ANNEX XIV

SCOR WORKING GROUP 46 (WITH ECOR/IAHS/ACMRR/UNESCO)
RIVER INPUTS TO OCEAN SYSTEMS
Report of first meeting, Paris, 24 to 27 June 1974

Participants:

(i) Members of RIOS working group

1. D. Lal	India	(SCOR)	Chairman
2. J. S. Alabaster	UK	(ACMRR)	
3. R. Chesselet	France	(SCOR)	
4. J. A. da Costa		(UNESCO)	
5. D. Eisma	Netherlands	(SCOR)	
6. F. Fournier	France	(IAHS)	
7. P. Storrs	USA	(ECOR)	
8. K. K. Turekian	USA	(SCOR)	

(J. S. Burton and E. Eriksson could not attend)

(ii) Co-opted Experts

Jean-Marie Martin	France
A. Walton	Canada

(iii) Observers

F. W. G. Baker, Executive Secretary, ICSU

T. F. Gaskell, SCOR executive committee

R. C. Griffiths, Assistant Secretary, IOC/UNESCO

The working group unanimously decided that it should concern itself primarily with the basic physical, chemical and biological processes occurring in the river-estuary-ocean systems. Following this discussion the group proceeded to consider its future work and developed a number of objectives for the scientific programme. Thought was also given to the manner by which these objectives could be accomplished.

The terms of reference provided to the group were noted, but the group decided to amplify them so that its scope and aims were spelled out clearly.

On the morning of 25 June the WG met with four UNESCO/IHD Consultants (Messrs Knöpp, Hendricks, Ionescu and Nöthlich) who are charged with drawing up plans for the preparation of a World Registry of Rivers. The WG were informed of their proposed approach and there was a useful interchange of ideas. They agreed to keep the WG informed of their work.

I. AMPLIFICATION OF TERMS OF REFERENCE OF SCOR WORKING GROUP 46:

The questions with which this group is concerned are:

1. How does river water and its sediment load acquire their chemical qualities in response to climatic, geological and cultural factors?
2. What transformations occur when a river meets the sea?
3. What is the ultimate flux of constituents to the open oceans via river systems?

The working group intends to propose plans of action to enable acquisition of relevant data on a global basis, taking into consideration that useful data are, and will become, available from other international groups interested in the dissemination of natural and man made substances in the hydrosphere. The ultimate goal of this effort would be to develop suitable generalized models capable of describing the physical, chemical and biological processes operative in the river-ocean systems and interfaces, thus advancing our predictive capabilities.

II. PURPOSES OF SCOR WORKING GROUP 46:

It was generally felt that SCOR Working Group 46, being essentially scientifically oriented, has a significant contribution to make to the advancement of the understanding of the influence of continents on the oceans. This would be fundamental to marine geoscience and to chemical and biological oceanography; moreover, in the long term, it would provide a scientific basis for the design of rational policies for the management of man's activities in the coastal zone, particularly for example with regard to problems of resources, pollution, and coastal engineering.

The main need is for descriptive generalized models of the physical, chemical and biological processes occurring in estuaries and adjacent seaward areas, which could be developed to encompass local situations. This will involve the integration of many scientific disciplines and require studies in representative areas of the globe, for which international cooperation is clearly necessary.

The studies should be designed to obtain field and laboratory data adequate to describe and account for the conditions in estuaries and the neighbouring areas. Such data would include measurements of the quantity and quality of suspended and dissolved substances present in rivers and of their subsequent transport, sedimentation and transformation in nearshore waters.

Studies in different parts of the world would enable comparisons to be made of situations having differing climates, land use and morphology, coastal and near-shore topography, tidal and current regimes, population and degree of river impact. They would enable existing input loads to be estimated and provide the means whereby significant changes could be monitored.

Thus the role of the working group will be to foster scientific research and exchange of information, and to advise international organizations on the fundamental principles of processes at the river-ocean interface, so as to assist in the planning of scientific investigations and monitoring projects.

III. AN OUTLINE OF IMPORTANT PROCESSES IN RIVER INPUTS TO OCEANS:

The riverine inputs to the ocean system must be viewed as more complex than that derived from the image of a simple channel transport of a fluid to a basin. First, the processes imparting to a stream its chemical properties are diverse and variable, even within a given drainage basin. Second, the encounter between the river with its dissolved and particulate load, with the salty ocean causes radical changes in chemical and physical properties of the components. Thirdly, the particulate load, while on the estuarine floor, for whatever length of time, is subject to the peculiar biological, chemical and physical forces acting there which further modify the composition of water and the suspended matter. The resulting materials are subsequently capable of being transported to the open ocean.

In this section we briefly review the behaviour of particles and dissolved materials on this aqueous journey and the manner in which the composition of marine waters in both the coastal and open ocean may be altered. We further seek to identify the types of studies that will enhance our understanding of the processes involved.

A. Streams

The transport of materials by streams to the coastal zone occurs via both dissolved and suspended load. There is an interaction between these two phases that may change the distribution of elements between them as a function of distance downstream, or of seasonal and sporadic events affecting the drainage basin.

The composition of precipitation falling on the drainage basin sets the initial chemical quality of the water, but this is soon altered by interaction with the vegetation, the weathering profile and impervious artificial substances. The changes that occur are:

(i) The increase of the concentration of dissolved solids by the solution of aerosols collected on the vegetation and impervious substances, and by evaporation;

(ii) the addition of sulphate from the oxidation of sulphide minerals during weathering and the addition of bicarbonate through the oxidation of organic mineral or passage through limestone or chalk aquifers in both cases cations are also added to maintain charge balance;

(iii) the mobilization of certain elements from weathering profiles;

(iv) the addition of humic acids.

The particulate load of a stream is made up of the erosion products of the land and includes both silicate and oxide minerals characteristic of weathering profiles, as well as organic matter, possibly in the form of coatings on these minerals or as separate aggregates.

As the dissolved and particulate load of a stream is carried along, several changes can take place:

(i) If acid waters are neutralized (say by the dissolution of calcium carbonate or by the alteration of silicate) dissolved iron and manganese will precipitate on the stream bed and on suspended particles. A seasonal increase of stream acidity due, for example, to the oxidation of forest litter, will result in release

of manganese and iron from suspended particles with an increase in the dissolved load. These reactions may influence the distribution of heavy metals between the dissolved and particulate phases.

(ii) The adsorption of heavy metals, in particular, is effected primarily by the suspended organic particles. A secondary adsorption mechanism involves the clay minerals, but the organic particulate load plays the dominant role. The metal-sequestering capacity of these materials is large; thus there is a tendency to maintain the dissolved heavy metal concentration at low levels even after injection of metal in solution from man-made sources.

(iii) The relatively "non-reactive" ions, such as sodium, sulphate and chloride will remain as part of the dissolved load.

Thus, by the time stream water encounters the sea, it has already been subject to many processes that may influence its future impact on the ocean system.

B. The behaviour of riverine materials in estuaries

Soluble and particulate constituents supplied to the ocean by rivers are subject to new physicochemical, biological, hydrodynamical and sedimentological conditions in estuarine and nearshore areas - this new environment modifies the chemical speciation, the concentration and ultimately the budget of these elements in the ocean. These modifications take place from the beginning of the mixing zone between fresh and seawater to off-shore areas where normal marine salinities are encountered.

For heavy metals, in particular, there is good evidence that the following processes occur in the estuarine system:

(i) the release of metals from the particulate phase in low-salinity areas possibly through chelation by dissolved organic compounds or some other mechanism peculiar to this interface; and

(ii) the removal of material from solution by inorganic and organic processes mainly observed in the higher salinity areas of the estuarine system.

Much of our present knowledge of these processes in estuaries comes from studies of systems in industrialized areas, and from laboratory experiments using well defined solid phases.

C. Modifications resulting from estuarine sedimentary processes

Once particles have been deposited on the estuarine floor they can remain there for a short period of time before resuspension or they can gradually accumulate over longer periods of time. During their residence on the estuarine floor, chemical changes can take place that will influence the sensible flux of materials to, and ultimately out of, the estuarine system.

Sedimentation, resuspension and erosion depend on the local physical conditions of currents, tides, waves and topography. The mixing of salt and fresh water also results in flocculation and rapid sedimentation of fine materials. Important are the exceptional situations of extremely high river floods, extreme weather conditions (such as hurricanes), high sea levels and tides, all of which in a short period may alter com-

pletely the existing pattern of sedimentation. In some tidal areas most of the suspended matter is trapped in the estuary for a time before it is moved seaward, whereas in protected tidal inlets mud may be effectively retained, resulting in the formation of extensive mud flats and salt marshes.

There may be an exchange of particles between the bottom and the suspension above it; the thickness of this boundary layer being related to such factors as current velocity, particle size and bioturbation.

In the sedimentary column the action of sulphate-reducing bacteria at depth in the anoxic zone can cause the mobilization of iron and manganese. Except where strong organic complexes can solubilize the heavy metals most of them will be retained in the sediment, probably as refractory sulphides. Burrowing organisms act to release elements into the overlying water column. The mobilized manganese and iron, unless transported away from the point of release, will precipitate in oxygenated waters and act to trap heavy metals.

D. Supply to the "Open Ocean"

Following the major chemical and physical modifications that occur in the estuarine zone, a variety of physical oceanographic regimes must be considered. At least four such regimes can be recognized, two of which may, in certain circumstances, be considered to represent the "open ocean". These regimes are:

(i) enclosed sea where a further physical barrier exists in advance of "open ocean" conditions, e.g. Baltic Sea;

(ii) Semi-enclosed sea such as the Gulf of St Lawrence where there is no sill but where physical and chemical transformation processes may occur prior to the input to the "open ocean";

(iii) estuarine system entering into a shallow "open ocean" environment such as the North Sea, e.g. Thames Estuary;

(iv) estuarine system entering immediately into deep ocean, e.g. Congo.

It is recognized that many of the processes taking place in estuaries will continue to occur in the enclosed or semi-enclosed seas of regimes (i) and (ii), e.g., influence of biota and adsorption/dissolution of chemical species via suspended particulate matter and at sediment-water interfaces. Seasonal variations play an important role in these zones, and the influence of atmospheric processes in regimes of substantial size such as the Baltic Sea and the Gulf of St Lawrence, is important.

In the remaining two regimes where the estuarine outputs are in more direct contact with the "open ocean" fewer processes have to be taken into account in assessing the chemical and physical inputs to the "open ocean". Of prime importance is the examination of sediment transport processes within the shallower zones of the type (iii) regime. Similarly in the case of type (iv) attention must be given to sediment transport processes and the possible occurrence of sediment traps in depressions.

E. The influence of man

The basic geochemical, biochemical and sedimentological profiles have been

biased in many rivers and estuaries as a result of human activities, and it is important to quantify to what extent this has taken place.

IV. RECOMMENDATIONS

A. Methodology and Quality of Data

In view of the long and short-term requirements of the RIOS programme proposed here, it is essential that all data acquired have the required precision and accuracy. Methodology will need to be carefully documented, to evaluate the utility of the data.

A system of inter-calibration between laboratories working within the RIOS concept should be established and periodic evaluations of the data will be essential to assure their validity.

Where seasonal and other temporal effects are known or expected to be of significance special attention must be given to the frequency of observations.

B. Measurements to be made

In order to obtain a better knowledge of the many problems related to the fate of nutrients, trace metals, organic compounds and organisms in estuaries, it is necessary to measure a number of basic parameters, such as salinity, temperature, pH, oxygen content, flow, river discharge, precipitation, particle load, populations of bacteria, algae and other organisms and biological processes including primary productivity and denitrification.

The study of a number of constituents promises to give a more general insight into estuarine processes. These can be listed as follows, viz: silicon and Si^{32}, transitional elements, with special attention to Fe and Mn, toxic metals, with special attention to Hg Pb and Cu (it should be emphasized that this list is not a limiting one in itself).

Also there are a number of determinations that can be made to give a better insight into the various estuarine phenomena viz: C^{12}/C^{13}, S^{34}/S^{32}, Sr^{84}/Sr^{86}, U^{238}/U^{234}, Ra^{286}/Ra^{288} and Pb^{210}.

The different types of measurements that seem useful in the context of RIOS are summarized in Table 1; it may, however, be mentioned that in several cases techniques have already been adequately developed, whereas, in other cases, they have yet to be explored.

C. Implementation of the RIOS Programme

The following fundamental questions regarding the transport of material by rivers to the oceans have already been expanded, viz. the source elements, the physico-chemical changes occurring in the near-coastal areas and the final form and quantity of discharge to the oceans. There remains the obvious need for experimental studies on the multitude of river-ocean systems of the world. It is recognized at the outset that the task is of substantial proportions and it is recommended that a number of characteristic systems be examined initially. The choice of these systems should be based on at least the following characteristics:

(1) climate
(2) geology
(3) topography
(4) estuarine mixing characteristics
(5) size of river/drainage basin/estuary/sediment load
(6) impact of man

V. FUTURE ACTION PLAN FOR RIOS

The SCOR WG 46 should be represented by at least two members at the International Hydrological Decade Conference to be held in Paris (at Unesco) from 2 to 24 September 1974. These members should report on this Conference to the next session of the WG.

At its second meeting in late 1974 or early 1975, but in any case after the IHD Conference, the SCOR WG 46 should plan a scientific workshop on river inputs and, through SCOR, call for contributions to the workshop from selected scientists actively working on RIOS problems. These scientists would be drawn from a broad spectrum of countries covering major physiographic regions (tundra, temperate and tropical zones) and types of river systems (e. g. with delta or estuary, or without; with high sediment load in relation to total discharge, or not, etc.). The subject matter of the workshop would also cover the main sub-systems such as the river itself, the estuary, and the interface between river and sea in the liquid and solid phases. It is expected that such a workshop will provide the basis for a statement of present knowledge of river inputs to ocean systems. This workshop is expected to form part of a broad ocean programme under which project proposals will be submitted to UNEP by IOC. The workshop would take place towards the end of 1975 and would last from 3 to 5 days.

Meanwhile, the SCOR WG 46, in whole or in part, would expect to meet, at least informally, when the members happened to be attending major international meetings such as that of the IUGG in Grenoble in August-September 1975. Also, if it were thought essential, the WG could arrange for regional scientific meetings of its own.

TABLE 1

LIST OF PROPERTIES TO BE CONSIDERED FOR MEASUREMENT IN VARIOUS PHASES WITHIN THE RIOS PROGRAMME

Basic Measurements	Water	Suspended Particles	Sediments	Interstitial Waters	Precipitation	Biota
a) Physical						
Flow/discharge	+	+		+	+	
Temperature	+			+	+	
Particulate load	+	+				
b) Chemical						
Salinity	+			+	+	
Major Constituents:						
Na, K, Mg, Ca, SO_4, ce, HCO_3 SiO_2	+	+	+	+	+	+
Nutrients	+	+	+	+	+	+
Organic Carbon	+	+	+	+	+	+
Dissolved oxygen, hydrogen sulphide	+			+		
Fe, Mn	+	+	+	+	+	+
pH	+			+	+	
B.O.D.	+					
Organic Constituents, e.g. Petroleum, Hydrocarbon, Pesticides	+	+	+	+	+	+
Inorganic: Cd, Hg, Se, etc.	+	+	+	+	+	+
c) Stable and Radioactive Isotope Measurements						
C^{12}, C^{13}, C^{14}	+	+	+			+
S^{32}, S^{34}	+	+	+	+	+	
Sr^{86}, Sr^{87}	+	+	+			
Pb^{210}, Po^{210}	+	+	+		+	+
Ra^{226}, Ra^{228}	+	+	+	+		+
Th^{228}, Th^{232}, Th^{234}	+	+	+			+
U^{238}, U^{234}	+	+	+			+
Si^{32}	+		+			+
Rn^{222}	+			+		
Pu^{239}, Cs^{137}, Fe^{55} (and others)		+	+			