runoff >750 mm/yr
Season of maximum runoff	
	Runoff more or less constant throughout the year (**C**)
	Maximum runoff generally in Winter (**W**)
	Maximum runoff generally in Spring (**Sp**)
	Maximum runoff generally in Summer (**S**)
	Maximum runoff generally in Autumn (**Au**)
	Desert (generally no flow; rainfall extremely episodic) (**D**)

Climate

There are many ways to classify climatic regimes, but to be useful, any classification should include watershed temperature and the magnitude and timing of flow. Meybeck *et al.* (1989), for example, include the following climates: glacial (water from glacier melt, normally in early summer); nival (snow melt, high flow in late spring, early summer); pluvial (peak flow in late autumn to early winter); dry tropical (high flow during summer rainy season, but less regular flow away from the equator); monsoon (contrasting dry and wet seasons); equatorial (regular, year-round runoff); desert (irregular, non-perennial rivers). The Köppen–Geiger (1954) system, a comprehensive classification used by many workers to categorize global climate, is based on air temperature (tropical, arid, warm temperate, snow, and polar, as well as the number of months during which temperatures exceed or are less than specific values) and the season of least rainfall. Haines *et al.* (1988) attempted to classify global rivers on the basis of seasonal variation in river flow, but the Köppen–Geiger classification, which was subsequently modified by Beckinsale (1969) and further simplified by Burt (1992), remains a favorite for many geographers and climatologists.

Unfortunately, the Köppen–Beckinsale–Burt climate classification has several flaws that ultimately persuaded us not to use it in our database. First, the symbols in this classification are sufficiently complex that one cannot easily distinguish various zones without referring to a classification key: quick, what is the difference between an AM and an AC/AW climate? Second, classifying a fluvial climate based on the timing of low flow seems counter-intuitive in terms of classifying rivers, since peak discharge more often defines the character of the river (and the estuary into which it enters). Accordingly we present a climatic classification that gives the three climatologic categories that we think best define the fluvial regime: mean air temperature, pre-diversion runoff (which effectively integrates precipitation and evapotranspiration over the entire watershed), and the season of maximum discharge. The categories used in this classification are shown in Appendix Table A.1.

In some rivers, however, average climate can be misleading. The Santa Clara River (between Los Angeles and Santa Barbara, California), for instance, has a subtropical climate and an average runoff less than 50 mm/yr, most of which occurs between January and early March. We therefore classify this river's climate as Subtropical–Arid–Winter (STr-A-W). In contrast, the Tijuana River, bordering Baja California and California, has been known to remain dry for many years; accordingly, we classify the Tijuana as STr-A-D (the D standing for desert). But during the cold PDO between the mid 1940s to late 1960s, the Santa Clara's precipitation and therefore river discharge were episodic, such that the Santa Clara could have been classified as STr-A-D. With the return of the warm PDO and re-intensification of El Niño events in the early 1970s, rainfall increased and the Santa Clara discharge in some years was greater than 250 mm/yr (STr-H-W). Fortunately, these climatic shifts are most apparent in smaller rivers, particularly subarid basins.

Another problem is that basin-wide climate may not take into account local climatic variations. This is particularly a problem in larger rivers, where different tributaries may have entirely different climates (e.g. the subarid Missouri and Arkansas in contrast to the humid Ohio, all of which drain into the Mississippi River; see Chapter 4). Moreover, mountainous parts of a river basin may have entirely different temperature and precipitation regimes than the lower portions of that basin.

Despite these uncertainties, the modified classification used in the database appears to delineate the long-term mean climatic factors that help control a basin's runoff.

Discharge (Q)
We list mean annual discharge measured at the seaward-most hydrologic station. These values are expressed in terms of km^3/yr (multiplying these discharge values by 32 gives an approximate mean flow in terms of m^3/s). Because the seaward-most station can be some distance landward of the river mouth, discharge can be under-estimated. The Amazon River, for example, includes 1700×10^3 km^2 of watershed (>25% of the area) seaward from Obidos, the river's downstream-most gauging station. Assuming an average runoff of 1 m/yr, a reasonable estimate considering basin-wide precipitation (see Fig. 2.2), the missing area downstream of Obidos may contribute 1700 km^3/yr of water to the Amazon's discharge, which is somewhat greater than the mean annual flow of the Congo! On the other hand, watersheds whose lower reaches are arid may lose considerable amounts of water through evapotranspiration, groundwater recharge or water removal for irrigation (e.g. Nile, Indus); as such they discharge less water than gauging station measurements would suggest.

Discharge for many rivers has changed appreciably in recent years because of river diversion, dam/reservoir construction and irrigation. Where data are available we list pre-diversion discharge in parentheses, as these pre-diversion data allow us to better define natural runoff (thus aiding our climate classification scheme mentioned above) as well as to delineate natural environmental factors that control discharge and load. Post-diversion discharge indicates how much fresh water, on average, is presently discharged to the coastal ocean.

Runoff (in digital database)
Runoff is calculated as the discharge divided by drainage basin area. Pre-diversion discharge, if available, is used to calculate runoff, since this helps define watershed climate.

Geology
The quantity and quality of both suspended and dissolved solids within a river system depend on the nature of the soils and rocks of the watershed, which is a function of both lithology (erodibility of mudstone > limestone > extrusive igneous > sandstone > intrusive igneous > metamorphic rocks) and age (younger rocks generally considered to be more erodible than older rocks). Assuming that much/most of the suspended and dissolved solids are derived from the higher elevations within the watershed, we have characterized the general surface geology of the headwaters using Larsen's and Pittman's (1985) bedrock geology of the world.

Cenozoic Sedimentary and Metamorphic (**Cen S/M**)
Cenozoic Igneous (**Cen Ig**)
Mesozoic Sedimentary and Metamorphic (**Mes S/M**)
Mesozoic Igneous (**Mes Ig**)
Pre-Mesozoic (**Pre-Mes**)

Sediment load (TSS)
We list mean sediment load (Q_s; 10^6 t/yr (Mt/yr)) transported annually by the river. Hidden in these values, of course, are many caveats, such as the validity of reported loads and the significance of event-driven discharge, etc., many of which are discussed in some detail in Chapters 1 and 3. Moreover, some/much of the sediment reported at an upstream station may not actually reach the ocean, but rather is deposited along the downstream flood plain. Nevertheless, the >750 sediment loads in our database serve as an important resource in terms of delineating environmental factors controlling sediment loads in various types of rivers discussed in Chapter 2.

Nearly all reported values for sediment discharge represent suspended loads, not total sediment load, which would include bed load. In most rivers, however, bed load is assumed to represent no more than 10% of the suspended load (Milliman and Meade, 1983), meaning that for first-order purposes we can assume that suspended load approximates total load. This assumption breaks down in small mountainous rivers, where steep terrain and flashy flow events can lead to much greater bed-load transport. As with other numbers, we report only the first two digits of the load.

Sediment yield (in digital database)
Sediment yield is the mean annual sediment load normalized to basin area, expressed as $t/km^2/yr$, analogous to the relationship of runoff to discharge. Using sediment yield is helpful in relating loads of big and small rivers, but also in terms of visualizing the relative denudation of a river basin; see Chapter 2 for further discussion.

Sediment concentration (in digital database)
We calculate mean suspended sediment concentration (Q_{cs}), reported as mg/l, by dividing mean sediment load by mean discharge.

Dissolved-solid load (TDS)

As with sediment load, dissolved load (Q_d) values are expressed in Mt/yr. Approximately 80% of the numbers reported here come from the Meybeck and Ragu (1996) database.

Dissolved yield (in digital database)

We calculate this parameter by dividing dissolved load by basin area, the same as we have for sediment yield – Mt/km²/yr.

Dissolved concentration (in digital database)

We calculate dissolved concentration (Q_{cd}) in an analogous way to Q_{cs}, reported in mg/l.

References

We list the references from which we derived most or all of the values for each river. In some cases more recent references may have corrected earlier numbers.

Germany, Denmark, the Netherlands and Belgium

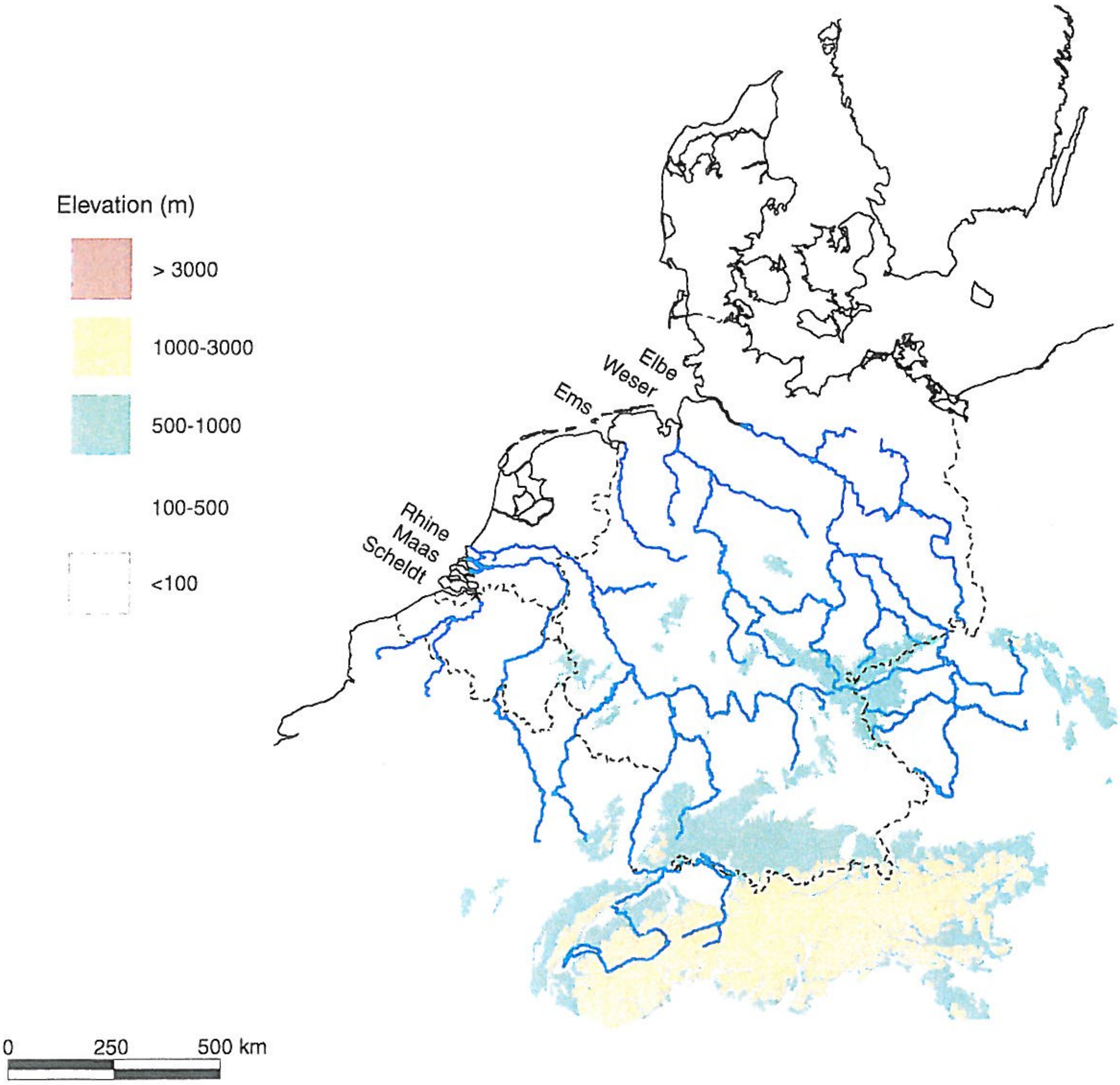
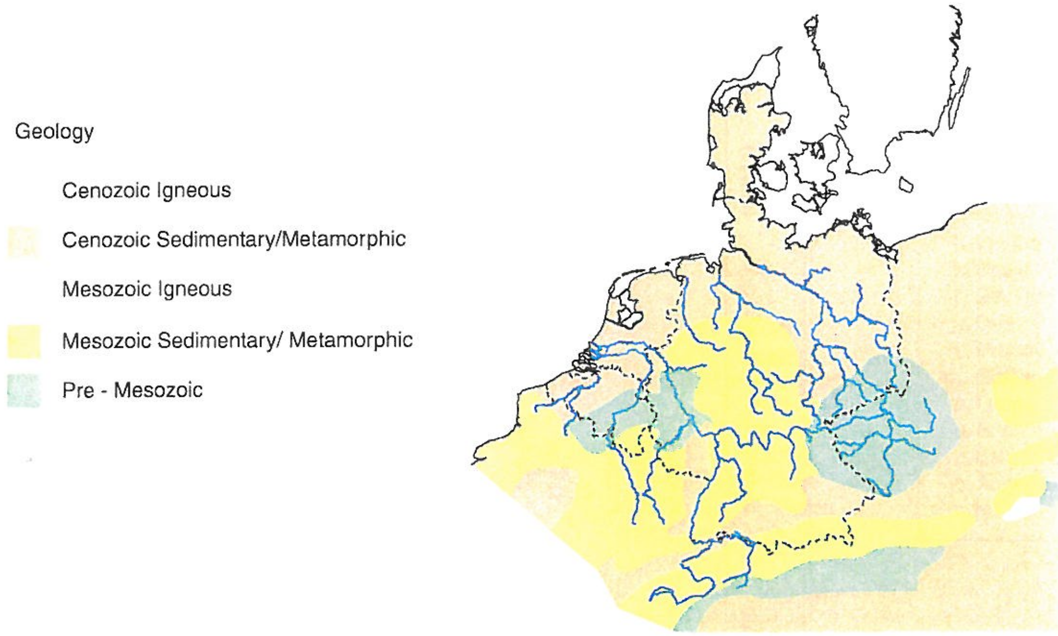


Figure C8

Germany, Denmark, the Netherlands and Belgium

Geology



Surface Runoff (mm/yr)

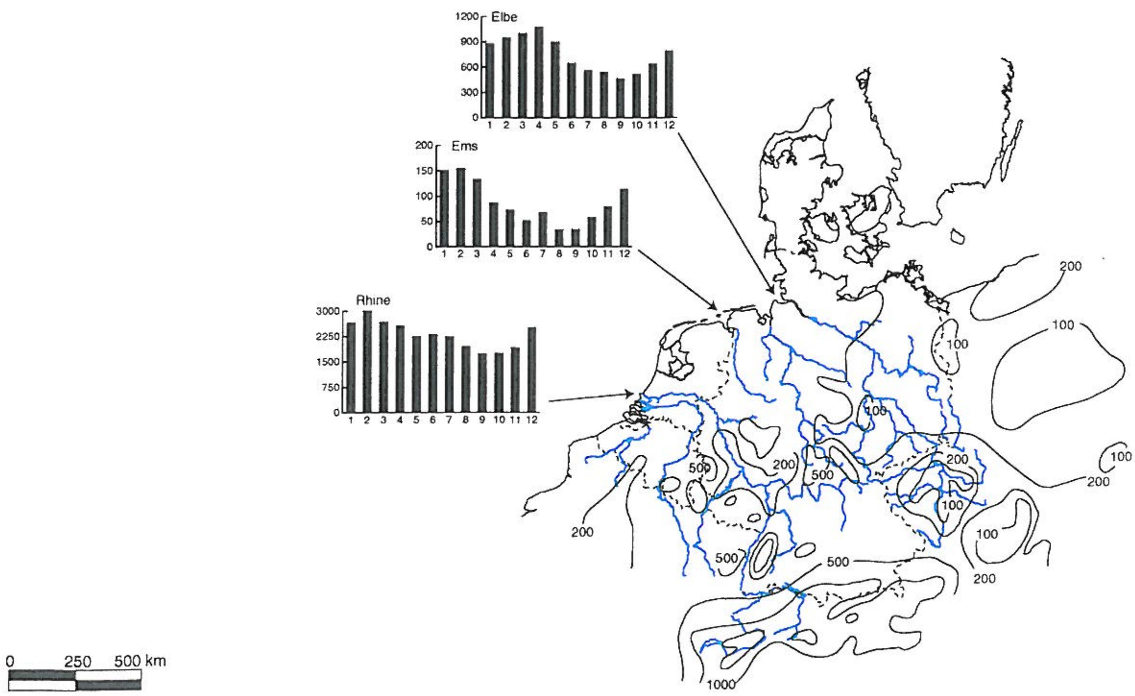


Figure C9

Table C4.

River name	Ocean	Area (10^3 km^2)	Length (km)	Max_elev (m)	Climate	Geology	Q (km^3/yr)	TSS (Mt/yr)	TDS (Mt/yr)	Refs.
Germany										
Elbe	North Sea	150	1100	>500	Te-SA-W	PreMes	24	0.84	14	7, 8, 9
Ems	North Sea	8.3	370	450	Te-H-W	PreMes	2.5		0.34	5, 7, 9, 12
Weser	North Sea	46	720	980	Te-SA-W	PreMes	11	0.33	23 (3.6)	1, 5, 7, 9, 12
Netherlands										
Maas	North Sea	36	920	>500	Te-SA-W	PreMes	10	0.7	1.7	1, 6, 9, 12
Rhine	North Sea	220	1400	1500	Te-H-C	PreMes	74	0.07	60	2, 3, 5, 6, 9, 12
Belgium										
Scheldt	North Sea	22	430	100	Te-H-C	PreMes	6	0.75	2.7	4, 5, 9, 10, 11

References:
1. Centre for Natural Resources, Energy and Transport (UN), 1978; 2. Eisma *et al.*, 1982; 3. Esser and Kohlmaier, 1991; 4. Fettweis *et al.*, 1998; 5. GEMS website, www.gemstat.org; 6. IAHS/UNESCO, 1974; 7. Kempe *et al.*, 1991; 8. Lisitzin, 1972; 9. Meybeck and Ragu, 1996; 10. Rand McNally, 1980; 11. Salomons and Mook, 1981; 12. UNESCO (WORRI), 1978

Scotland, England and Ireland

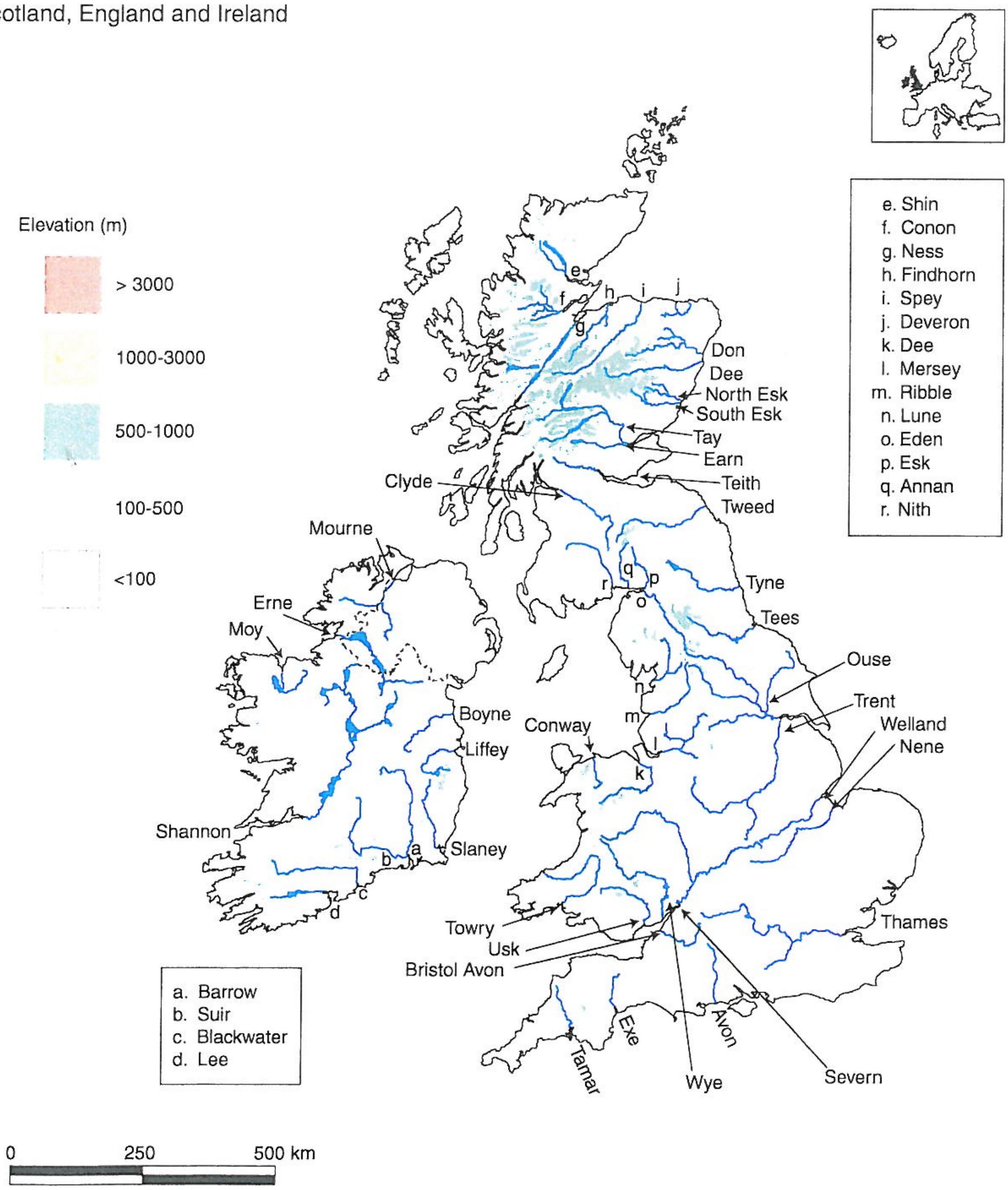


Figure C10

Scotland, England and Ireland

Geology

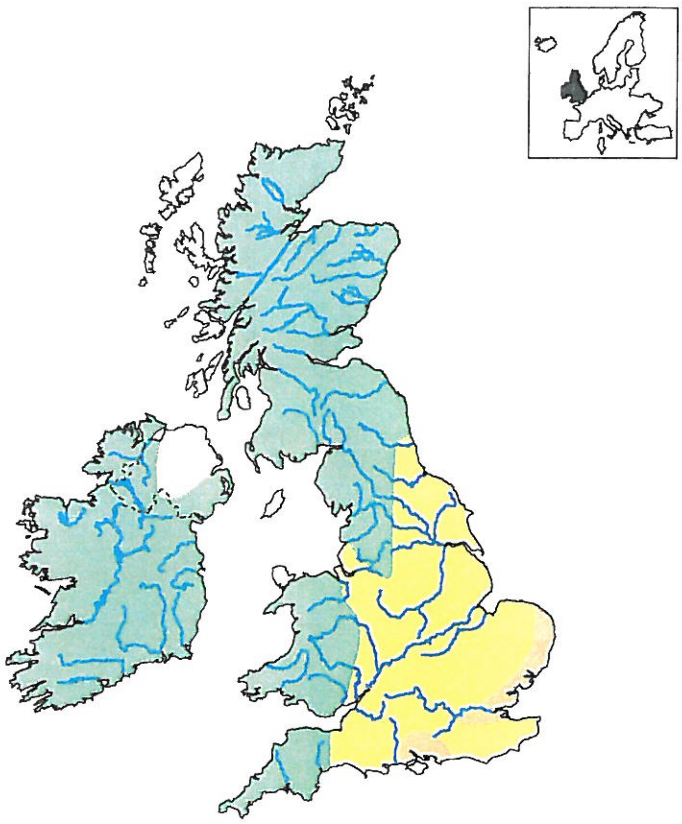
Cenozoic Igneous

Cenozoic Sedimentary/Metamorphic

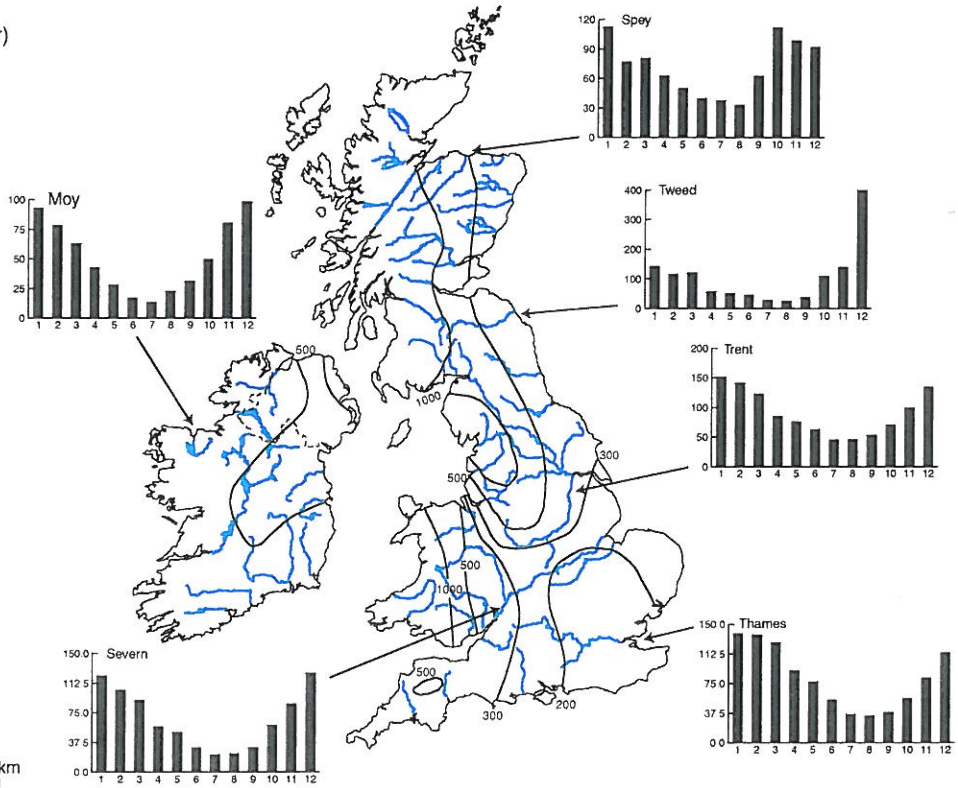
Mesozoic Igneous

Mesozoic Sedimentary/ Metamorphic

Pre - Mesozoic



Surface Runoff (mm/yr)



0 250 500 km

Figure C11

Table C5.

River name	Ocean	Area (10^3 km^2)	Length (km)	Max_elev (m)	Climate	Geology	Q (km^3/yr)	TSS (Mt/yr)	TDS (Mt/yr)	Refs.
Scotland										
Annan	Irish Sea	0.9	60	>500	Te-W-W	PreMes	0.9			6, 9
Clyde	North Sea	1.9	170	730	Te-H-W	PreMes	1.1	0.11		9, 13, 16, 17
Conon	North Sea	0.96	60	1000	Te-W-W	PreMes	1.5	0.006		19
Dee	North Sea	1.8	150	1300	Te-H-W	PreMes	1.5	0.03		8, 9, 14, 19
Deveron	North Sea	0.95	100	770	Te-W-W	PreMes	0.5	0.01		8, 9, 19
Don	North Sea	1.3	130	870	Te-W-W	PreMes		0.03		8, 9, 19
Earn	North Sea	0.78	90	980	Te-W-W	PreMes		0.06		8, 9, 19
Findhorn	North Sea	0.78	100	940	Te-W-W	PreMes	0.8	0.04		8, 9, 19
Ness	North Sea	1.8	50	1100	Te-H-W	PreMes	1.7	0.02		19
England										
Avon	English Channel	2.6	150	>100	Te-H-W	Mes S/M	0.62	0.42		1, 2, 13, 17
Bristol Avon	Irish Sea	2.3	120	>500	Te-H-W	Mes S/M	0.27	0.02	0.1	16
Conway	Irish Sea	0.6	45	1000	Te-H-W	PreMes				
Dee	Irish Sea	1	180	>100	Te-W-W	PreMes	1			6
Eden	Irish Sea	2.3	100	>200	Te-W-W	PreMes				8
Esk	Irish Sea	0.31	79	>500	Te-H-W	PreMes		0.18	0.016	1
Exe	English Channel	0.6	87	>200	Te-W-W	PreMes-Mes S/M	0.52	0.014	0.051	16
Lune	Irish Sea	0.8	90	>500	Te-H-W	PreMes				8
Mersey	Irish Sea	2	110	600	Te-H-W	Mes S/M	1.3			8, 10, 12
Nene	North Sea	1.6	140	120	Te-SA-W	Mes S/M	0.29	0.016		13, 17, 18
Ouse	North Sea	8.9	250	>100	Te-H-W	Mes S/M	2	0.11	0.28	2, 10, 12, 15, 16
Ribble	Irish Sea	1.6	160	>200	Te-W-W	PreMes	1.5			6, 8
Severn	Irish Sea	10	350	750	Te-H-W	Mes S/M	3.3	0.44	8.7	10, 13, 16, 17
Tamar	English Channel	1	100	>200	Te-H-W	PreMes				11
Tees	North Sea	2	100	>500	Te-H-W	Mes S/M	0.63			2, 12
Thames	North Sea	15	350	330	Te-SA-W	Mes S/M	2.8	0.04	0.82	4, 5, 7, 13, 17
Towry	Irish Sea	1	100	>200	Te-W-W	PreMes				
Trent	North Sea	9.5	290	640	Te-H-W	Mes S/M	2.6	0.08		2, 4, 5, 7, 13, 17
Tyne	North Sea	2.2	100	600	Te-H-W	Mes S/M	1.5	0.13	0.084	2, 13, 16, 17

Table C5. (*Continued*)

River name	Ocean	Area (10^3 km^2)	Length (km)	Max_elev (m)	Climate	Geology	Q (km^3/yr)	TSS (Mt/yr)	TDS (Mt/yr)	Refs.
Usk	North Sea	0.91	100	>200	Te-W-W	PreMes	0.95	0.042	0.12	8, 13, 16, 17
Welland	North Sea	0.53	110	>100	Te-SA-W	Mes S/M	0.11	0.007		18
Wye	North Sea	4.4	220	740	Te-H-W	Mes S/M	2.4	0.21	0.37	13, 16, 17
Ireland										
Barrow	Irish Sea	12	160	490	Te-H-W	PreMes	4.8	0.038		8, 19
Blackwater	Irish Sea	3.3	170	440	Te-H-W	PreMes	2.2	0.02		8, 19
Boyne	Irish Sea	3.3	110	140	Te-H-W	PreMes	1.1	0.011		8, 19
Erne	Atlantic (NE)	5.1	100	500	Te-H-W	PreMes	3	0.02		8, 19
Lee	Irish Sea	1.2	100	>500	Te-W-W	PreMes	1.3	0.01		8, 19
Liffey	Irish Sea	1.4	120	300	Te-H-W	PreMes	0.47	0.004		19
Mourne	Atlantic (NE)	2.9	110	670	Te-H-W	PreMes				3
Moy	Atlantic (NE)	2.1	100	510	Te-H-W	PreMes	1.6	0.01		3, 19
Shannon	Atlantic (NE)	23	320	570	Te-H-W	PreMes	8	0.64		8, 13, 19
Slaney	Irish Sea	1.8	120	930	Te-H-W	PreMes	1.1	0.006		3, 19
Suir	Irish Sea	3.6	180	450	Te-H-W	PreMes	2			3

References:
1. Collins, 1981; 2. Czaya, 1981; 3. Drainage Map of Ireland; 4. Eurosion, 2004; 5. GEMS website, www.gemstat.org; 6. GRDC website, www.gewex.org/grdc; 7. Meybeck, 1994; 8. Rand McNally, 1980; 9. Scottish Environment Protection Agency website, http://www.sepa.org.uk/; 10. Soulsby *et al.*, 2009; 11. Thornton and McManus, 1994; 12. UNESCO (WORRI), 1978; 13. UNESCO, 1971; 14. Vörösmarty *et al.*, 1996a; 15. Walling, 1999; 16. D. E. Walling, personal communication; 17. Willis, 1971 (cf. van der Leeden, 1975); 18. Wilmot and Collins, 1981; 19. J. Wilson, personal communication

France

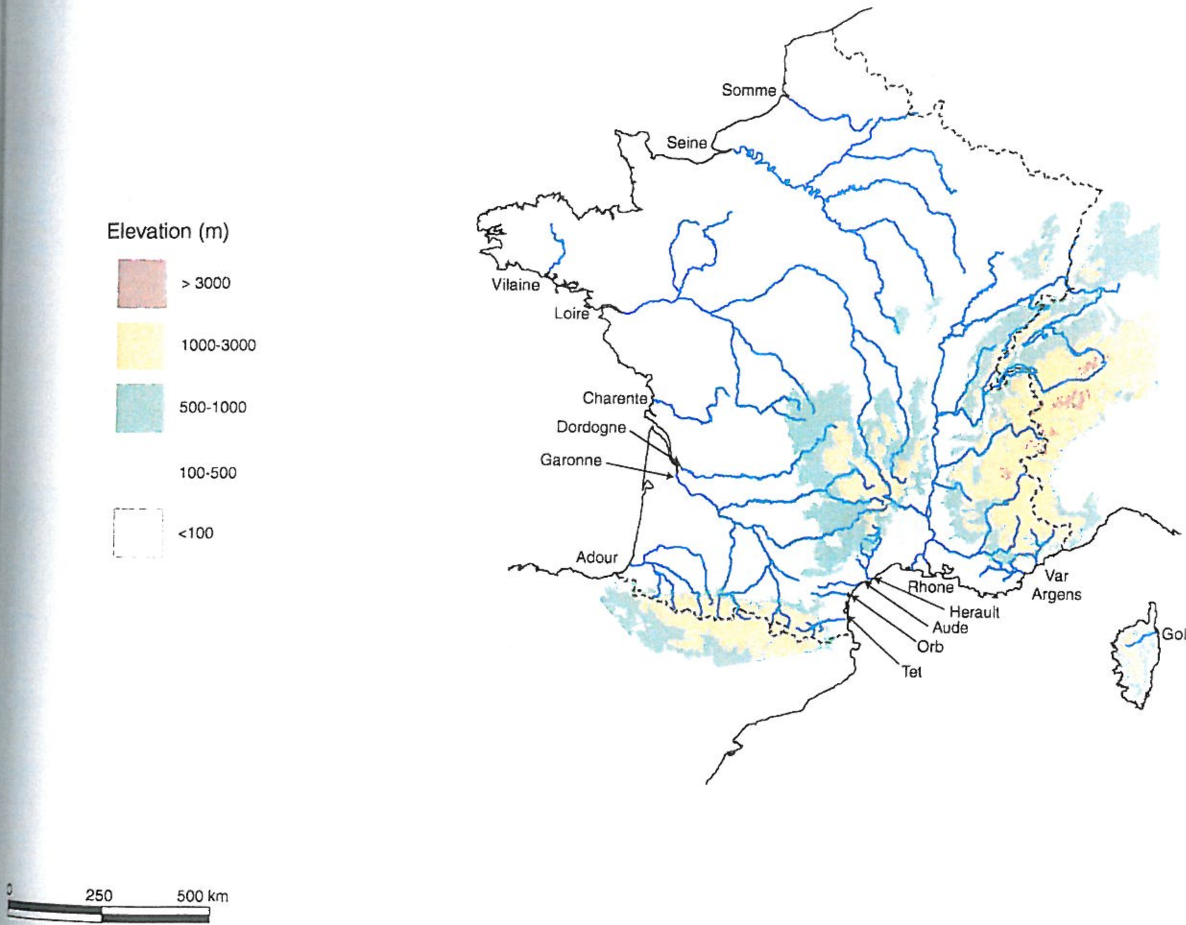
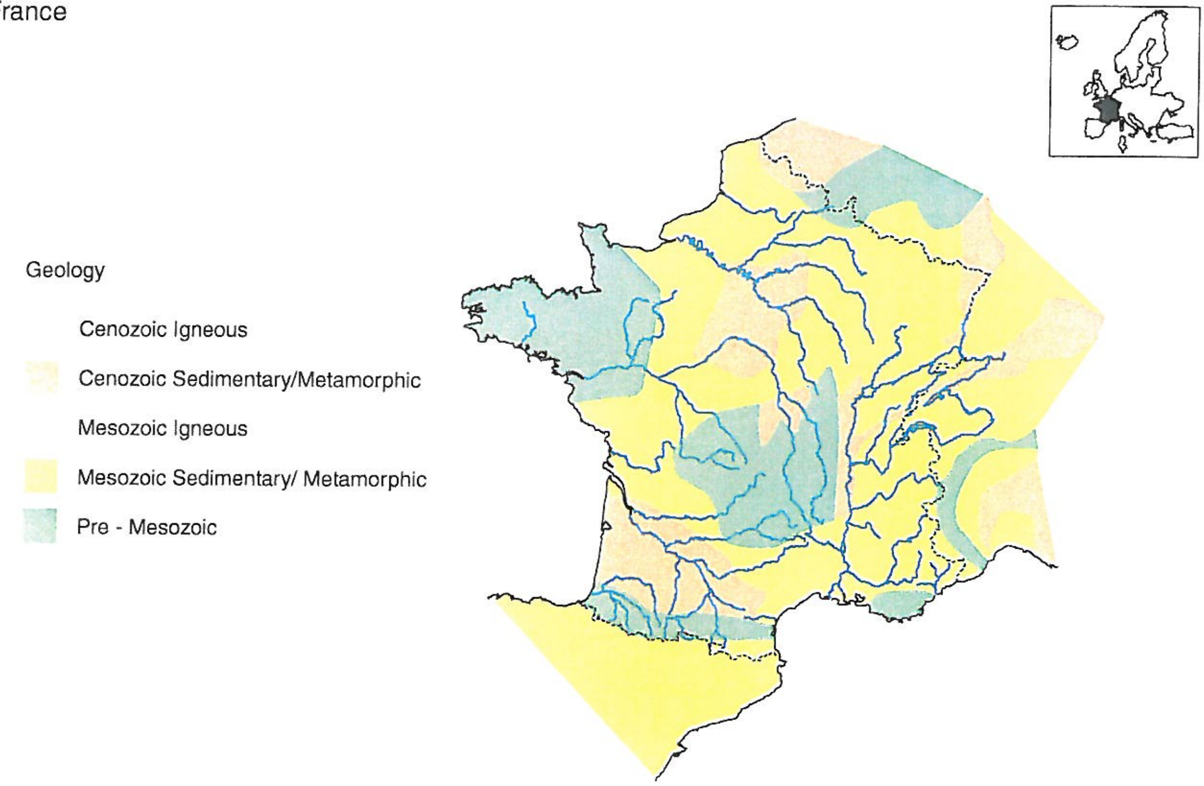


Figure C12

France



Surface Runoff (mm/yr)

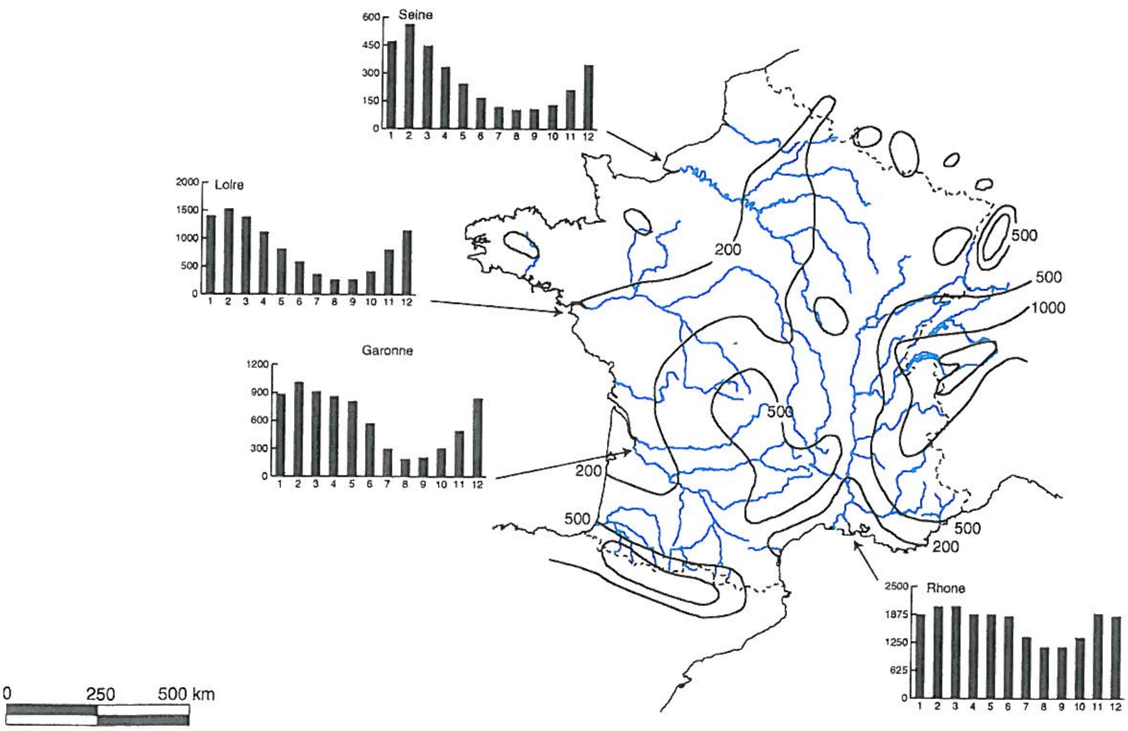


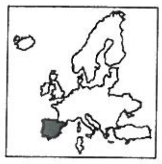
Figure C13

Table C6.

River name	Ocean	Area (10^3 km^2)	Length (km)	Max_elev (m)	Climate	Geology	Q (km^3/yr)	TSS (Mt/yr)	TDS (Mt/yr)	Refs.
France										
Mainland										
Adour	Atlantic (NE)	16	340	2800	Te-H-S	PreMes	11	0.29	1.9	8, 11, 12
Argens	Med. (W)	2.6	120	>1000	Te-H-W	PreMes	0.6	0.03		4
Aude	Med. (W)	5.9	220	>500	Te-H-S	Mes S/M	1.3	0.07		4, 9
Charente	Atlantic (NE)	9.1	350	>200	Te-H-W	PreMes	1.8	0.2		3, 11, 13, 14
Dordogne	Atlantic (NE)	24	470	1700	Te-H-W	PreMes	14			2, 3, 11, 13
Garonne	Atlantic (NE)	56	570	3400	Te-H-W	PreMes	21	1.1 (2.2)	4.5	2, 3, 4, 5, 7, 8, 10, 13
Herault	G. du Lion	2.9	160	1000	Te-H-W	Mes S/M	1.5	0.09		4, 9
Loire	Atlantic (NE)	120	1100	1900	Te-SA-W	PreMes	27	0.5	6.4	3, 5, 7, 8, 13
Orb	G. du Lion	1.8	100	>500	Te-H-W	Mes S/M	1.3	0.05		3, 4, 9, 13
Rhone	Med. (W)	96	1000	3600	Te-H-Sp	Mes S/M	54	6.2 (59)	17	3, 5, 7, 8, 9, 13
Seine	Atlantic (NE)	79	780	900	Te-SA-W	Mes S/M	13	0.7 (3.5)	7.7	3, 5, 7, 8, 13
Somme	Atlantic (NE)	5.5	240	>100	Te-SA-W	Mes S/M	0.85			3, 11, 13
Tet	Med. (W)	1.6	120	2400	Te-H-W	Mes S/M	0.3	0.5		6, 9
Var	Ligurian Sea	2.8	130	2500	Te-H-W	Mes S/M	1.3	1		1, 8, 15
Vilaine	Atlantic (NE)	11	230	150	Te-H-W	PreMes	2.5	0.2		11, 14
Corsica										
Golo	Med.	0.9	90	>1000	Te-H-S	Cen I	0.5	0.002		4

References:
1. Anthony and Julian, 1997; 2. Dauta *et al.*, 2009; 3. Direction du Gaz et de l'Electricite, 1966 (cf. van der Leeden, 1975); 4. European Environment Agency website, www.eea.europa.eu; 5. GEMS website, www.gemstat.org; 6. Guillén *et al.*, 2006; 7. Kempe, 1982; 8. Meybeck and Ragu, 1996; 9. Pont, 1997; 10. Probst, 1992; 11. Rand McNally, 1980; 12. Snoussi *et al.*, 1990; 13. UNESCO, 1967 (cf. van der Leeden, 1975); 14. Uriarte *et al.*, 2004; 15. Mulder *et al.*, 1998

Spain and Portugal



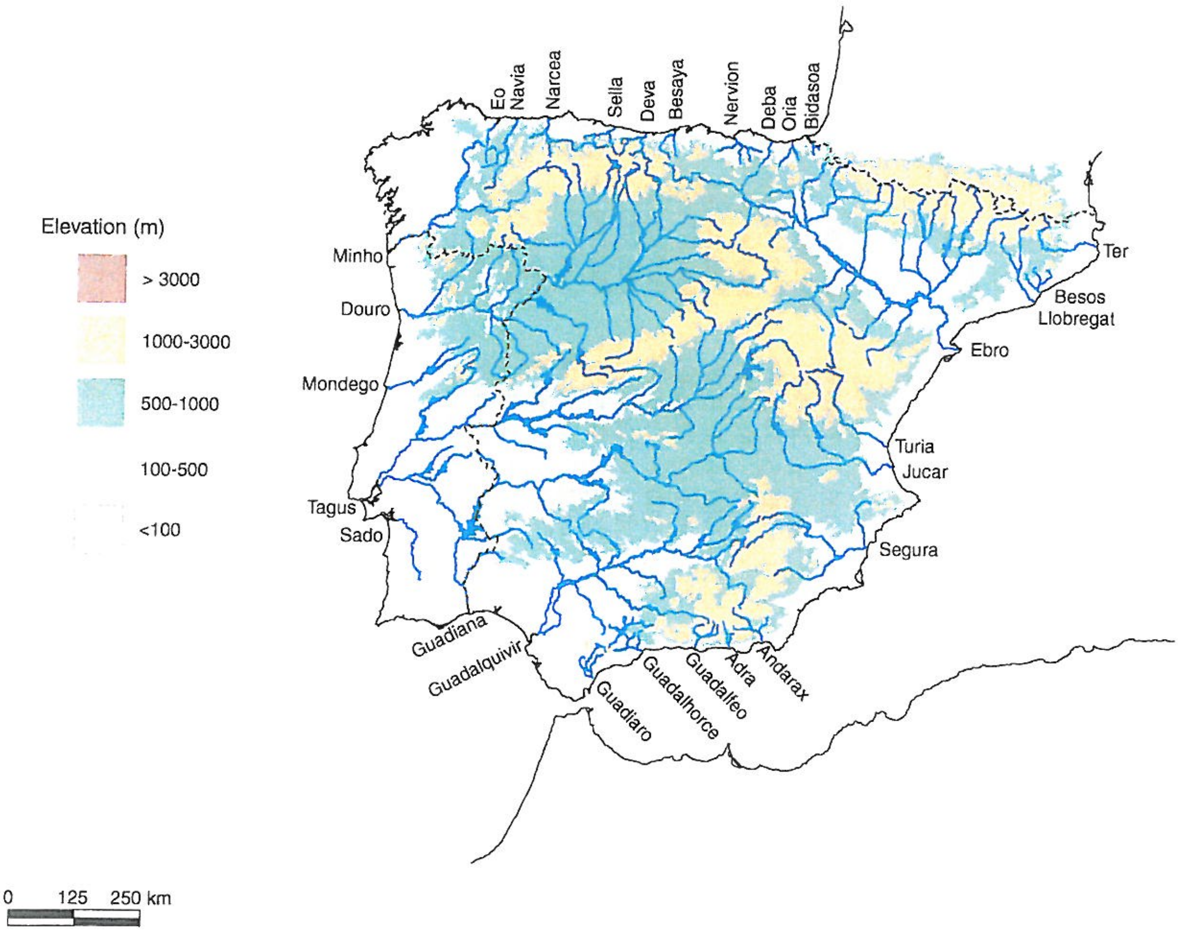
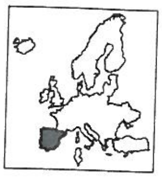
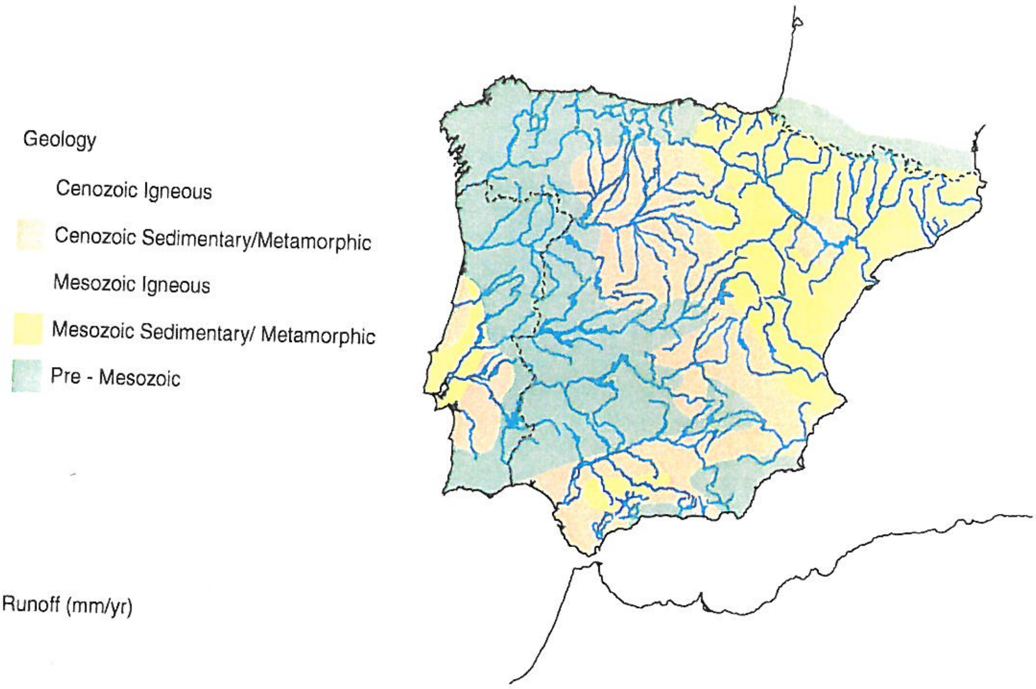


Figure C14

Spain and Portugal





Surface Runoff (mm/yr)

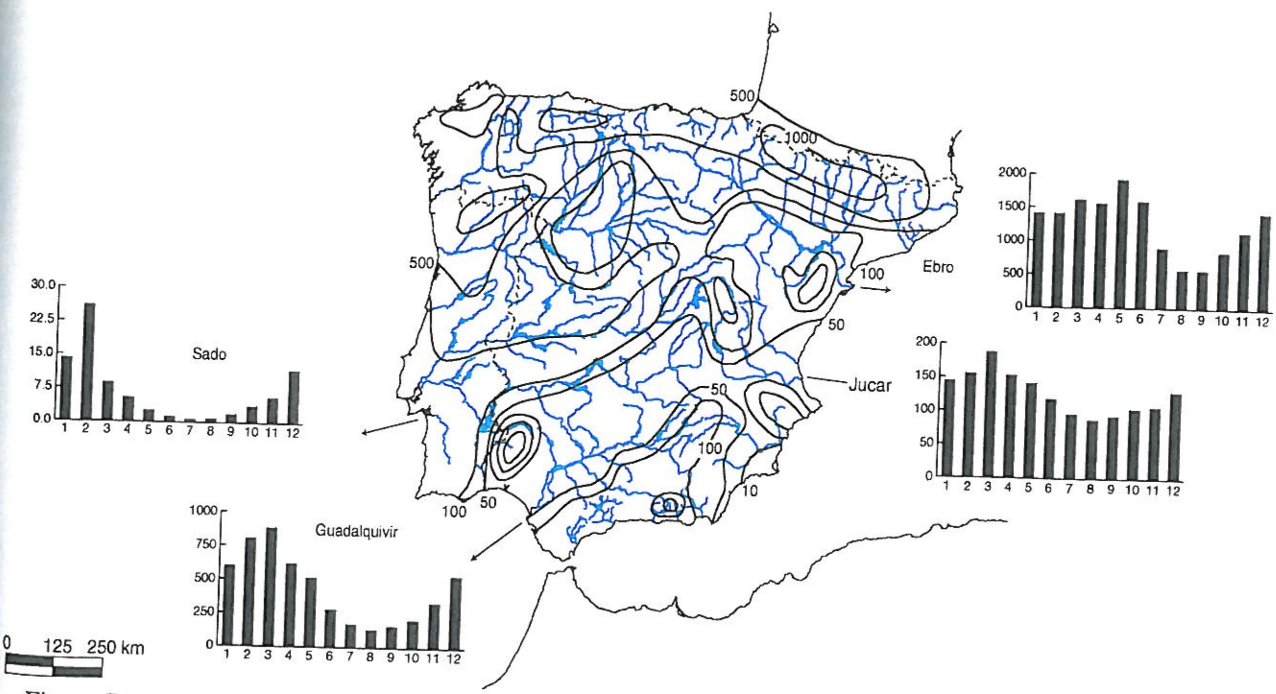


Figure C15

Table C7.

River name	Ocean	Area (10^3 km^2)	Length (km)	Max_elev (m)	Climate	Geology	Q (km^3/yr)	TSS (Mt/yr)	TDS (Mt/yr)	Refs.
Spain										
Adra	Med. (W)	0.75	51	2700	Te-SA-W	Cen S/M	0.03	0.15		8
Andarax	Med. (W)	2.2	74	2500	Te-A-W	PreMes	0.01	0.18		8
Besaya	Atlantic (NE)	1		<1000	Te-W-W	PreMes	0.8	0.1		2, 13
Besos	Med. (W)	1	52	800	Te-SA-W	Mes S/M				9
Bidasoa	Bay of Biscay	0.71	66	780	Te-W-W	PreMes	0.9	0.15		13, 19
Deba	Bay of Biscay	0.5	62	750	Te-W-W	PreMes	0.5	0.03		13, 19
Deva	Atlantic (E)	1.2		<1000	Te-W-W	PreMes	1	0.13		2, 13
Ebro	Med. (W)	87	930	>2000	Te-SA-W	Cen S/M-Mes S/M	17 (50)	0.15 (18)	9	5, 11, 12, 15, 18
Eo	Bay of Biscay	0.93		>500	Te-W-W	PreMes				13
Guadalfeo	Med. (W)	1.3	72	3200	Te-SA-W	PreMes-Cen S/M	0.02	0.08		8
Guadalhorce	Med. (W)	3.2	154	1700	Te-SA-W	PreMes-Cen S/M	0.2	0.09		8
Guadalquivir	Atlantic (NE)	56	680	>1500	Te-SA-W	PreMes	2 (7.3)		5.9	3, 5, 11, 14, 17, 18
Guadiaro	Med. (W)	1.5	100	1600	Te-SA-W	Cen S/M	0.3	0.04		8
Jucar	Med. (W)	22	510	>500	Te-A-W	Mes S/M	1.2 (4.5)	0.8	1	11, 18
Llobregat	Med. (W)	5.2	170	1700	Te-SA-W	Mes S/M	0.69	0.07		9, 11, 14, 17
Narcea	Bay of Biscay	4.9	220	>1500	Te-H-W	PreMes	3.4	0.38		2, 13
Navia	Bay of Biscay	2.6	210	>1000	Te-H-W	PreMes	2.1	0.13		2, 13
Nervion	Atlantic (NE)	1.4		<1000	Te-W-W	PreMes	1.1	0.06		2
Oria	Bay of Biscay	0.86	78	750	Te-W-W	PreMes	0.9	0.07		13, 19
Segura	Med. (W)	19	340	1400	Te-A-W	PreMes	0.8 (3.1)	1.1		4, 5, 11, 16
Sella	Atlantic (NE)	1.3		<1000	Te-W-W	PreMes	1.1	0.03		2, 13
Ter	Med. (W)	3	210	2400	Te-H-W	Mes S/M	0.84			15
Turia	Med. (W)	6.4	240	>2000	Te-A-W	Mes S/M	0.46			14
Portugal										
Douro	Atlantic (NE)	98	930	2100	Te-H-W	PreMes	13 (20)	1.8	5.5	1, 10, 16
Guadiana	Atlantic (NE)	72	830	>500	Te-H-W	PreMes	9	0.07	4.6	5, 10, 11
Minho	Atlantic (NE)	20	260	>1500	Te-H-W	PreMes	13		0.63	11
Mondego	Atlantic (NE)	6.7	220	>1000	Te-H-W	PreMes	2.6			14, 16, 17
Sado	Atlantic (NE)	2.7	180	>200	STr-SA-W	Cen S/M	0.25			6, 14
Tagus	Atlantic (NE)	80	1000	>1500	Te-H-W	PreMes	9.6	0.4	3.1	5, 7, 10, 11, 17, 20

References:
1. Alt-Epping *et al.*, 2007; 2. Comisaria de Agua del Norte de España; 3. European Environment Agency website, www.eea.europa.eu; 4. Eurosion, 2004; 5. GEMS website, www.gemstat.org; 6. Global River Discharge Database, http://www.rivdis.sr.unh.edu/; 7. Jouanneau *et al.*, 1998; 8. Liquete *et al.*, 2005; 9. Liquete *et al.*, 2007; 10. Lugo, 1983; 11. Meybeck and Ragu, 1996; 12. Palanques *et al.*, 1990; 13. Prego *et al.*, 2008; 14. Rand McNally, 1980; 15. Sabater *et al.*, 1995; 16. Sabater *et al.*, 2009; 17. UNESCO (WORRI), 1978; 18. UNESCO, 1971; 19. Uriarte *et al.*, 2004; 20. Vörösmarty *et al.*, 1996a

Italy

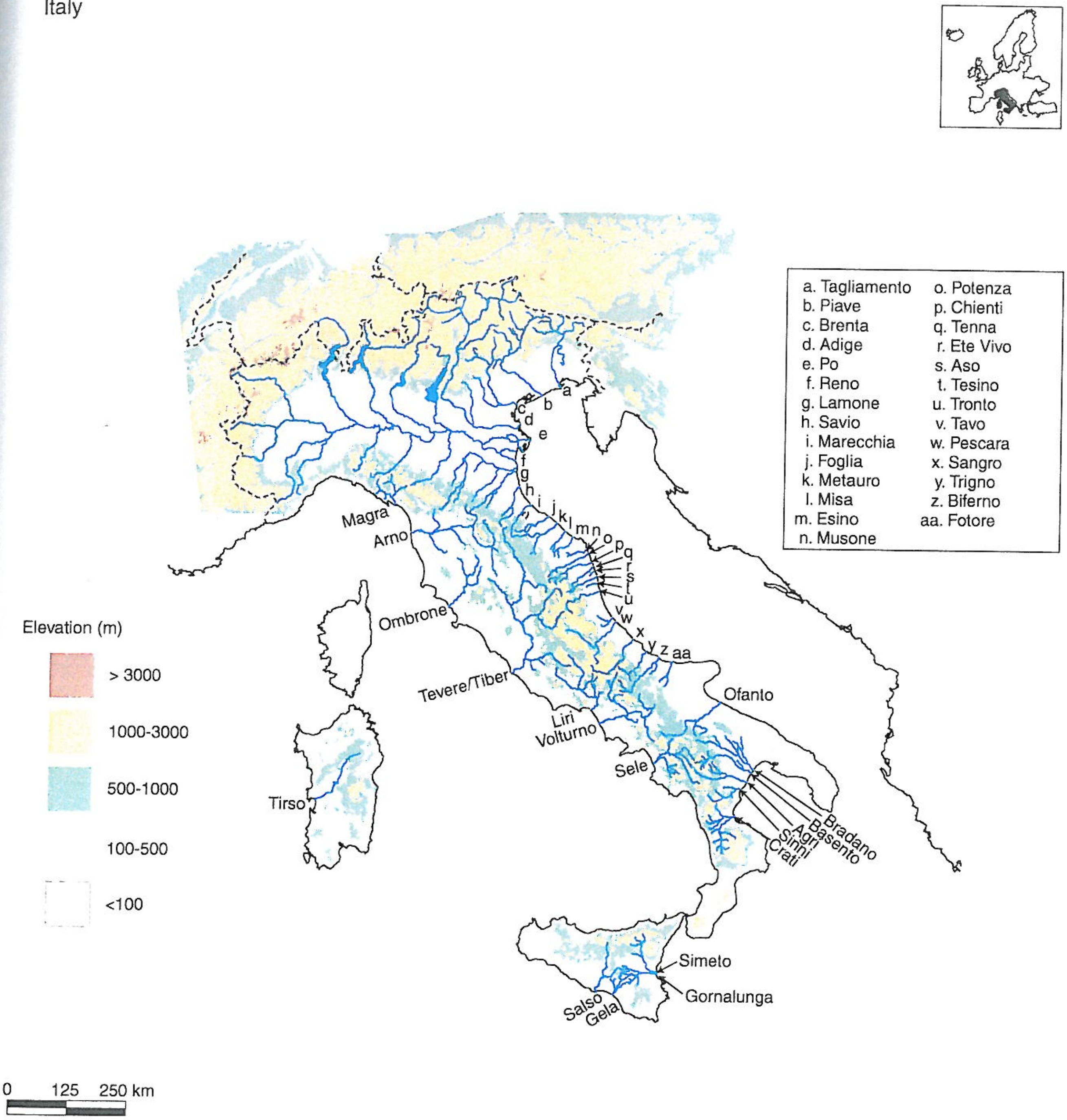


Figure C16

Italy

Geology

Cenozoic Igneous

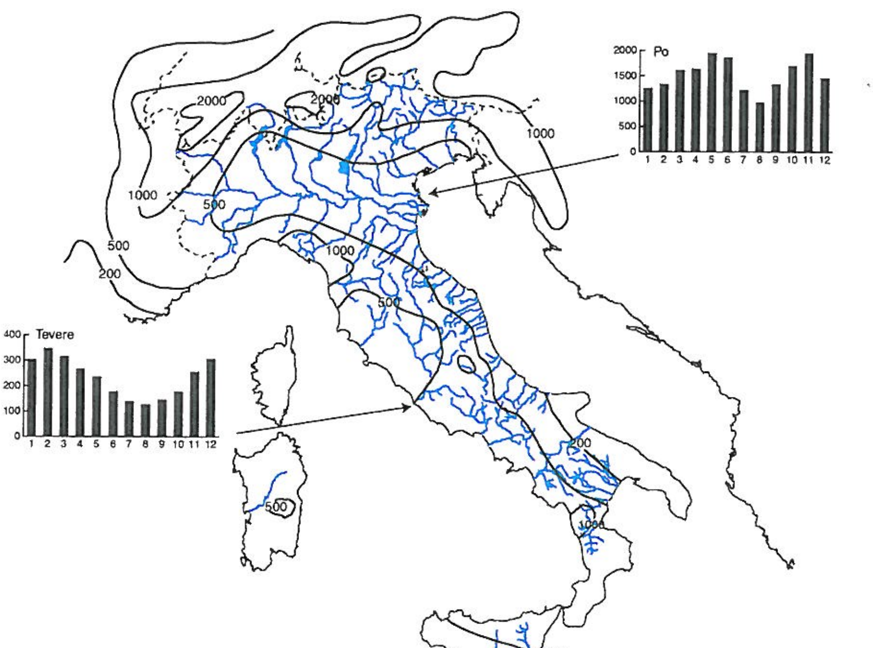
Cenozoic Sedimentary/Metamorphic

Mesozoic Igneous

Mesozoic Sedimentary/ Metamorphic

Pre - Mesozoic

Surface Runoff (mm/yr)



0 125 250 km

Figure C17

Table C8.

River name	Ocean	Area (10^3 km^2)	Length (km)	Max_elev (m)	Climate	Geology	Q (km^3/yr)	TSS (Mt/yr)	TDS (Mt/yr)	Refs.
Italy										
Mainland										
Adige	Adriatic Sea	12	410	2500	Te-H-W	Mes S/M	7.3	1.6	1.6	13, 14, 16, 21
Agri	G. of Tronto	0.28	110	2000	Te-W-W	Cen S/M	0.25	0.07		13, 17
Arno	Ligurian Sea	8.2	240	1700	Te-H-W	Cen S/M	1.8 (3.2)	2.2	1.4	11, 14, 16
Aso	Adriatic Sea	0.28	70	2500	Te-H-W	Cen S/M		0.18		1
Basento	G. of Tronto	1.4	25	1500	Te-H-W	Cen S/M				
Biferno	Adriatic Sea	1.3	95	1800	Te-H-W	Cen S/M	0.66	2.2		9, 13
Bradano	G. of Tronto	2.7	120	1100	Te-SA-W	Cen S/M	2	2.8		13
Brenta	Adriatic Sea	1.6	160	2100	Te-W-W	Mes S/M	2.3	0.19		13, 20
Chienti	Adriatic Sea	1.3	99	1600	Te-H-W	Cen S/M	0.3	0.56 (0.85)		1, 13, 19
Crati	G. of Tronto	2.4		1000	Te-H-W	Cen S/M	0.85	1.2		7, 13
Esino	Adriatic Sea	1.2	75	1400	Te-H-W	Cen S/M		0.9		1
Ete Vivo	Adriatic Sea	0.18	30	580	Te-H-W	Cen S/M		0.29		1
Foglia	Adriatic Sea	0.7	80	1500	Te-H-W	Cen S/M	0.25	1.4		1, 13
Fortore	Adriatic Sea	1.1		900	Te-H-W	Cen S/M	0.42	1.5		13
Lamone	Adriatic Sea	0.71	95	910	Te-H-W	Cen S/M	0.28	1.3		1, 13
Liri	Mediterranean	5	160	>1500	Te-H-W	Mes S/M				
Magra	Ligurian Sea	1.2		>500	Te-W-W	Mes S/M	1.3	0.5		13
Marecchia	Adriatic Sea	0.6		900	Te-H-W	Cen S/M	0.31	1.6		13
Metauro	Adriatic Sea	1.4	91	1600	Te-H-W	Cen S/M	0.3	0.55 (0.81)		1, 18, 19, 20
Misa	Adriatic Sea	0.38	35	790	Te-H-W	Cen S/M		0.47		1
Musone	Adriatic Sea	0.64	70	<100	Te-H-W	Cen S/M		1.1		1
Ofanto	Adriatic Sea	2.7	130	1100	Te-SA-W	Cen S/M	0.37	0.9		13, 17, 18
Ombrone	Mediterranean	3.2	160	1700	Te-H-W	Cen S/M	0.79	1.9 (10)		8, 13, 20
Pescara	Adriatic Sea	3.3	154	2700	Te-H-W	Cen S/M	0.9 (1.7)	1 (1.9)		13, 19, 20
Piave	Adriatic Sea	4.1	220	1900	Te-H-W	Mes S/M	3.2			18
Po	Adriatic Sea	74	680	4800	Te-H-W/Sp	Mes S/M-PreMes	46	10 (15)	17	1, 5, 6, 12, 13, 14, 16, 21
Potenza	Adriatic Sea	0.8	89	1500	Te-H-W	Cen S/M	0.2	0.35 (0.56)		1, 19
Reno	Adriatic Sea	3.4	210	1300	Te-H-W	Cen S/M	0.9	2.7		1, 18, 20
Sangro	Adriatic Sea	1.9	90	>200	Te-H-W	Cen S/M	0.75			10, 18

Table C8. (*Continued*)

River name	Ocean	Area (10^3 km^2)	Length (km)	Max_elev (m)	Climate	Geology	Q (km^3/yr)	TSS (Mt/yr)	TDS (Mt/yr)	Refs.
Savio	Adriatic Sea	0.67	90	1200	Te-H-W	Cen S/M	0.31	0.92		1, 2, 13, 14
Sele	Mediterranean	3.4	110	>1000	Te-H-W	Mes S/M				
Sinni	G. of Tronto	1.1	85	1000	Te-H-W	Cen S/M	0.65	2.5		13
Tagliamento	Adriatic Sea	3.6	170	>500	Te-H-W	Mes S/M	2.7			17, 18
Tavo	Adriatic Sea	0.25		>1000	Te-H-W	Cen S/M	0.06	0.04		13
Tenna	Adriatic Sea	0.49	70	2400	Te-H-W	Cen S/M		0.45		1
Tesino	Adriatic Sea	0.11	35	750	Te-H-W	Cen S/M		0.12		1
Tevere	Mediterranean	17	400	2500	Te-H-W	Mes S/M	7.4	0.33 (7.5)		1, 3, 14, 15, 20
Trigno	Adriatic Sea	1.2	80	>1000	Te-H-W	Cen S/M	0.1	0.42		13, 18
Tronto	Adriatic Sea	1.2	86	2300	Te-H-W	Cen S/M	0.3	0.5 (1)		13, 19, 20
Volturno	Mediterranean	5.5	170	2200	Te-H-W	Cen S/M	3.1	4.2		13, 14
Sardinia										
Tirso	Mediterranean	3.1	150	1800	Te-H-W	Cen S/M				4
Sicily										
Gela	Sicilian Channel	0.24		700	Te-SA-W	Cen S/M	0.02	0.13		13
Gornalunga	Sicilian Channel	0.23		600	Te-A-W	Cen S/M	0.005	0.03		13
Salso	Sicilian Channel	1.8	110	>1000	Te-SA-W	Cen S/M				17
Simeto	Ionian Sea	4.2	110	1700	Te-H-W	Cen	0.8	1 (3.5)		13

References:
1. Aquater, 1982; 2. Bartolini *et al.*, 1996; 3. Bellotti *et al.*, 1994; 4. Cattaneo, 1995; 5. Centre for Natural Resources, Energy and Transport (UN), 1978; 6. Correggiari *et al.*, 2005; 7. De Bartolo *et al.*, 2000; 8. Frangipane and Paris, 1994; 9. Global River Discharge Database, http://www.rivdis.sr.unh.edu/; 10. Gumiero *et al.*, 2009; 11. Holeman, 1968; 12. Hovius and Leeder, 1998; 13. IAHS/UNESCO, 1974; 14. Meybeck and Ragu, 1996; 15. Mikhailova *et al.*, 1998; 16. Pettine *et al.*, 1985; 17. Rand McNally, 1980; 18. Simeoni and Bondesan, 1997; 19. Syvitski and Kettner, 2007; 20. UNEP/MAP/MED_POL, 2003; 21. UNESCO (WORRI), 1978

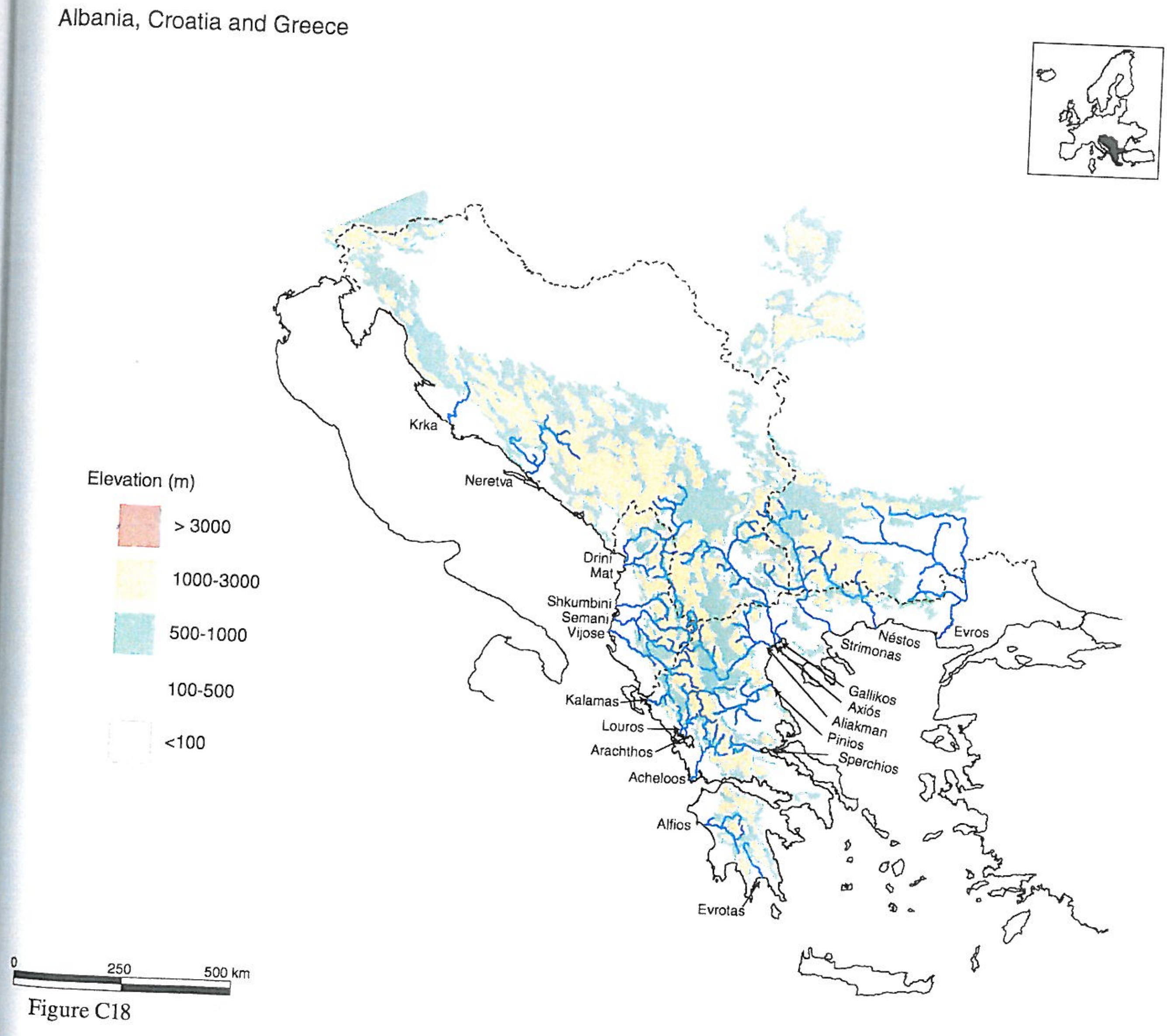

Albania, Croatia and Greece
Elevation (m)
> 3000
1000-3000
500-1000
100-500
<100
Krka
Neretva
Drini
Mat
Shkumbini
Semani
Vijose
Kalamas
Louros
Arachthos
Acheloos
Alfios
Evrotas
Nestos
Strimonas
Evros
Gallikos
Axiós
Aliakman
Pinios
Sperchios
0
250
500 km

Figure C18

Albania, Croatia and Greece

Geology

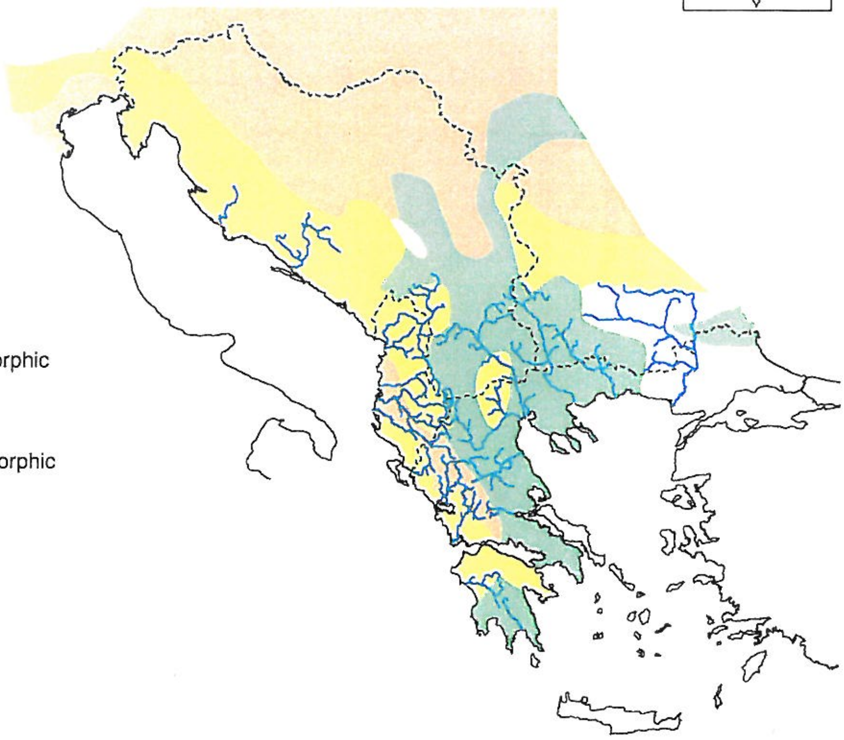
Cenozoic Igneous

Cenozoic Sedimentary/Metamorphic

Mesozoic Igneous

Mesozoic Sedimentary/ Metamorphic

Pre - Mesozoic



Surface Runoff (mm/yr)

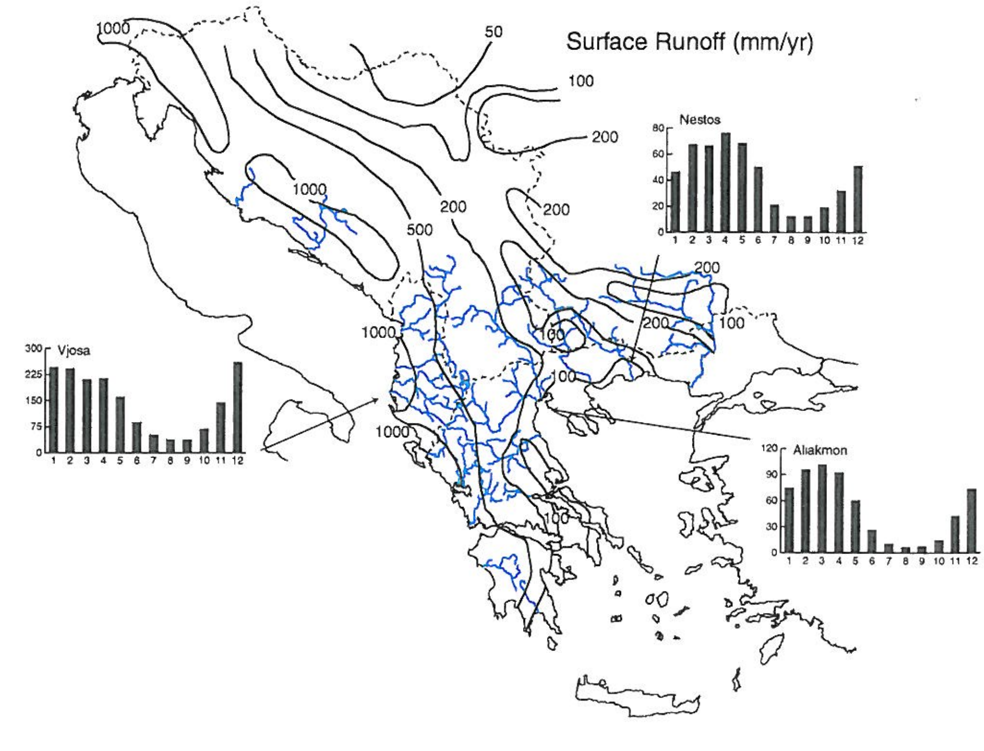


Figure C19

Table C9.

River name	Ocean	Area (10^3 km^2)	Length (km)	Max_elev (m)	Climate	Geology	Q (km^3/yr)	TSS (Mt/yr)	TDS (Mt/yr)	Refs.
Albania										
Drini	Adriatic Sea	20	280	2300	Te-W-W	Mes S/M	12	2.1 (16)		2, 4, 11, 13, 20, 23, 26
Mat	Adriatic Sea	2.3	110	>500	Te-W-W	Cen S/M	3.4	2.6		4, 13
Semani	Adriatic Sea	5.6	280	2500	Te-H-W	Mes S/M	2.9	16 (30)		4, 7, 13, 21, 22
Shkumbini	Adriatic Sea	2.4	180	2400	Te-H-W	Mes S/M	1.9	7.2		4, 8, 13, 21
Vijose	Adriatic Sea	6.8	260	2400	Te-W-W	Mes S/M	5.5	8.3 (29)		2, 4, 22, 23, 26
Croatia										
Krka	Adriatic Sea	2.2	70	>500	Te-W-W	Mes S/M				
Neretva	Adriatic Sea	13	220	>1000	Te-W-W	Mes S/M	12	14		5, 25
Greece										
Acheloos	Ionian Sea	5.4	190	2300	Te-W-W	Cen S/M	5.7	3.3	1.5	14, 19
Alfios	Ionian Sea	3.7	110	2200	Te-H-W	Cen S/M	1.7	3		12, 18
Aliakmon	Aegean Sea	9.5	310	2200	Te-SA-W	PreMes	3.1	4.4	1.2	10, 15, 18, 19, 20
Arachtos	Ionian Sea	1.9	100	2300	Te-W-W	Cen S/M	2.2	7.3		15, 19, 23
Axiós	Aegean Sea	24	310	2800	Te-SA-W	PreMes	4.9	4.7 (11)	1.7	5, 10, 15, 24
Évros	Aegean Sea	53	520	2900	Te-H-W	Mes S/M	6.8	8.5	2.6	1, 9, 10, 23
Evrotas	Aegean Sea	2.4	90	>2000	Te-H-W	Te-H-W	0.8			23
Gallikos	Aegean Sea	0.9	65	2200	Te-W-W	Cen S/M	1.2	0.004		17
Kalamas	Ionian Sea	1.8	100	>1000	Te-W-W	Mes S/M	6.8	1.9		6, 19, 23
Louros	Ionian Sea	0.8		1600	Te-W-W	Cen S/M	0.6	0.8	0.17	15
Néstos	Aegean Sea	6.2	210	2900	Te-H-W	Cen S/M	3.1	1	0.78	2, 3, 14
Pinios	Aegean Sea	11	220	1900	Te-SA-W	PreMes	3.2	4.4	1.6	10, 15, 20
Sperchios	Aegean Sea	1.8	70	2300	Te-H-W	PreMes	0.74	1.4	0.52	10, 15, 16
Strimonas	Aegean Sea	17	410	2700	Te-SA-W	Mes S/M	4.1	4	1.5	5, 20

References:
1. Artinyan *et al.*, 2008; 2. Center for Natural Resources, Energy and Transport (UN), 1978; 3. Chorafas, 1963 (cf. van der Leeden, 1975); 4. Ciavola *et al.*, 1999; 5. Eurosion, 2004; 6. GRDC website, www.gewex.org/grdc; 7. Holeman, 1968; 8. IAHS/UNESCO, 1974; 9. Kanellopoulos *et al.*, 2008; 10. Meybeck and Ragu, 1996; 11. Milliman and Meade, 1983; 12. Nicholas *et al.*, 1999; 13. Pano, 1992; 14. Poulos and Collins, 2002; 15. Poulos *et al.*, 1995; 16. Poulos *et al.*, 1996; 17. Poulos *et al.*, 2000; 18. Poulos *et al.*, 2002; 19. S. E. Poulos, personal communication; 20. Rand McNally, 1980; 21. Regional Activity Center for Environment Remote Sensing (RACERS), 1996; 22. Simeoni *et al.*, 1997; 23. Skoulikidis, 2009; 24. UNEP/MAP/MED_POL, 2003; 25. UNESCO (WORRI), 1978; 26. UNESCO, 1971

Bulgaria, Romania and Ukraine

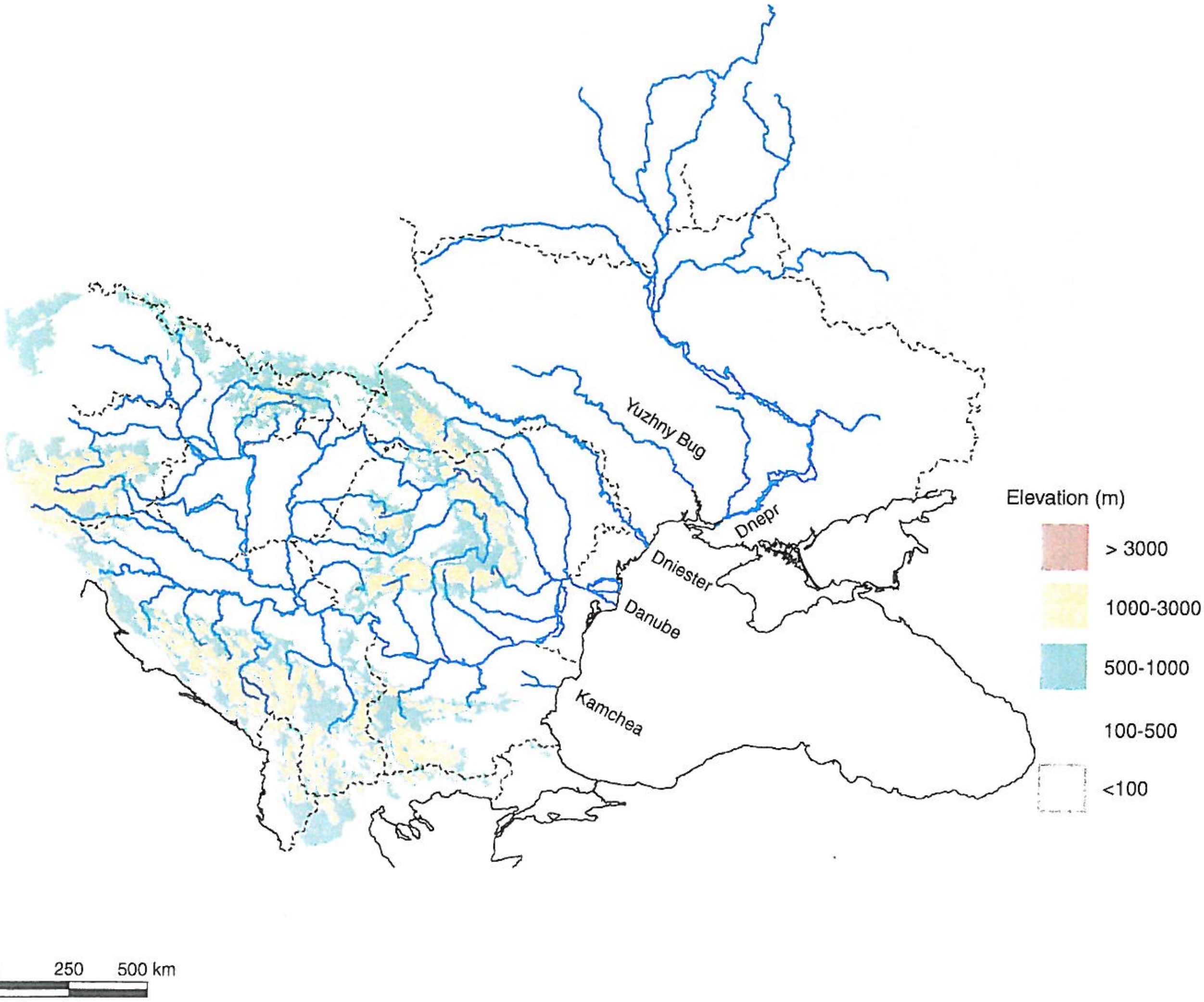


Figure C20

Bulgaria, Romania and Ukraine

Geology

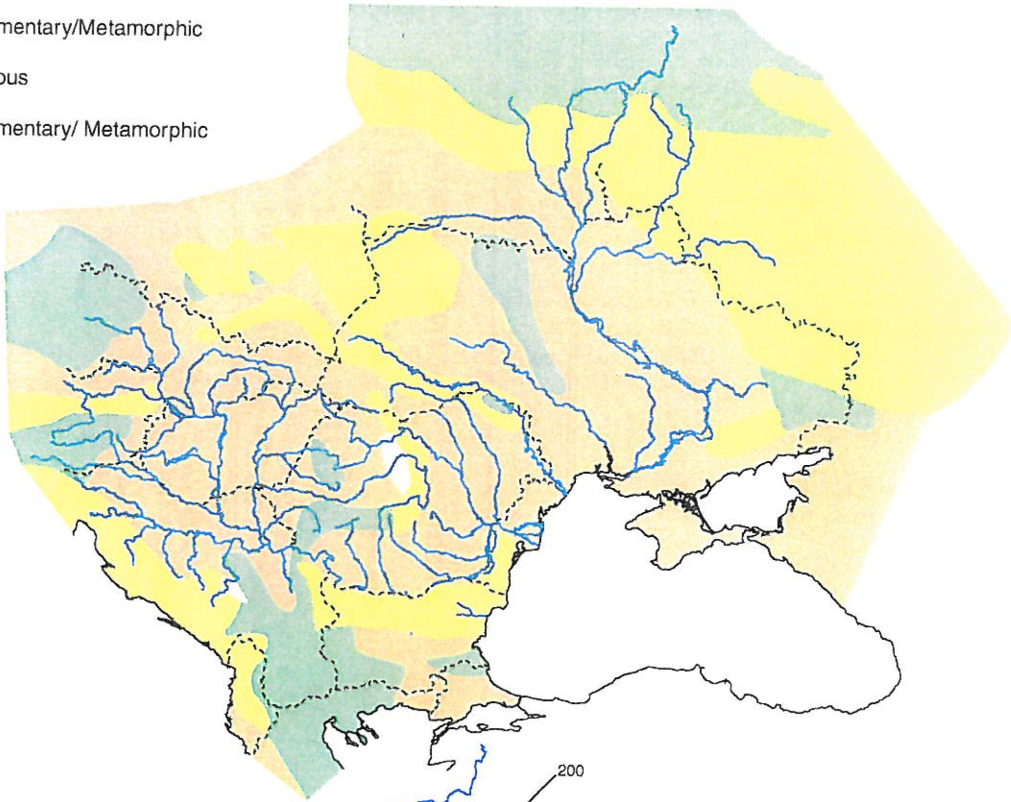
Cenozoic Igneous

Cenozoic Sedimentary/Metamorphic

Mesozoic Igneous

Mesozoic Sedimentary/ Metamorphic

Pre - Mesozoic



Surface Runoff (mm/yr)

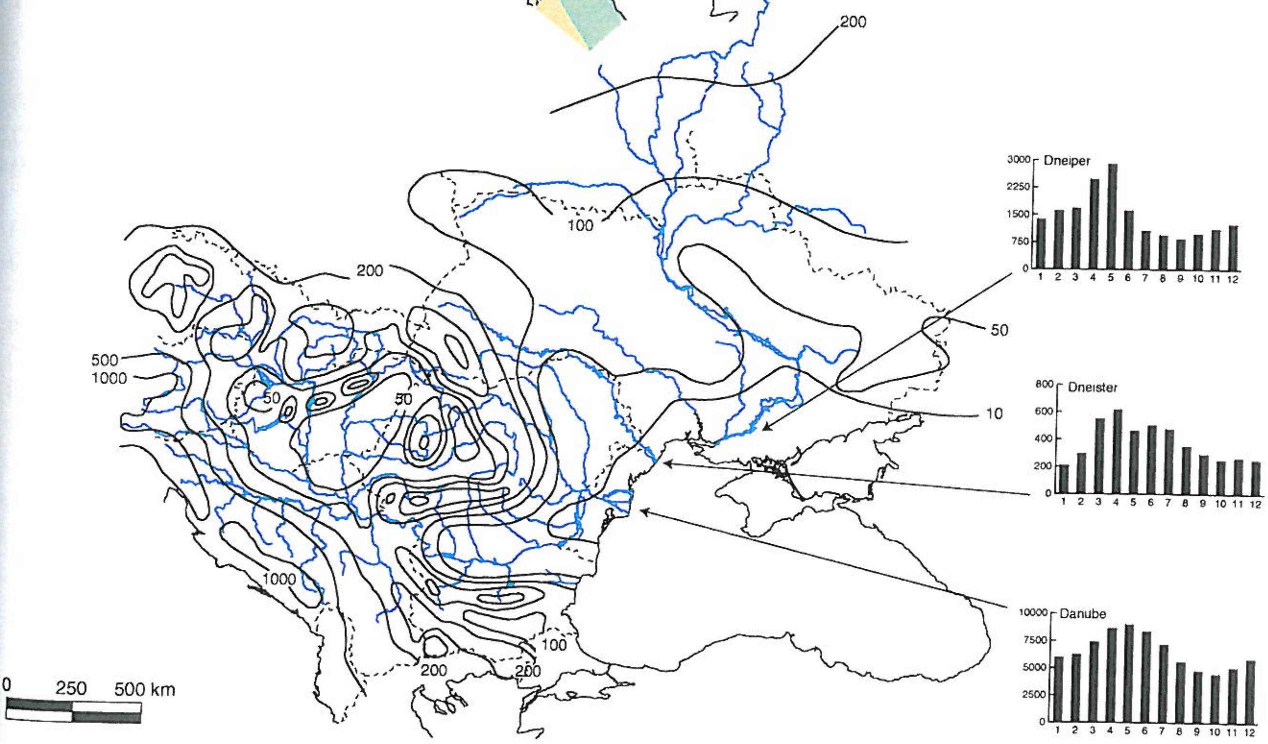


Figure C21

Table C10.

River name	Ocean	Area (10^3 km^2)	Length (km)	Max_elev (m)	Climate	Geology	Q (km^3/yr)	TSS (Mt/yr)	TDS (Mt/yr)	Refs.
Bulgaria										
Kamchea	Black Sea	5.3	165	>500	Te-SA-W	Mes S/M	0.3 (0.9)	0.46 (1.1)		3, 5
Romania										
Danube	Black Sea	820	2900	4100	Te-H-S	Cen S/M	210	42 (67)	80	2, 4, 6, 7, 8, 10
Ukraine										
Dnepr	Black Sea	510	2200	330	Te-A-S	PreMes-Mes S/M	43 (53)	2.3	15	1, 4, 6, 8, 9, 10
Dniester	Black Sea	72	1400	900	Te-SA-S	Cen-Mes-PreMes	9.3	0.49 (3)	6.1	2, 4, 8, 10
Yuzhny Bug	Black Sea	64	860	390	Te-A-S	Cen S/M-Mes S/M	2.8 (3.4)	0.2	1 (0.83)	6, 8, 10, 11

References:
1.Algan *et al.*, 1997; 2. GEMS website, www.gemstat.org; 3. GRDC website, www.gewex.org/grdc; 4. Hay, 1994; 5. Jaoshvili, 2002; 6. Kostianitsin, 1964; 7. Levashova *et al.*, 2004; 8. Meybeck and Ragu, 1996; 9. Skoulikidis, 2009; 10. Varga *et al.*, 1989; 11. Zhukinsky *et al.*, 1989

Sudan, Egypt and Lybia

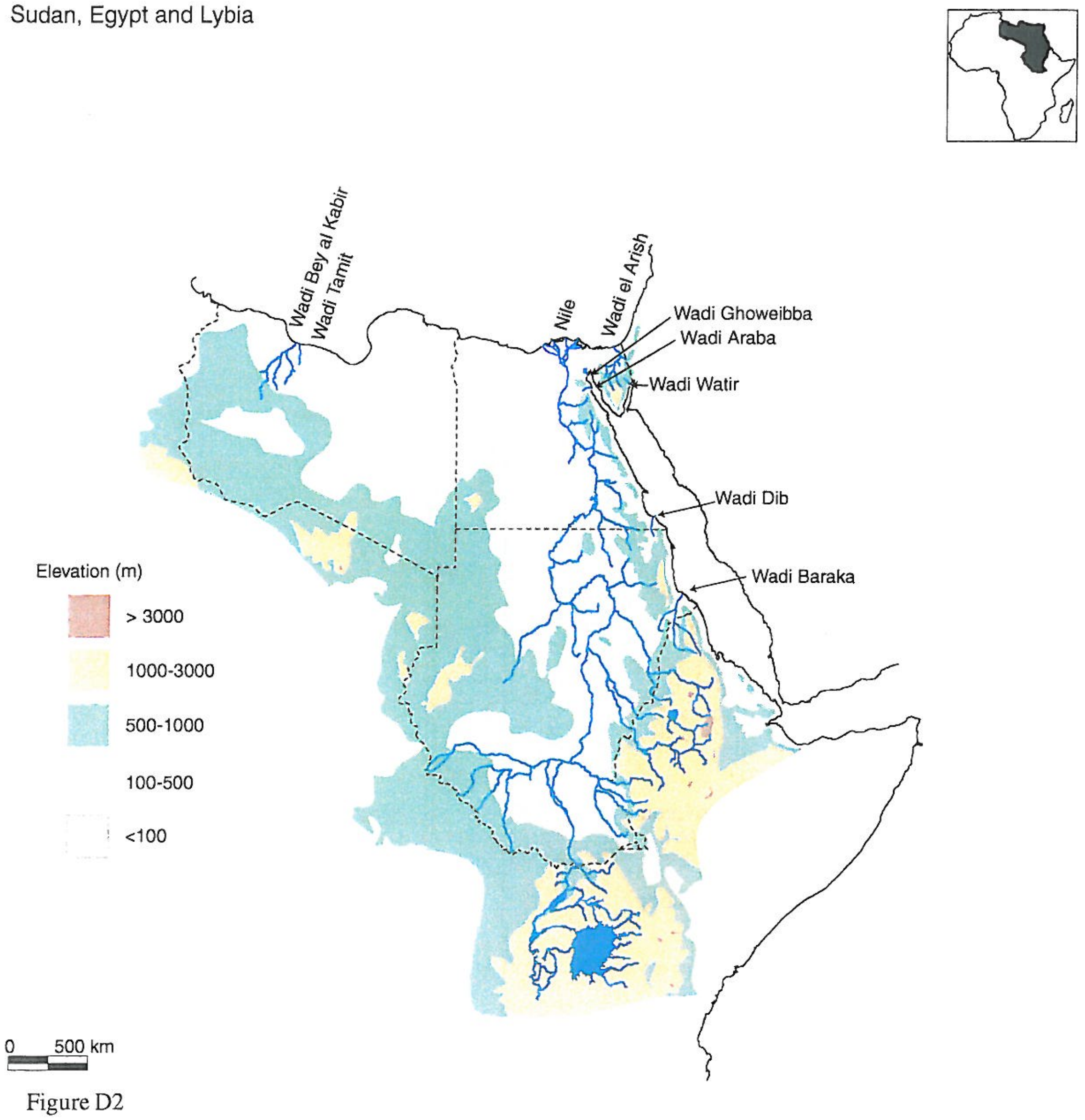
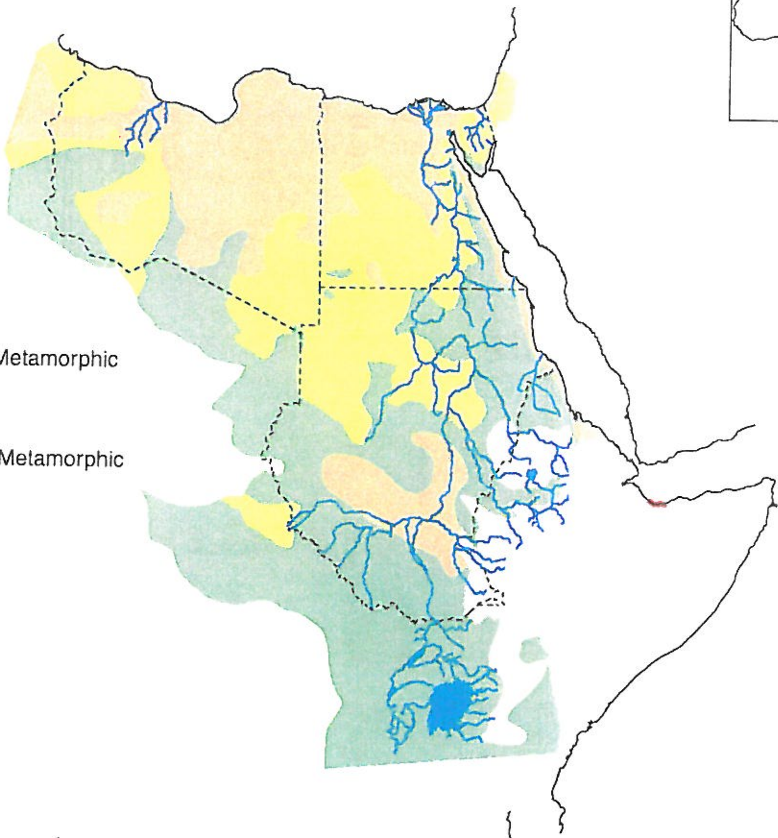


Figure D2

Sudan, Egypt and Lybia

Geology



Cenozoic Igneous

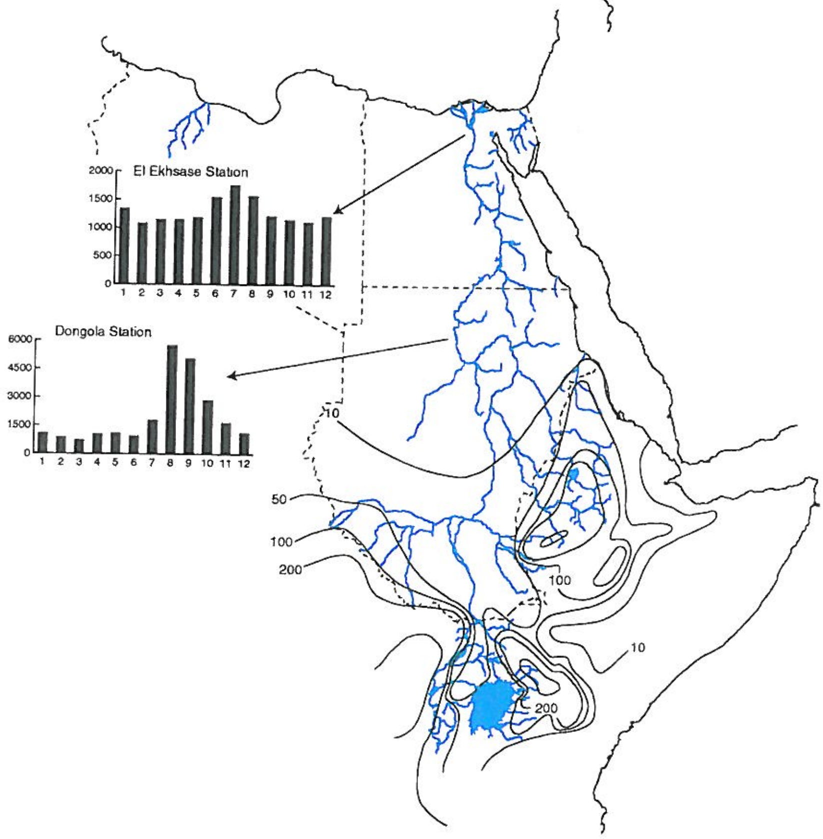
Cenozoic Sedimentary/Metamorphic

Mesozoic Igneous

Mesozoic Sedimentary/ Metamorphic

Pre - Mesozoic

Surface Runoff (mm/yr)



0 500 km

Figure D3

Table D1.

River name	Ocean	Area (10^3 km^2)	Length (km)	Max_elev (m)	Climate	Geology	Q (km^3/yr)	TSS (Mt/yr)	TDS (Mt/yr)	Refs.
Sudan										
Wadi Baraka	Red Sea	9	250	2500	Tr-A-D	PreMes				
Egypt										
Nile	Med. (E)	2900	6700	3800	STr-A-W	PreMes-Cen I	30 (80)	0.2 (120)	1.2 (6.1)	2, 3, 4, 5, 7, 8, 9
Wadi Araba	Red Sea	3.9	140	>1000	STr-A-D	PreMes				
Wadi Dib	Red Sea	3.9	160	>500	STr-A-D	PreMes				
Wadi el Arish	Med. (E)	19	140	1000	STr-A-D	Mes S/M				1
Wadi Ghoweibba	Red Sea	3.3	110	1200	STr-A-D	PreMes				
Wadi Watir	Red Sea	3.9	90	1500	STr-A-D	PreMes				6
Lybia										
Wadi Bey al Kabir	Med. (E)	36	390	>500	STr-A-D	Cen S/M				
Wadi Tamit	Med. (E)	18	220	>500	STr-A-D	Cen S/M				

References:
1. El-Etr *et al.*, 1999; 2. GEMS website, www.gemstat.org; 3. Global River Discharge Database, http://www.rivdis.sr.unh.edu/; 4. Meybeck and Ragu, 1996; 5. Probst, 1992; 6. Schick and Lekach, 1987; 7. Sestini, 1991; 8. Shahin, 2002; 9. UNEP/MAP/MED_POL, 2003

Tunisia, Algeria, Morroco and Western Sahara

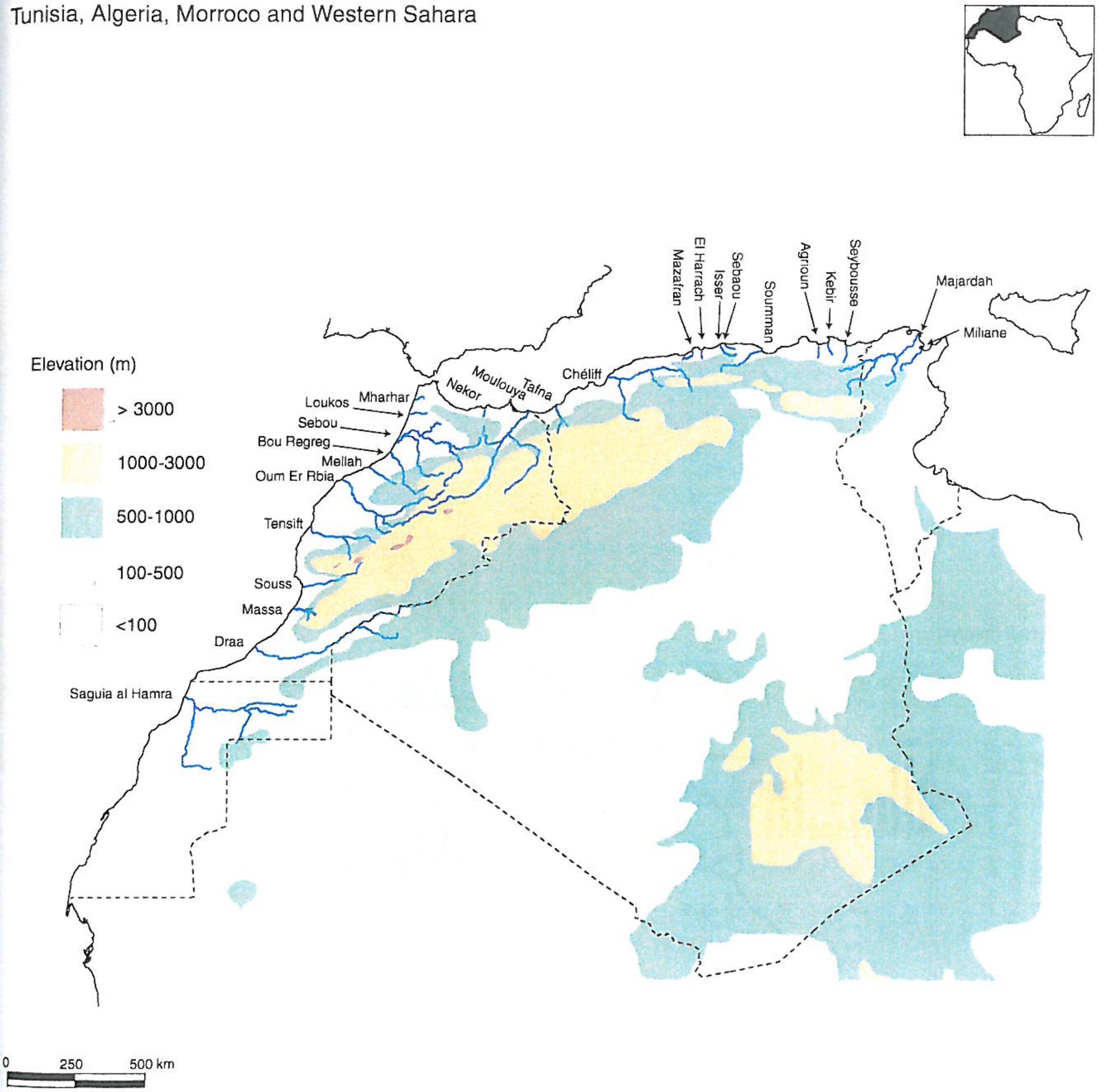
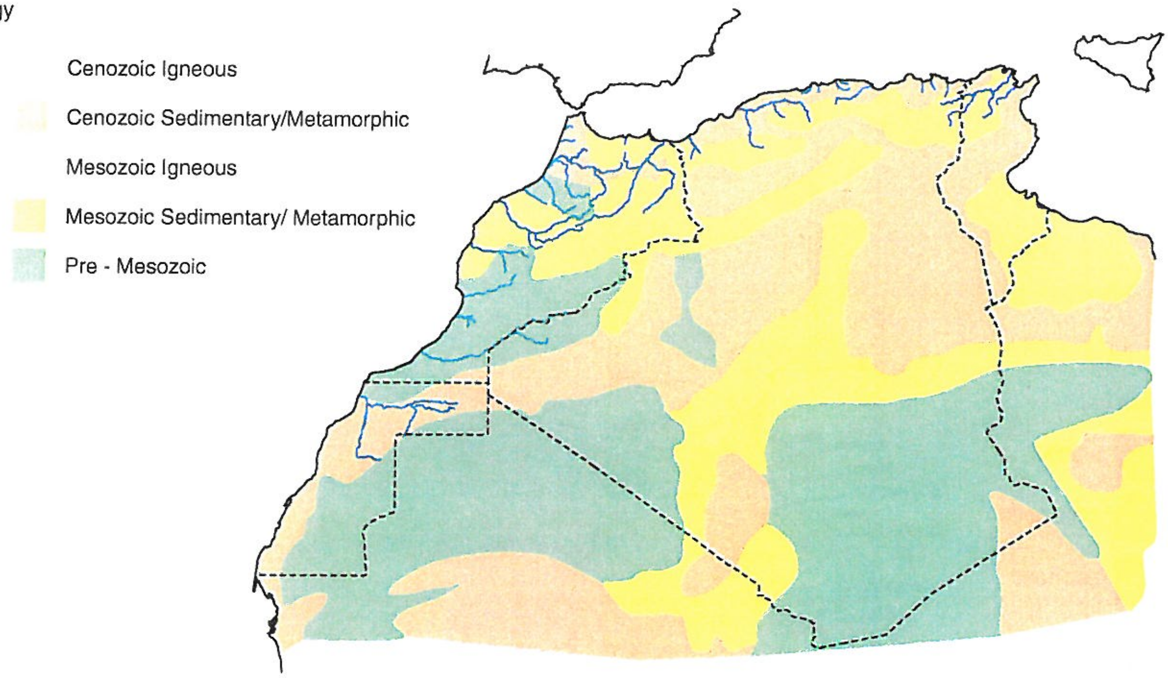


Figure D4

Tunisia, Algeria, Morroco, and Western Sahara

Geology



Surface Runoff (mm/yr)

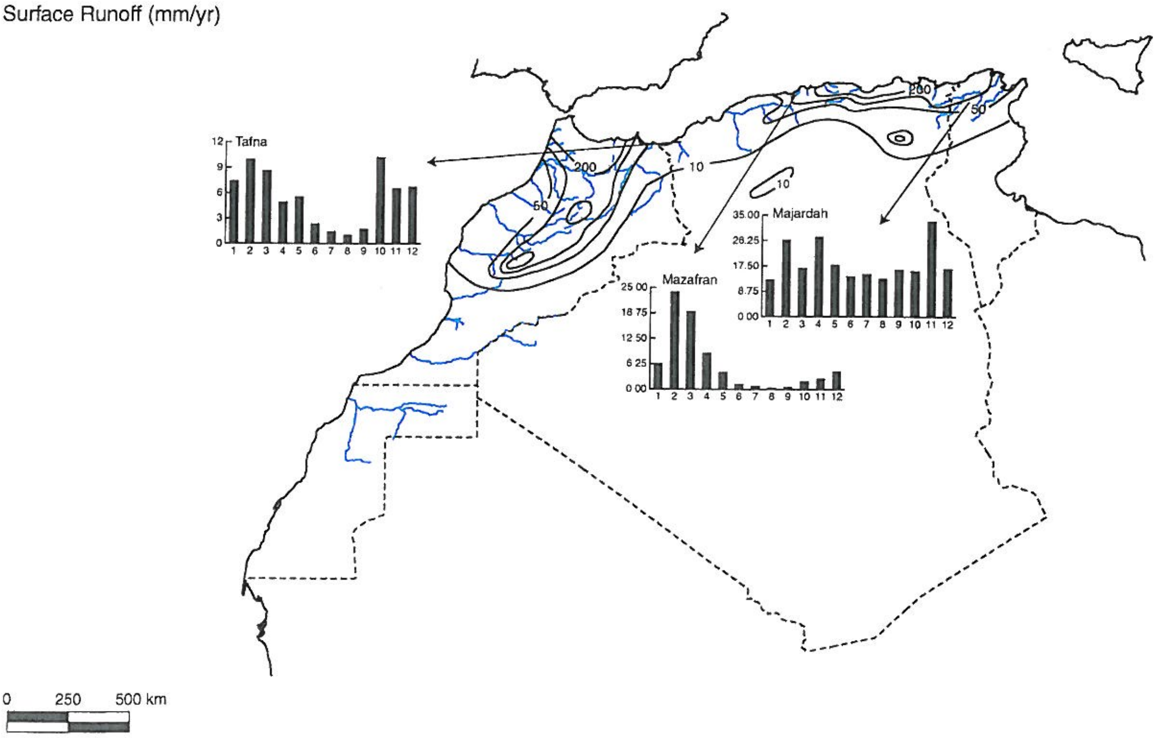


Figure D5

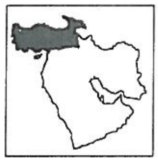
Table D2.

River name	Ocean	Area (10^3 km^2)	Length (km)	Max_elev (m)	Climate	Geology	Q (km^3/yr)	TSS (Mt/yr)	TDS (Mt/yr)	Refs.
Algeria										
Agrioun	Med. (W)	0.66	70	>1000	STr-H-W	Mes S/M	0.17	4.8		6
Chéliff	Med. (W)	44	720	1900	STr-A-W	Mes S/M	1.3	4		6, 7, 19
El Harrach	Med. (W)	0.39	60	>1000	STr-H-W	Mes S/M	0.13	0.63		18
Isser	Med. (W)	4.2	90	>500	STr-A-W	Mes S/M	0.36	8.3		3, 6
Kebir	Med. (W)	1.1	80	>1000	STr-SA-W	Mes S/M	0.23	0.22		6
Mazafran	Med. (W)	1.9	70	>500	STr-H-W	Mes S/M	0.44	3		6, 17
Sebaou	Med. (W)	2.5	80	>500	STr-H-W	Mes S/M	0.51	1.2		3, 6
Seybousse	Med. (W)	5.5	200	>500	STr-A-W	Mes S/M	0.43	1.2		6, 9
Soumman	Med. (W)	8.5	200	>500	STr-A-W	Mes S/M	0.79	4.1		6, 7, 9
Tafna	Med. (W)	8.8	80	>500	STr-A-W	Mes S/M	0.28	1		5, 9
Morroco										
Bou Regreg	Atlantic (NE)	9.8	180	>500	STr-A-W	PreMes	0.56	4.7		5, 9
Draa	Atlantic (NE)	114	1100	>1500	STr-A-W	PreMes	0.4 (0.8)	14		2, 5, 9
Loukos	Atlantic (NE)	1.8	190	>500	STr-H-W	Cen S/M	0.9	1.8		5, 9
Massa	Atlantic (NE)	3.8	90	>200	STr-A-W	PreMes	0.16	1.6		5
Mellah	Atlantic (NE)	1.8	80	>500	STr-A-W	PreMes	0.16	1		5
Mharhar	Atlantic (NE)	0.18	20	>500	STr-H-W	Cen S/M	0.06	0.21		5
Moulouya	Med. (W)	51	450	>1500	STr-A-W	Mes S/M	0.2 (1.3)	0.8 (12)		2, 4, 13, 16
Nekor	Med. (W)	0.79	40	>100	STr-H-W	Mes S/M	0.9	2.8		1
Oum Er Rbia	Atlantic (NE)	30	560	>1500	STr-SA-W	Mes S/M	3.3	6.6		4, 9
Sebou	Atlantic (NE)	37	500	>1000	STr-SA-W	Cen S/M	1.4 (4.4)	2 (37)	3.1	7, 10, 11, 12, 13, 14
Souss	Atlantic (NE)	16	230	2700	STr-A-W	Mes S/M	0.31	4.2	0.03	8, 12
Tensift	Atlantic (NE)	20	240	3600	STr-A-W	Mes S/M	0.91			
Tunisia										
Majardah	Med. (W)	22	370	1700	STr-A-W	Mes S/M	0.94	9.4		7, 9, 15
Miliane	Med. (W)	2	130	>200	STr-A-D	Mes S/M	0.02	0.9		9
Western Sahara										
Saguia al Hamra	Atlantic (NE)	68	210	>500	STr-A-D	Cen S/M				

References:

1. Boufous, 1982; 2. Combe, M., 1968, c.f. van der Leeden (1975); 2. FAO, 1997; 3. Global River Discharge Database, http://www.rivdis.sr.unh.edu/; 4. Heusch and Milles-Lacrois, 1971; 5. Lahlou, 1982; 6. Licitri and Normand, 1969; 7. Meybeck and Ragu, 1996; 8. Olivera F, Website, 6/7/99 https://ceprofs.civil.tamu.edu/folivera/UTexas/morocco/report.htm; 9. Rand McNally, 1980; 10. Shahin, 2002; 11. Shahin, 2007; 12. Snoussi *et al.*, 1990; 13. Snoussi *et al.*, 2002; 14. Snoussi, 1988; 15. Tiveront, 1960; 16. UNEP/MAP/MED_POL, 2003; 17. Vörösmarty *et al.*, 1996d; 18. Walling, 1985; 19. D. E. Walling, personal communication

Turkey and Georgia



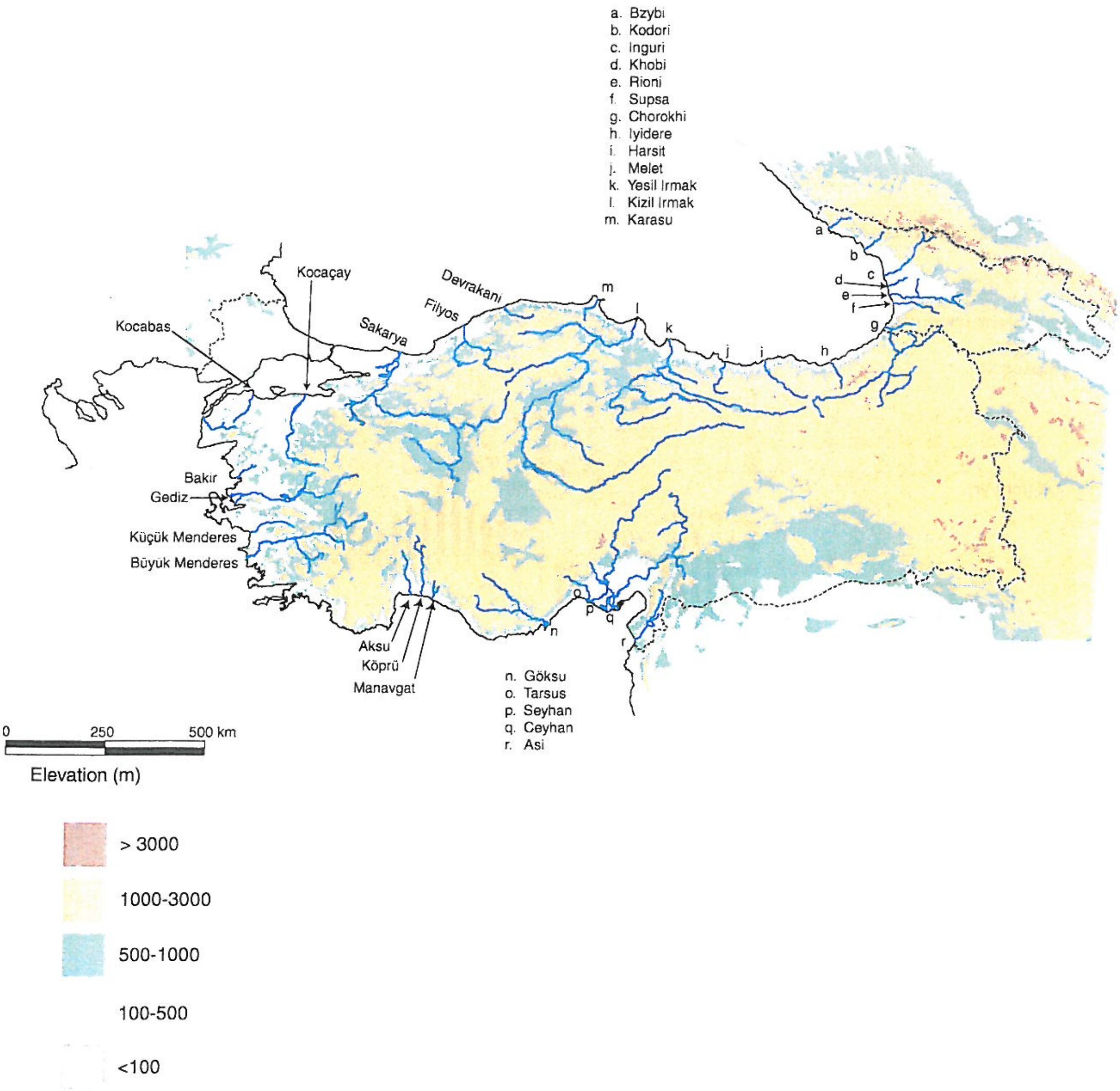
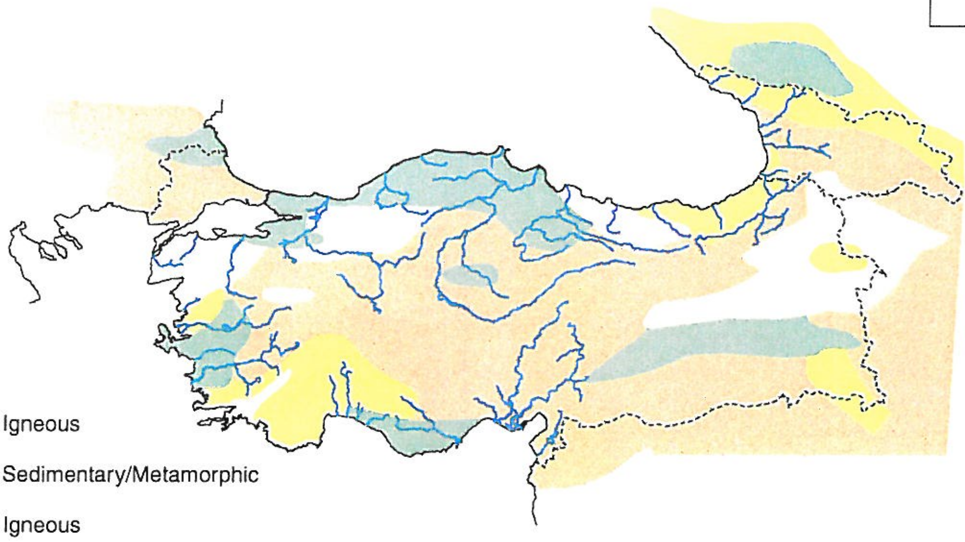


Figure E2

Turkey and Georgia



Geology

Cenozoic Igneous

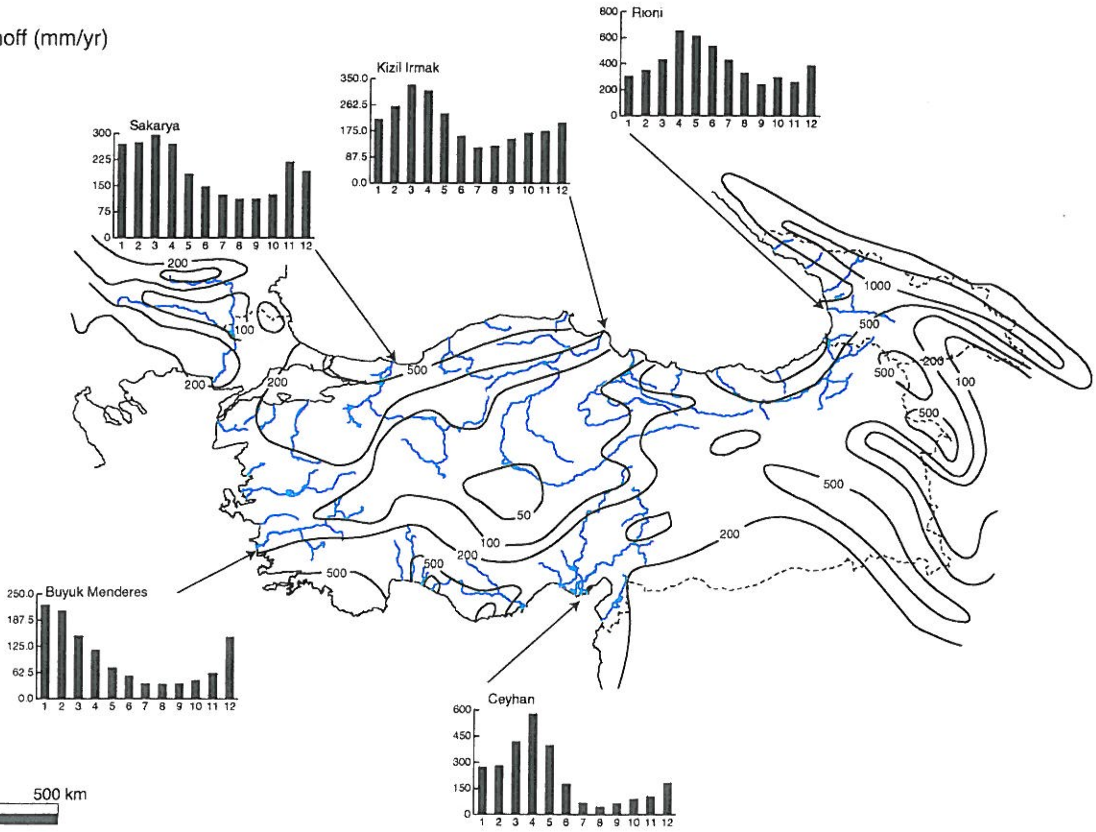
Cenozoic Sedimentary/Metamorphic

Mesozoic Igneous

Mesozoic Sedimentary/ Metamorphic

Pre - Mesozoic

Surface Runoff (mm/yr)



0 250 500 km

Figure E3

Table E1.

River name	Ocean	Area (10³ km²)	Length (km)	Max_elev (m)	Climate	Geology	Q (km³/yr)	TSS (Mt/yr)	TDS (Mt/yr)	Refs.
Turkey										
Aksu	Black Sea	20	120	2000	Te-H-W	Mes S/M	14			10
Asi	Med. (E)	23	500	3100	STr-SA-W	Cen S/M	2.7	0.36 (19)	1	10
Bakir	Aegean Sea	3.4	100	1400	Te-SA-W	Mes I				
Büyük Menderes	Aegean Sea	20	560	2000	Te-SA-W	Cen S/M-Mes S/M	4.7	0.78	3.4	10, 13, 14
Ceyhan	Med. (E)	21	380	2800	Te-H-Sp	Cen S/M	7	4.8 (5.5)	2	10, 13, 14
Devrekani	Black Sea	1.1		>1000	Te-H-W	PreMes	0.25	0.18		2, 7
Filyos	Black Sea	13	230	2400	Te-H-W	PreMes	3.1	0.1 (3.7)		2, 7, 10, 17
Gediz	Aegean Sea	18	350	1500	Te-SA-W	Cen S/M-Mes S/M	2.3	1.3	0.32	10, 13, 14, 15
Göksu	Med. (E)	10	180	2400	STr-H-W	Cen S/M-Mes S/M	2.5	2.5		10, 14
Harsit	Black Sea	2.6	160	3000	Te-H-W	Cen S/M	0.8	0.52		2, 8, 17
Iyidere	Black Sea	0.84		>3000	Te-H-W	Mes S/M	0.92	0.18		2, 3
Karasu	Sea of Marmara	2.9		>200	Te-H-W	PreMes	0.6	0.04		2, 6
Kizil Irmark	Black Sea	79	1400	>1500	Te-A-W	Cen S/M	7.6	0.44 (17)	5.5	2, 3, 7, 9, 10, 13, 17
Kocabas	Sea of Marmara	2.3	75	<1000	Te-SA-W	Mes I				
Kocaçay	Sea of Marmara	23		>1000	Te-SA-W	Cen S/M	4.4		1.2	10
Köprü	Med. (E)	2.8	130	3000	STr-H-W	Cen S/M				
Küçük Menderes	Aegean Sea	3.6	400	2100	Te-SA-W	PreMes	1	0.6		1, 3, 13, 15
Manavgat	Med. (E)	1.3	640	>1000	STr-H-W	Mes S/M	4.1		0.9	10, 14
Melet	Black Sea	1	170	>1500	Te-H-W	Cen	0.4	0.27		2, 7, 18
Sakarya	Black Sea	57	820	>1000	Te-SA-W	Cen S/M	3.6 (5.6)	3.8 (12)	2.9	2, 7, 9, 10, 13, 14, 17, 18
Seyhan	Med. (E)	22	510	3000	Te-H-W	Cen S/M	8	5.2	1.3	1, 10, 14
Tarsus	Med. (E)	1.4	100	2600	STr-SA-W	Cen S/M	0.1	0.13		10
Yesil Irmak	Black Sea	65	520	2600	Te-SA-W	Cen	7.2	6.2	1	7, 10, 13, 17
Georgia										
Bzybi	Black Sea	1.5	110	3000	Te-W-S	Mes S/M	3	0.48	0.23	5, 10, 16
Chorokhi	Black Sea	22	440	3100	Te-H-S	PreMes-Mes S/M	9	8.2		2, 4, 5, 7, 12, 16
Inguri	Black Sea	4.1	210	5000	Te-H-S	Cen S/M	1.6 (6)	0.13 (1.8)	0.51	5, 10, 16, 20
Khobi	Black Sea	1.3	95	3000	Te-W-S	Cen S/M	1.6	0.45 (2.7)		9
Kodori	Black Sea	2	80	2780	Te-W-S	Cen S/M	3.9	0.82	0.39	5, 10, 16, 19
Rioni	Black Sea	13	330	2600	Te-W-S	Cen S/M	13	6.9	2.8	5, 7, 10, 11, 16, 20
Supsa	Black Sea	1.1		>1000	Te-W-S	Cen S/M	1.5	0.25		9

References:
1. Akbulut *et al.*, 2009; 2. Algan *et al.*, 1997; 3. Cecen, Wasser (cf. van der Leeden, 1975); 4. Center for Natural Resources Energy and Transport (UN), 1978; 5. Dzhaoshvili, 1986; 6. GEMS website, www.gemstat.org; 7. Hay, 1994; 8. IAHS/UNESCO, 1974; 9. Jaoshvili, 2002; 10. Meybeck and Ragu, 1996; 11. Mikhailova and Dzhaoshvili, 1998; 12. Nace, 1970; 13. Ozturk, 1996; 14. X. Piper, personal communication; 15. Rand McNally, 1980; 16. Sovetskaya Entsiklopediya, 1989; 17. Tuncer *et al.*, 1998; 18. UNESCO (WORRI), 1978; 19. UNESCO, 1971; 20. Varga *et al.*, 1989

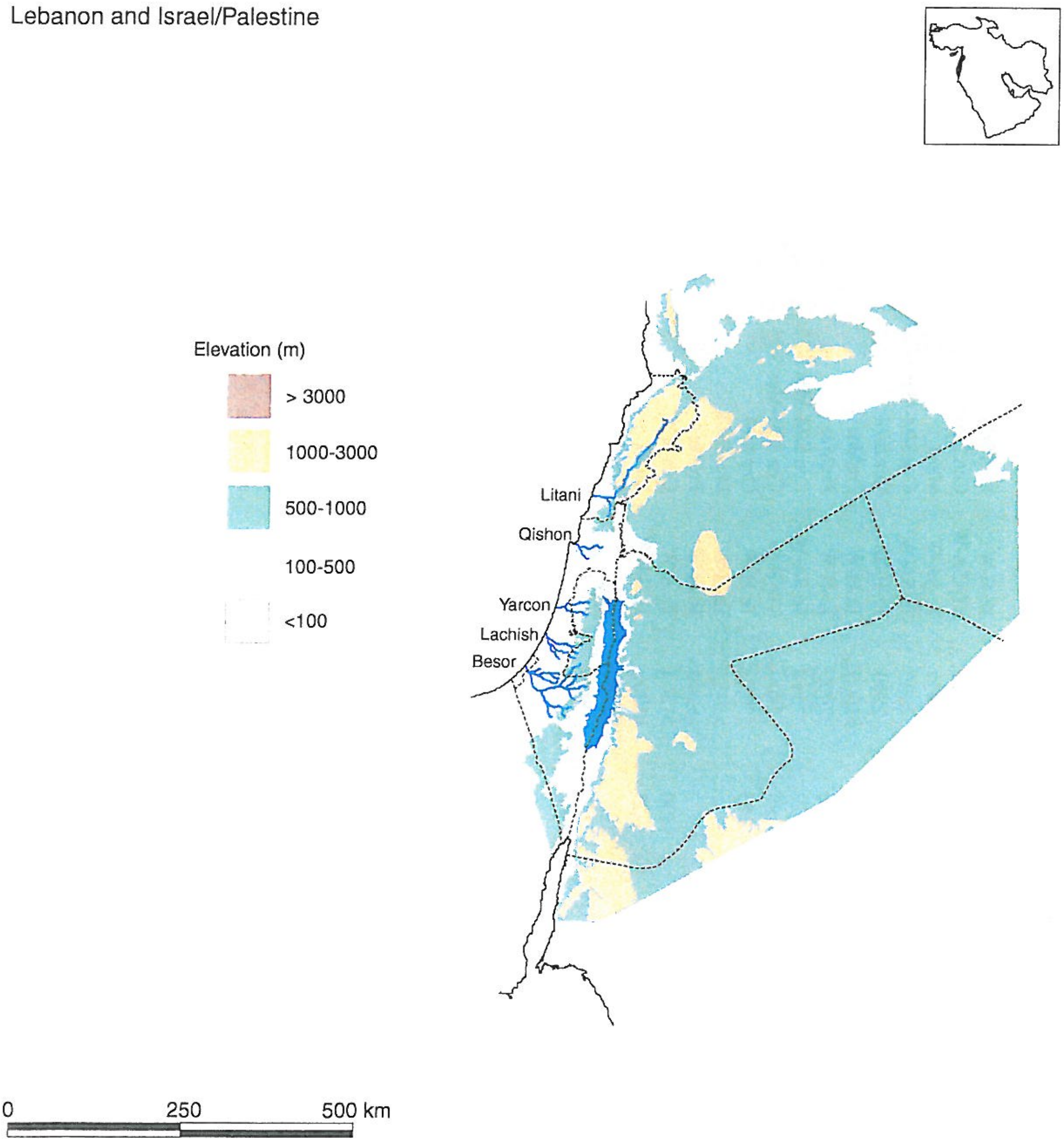

Lebanon and Israel/Palestine
Elevation (m)
> 3000
1000-3000
500-1000
100-500
<100
Litani
Qishon
Yarcon
Lachish
Besor
0
250
500 km

Figure E4

Lebanon and Israel/Palestine

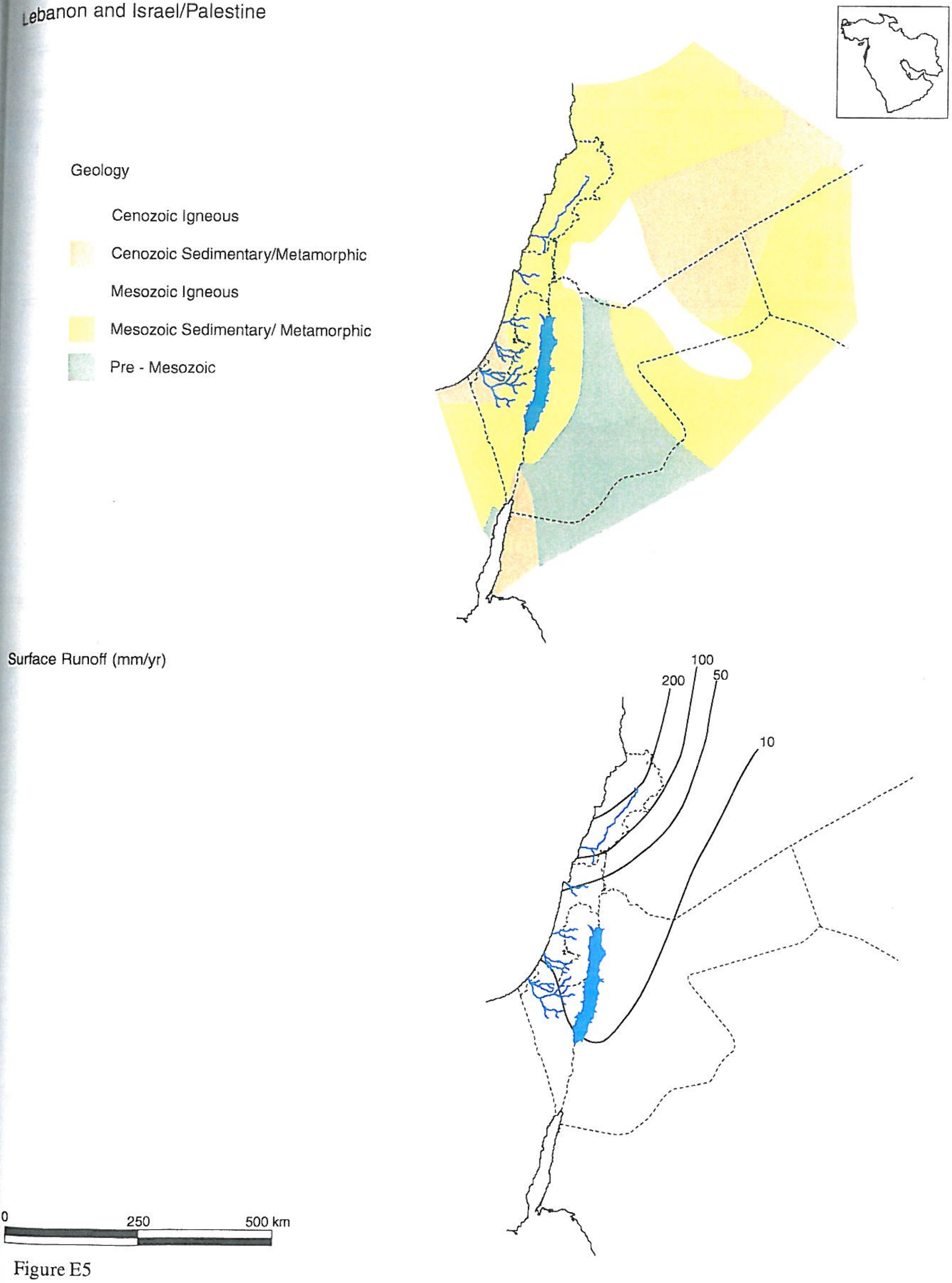


Figure E5

Table E2.

River name	Ocean	Area (10^3 km^2)	Length (km)	Max_elev (m)	Climate	Geology	*Q* (km^3/yr)	TSS (Mt/yr)	TDS (Mt/yr)	Ref.
Lebanon										
Litani	Med. (E)	2.5	140	>1000	STr-A-W	Mes S/M				1
Israel										
Besor	Med. (E)	3.7	110	>500	STr-A-W	Mes S/M-CenS/M	0.01			
Lachish	Med. (E)	1	70	>500	STr-A-W	Cen S/M				
Qishon	Med. (E)	1.1	70	>100	STr-A-W	Cen S/M				
Yarcon	Med. (E)	1.8	28	>600	STr-A-W	Mes S/M	0.03 (0.2)			

Reference:

1. Amery, 1993

Saudi Arabia, Yemen, Iraq and Iran

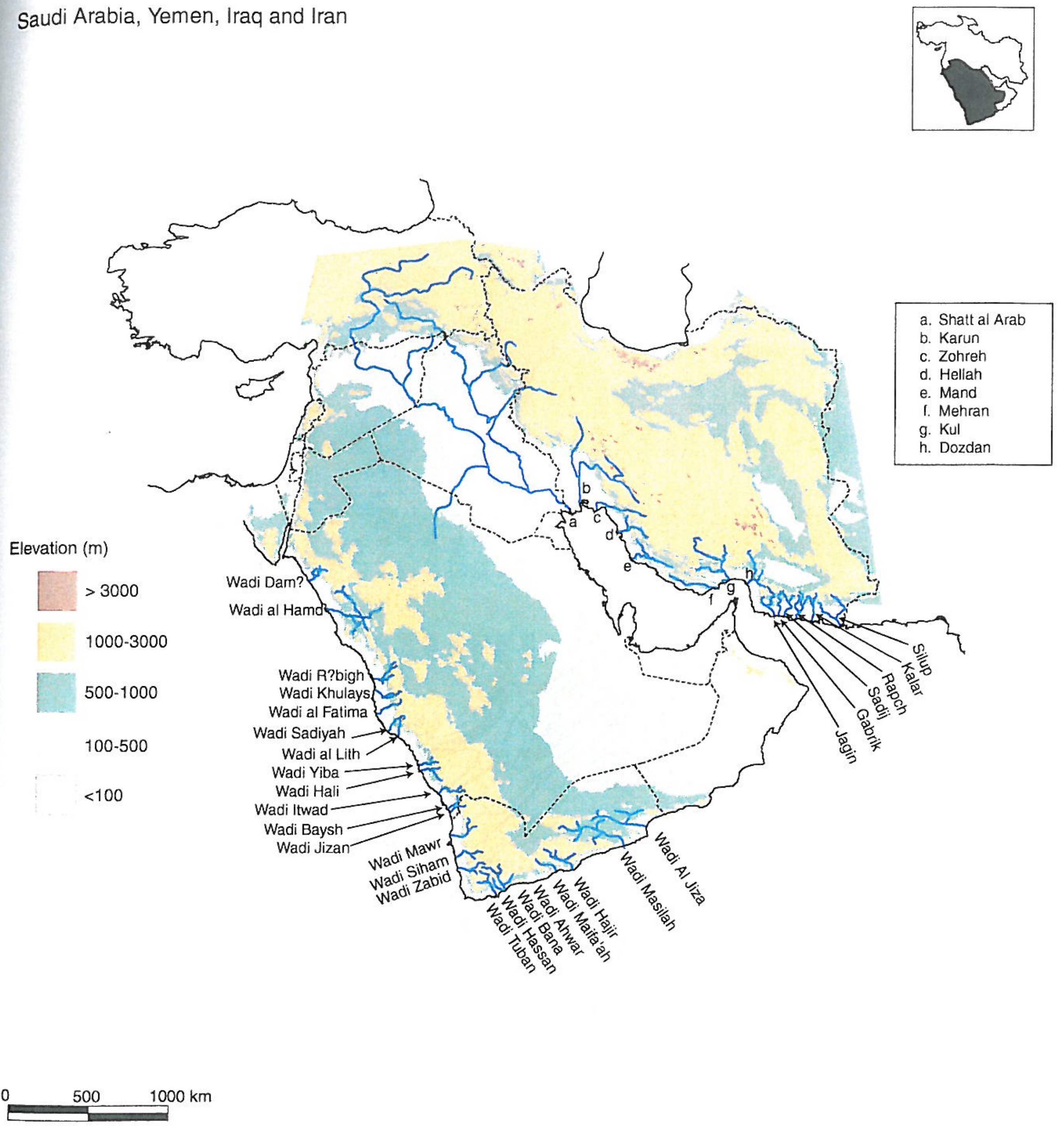


Figure E6

Saudi Arabia, Yemen, Iraq and Iran

Geology

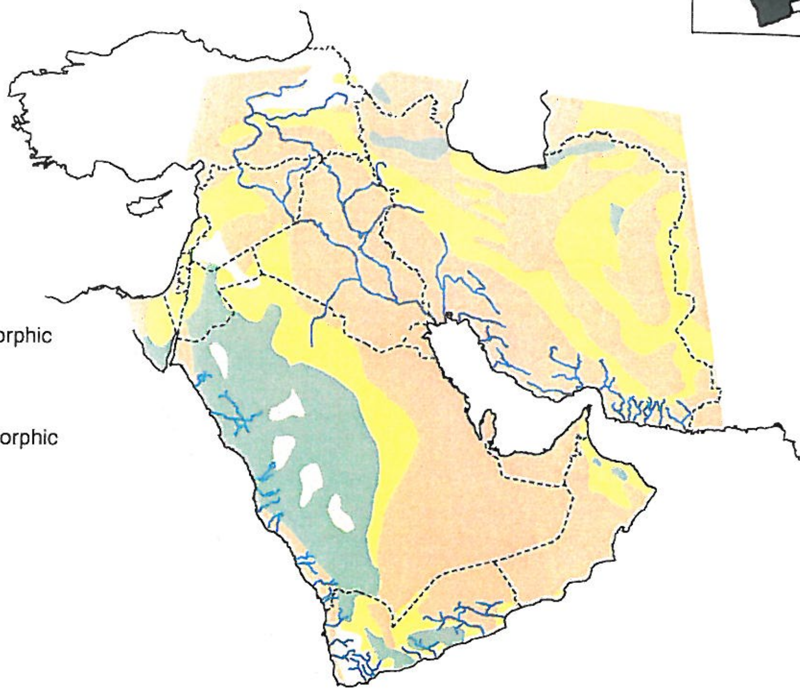
Cenozoic Igneous

Cenozoic Sedimentary/Metamorphic

Mesozoic Igneous

Mesozoic Sedimentary/ Metamorphic

Pre - Mesozoic



Surface Runoff (mm/yr)

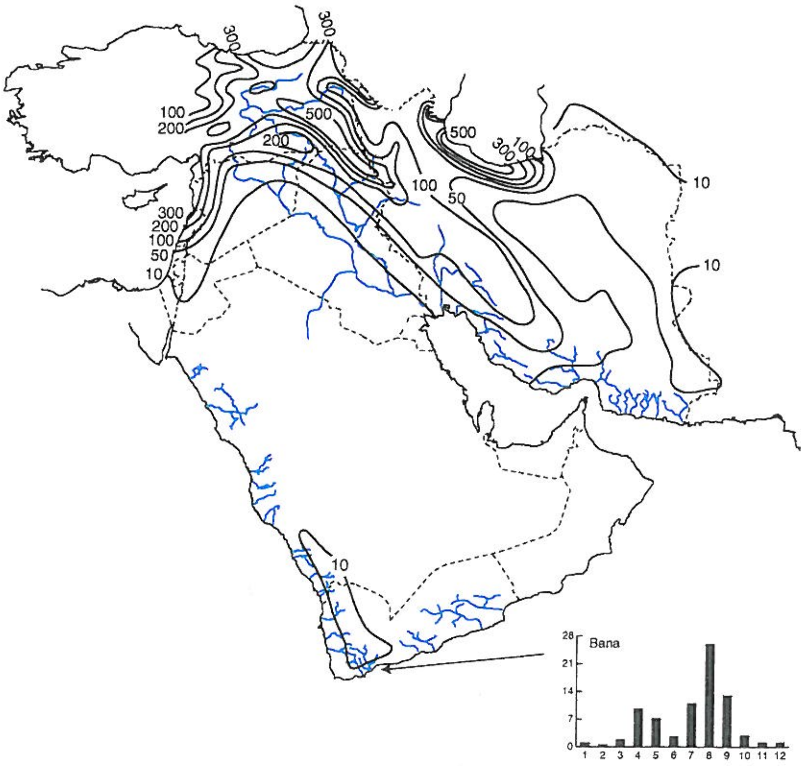


Figure E7

Table E3.

River name	Ocean	Area (10^3 km^2)	Length (km)	Max_elev (m)	Climate	Geology	Q (km^3/yr)	TSS (Mt/yr)	TDS (Mt/yr)	Refs.
Saudi Arabia										
Wadi al Fatima	Red Sea		180	>1000	STr-A-D	PreMes	0.04			5, 7, 9
Wadi al Hamd	Red Sea	62	380	>200	STr-A-D	PreMes				
Wadi al Lith	Red Sea	3	98	>1000	STr-A-D	Cen S/M	0.05			10, 12
Wadi Baysh	Red Sea	5.2	120	2100	STr-A-D	Cen S/M	0.2			10
Wadi Damā	Red Sea	5.5		1300	STr-A-D	PreMes	0.06			12
Wadi Hali	Red Sea	4.5	120	2500	STr-A-D	Cen S/M	0.09			10
Wadi Itwad	Red Sea	1.5	60	2000	STr-A-D	Cen S/M	0.003			10
Wadi Jizan	Red Sea	1.2	70	980	STr-A-D	Cen S/M	0.07			9, 10
Wadi Khulays	Red Sea	5.2		>1000	STr-A-D	PreMes	0.06			9
Wadi Rābigh	Red Sea	5		500	STr-A-D	PreMes	0.06			12
Wadi Sadiyah	Red Sea	1.4	110	>1000	STr-A-D	Cen S/M	0.001			10
Wadi Yiba	Red Sea	2.7	99	1500	STr-A-D	Cen S/M	0.02			10
Yemen										
Wadi Ahwar	G. of Aden	6.4		>560	STr-A-D	Mes I	0.07			9
Wadi al Jiza	G. of Aden	19	260	>1000	STr-A-D	Cen S/M	0.1			6
Wadi Bana	G. of Aden	6.4	200	2000	STr-A-D	PreMes	0.17			6, 8
Wadi Hajir	G. of Aden	8.3	170	>1000	STr-A-D	Mes S/M	0.05			8, 9
Wadi Hassan	G. of Aden	3.5		<500	STr-A-D	Mes I	0.04			9
Wadi Maifa'ah	G. of Aden	8.6		>1000	STr-A-D	Mes S/M	0.08			9
Wadi Masilah	G. of Aden	45	460	>1000	STr-A-D	Cen S/M				
Wadi Mawr	Red Sea	8	300	2000	STr-A-D	Mes S/M-Cen S/M	0.15			
Wadi Siham	Red Sea	4.9		>1000	STr-A-D	Mes I	0.1	2.8		6
Wadi Tuban	G. of Aden	6.5		<1000	STr-A-D	Mes I	0.1	3		1, 14
Wadi Zabid	Arabian Sea	4.6	250	1500	STr-A-D	Mes I	0.14			8, 9
Iraq										
Shatt el Arab	Persian Gulf	420	2500	>2500	Te-A-W	Mes S/M	46 (77)	(100)	18	4, 11
Iran										
Dozdan	Strt. of Hormuz	11	260	>1500	STr-A-W	Mes S/M	0.3			3

Table E3. (*Continued*)

River name	Ocean	Area (10^3 km^2)	Length (km)	Max_elev (m)	Climate	Geology	Q (km^3/yr)	TSS (Mt/yr)	TDS (Mt/yr)	Refs.
Gabrik	G. of Oman	4.2	160	>1500	STr-A-W	Mes S/M				
Hellah	Persian Gulf	4.8	210	>1000	STr-A-W	Mes S/M				
Jagin	G. of Oman	5.6	180	1500	STr-A-W	Mes S/M				
Kalar	G. of Oman	3.7	160	>1500	STr-A-W	Mes S/M				
Karun	Persian Gulf	61	850	>2000	STr-SA-W	Mes S/M	18			2, 7, 13
Kul	Strt. of Hormuz	35	400	>1000	STr-A-W	Cen S/M				
Mand	Persian Gulf	41	480	>2000	STr-A-W	Mes S/M				7
Mehran	Persian Gulf	14	410	>500	STr-A-W	Cen S/M				
Rapch	G. of Oman	6.2	160	>1000	STr-A-W	Mes S/M				
Sadij	G. of Oman	4.6	150	1500	STr-A-W	Mes S/M				
Silup	G. of Oman	6.1	13	500	STr-A-W	Cen S/M				
Zohreh	Persian Gulf	14	320	>2000	STr-A-W	Mes S/M				7

References:
1. FAO, 1997; 2. GEMS website, www.gemstat.org; 3. Global River Discharge Database, http://www.rivdis.sr.unh.edu/; 4. Meybeck and Ragu, 1996; 5. Ministry of Agriculture and Water, 1984; 6. Nouh, 2006; 7. Rand McNally, 1980; 8. Riggs, 1977; 9. Shahin, 2007; 10. Sorman and Abdulrazzak, 1987; 11. UNESCO (WORRI), 1978; 12. Vincent, 2008; 13. Vörösmarty *et al.*, 1996e; 14. (http://www.fao.org/landwater laglw/sediment/default.asp)