(Paragraph 15.2.7) APPENDIX 15.1

Assessment of Water Resources

Extract from the paper "Water Resources of India" by Shri Balwant Singh Nag, Member and Shri G. N. Kathpalia, Specialist (Water Utilisation) National Commission on Agriculture contributed to the Second World Congress on Water Resources—1975.

1 Water of the Earth

1.1 The water resources of the country constitute only a tiny fraction of the total water resources of the earth and it would be of interest to have a look at the latter. The total amount of water in the hydrosphere has been estimated at about 1500 million km^3. About 95 per cent of it is contained in the oceans and seas. The remaining five per cent is fresh water, of which four-fifths is stored in the form of snow and ice or permafrost. About half of this frozen water is contained in the polar ice caps. Thus the fresh and unfrozen water of the earth constitutes only one per cent of that in the hydrosphere. Bulk of it, estimated at 99 per cent, is groundwater and only one per cent is in lakes, rivers, soil and atmosphere. About half of the groundwater is more than 1000 metres below the surface and a good amount between 500 to 1000 metres. Water at these depths is very expensive to draw. Some fresh water can be obtained from the abundant sea-water by desalination, but here again the process is expensive and, therefore, use of such water can be contemplated only in comparatively shall quantities, mainly for domestic and industrial purposes. With the present stage of development of technology, it would be too expensive for irrigation. Thus, altogether, it is only a tiny fraction of the water on the earth which man can put to use as fresh water for his purposes.

2 Precipitation in India

2.1 The summer monsoon starting from the equatorial belt comes over the Indian subcontinent in two distinct currents known as the Bay of Bengal branch and the Arabian Sea branch. It has been estimated that during the four rainy months of June to September, the Arabian Sea branch of the monsoon carries moisture amounting to about 770 Mham and the Bay of Bengal and about 340 Mham of water. Of the monsoon moisture about 25 to 30 per cent precipitates in the form of rainfall. During the remaining eight months of the year also, there is a substantial amount of moisture over the country. This, however, has not as yet been scientifically assessed. It contributes a precipitation of the order of 100 Mham, a small part of it being in the form of snowfall.

2.2 Rainfall in the country varies from place to place and from year to year. It is recorded by about 3000 rain gauges set up by the Indian Meteorological Department and the State Governments. The country's average annual rainfall is about 119.4 cm and the average annual precipitation 392 Mham. This may be rounded off to 400 Mham including snowfall which is not yet fully recorded.

2.3 When rain falls, a portion of it soon evaporates from the ground or the vegetation that may intercept it, a portion soaks into the ground and the rest flows away over land as runoff. When a shower is very light, say of the order of 2.5 mm or less, it only moistens a few millimetres of top soil and then evaporates rapidly. It neither contributes to surface water nor to groundwater. There are on an average 130 rainy days in a year in the country and on 75 days the rainfall is of the above magnitude. Also, on the remaining 55 days of rainfall, there is similar evaporation at the commencement of rainfall. Taking these factors into consideration, it is estimated that out of the average annual precipitation of 400 Mham, about 70 Mham is lost to atmosphere. Of the remaining 330 Mham, about 115 Mham flows as surface runoff and the rest, 215 Mham, soaks into the ground.

3 Surface flows

3.1 The surface water flows consist of direct runoff from rainfall, snowmelt and flows in streams regenerated from groundwater. The Irrigation Commission of India has placed the total annual surface water flows in the country at 180 Mham. This figure was based largely on statistical analysis of the flow data wherever available and on suitable rainfall-runoff relationship where observed data were meagre. It includes about 20 Mham brought in by streams and rivers from catchments lying outside the country. About 45 Mham pertain to regenerated flow from groundwater as assessed from river flows during non-rainy months. The remaining 115 Mham constitute direct contribution by precipitation of which about 10 Mham is received as snowfall.

3.2 The surface water is disposed of in three ways. Part of it is stored in reservoirs or is utilised directly by diversion or pumping, part disappears as percolation from streams where groundwater table is below the stream surface and the rest finds its way to the sea, a small portion evaporating in the process. A portion of the water stored in reservoirs is lost through evaporation and a small amount through seepage; the rest is utilised for various purposes, mainly irrigation. With the construction of more projects, there would be a change in the quantities involved in the various processes through which surface water passes. More of it would be utilised and there would be less flowing down to the sea.

3.3 Of the total surface water of 180 Mham available in the country in an average year, about 15 Mham is stored in various reservoirs and tanks. There is evaporation loss of the order of 20 per cent from major and medium reservoirs and 40 per cent from tanks. The percentage loss is greater in tanks because they are relatively shallow. This evaporation loss is about 5 Mham per annum at present. But with future construction of projects, the storage water would ultimately be about 35 Mham and the loss about 10 Mham.

3.4 Of the 165 Mham of water that flows in the rivers annually at present, the utilisation through diversion works and direct pumping aggregates to 15 Mham, which is more than that from storage works. The remaining river flow of 150 Mham goes to the sea and some adjoining countries. On full development, the use of water through diversion works or direct pumping is expected to increase to 45 Mham. The balance 105 Mham would continue to flow to the sea and outside the country.

4 Infiltration

4.1 When it rains, the first claim on rainwater is that of soil to bring

the soil moisture to field capacity. Of course when the intensity of rainfall is higher than the rate of infiltration into the soil, there is surface flow even before the soil is saturated. But it is only after the soil has absorbed water to field capacity that water starts percolating down to watertable and adds to groundwater reservoir. The contribution of rainfall to groundwater in any area depends upon the intensity of rainfall, the depth and permeability of the soil and the nature of vegetable cover. On the basis of permeability of soils in different regions and the rainfall there, it has been estimated that for the country as a whole about 12.5 per cent of the total precipitation infiltrates to the groundwater table. Thus, out of 215 Mham that soaks into ground in an average year, only about 50 Mham percolates to watertable and the rest is retained by the soil as soil moisture. In future, various soil conservation and water harvesting measures should increase the groundwater recharge but that is likely to be offset by reduced percolation due to expansion of urban areas, roads and other non-absorbent surfaces. Therefore, no significant change is to be expected in the contribution to groundwater from rainfall.

4.2 In an irrigation system there are seepage losses both from channels and the irrigated fields and only a portion of irrigation supplies are actually utilised by crops. A portion of the water that seeps is retained in the soil as soil moisture and the rest percolates to the watertable. In the alluvial plains of north India, about 45 per cent of the water that is let in at the head of an unlined canal system is lost from channels through seepage. Of the remaining 55 per cent which reaches the field, another 17 per cent is lost from the field itself. Thus only about two-fifths of the water let into a canal is actually utilised. In heavier soils, or where the channels are lined, the loss is less. It is estimated that at present about 5 Mham is retained in the soil as soil-moisture and about 12 Mham is added to groundwater in this manner. On full development of irrigation in the country, the contribution to soil moisture and groundwater is expected to be about 15 Mham and 25 Mham respectively.

4.3 During the rainy season when a river is in a high stage of flow, its water surface along most of its course is higher than the adjoining groundwater table. Some river water, therefore, infiltrates and adds to groundwater. Such additions, in an average year, have been estimated to be of the order of 5 Mham. For inducing greater groundwater recharge, the watertable along the streams should be depressed through greater exploitation of groundwater before the rainy season so that a larger quantity of water may infiltrate during their high flows. In course of time when this gets done, the contribution to groundwater from rivers and streams may be of the order of 10 Mham.

5 Groundwater

5.1 With the addition of 5 Mham from flood flows and 12 Mham from irrigation systems to the 50 Mham from precipitation the total groundwater, excluding soil moisture, comes to 67 Mham. This, on development of water resources, is likely to increase to 85 Mham. A portion of the groundwater evaporates through capillary action or is drawn by plants for transpiration in areas where the watertable is high, a portion is extracted through wells, tubewells, etc. for irrigation and other purposes and a large portion is returned to the surface is regenerated flows in rivers Any portion that is not disposed of in the above manner makes an addition

to the groundwater reservoir and raises the watertable. It is estimated that at present, of the total groundwater amounting to 67 Mham replenished on an average annually, 13 Mham is extracted for various uses, about 45 Mham regenerates into rivers and the rest is accounted for by evapotranspiration and raising of groundwater table, etc. On near full development of water resources, the extraction is expected to rise to 35 Mham, evapotranspiration reduced to 5 Mham because of lowering of watertable and the remaining 45 Mham returned to surface on regeneration. It may not be desirable to reduce the regeneration in the streams by excessive extraction of groundwater, as the low stream flows in the non-rainy season consist mostly of regenerated water. These low flows in most of the streams are utilised for various purposes along their course and any reduction in them would affect these uses and also aggravate the problem of river water pollution.

6 Transpiration

6.1 Transpiration takes place from irrigated crops, unirrigated crops, and forests and other vegetation. On the basis of the prevailing temperatures and humidity and consequently the rate of transpiration, in different regions for each crop period, the amount of transpiration from irrigated crops has been estimated to be 13 Maham. Likewise, that from unirrigated crops amounts to 42 Mham and from forests and other vegetation 55 Mham. The present total transpiration thus amounts to 110 Mham. With development of irrigation, the irrigated area will increase and there will be a corresponding reduction in unirrigated cropped area although there will be an overall increase in the gross area sown. No significant change is expected in the forest area in future. On full development of irrigation, the transpiration from these categories of vegetation is expected to be 35 Mham from irrigated crops, 35 Mham from unirrigated crops and 55 Mham from forests and other vegetation, a total of 125 Mham.

7 Evaporation

7.1 In the hydrological cycle, evaporation is a major item. It has earlier been stated that as rain falls, about 70 Mham evaporates out of the total precipitation of 400 Mham. At present, about 5 Mham evaporates from reservoirs, tanks etc. and a similar amount from high groundwater areas. Of the total soil moisture of 170 Mham, which on an average is replenished annually, 110 Mham is utilised by crops, trees and other vegetation and the remaining 60 Mham evaporates. Assuming that there would be no significant change in precipitation in the near future, the evaporation from it would remain more or less the same. That from storage reservoirs, tanks, etc., would increase to about 10 Mham on development of water resources. On the other hand, with exploitation of groundwater, the area having high groundwater table and consequently evaporation from it would decrease. With an increase in the gross cropped area, more soil moisture would be utilised for transpiration and less would be left for evaporation. These reductions, however, would be relatively small.

Approximate Distribution of Average Annual Water Resources of India as in 1974, (2000 A.D.) & 2025 A.D.

(million hectare metre)