Country Policy Support Programme (CPSP)

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Proceedings of

IWMI / ICID Scenario Development Orientation Workshop for India & China

3 - 4 September 2004
Moscow, Russia

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International Commission on Irrigation and drainage (ICID)

IWMI / ICID Scenario Development Orientation Workshop for India & China

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1. Introduction

With the funding support of the Sustainable Economic Development Department, National Policy Environment Division, Govt. of The Netherlands, International Commission of Irrigation and Drainage (ICID) launched in August 2002 the Country Policy Support Program (CPSP) to contribute objectively by developing effective options for water resource development and management to achieve an acceptable food security level and sustainable rural development in five countries viz. China, India, Egypt, Mexico and Pakistan.

As part of the CPSP studies, International Water Management Institute (IWMI) and International Food Policy Research Institute (IFPRI) were to upgrade the IWMI'S PODIUM and IFPRI's IMPACT-WATER models to address country specific issues for wider use by the policy makers and researchers and also to increase the interaction between the two models. Policy Dialogue Model (PODIUM) developed by the IWMI in 1999, as part of the World Water Vision exercise, was extensively used by researchers and policy makers in developing country vision scenarios. The upgraded PODIUM model, called PODIUMSIM is adapted for two countries India and China. The PODIUMSIM model for India and China facilitates generating future water supply and demand scenarios at river basin level.

The Scenario Development Orientation Workshop[1], held on 3rd and 4th of September 2004 in Moscow, Russia, was a part of the IWMI/IFPRI component of CPSP studies. The overall purpose of the workshop is to bring policymakers and researchers of India and China to provide information and generate future scenarios of water supply and demand for the two countries. The information generated by PODIUMSIM facilitates the discussion around key issues of water supply and demand. The Agenda of the workshop is kept as **Annex 1.**

The workshop to consider the above provided a platform for ICID also to introduce the works accomplished by them in respect of evolving an Integrated Basin Model for Land and Water Resources Development and Management. Such scenario development with corresponding impacts could help better decision making.

The workshop was attended by 24 professionals comprising wide array of relevant disciplines like engineers, economists, environmentalists, sociologists, policy makers/planners, agronomists from China and India besides experts from ICID, IWMI, IUCN and WWF. **Annex 2** provides list participants along with their contact co-ordinates.

This document is an overview of the proceedings of the workshop, including the major findings of basin assessments with a summary of presentations of the group discussions for India and China, and conclusions. Workshop background papers and other written inputs received from some participants are included as **Annexes**.

2. Overview of Workshop Proceedings

IWMI and ICID jointly handled the session proceedings integrating the efforts of the two organisations under CPSP. Dr. David Molden, Leader, Comprehensive Assessment Program welcomed the participants on behalf of IWMI and appreciated their enthusiasm to attend the workshop. He expressed desire to have a fruitful dialogue among experts of various disciplines.

Er. M. Gopalakrishnan, Secretary General, ICID while welcoming participants provided a brief background of the CPSP funded by Sustainable Economic Development Department, National Policy Environment Division of the Govt. of The Netherlands. The Secretary General emphasized the value of

[1] The workshop was originally planned in August 2003, however, it was getting postponed since then due to certain difficulties and the same was held in Moscow coinciding with the 55th meeting of the International Executive Council (IEC) of ICID

the workshop for exchanging ideas between researchers and policy makers in various disciplines in assessing future water needs of different sectors and their inputs to the CPSP study.

Delivering key note address Ir. Keizrul bin Abdullah, President, ICID touched upon the genesis of the CPSP and the workshop and said that there was a need for more scientific basis to decide future water demands for irrigated agriculture and food production. He emphasized the importance of dialogue to increase communications between different stakeholders of water use. Ir. Keizrul said that the present workshop is significant as stakeholders from different disciplines and concerns (especially engineers, environmentalist, scientists and socio-economists) dealing with the water policy could be brought together under the programme. He mentioned that the interactive roles of different disciplines need to be recognized while suggesting desirable future directions in water policies. The workshop provides a platform for policy makers and researchers of various disciplines to exchange ideas, enhance knowledge base and appreciate concerns of other disciplines; the process that would lead to generating realistic supply and demand scenarios for water use for different sectors, especially for food, people and environment. He hoped that the new model viz. Basin wide Holistic Integrated Water Assessment (BHIWA) evolved by ICID under CPSP study would be a valuable contribution for scenario development. Although models cannot be a substitute to "Dialogue process", yet they are important to provide a basis for furthering the dialogue objectively, rather than in a subjective manner.

Application of BHIWA model to select river basins of India and China and implications of findings at national level were presented on the first day morning session. Rest of the workshop time was devoted for discussions of scenario development and of the key drivers of the PODIUMSIM model.

3. Major Findings of Basin Studies in India and China

3.1 *River Basin Studies of India*

Messrs A.D. Mohile and L.N. Gupta of CPSP India Study Team Leaders presented the findings of two river basin studies selected under CPSP in India. The studies addressed one water surplus river basin (Brahmani river basin in the east) and one water deficit river basin (Sabarmati in the west of India).

The Basin wide Holistic Integrated Water Assessment (BHIWA) computer model developed for assessment of water resources at the basin scale was used in both India and China basin studies. The model accounts for natural and anthropogenic interactions within the hydrologic cycle, provides an overall water balance account at basin level and enables the user to formulate and analyse alternative scenarios of integrated water resource development and management (IWRDM) and their implications on the surface and ground water regime. Thus it helps decision makers to appreciate the impacts on choices leading to appropriate and acceptable interventions.

Brahmani river basin: The application of the CPSP model had demonstrated that this basin would not be water short even with an increase in agricultural and industrial water use scenarios. The study showed that the nature sector is by far the largest consumptive water use sector. There is a risk of water logging in the future, if ground water use is not enhanced and further storage development would be required for meeting additional withdrawal requirements. Better watershed management for increasing productivity in the rainfed agriculture has also been indicated.

Sabarmati river basin: The studies in respect of this basin had indicated that the potential strategies for water management are to use water harvesting and soil and water management to reduce non-beneficial Evapo-transpiration (ET) in the nature and agriculture sectors, which exceeds annual river flow. The study found unsustainable ground water exploitation at present with increased risk of water pollution. The contemplated water diversions from the Narmada river basin would reduce unsustainable water use to some extent and deserves support for meeting future water withdrawals and improving low flows, a desirable measure to enhance the environmental quality.

Extrapolation to other river basins of India

- The model results were helpful to attempt an extrapolation of the results of the two sample basin studies for a scenario projection at country level and provide support for policy decisions.
- The extrapolation showed similarities of inference of surface water issues of

the Sabramati basin to the issues in the Pennar, Cauvery, Indus, Ganga, Subarnarekha, Mahanadi and Tapi river basins and groundwater issues of the Sabramati basin to the issues of Indus, Ganga, Subarnarekha, Krishna, Pennar and Cauvery.

- The implications of issues arising at the Brahmaputra and Godavari river basins are similar to those due to high flows and low groundwater use in the Brahmani river basin.

3.2 *River Basin Studies of China*

Dr. Gao Zhanyi, Mrs. Wang Shaoli, and Mrs. Mu Jianxin of Chinese National Committee (CNCID) presented the findings of two river basin studies in China, which included Jiaodong peninsular basin in the south-east and Qiantang river basin in the north-east of China.

Jiaodong river basin: The application of the BHIWA model in respect of this basin, which is water deficit, indicate that consumptive use of the nature sector would increase with expanding area for forest and non-beneficial ET in agriculture would decrease. Compared with the increase in command area, the beneficial ET in the basin would considerably increase with better water management. The groundwater use is high (86%) at present and should be moderately exploited in the future. Water requirement for agriculture is likely to be increased by 40% in future. With increase in D&I water use in future, the agriculture is likely to face serious water shortage. The expansion of forest area should be consistent with the local water resource availability and agricultural development. With increase in water use and changing water use pattern, the rate of return flows to surface water would increase, leading to risk of water pollution. Thus, measures to prevent/ reduce water pollution need to be adopted.

Increasing return flows would risk water pollution and preventive measures are required which have been brought out in the policy support measures.

Qiantang river basin: Due to relatively abundant surface water resources in the basin, almost entire irrigated agriculture including fisheries is presently dependent on surface water resources. The proportion of irrigation withdrawal to total withdrawal is expected to be reduced from the present 0.76 to 0.45 in future. Surface water withdrawal constitutes only a small fraction of available supplies and seems to be constrained by availability of cultivable land. At present, a small proportion of groundwater is exploited for Irrigation and D&I use, and thus there is a huge potential for increasing groundwater withdrawals in future. With the rapid growth of population and quick development of industry and urban area, withdrawals for D&I use are likely to be doubled in future.

Consumptive use under nature sector is expected to increase significantly in future due to the expansion of forest area. This in turn would tend to reduce river flow. Part of this decrease can however be restored through better soil and water management initiatives. As surface and ground water resource are abundant in the basin, there is a scope to export water to other basins.

Extrapolation to other river basins in China: China is a vast country and water supply and demand vary substantially in large river basins. However, similarities with respect to ratio of water withdrawals to runoff in both surface and groundwater do exist respectively between Jiaodong and Songliao, Yellow river, Huaihe and Haihe river basins and Qiantang and Yangtze, Pearl, Southwest and Southeast river basins.

4. Scenario Development

Soon after the joint session in which expert presentation of IWMI & ICID, participants regrouped themselves in groups so as to concentrate on focus areas. Given the issues of addressing options for water supply and demand to meet food security with due concern to environment, two groups of Indian participants and one group of Chinese participants were formed. All plausible scenarios were discussed so as to analyze quantitatively and qualitatively the implications of the developed frameworks and their assumptions. One scenario prioritized water for food and people and the other prioritized water for people and nature.

India Group 1 - Water for food and people: This group built the framework in line of “Development of water resources (storages) for food and water security”. The group noted several recent trends including the attainment of a plateau in net sown area, contribution of irrigation for increasing cropping intensity, and achieving stable crop yields, problems in classification of rainfed lands, and national self

sufficiency targets for food production. The group felt that globalisation of world economy by removing migration barriers (labour mobility) along with trade barriers will change scenario of virtual water trade. The main paths to rural poverty alleviation in the future could be through increasing urbanization, generating employment in the services sectors and extending irrigation facility to more cultivable area. The quantification of the main drivers is given in following table.

Drivers	Present condition			Desired future (in 2025)		
	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total
Net cultivated area (Mha)	60	80	140	80	60	140
Gross cultivated area (M ha)						
1st season (Rabi+hot weather)	35	30	65	50	20	70
2nd season (Kharif)	60	70	130	80	80	160
Total (Mha)	95	100	195	130	100	230
Grain production						
Area (M ha)	95	100	195	130	80	210
Yield (ton/ha)	1.5	0.7		2.5	1.3	
Production (M ton)	142.5	70	212.5	325	104	429

Though storage requirement to meet the needed irrigation expansion was not quantified by the group, creation of storages through local initiatives (e.g. rain water/ runoff harvesting, ground water recharge) and large scale measures through major and medium irrigation schemes stood acknowledged as essential.

India Group 2 - Water for people and nature: This group developed framework for three scenarios and the drivers (mainly qualitative) area as follows:

Scenario 1

- Find best ways to use water at local scale
- Respect historical rights of water use, implying that creation of large storage reservoirs may be reduced to some extend (like in Mekong)
- Design systems based on needs
- Apply similar considerations to regional countries (as Prime Minister of India mentioned in the last South Asian Association for Regional Cooperation (SAARC)[2] summit held at Islamabad, Pakistan in July 2004)
- Pass on experiences of reform process to other SAARC countries, and
- Give priority to ground water development, water harvesting, watershed development and local ponds as appropriate and needed.

Scenario 2

- River basin planning with increase in storages - leading to conjunctive use
- Developing operational strategies for local level water management institutions, community collateral for financing, and new organisations
- Assessing the technology potential in highly stressed regions and looked into very seriously in achieving them, and
- Making them compatible with WTO guidelines as set at Geneva, but if progress is slow develop alternative scenarios.

Scenario 3

- Developing scenarios for high, low population projections and also for stabilisation year around 2050
- Developing scenario with regard to food production based on agro-climatic donations
- Appropriating rights, for both existing and new storages, are not based on water but based on function (land) and water saving should lead to greater equity

[2] The South Asian Association for Regional Cooperation (SAARC) comprises Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan and Sri Lanka. SAARC is a manifestation of the determination of the peoples of South Asia to work together towards finding solutions to their common problems in a spirit of friendship, trust and understanding and to create an order based on mutual respect, equity and shared benefits. The main goal of the Association is to accelerate the process of economic and social development in member states, through joint action in the agreed areas of cooperation

- Developing a policy on conjunctive use (watershed, upstream, storages)
- Improving existing canal systems
- Releasing 7-10 percent of gross storage in the non-monsoon period as minimum river water flow
- Progressive increase in water rates based on volumetric releases
- Measuring storage in October and sharing the deficit/ surplus by all riparian water rights holders, and
- Shifting the investment allocations to 40:30:30 amongst large storage, watershed and ground water development.

China Group

This group mainly built the framework keeping a balance approach to water for food and environment. Group noted following important trends.

- Population is still increasing though growth rate is decreasing
- Present agriculture share is 70 percent of the water withdrawals (about 550km^3) but there is an increasing demand from the domestic and industrial sectors
- Irrigated farm land produces about 75 percent of the total grain production and 95 percent of the cash crops
- Increasing demand for water for people due to urbanization
- Ecological degradation, drying up of rivers, peoples desire for better environment for leisure activities thus requirement of more water for nature sector

The China Group noted that future scenarios need to consider following –

- The level of water use efficiency increase in irrigation under different national self sufficiency targets
- Same level of water withdrawals for irrigation in the future
- WTO guidelines and international trade
- The water availability under basin water transfer projects from south to north.

5. Key Drivers of PODIUMSIM

Dr. Upali Amarasinghe (IWMI) presented the analysis and findings of the PODIUMSIM. The participant provided several constructive comments on the key drivers of the PODIUMSIM. The default scenario of the models at present describes the Business as Usual scenarios (BAU) of the water vision exercise. The group noted that for effective use of the model by the policy makers and researchers in respective countries, it should use scenario drivers as used by Planning Commission or similar Authorities of respective countries, in place of present default scenario drivers. This is especially true for PODIUMSIM India model, as several modeling groups have developed scenarios separately for different component such as consumption, production, water supply and demand. Integrating them into the PODIUMSIM model would help especially to look into the issues related to integrated water resources development and management of river basins. Participant's emphasized the fact that the model can be used to do a sensitivity analysis of the national projections with respect to the changes in the drivers of the model.

6. WATERSim

To provide an objective and scientifically sound basis to debates on water for food and environment, the International Water Management Institute (IWMI) and International Food Policy Research Institute (IFPRI) embarked on a joint modeling exercise, resulting in the WATERSim (Water, Agriculture, Technology, Environment and Resources Simulation Model).

The WATERSim[3] model builds on IMPACT-WATER, an economic and water simulation model developed by IFPRI and PODIUM, an agro-hydrological model developed by IWMI and aims to explore the impact of water and

[3] The possibility of integration of ICID's BHIWA and the IWMI's PODIUMSIM models was also discussed in the workshop. However, IWMI felt that it was not necessary at the moment as IWMI and IFPRI are working on integrating the PODIUM and IMPACT-water models. However, as the Integrated model i.e. WATERSIM is likely to take more time, incorporating the input of this model in the phase I of CPSP study is not possible, at this juncture. Not only these models require improvements but also verification so as to make them effective in facilitating the dialogues discussion on different water use sectors.

food related policies on water scarcity, food production, food security and environment.

IWMI indicated that that WATERSim is in early stage of its development. It will take some time before it is completed. It needs to be tested on trial basis, revamped if necessary, and then becomes operational. The consensus was that scope of WATERSim could spill over to a possible future programme & hence be dropped from CPSP phase I.

7. Environmental Flow Assessment

The discussion of the environmental flow assessment and its implementation in the models was an important point of discussion for all participants. ICID's CPSP envisages an approach for looking into environmental flow assessment in the BHIWA model. The BHIWA model can consider externally specified monthly values of EFR, and would adjust the surface and groundwater withdrawals to meet the EFR requirements, as far as possible. However, the model does not internally decide or give guidance about EFR in the absence of an accepted methodology. An acceptable methodology for a quick assessment of EFR could be included within the model in future accounting for further research & development by other agencies. This methodology may have to be country specific, since there would be subjectivity about what is acceptable.

The participants who research on issues in environmental water requirements assessment strongly expressed a view that one has to go beyond hydrology or the minimum river flow estimation for environmental flow assessment. Ecological factors are complex and still indeterminate.

All participants agreed that more dialogue is needed between the water resources engineers assessing water needs for food and people sectors and ecologists/ biotechnologists in assessing water needs of the nature/ environment sector. The cross cutting interests are well appreciated and such interactive sessions by experts belonging to different disciplines and interest groups are extremely useful and timely. Dialogue process should continue.

8. Conclusions

The general consensus of the workshop was that water is a crucial factor for food security, livelihood, and poverty alleviation especially of rural people and also for a healthy environment.

The methodology of environmental water needs assessment including minimum river flow requirements needs be further development for objective inclusion in river basin water use assessment. The priority or first charge is a question which will be specific to a particular case depending on the settings in which a basin is placed besides other affecting socio-economic factors, development level and requirements based on population stress. Other options for assessing water for environment (ecological flows using eco-systems approach) are in developing stage.

ICID's efforts in development of the BHIWA methodology stood acknowledged. The model may need further upgradation to consider the interactions between land, water, production, environment and technology.

As there are wide variations of water supply and demand in large basins, the extrapolation of the findings from the selected river basins (which are relatively of smaller size) to large basin may have to be cautiously handled.

In basins likely to be closed or even in basins where all the available low flows are already allocated for in stream uses like navigation or ecology, there is no "wastage" of water. Thus, basin efficiency concept is more relevant in hydrological terms, than efficiencies of individual system. System efficiencies would continue to be important, if not for water saving, for saving investments or improving productivity elsewhere. However, the concept of 'closed basin' is itself a matter requiring reconsideration as 'import' can modify the situation.

The PODIUMSIM needs to be modified to include the scenarios developed by the countries concerned as its default scenario. These would help the policy makers and researchers of the respective countries to assess the sensitivity of different drivers on their assessments and projections. It was suggested that water assessment need to be projected up to a time by which population is likely to stabilise. Similarly, while developing scenarios only such scenario which have some possibility of acceptability and achievability should be developed. Local area requirements may be given importance and local solutions may be preferred. PODIUMSIM is however useful in stimulating the discussion among the various groups.

Relative merits of different types of water resources investments are difficult to gauge. The potential for groundwater development, water harvesting, upgrading rainfed agriculture systems and their effects on basin hydrology needs careful consideration and development plans should factor them given their importance to achieving equity & spread.

The group ended with a positive note as to some convergence of opinion is feasible by such intervention and the process should be encouraged. The CPSP phase I addressed, in a limited time and manner, a few basins in India & China and facilitated an overview of policies in Egypt, Mexico and Pakistan, given the future pressure for food security and environmental needs. More works are to be undertaken and meaningful dialogue should be encouraged. Such a programme can be extended to cover the unexplored aspects and extensive coverage of more basins, not only in India & China but also in other countries.

Annex 1

Agenda of the workshop

IWMI / ICID Scenario Development Orientation Workshop for India & China
September 3rd and 4th 2004, Moscow, Russia

Background

The goal of the "Country Policy Support Programme (CPSP)" of the ICID is to contribute to develop effective options for water management to achieve an acceptable food security level and sustainable rural development while integrating needs of the three sectors, through assessments made primarily in India and China. The CPSP outputs will be available for the Dialogue on Water, Food and Environment which aims at bridging the gap between food and environmental sectors through open and transparent dialogue after generating necessary knowledge base where necessary.

The IWMI and IFPRI component of the CPSP is to improve and upgrade the PODIUM and integrate it with IMPACT-Water[3] model for wider use by policy makers and researchers in developing countries. The improved models will help assess future food and water needs and support the preparation of National Water Policy interventions for India and China. The improved version of the PODIUM model, PODIUMSIM has been applied for India and China at the country level, and in two detailed basin studies in each country. PODIUMSIM allows for the development of alternative scenarios by changing such variables as irrigated and rainfed area and yield, levels of national food self sufficiency and trade, and population and nutrition levels, and environmental flow requirements. As such, the model is ideal for achieving objectives of CPSP and lead to facilitate Dialogue on Water, Food and Environment.

The overall purpose of the orientation workshop, in line with CPSP objectives is to provide information and generate ideas in support of country policy development. It will bring together people of scientific perspectives to jointly explore different scenarios of future water use. PODIUMSIM will be used as a tool to stimulate discussion around key issues. The workshop aims to bring better understanding of various points of view; to build bridges between proponents of various viewpoints; and to hopefully spark new thinking on improved future water management.

Workshop Objectives

- To share the results of CPSP basin studies and PODIUMSIM applications of India and China and on their contribution in generating primarily consumptive water allocation sceneries in the two countries for the three sectors food, people and nature
- To improve understanding of issues of water, food and environment by generating alternative scenarios and considering their implications for food security and environmental sustainability.
- To provide feedback to future model development.

Process

To achieve the objectives, a two days workshop is proposed on 3rd and 4th of September 2004 in **Moscow, Russia**. The participants of the workshop are expected to discuss the important issues and drivers of future water supply and demand scenarios for the two countries and the food security, and environmental sustainability implications that would arise from different scenarios. A workshop report will be prepared that highlights key points and issues discussed during the event, and plans for future action.

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[3] IWMI and IFPRI are joining efforts to produce WaterSIM under the Comprehensive Assessment of Water Management in Agriculture. PODIUMSIM, developed as part of the WaterSIM package, is ready for both India and China.

IWMI / ICID Workshop
3-4 September 2004, Moscow, Russia

Day 1 – September 03, 2004

08:15-08:45	Registration
08:45-09:00	Welcome speech by the Secretary General ICID
09:00-09:15	Key note speech by the President ICID
09.15-09.30	CPSP basin assessment model – an introduction
09.30-10.45	CPSP basin assessments for selected basins in India and China
10.45-11:15	Tea/Coffee
11.15-12.00	CPSP basin assessments for selected basins in India and China (contd..)
12.00-12.45	CPSP basin assessment results – policy interventions as also EFR and other improvements needed
12.45-13:45	Lunch
13:45-14:15	PODIUMSIM/Key issues for scenario development Diet, Population, Irrigated and Rain-fed agriculture, water transfers, Needs for domestic/industrial purposes, water consumed by ecosystems needs and Trade
14.15-14:45	Introduction to the working groups (what should be done in the next 2 days. How it should be done? Explanation of four working groups and rationale for grouping participants into groups)
14.45-16:00	Scenario Development (4 working groups– 2 from India and 2 from China). The two working groups from each country work on two different themes. <u>Group 1 and 3</u> Water for Food: Meeting national food demand through efficient water utilisation and further development- Issues and Impacts on consumptive water sharing between Food, People & Nature Sector <u>Group 2 and 4</u> Water for People & Nature: Meeting requirements in the basins- for terrestrial & aquatic eco-systems, degradation due to domestic and industrial waste-waters
16:00-16:15	Tea/Coffee
16:15-17:15	Interactive session with PODIUMSIM
17:15-17:45	Wrap up of the discussions within the groups and finalization of group outcomes for “Report Back” session the next day. Group facilitator to prepare the finding/outcome notes.
17.45	Group dinner

Day 2 – September 4, 2004

09:00-09:10 De-briefing on day 1

9.10-10:30 Report back sessions focuses on-.

- Scenarios
- Processes on scenario development
- Issues identified in the process
- Implications on food security and environmental sustainability

Group 1: Water for Food & People (Indian scenario)
Group 2: Water for Nature (Indian scenario)

	Group 3: Water for Food & People – (China scenario) Group 4: Water for Nature – (China scenario)
10.30-11:15	Discussion on water for food, people and nature- generated scenarios
11:15-11:45	Tea/Coffee
11.45-13:15	Water for food, people and nature Scenarios (India and China groups)
13:15-14:15	Lunch
14:15-15:15	Reporting Back session on the group discussions of China and India
15:15-15:45	Tea/Coffee
15:45-16:15	Introduction to framework of WATERSIM
16:15-17:00	Discussion on WATERSIM
17:00-17:30	Summary of key issues and sum-up plenary and recommendations
17.30	Free evening

Annex 2

IWMI/ ICID Scenario Development Orientation Workshop for India & China
3-4 September 2004, Moscow, Russia

List of participants

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Annex 3

Workshop Background Papers
IWMI / ICID Scenario Development Orientation Workshop for India & China

Background paper

Upali A. Amarasinghe

The IWMI/IFPRI component of the ICID's Country Policy Support Program improve and upgrade the Policy Dialogue Model, PODIUM and integrate it with IMPACT-Water model for wider use by policy makers and researchers in developing countries. The upgraded PODIUM models, now called PODIUMSIM are available for the two countries India and China. The PODIUMSIM allows for development of alternative scenarios of food and water supply and demand. The model generates scenarios according to changes in key factors, called drivers, including population and nutritional requirement, irrigated and rainfed area and yield of different crops, food self sufficiency and trade, water requirements of irrigation, domestic, industrial and environmental sectors. The PODIUMSIM model is an interactive tool in simulating discussion around key issues of water for food, people and nature.

The primary objectives of the IWMI/ICID workshop are

1. to share the results of detailed studies of two basins in India and China by the INCID and CNCID and
2. to develop alternative scenarios of water for food, people and nature for India and China using PODIUMSIM as a supporting tool.

The scenario development in objective 2 includes

1. investigating options for meeting water for people and water for national food demand through better utilization and new development and their implications on environmental sustainability
2. investigating options for meeting water for people and water for nature and their implications for meeting national food security and
3. investigating options for meeting water demand for people, food and environment and their implications on food security and environmental sustainability.

Default Scenario in PODIUMSIM

To assist developing alternative scenarios, PODIUMSIM provides default scenarios for river basins of India and China. The default scenarios are mainly based on the assumptions of the Global Water Vision Business as Usual (BAU) scenario (Rijsberman 2000) and also on the assumptions of IWMI base scenario (IWMI 2000) and the country panning commission reports (GOI 2000,). Changes to drivers of default scenario generate different options under alternative scenarios. The projections and the growth rates of the key drivers under default scenarios are provided here. The detailed information of river basins for India and China is available in the PODIUMSIM India and PODIUMSIM China models.

Key drivers of PODIUMSIM model

The PODIUMSIM model has four main components estimating crop consumption, crop production, water demand and water supply.

Crop requirement estimation module has following key drivers.

1. Urban and Rural population growth
2. Growth of total calorie supply per person

2.1 Growth of calorie supply from grain (including rice, wheat, maize, other cereals, Pulses for India and including roots and tubers for China.
2.2 Growth of calorie supply from oil crops
2.3 Growth of Calorie supply from fruits and vegetables
2.4 Calorie supply from animal product

3. Per capita food consumption of rice, wheat, maize, other cereals, pulses, oil crops (equivalent), vegetables,
4. Conversion ratios of feed to calorie supply from animal products(kg of feed per 1000 calories)
5. Seeds+Waste+other use as a percent of total consumption

Annex tables 1a and 1b show the total grain requirement of different basins under the default scenario in India and China.

The domestic grain consumption (rice, wheat, maize, other cereals and pulses) in India under the default scenario is projected to increase from 187 M MT in 1995 to 284 M MT by 2025. In per capita terms it increases from 552 grams per day to 586 grams per day. The food consumption is projected to increase slightly from 490 grams/day per person in 1995 to 509 grams/day per person in 2025.

The domestic grain consumption (rice, wheat, maize, other cereals, pulses, dry equivalent roots and tubers) in China is projected to increase from 403 M MT in 2000 to 532 M MT by 2025. Per capita domestic requirement is projected to increase from 862 grams/day to 1015 grams/day. Of this per capita food consumption is projected to decrease from 549 grams/day to 500 grams/day.

Crop production estimation module has following key drivers.

1. Net crop area
2. Gross crop area
3. Net irrigated area
4. Gross irrigated area
5. Irrigated and rainfed area of rice, wheat, maize, other cereals, pulses, oil crops, vegetables, roots and tubers, sugar, fruits and cotton and
6. Irrigated and rainfed yield of rice, wheat, maize, other cereals, pulses, oil crops, vegetables, roots and tubers, sugar, fruits and cotton.

Annex tables 2 (a & b), 3 (a & b) and 4 (a & b) give the irrigated and rainfed grain crop area, yield and production of different basins in India and China.

The grain production in India is projected to increase from 187 M Mt in 1995 to 255 M MT in 2025. In 1995, the grain area was 65 percent of the gross sown area. This is projected to decrease to 62 percent by 2025. Irrigated grain area is projected to increase from 39 percent of the total crop area in 1995 to 50 percent of the grain area in 2025. The contribution irrigated area to total grain production is projected to increase from 61 percent in 1995 to 74 percent in 2025.

In China, the total grain area is projected to decrease from 561 percent to 58 percent over the period from 1995 to 2025. The irrigated grain area and production is projected to increase from 56 and 64 percents in 1995 to 59 and 71 percents respectively.

Crop Production surplus/deficits

The production of different crops, individually and also as aggregates for grains and non-grain crops are compared with crop requirements. The crop production surplus or deficit, the difference between crop production and requirement as percent of crop requirements shows the extent of trade required to meet domestic consumption requirement.

Table 1 (a & b) show crop production surplus or deficit as a percent of total crop requirements of different river basins in India and China.

Under the default scenario both countries are projected to record substantial grain production deficits. In India, small grain production surplus (0.1% of the consumption) in 1995 is projected to change to 8 percent production deficits in 2025. In China production deficits is projected to increase from 1.2 percent of crop requirements to 7.3 percent of the domestic requirement.

Table 1a. Grain crop production surplus/deficits - % of total requirement of Indian River basins

River Basins	Crop production surplus/deficit - % of total requirement					
	1995			2025 Default scenario		
	Grain crops	Non-grain crops	Total crops	Grain crops	Non-grain crops	Total crops
	%	**%**	**%**	**%**	**%**	**%**
Indus	226	-18	66	190	-51	13
Ganga	-17	-11	-13	-28	-33	-32
Bramhaputra	14	11	12	7	-23	-15
Barak & Others	-41	37	10	-49	-5	-17
Subernarekha	5	26	19	-7	-9	-8
Brahmani-Baitarni	15	87	62	6	41	32
Mahanadi	57	110	92	44	131	108
Godavari	-6	-9	-8	-6	-27	-22
Krishna	-14	-8	-10	-16	-21	-20
Pennar	19	-6	3	9	-21	-13
Cauvery	-19	-1	-7	-21	-9	-12
Tapi	-37	-24	-28	-53	-38	-42
Narmada	36	-42	-15	24	-54	-33
Mahi	-14	-33	-26	-31	-47	-42
Sabarmati	-45	-15	-25	-52	-44	-46
West flowing rivers 1	-32	-29	-30	-46	-58	-55
West flowing rivers 2	-56	40	7	-54	27	5
East flowing rivers 1	35	56	48	42	36	38
East flowing rivers 2	-10	-6	-8	-6	-16	-13
India	0.1	-1.2	-0.7	-9	-22	-19

Table 1b. Grain crop production surplus/deficits - % of total requirement of Chinese river basins

River Basins	Crop production surplus/deficit - % of total requirement					
	2000			2025 Default scenario		
	Grain crops	Non-grain crops	Total crops	Grain crops	Non-grain crops	Total crops
	%	%	%	%	%	%
Songliaohe	52	-43	-27	38	-35	-21
Haihe	-5	39	32	-10	39	30
Huaihe	19	23	23	11	15	14
Yellow river	23	-16	-9	9	-18	-13
Yangtze river	-7	-13	-12	-15	-14	-14
Pearl river	-41	7	-1	-46	5	-5
Southeast	-41	-12	-17	-46	4	-5
Southwest	-3	3	2	-17	6	1
Inland	46	59	57	45	45	45
China	0.9	-0.7	-0.5	-7.3	-1.6	-2.6

Water requirement module's four components estimate water requirements for agriculture, domestic, industry and environment. Following are the key drivers estimating water requirements of different sectors.

Agriculture water requirements:

1. Irrigated area of different crops
2. Groundwater irrigated area
3. Field scale irrigation efficiency of surface withdrawals
4. Field scale irrigation efficiency of groundwater withdrawals

Domestic water requirements

1. Per capita water demand in the rural sector
2. Per capita water demand in the urban sector
3. % population with pipe water supply in the urban and rural sectors
4. % water withdrawals from the groundwater resources

Industrial water requirements

1. Total industrial water requirement
2. % water withdrawals from the groundwater resources

Environmental Water requirements

1. River flow requirement
2. Percentage of river flow to be met from the potentially utilizable water resources

Annex tables 5(a & b), 6(a & b), 7(a & b), 8(a & b) show the key drivers of agriculture, domestic, industrial and environmental water withdrawals of river basins for India and China.

Total water withdrawals of river basins in India and China are given in tables 9 (a & b)

Water Supply module has following key drivers.

1. Potentially utilizable surface water resources
2. Potentially utilizable groundwater resources
3. Water transfers in and water transfers out of basins
4. Environmental water demand
5. Reservoir storage
6. Evaporation from reservoir storage

Annex table 10 (a & b) gives utilizable water resources of river basins in India and China.

PODIUMSIM present three indicators to assess the extent of water development and water scarcity in river basins. These are degree of development (ratio of primary water withdrawals to utilizable water resources), depletion fraction (process and non-process evapotranspiration and flows to sinks) and groundwater abstraction ratio (ratio of groundwater withdrawals to total available groundwater resources). These ratios for the basins in India and China are given in tables 2 (a & b).

Alternative scenarios

The default scenarios of the two countries show substantial grain production deficits (9% and 7% of the requirements for India and China). Though the degree of development under this scenario in both countries is close to 50 percent, several major basins will experience either physical water scarcity (high degree of development (IWMI 2000) or economic water scarcity (high growth of development).

The first alternative scenario can investigate alternative growth scenarios of several factors, especially

- population growth
- changes in consumption patterns including more livestock products
- locations and extent of crop area growth (irrigated and rainfed)
- cropping patterns change
- growth in crop yield increase in irrigated and rainfed agriculture

Table 2a. Degree of development, Depletion fraction and groundwater abstraction ratio of Indian River basins

River Basins	Indicators								
	Degree of development			Depletion fraction			Groundwater abstraction ratio		
	1995	2025 Default scenario	Total growth	1995	2025 Default scenario	Change	1995	2025 Default scenario	Change
	%	%	%	%	%	%	%	%	%
Indus	84	83	-1	93	93	0	70	82	12
Ganga	43	53	22	93	94	1	54	70	15
Bramhaputra	10	19	85	76	78	2	4	8	4
Barak & Others	14	31	115	82	81	-1	3	9	6
Subernarekha	41	57	37	91	92	1	49	69	20
Brahmani-Baitarni	25	33	31	92	93	1	54	72	18
Mahanadi	21	27	31	89	90	1	26	36	10
Godavari	27	35	29	92	92	0	36	48	12
Krishna	41	52	27	95	95	0	42	57	16
Pennar	108	112	3	91	92	1	63	76	13
Cauvery	48	57	21	93	94	1	52	67	15
Tapi	36	43	20	96	96	0	49	63	14
Narmada	20	28	40	94	94	0	30	42	12
Mahi	64	84	31	96	96	0	60	81	22
Sabarmati	67	82	22	95	95	0	91	107	16
West flowing rivers 1	150	154	3	93	93	0	194	210	16
West flowing rivers 2	22	33	47	94	94	0	40	62	22
East flowing rivers 1	45	55	23	86	87	1	24	32	8
East flowing rivers 2	76	88	17	92	93	1	46	59	12
India	42	51	21	93	93	0	51	64	12

On the water demand side this scenario can investigate alternative options of expansion of groundwater irrigated area, increase in field scale efficiencies in meeting the required water withdrawals. The discussion on this scenario should include an assessment of implications of the above growth rates on the environmental sustainability of river basins.

Table 2b. Degree of development, Depletion fraction and groundwater abstraction ratio of Chinese river basins

River Basins	Indicators								
	Degree of development			Depletion fraction			Groundwater abstraction ratio		
	1995	2025 Default scenario	Total growth	1995	2025 Default scenario	Change	1995	2025 Default scenario	Change
	Km^3	Km^3		Km^3	Km^3		Km^3	Km^3	
Songliaohe	44	44	-1	84	87	2	57	66	9
Haihe	96	105	10	89	90	1	92	109	18
Huaihe	72	73	1	87	89	1	62	78	15
Yellow river	64	75	17	86	87	1	63	97	34
Yangtze river	40	44	11	70	72	2	10	30	20
Pearl river	40	47	17	69	70	2	6	22	15
Southeast	55	55	0	72	76	4	5	15	10
Southwest	25	28	11	73	76	3	3	7	4
Inland	44	48	8	95	96	1	42	53	11
China	47	51	8	78	80	2	41	58	17

The default scenario assumes bare minimum river flow requirements as environmental water requirements. The second alternative scenario can investigate alternative options of higher environmental water requirements and their impact on meeting water for people and national food production demand.

Third alternative scenario can investigate alternative options from the first two scenarios for attaining both national food security and environmental sustainability.

Annex table 1a. Grain requirements of Indian river basins

Basins	Grain requirement of India (Grains include rice, wheat, maize, other cereals, Pulses)		
	1995	2025 Default scenario	Annual Growth
	M MT	M MT	%
Indus	9.8	15.6	1.55
Ganga	74.6	118.8	1.57
Bramhaputra	6.7	10.0	1.34
Barak & Others	2.0	3.2	1.54
Subernarekha	3.0	4.6	1.41
Brahmani-Baitarni	3.4	5.1	1.40
Mahanadi	5.5	8.0	1.26
Godavari	15.5	22.8	1.31
Krishna	13.9	19.8	1.20
Pennar	2.9	3.9	1.02
Cauvery	6.6	8.7	0.93
Tapi	3.6	5.6	1.45
Narmada	3.6	5.6	1.45
Mahi	1.3	2.1	1.54
Sabarmati	1.2	1.9	1.47
West flowing rivers of Kutch & Saurastra Including Luni	11.9	19.0	1.58
West flowing rivers South of Tapi	10.5	14.0	0.98
East flowing rivers bet Mahanadi & Pennar	3.9	5.3	1.02
East flowing rivers bet Pennar & kanyakumari	7.9	10.2	0.88
Total (19 basins)	187	284	1.39

Annex table 1b. Grain requirements of Chinese river basins

Basins	Grain requirement of China (Grains include rice, wheat, maize, other cereals, Pulses and roots and tubers (dry equivalent))		
	2000	2025 Default scenario	Annual Growth (%)
	M MT	M MT	%
Songliaohe	38.4	49.7	1.03
Haihe	40.8	51.9	0.97
Huaihe	63.0	83.1	1.11
Yellow river	35.9	47.2	1.10
Yangtze river	139.2	183.4	1.11
Pearl river	47.7	65.4	1.27
Southeast	22.6	29.2	1.04
Southwest	6.8	9.2	1.24
Inland	9.0	12.6	1.35
Total (9 basins)	403.4	531.8	1.11

Annex table 2a. Grain crop area of Indan river basins

River basin	Grain crop area								
	Irrigated area			Rainfed area			Total area		
	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates
	M Ha	M Ha	%	M Ha	M Ha	%	M Ha	M Ha	%
Indus	7.2	7.2	0.00	2.1	2.1	0.00	9.3	9.3	0.00
Ganga	22.9	31.2	1.03	25.3	19.5	-0.86	48.2	50.7	0.17
Bramhaputra	0.7	1.3	1.93	3.0	2.5	-0.68	3.8	3.8	0.00
Barak & Others	0.1	0.3	3.52	0.8	0.7	-0.78	0.9	0.9	0.02
Subernarekha	0.6	0.8	1.10	1.0	0.8	-0.83	1.6	1.6	0.01
Brahmani-Baitarni	0.9	1.2	1.05	1.6	1.2	-0.87	2.5	2.4	-0.06
Mahanadi	1.6	2.0	0.74	4.3	3.8	-0.41	5.8	5.7	-0.06
Godavari	2.7	3.9	1.22	8.7	7.8	-0.37	11.4	11.7	0.08
Krishna	2.4	2.9	0.68	6.3	4.9	-0.83	8.7	7.9	-0.34
Pennar	0.8	0.7	-0.26	0.7	0.6	-0.44	1.5	1.4	-0.35
Cauvery	1.0	1.1	0.18	1.5	1.1	-1.11	2.5	2.1	-0.52
Tapi	0.4	0.4	0.38	2.3	2.2	-0.21	2.7	2.6	-0.12
Narmada	0.9	1.2	1.03	2.8	2.5	-0.48	3.7	3.7	-0.05
Mahi	0.3	0.3	0.14	0.9	0.8	-0.30	1.1	1.1	-0.19
Sabarmati	0.2	0.2	0.11	0.5	0.5	-0.07	0.6	0.6	-0.02
West flowing rivers 1	2.2	2.1	-0.15	7.1	7.1	0.00	9.3	9.2	-0.03
West flowing rivers 2	0.8	1.2	1.35	2.6	1.4	-1.91	3.4	2.6	-0.82
East flowing rivers 1	1.1	1.3	0.45	1.3	1.0	-0.99	2.5	2.3	-0.25
East flowing rivers 2	1.4	1.5	0.15	1.2	0.8	-1.19	2.6	2.3	-0.40
India	48.1	60.8	0.78	74.1	61.2	-0.63	122	122	-0.01

Annex table 2b. Grain crop area of Chinese river basins

River basin	Grain crop area								
	Irrigated area			Rainfed area			Total area		
	2000	2025 Default scenario	Annual growth rates	2000	2025 Default scenario	Annual growth rates	2000	2025 Default scenario	Annual growth rates
	M Ha	M Ha	%	M Ha	M Ha	%	M Ha	M Ha	%
Songliaohe	4.1	4.4	0.26	10.2	9.4	-0.32	14.3	13.8	-0.14
Haihe	5.7	5.7	0.01	3.2	2.5	-0.97	8.9	8.2	-0.32
Huaihe	10.9	10.8	-0.02	4.2	3.6	-0.59	15.1	14.4	-0.17
Yellow river	4.4	4.4	-0.01	7.1	6.4	-0.44	11.5	10.8	-0.27
Yangtze river	18.7	19.1	0.08	15.5	14.5	-0.27	34.2	33.6	-0.07
Pearl river	5.9	6.0	0.05	2.2	1.8	-0.89	8.1	7.7	-0.19
Southeast	3.2	3.0	-0.22	0.4	0.3	-1.91	3.6	3.3	-0.38
Southwest	1.3	1.3	0.09	1.0	0.8	-1.11	2.3	2.1	-0.40
Inland	2.7	2.8	0.13	0.2	0.1	-1.35	2.9	2.9	0.04
China	56.8	57.4	0.04	44.3	39.3	-0.45	100.	97.0	-0.16

Annex table 3a. Grain yields of Indan river basins

River basin	Grain crop yield								
	Irrigated yield			Rainfed yield			Average yield		
	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates
	Ton/ha	Ton/ha	%	Ton/ha	Ton/ha	%	Ton/ha	Ton/ha	%
Indus	4.8	6.7	1.10	1.4	1.56	0.43	4.0	5.53	1.05
Ganga	1.4	2.0	1.11	1.1	1.29	0.40	1.3	1.70	0.98
Bramhaputra	2.1	3.1	1.23	1.4	1.63	0.43	1.6	2.12	1.01
Barak & Others	1.1	1.7	1.38	1.0	1.09	0.42	1.0	1.26	0.86
Subernarekha	2.2	3.2	1.16	1.3	1.49	0.42	1.7	2.35	1.17
Brahmani-Baitarni	2.0	2.9	1.23	1.0	1.11	0.39	1.3	1.97	1.30
Mahanadi	2.1	3.0	1.21	1.0	1.11	0.35	1.3	1.76	1.02
Godavari	2.4	3.4	1.17	0.9	0.95	0.33	1.2	1.78	1.23
Krishna	2.7	3.7	1.12	0.8	0.91	0.31	1.3	1.97	1.29
Pennar	2.9	4.0	1.11	0.8	0.86	0.29	1.9	2.53	1.01
Cauvery	3.3	4.4	0.98	0.9	0.92	0.21	1.9	2.70	1.23
Tapi	1.9	2.3	0.67	0.8	0.92	0.35	1.0	1.14	0.54
Narmada	2.5	3.3	0.90	1.0	1.15	0.42	1.4	1.86	1.01
Mahi	2.6	3.3	0.85	0.7	0.84	0.39	1.2	1.49	0.78
Sabarmati	2.8	4.0	1.14	0.7	0.83	0.40	1.3	1.68	0.91
West flowing rivers 1	2.6	3.7	1.18	0.6	0.71	0.43	1.1	1.38	0.81
West flowing rivers 2	2.5	3.4	1.09	0.9	1.11	0.54	1.3	2.16	1.70
East flowing rivers 1	2.6	3.6	1.11	0.9	0.97	0.38	1.7	2.49	1.33
East flowing rivers 2	3.4	4.6	0.97	0.8	0.89	0.30	2.2	3.22	1.27
India	2.3	3.1	0.91	1.0	1.1	0.36	1.5	2.1	1.05

Annex table 3b. Grain yields of Chinese river basins

River basin	Grain crop yield								
	Irrigated yield			Irrigated yield			Irrigated yield		
	2000	2025 Default scenario	Annual growth rates	2000	2025 Default scenario	Annual growth rates	2000	2025 Default scenario	Annual growth rates
	Ton/ha	Ton/ha	Ton/ha	Ton/ha	Ton/ha	Ton/ha	Ton/ha	Ton/ha	Ton/ha
Songliaohe	4.5	6.2	1.29	4.1	4.6	0.43	4.2	5.1	0.75
Haihe	5.2	6.8	1.05	2.7	3.0	0.39	4.3	5.6	1.07
Huaihe	5.3	6.9	1.06	3.7	4.0	0.32	4.9	6.2	0.97
Yellow river	4.8	6.5	1.17	3.0	3.4	0.40	3.7	4.6	0.87
Yangtze river	4.4	5.7	0.99	3.1	3.3	0.34	3.8	4.6	0.81
Pearl river	3.7	5.0	1.19	3.1	3.4	0.34	3.6	4.7	1.07
Southeast	3.8	4.9	1.04	3.3	3.4	0.11	3.7	4.8	1.01
Southwest	3.4	4.5	1.10	2.5	2.8	0.37	3.0	3.9	0.98
Inland	4.7	6.4	1.21	0.9	1.0	0.38	4.5	6.1	1.28
China	4.6	6.0	1.08	3.3	3.7	0.39	4.0	5.1	0.90

Annex table 4a. Grain production of Indan river basins

River basin	Grain production								
	Irrigated production			Rainfed production			Total production		
	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates
	M MT	M MT	M MT	M MT	M MT	M MT	M MT	M MT	M MT
Indus	34.7	48.2	1.10	2.9	3.3	0.43	37.7	51.6	1.05
Ganga	32.4	61.3	2.15	28.8	25.0	-0.47	61.2	86.3	1.15
Bramhaputra	1.5	4.0	3.19	4.4	4.0	-0.26	5.9	8.0	1.01
Barak & Others	0.1	0.5	4.94	0.8	0.7	-0.37	0.9	1.2	0.87
Subernarekha	1.3	2.6	2.28	1.3	1.2	-0.41	2.7	3.8	1.18
Brahmani-Baitarni	1.7	3.4	2.29	1.6	1.4	-0.48	3.3	4.8	1.24
Mahanadi	3.3	5.9	1.96	4.3	4.2	-0.07	7.6	10.1	0.96
Godavari	6.6	13.5	2.41	7.5	7.4	-0.04	14.1	20.8	1.32
Krishna	6.4	11.0	1.81	5.2	4.5	-0.51	11.7	15.5	0.95
Pennar	2.3	2.9	0.84	0.6	0.6	-0.14	2.9	3.5	0.66
Cauvery	3.4	4.8	1.16	1.3	1.0	-0.90	4.7	5.8	0.71
Tapi	0.7	0.9	1.05	1.9	2.0	0.14	2.6	2.9	0.41
Narmada	2.3	4.0	1.94	2.9	2.8	-0.06	5.1	6.8	0.96
Mahi	0.7	0.9	0.98	0.6	0.7	0.09	1.3	1.6	0.58
Sabarmati	0.5	0.7	1.25	0.3	0.4	0.33	0.8	1.1	0.89
West flowing rivers 1	5.6	7.6	1.03	4.4	5.0	0.43	10.1	12.7	0.78
West flowing rivers 2	2.0	4.1	2.46	2.4	1.6	-1.38	4.4	5.7	0.86
East flowing rivers 1	3.0	4.8	1.56	1.2	1.0	-0.61	4.2	5.7	1.08
East flowing rivers 2	4.8	6.7	1.12	1.0	0.7	-0.89	5.8	7.4	0.86
India	113.3	187.8	1.7	73.4	67.5	-0.28	186.7	255.3	1.05

Annex table 4b. Grain production of Chinese river basins

River basin	Grain production								
	Irrigated production			Irrigated production			Irrigated production		
	2000	2025 Default scenario	Annual growth rates	2000	2025 Default scenario	Annual growth rates	2000	2025 Default scenario	Annual growth rates
	M MT	M MT	M MT	M MT	M MT	M MT	M MT	M MT	M MT
Songliaohe	18.4	27.1	1.55	41.6	42.8	0.11	60.1	69.9	0.61
Haihe	29.6	38.6	1.07	8.7	7.5	-0.58	38.3	46.1	0.75
Huaihe	58.1	75.2	1.03	15.4	14.4	-0.27	73.5	89.6	0.79
Yellow river	21.3	28.4	1.16	21.7	21.5	-0.04	43.0	49.9	0.60
Yangtze river	82.6	107.8	1.07	47.4	48.2	0.07	130.0	156.1	0.74
Pearl river	22.0	30.0	1.24	6.8	6.0	-0.55	28.8	35.9	0.88
Southeast	12.0	14.8	0.82	1.4	0.9	-1.80	13.4	15.6	0.62
Southwest	4.4	5.9	1.19	2.5	2.1	-0.74	6.9	8.0	0.58
Inland	12.8	17.9	1.35	0.2	0.1	-0.98	13.0	18.0	1.32
China	261.3	345.7	1.13	145.7	143.5	-0.06	407.0	489.2	0.74

Annex table 5a. Irrigation water requirements of Indian River basins

River Basins	Irrigation water withdrawals								
	Surface water			Groundwater			Total		
	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates
	Km^3	Km^3	%	Km^3	Km^3	%	Km^3	Km^3	%
Indus	47.9	40.1	-0.59	31.0	30.0	-0.12	79.0	70.1	-0.40
Ganga	129.3	126.3	-0.08	114.7	132.9	0.49	244.0	259.1	0.20
Bramhaputra	7.8	12.6	1.60	0.2	0.4	1.83	8.1	13.0	1.60
Barak & Others	1.9	3.8	2.30	0.0	0.1	2.47	1.9	3.8	2.30
Subernarekha	3.8	4.2	0.32	1.7	2.1	0.68	5.6	6.4	0.44
Brahmani-Baitarni	4.6	5.0	0.30	3.4	4.2	0.76	7.9	9.2	0.50
Mahanadi	13.4	15.4	0.45	4.7	5.9	0.77	18.2	21.3	0.54
Godavari	22.4	24.7	0.33	14.9	18.3	0.70	37.3	43.0	0.48
Krishna	25.4	28.6	0.40	11.5	14.2	0.70	36.9	42.8	0.50
Pennar	8.1	7.0	-0.47	5.1	4.9	-0.13	13.2	11.9	-0.34
Cauvery	9.1	8.8	-0.11	6.8	7.6	0.36	15.9	16.3	0.10
Tapi	3.0	2.8	-0.20	3.9	4.4	0.40	6.8	7.1	0.15
Narmada	7.8	10.2	0.91	3.6	5.2	1.20	11.4	15.4	1.01
Mahi	2.0	2.2	0.26	2.7	3.5	0.89	4.7	5.7	0.63
Sabarmati	0.5	0.5	-0.11	3.0	2.9	-0.10	3.45	3.3	-0.10
West flowing rivers 1	2.8	2.5	-0.34	35.4	32.1	-0.33	38.2	34.6	-0.33
West flowing rivers 2	4.9	5.8	0.59	6.5	9.4	1.26	11.4	15.3	0.99
East flowing rivers 1	12.9	13.7	0.20	4.2	4.8	0.51	17.1	18.6	0.27
East flowing rivers 2	18.7	18.1	-0.11	10.1	11.0	0.31	28.8	29.2	0.04
India	326	332	0.06	263	293	0.37	590	626	0.20

Annex table 5b. Irrigation water requirements of Chinese river basins

River Basins	Irrigation water withdrawals								
	Surface water			Groundwater			Total		
	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates
	Km^3	Km^3	%	Km^3	Km^3	%	Km^3	Km^3	%
Songliaohe	25.1	19.8	-0.94	15.2	13.9	-0.35	40.3	33.7	-0.71
Haihe	12.7	10.2	-0.88	19.0	18.0	-0.22	31.6	28.1	-0.47
Huaihe	38.8	29.9	-1.04	19.2	16.6	-0.58	58.0	46.5	-0.88
Yellow river	18.3	15.7	-0.59	6.8	6.6	-0.11	25.1	22.3	-0.46
Yangtze river	111.8	88.5	-0.93	1.8	1.5	-0.72	113.6	90.0	-0.93
Pearl river	44.1	34.8	-0.94	0.1	0.1	-0.73	44.2	34.9	-0.94
Southeast	22.6	17.9	-0.92	0.3	0.3	-0.71	22.9	18.2	-0.91
Southwest	8.5	7.8	-0.34	0.0	0.0	-0.13	8.5	7.8	-0.34
Inland	28.9	26.4	-0.37	10.8	10.6	-0.06	39.7	37.0	-0.28
China	311.0	251.1	-0.85	73.0	67.5	-0.32	384.0	318.5	-0.74

Annex table 6a. Domestic water requirements of Indian river basins

River Basins	Domestic water withdrawals								
	Surface water			Groundwater			Total		
	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates
	Km^3	Km^3	%	Km^3	Km^3	%	Km^3	Km^3	%
Indus	0.74	2.1	3.48	0.81	2.1	3.26	1.55	4.2	3.37
Ganga	4.89	14.1	3.60	5.27	13.6	3.22	10.2	27.7	3.41
Bramhaputra	0.31	1.0	3.90	0.42	1.0	2.99	0.7	2.0	3.41
Barak & Others	0.11	0.5	5.01	0.14	0.7	5.29	0.2	1.1	5.17
Subernarekha	0.19	0.6	3.73	0.21	0.6	3.59	0.4	1.2	3.66
Brahmani-Baitarni	0.16	0.5	4.17	0.22	0.6	3.46	0.4	1.2	3.77
Mahanadi	0.33	0.9	3.54	0.41	1.0	3.03	0.7	2.0	3.26
Godavari	0.74	2.5	4.20	0.96	2.3	2.97	1.7	4.9	3.55
Krishna	1.06	2.3	2.62	1.01	2.2	2.56	2.1	4.5	2.59
Pennar	0.18	0.5	3.51	0.23	0.6	3.40	0.4	1.1	3.45
Cauvery	0.49	1.1	2.78	0.49	1.0	2.48	1.0	2.1	2.63
Tapi	0.29	0.7	3.01	0.24	0.5	2.75	0.5	1.2	2.89
Narmada	0.21	0.6	3.58	0.26	0.6	2.97	0.5	1.2	3.26
Mahi	0.10	0.2	3.20	0.12	0.2	2.31	0.2	0.5	2.73
Sabarmati	0.25	0.4	1.92	0.40	0.6	1.38	0.6	1.0	1.60
West flowing rivers 1	0.81	2.4	3.67	0.78	2.3	3.61	1.6	4.6	3.64
West flowing rivers 2	0.92	1.9	2.43	0.68	1.4	2.37	1.6	3.3	2.40
East flowing rivers 1	0.27	0.7	3.07	0.31	0.7	2.73	0.6	1.4	2.90
East flowing rivers 2	0.70	1.4	2.25	0.60	1.1	1.89	1.3	2.4	2.09
India	12.7	34.5	3.37	13.6	33.1	3.02	26.3	67.6	3.20

Annex table 6b. Domestic water requirements of Chinese river basins

River Basins	Domestic water withdrawals								
	Surface water			Groundwater			Total		
	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates
	Km^3	Km^3	%	Km^3	Km^3	%	Km^3	Km^3	%
Songliaohe	0.1	0.1	1.5	4.1	6.5	1.5	4.21	6.6	1.5
Haihe	0.7	1.5	2.3	3.4	6.7	2.3	4.10	8.1	2.3
Huaihe	1.8	3.7	2.5	3.0	6.3	2.5	4.80	10.1	2.5
Yellow river	0.4	0.6	1.8	2.6	4.6	1.8	3.01	5.2	1.8
Yangtze river	15.1	23.3	1.5	1.7	2.6	1.5	16.79	25.9	1.5
Pearl river	7.9	16.4	2.5	0.6	1.2	2.5	8.51	17.6	2.5
Southeast	2.6	4.8	2.1	0.1	0.2	2.1	2.67	5.0	2.1
Southwest	0.6	1.4	2.7	0.1	0.1	2.7	0.70	1.6	2.7
Inland	0.4	1.0	2.6	0.2	0.5	2.6	0.68	1.5	2.6
China	29.6	52.8	2.0	15.8	28.7	2.0	45.5	81.5	2.0

Annex table 7a. Industrial water requirements of Indian river basins

River Basins	Industrial water withdrawals								
	Surface water			Groundwater			Total		
	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates
	Km^3	Km^3	%	Km^3	Km^3	%	Km^3	Km^3	%
Indus	0.63	1.92	3.80	0.63	1.6	3.11	1.3	3.5	3.47
Ganga	5.37	16.43	3.80	5.37	13.4	3.11	10.7	29.9	3.47
Bramhaputra	0.44	1.33	3.80	0.44	1.1	3.11	0.9	2.4	3.47
Barak & Others	0.09	0.28	3.78	0.09	0.2	3.09	0.2	0.5	3.45
Subernarekha	0.14	0.43	3.80	0.14	0.4	3.11	0.3	0.8	3.47
Brahmani-Baitarni	0.15	0.45	3.80	0.15	0.4	3.11	0.3	0.8	3.47
Mahanadi	0.40	1.22	3.80	0.40	1.0	3.11	0.8	2.2	3.47
Godavari	0.81	2.48	3.81	0.81	2.0	3.12	1.616	4.5	3.48
Krishna	0.91	2.78	3.80	0.91	2.3	3.11	1.8	5.1	3.47
Pennar	0.15	0.44	3.80	0.15	0.4	3.11	0.3	0.8	3.47
Cauvery	0.44	1.34	3.80	0.44	1.1	3.11	0.9	2.4	3.47
Tapi	0.22	0.68	3.79	0.22	0.6	3.10	0.4	1.2	3.46
Narmada	0.22	0.67	3.80	0.22	0.6	3.11	0.4	1.2	3.47
Mahi	0.16	0.48	3.80	0.16	0.4	3.11	0.3	0.9	3.47
Sabarmati	0.16	0.67	4.95	0.16	0.5	4.25	0.3	1.2	4.61
West flowing rivers 1	0.33	1.01	3.80	0.33	0.8	3.11	0.7	1.8	3.47
West flowing rivers 2	0.87	2.67	3.80	0.87	2.2	3.11	1.7	4.9	3.47
East flowing rivers 1	0.35	1.08	3.80	0.35	0.9	3.11	0.7	2.0	3.47
East flowing rivers 2	0.67	2.06	3.80	0.67	1.7	3.10	1.3	3.7	3.47
India	12.5	38.4	3.82	12.5	31.4	3.1	25.0	70.0	3.5

Annex table 7b. Industrial water requirements of Chinese river basins

River Basins	Industrial water withdrawals								
	Surface water			Groundwater			Total		
	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates
	Km^3	Km^3	%	Km^3	Km^3	%	Km^3	Km^3	%
Songliaohe	6.9	6.5	-0.24	7.7	8.9	0.58	14.5	15.3	0.21
Haihe	1.7	1.8	0.36	4.9	7.2	1.52	6.6	9.0	1.26
Huaihe	5.8	8.1	1.36	4.2	7.2	2.19	10.0	15.3	1.73
Yellow river	2.0	3.6	2.32	3.6	8.1	3.25	5.6	11.7	2.94
Yangtze river	47.7	69.0	1.49	2.9	12.8	6.18	50.6	81.8	1.94
Pearl river	14.7	22.2	1.67	1.2	4.8	5.58	15.9	27.0	2.14
Southeast	8.1	8.1	-0.02	0.3	1.2	6.45	8.4	9.3	0.42
Southwest	0.6	1.0	2.23	0.1	0.3	3.59	0.7	1.2	2.48
Inland	0.7	1.7	3.76	1.0	3.1	4.64	1.6	4.7	4.31
China	88.1	121.9	1.31	25.8	53.4	2.95	113.9	175	1.7

Annex table 8a. Environmental water requirements of Indian river basins

River Basins	Environmental water requirements								
	Minimum flow			Other requirements			Environmental water requirements to be met from the potentially utilizable water resources[3]		
	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates
	Km^3	Km^3	%	Km^3	Km^3	%	Km^3	Km^3	%
Indus	46.0	46.0	0	0	0	0	0.00	0.00	0
Ganga	250.0	250.0	0	0	0	0	0.00	0.00	0
Bramhaputra	22.3	22.3	0	0	0	0	0.00	0.00	0
Barak & Others	1.7	1.7	0	0	0	0	0.00	0.00	0
Subernarekha	6.8	6.8	0	0	0	0	0.00	0.00	0
Brahmani-Baitarni	18.3	18.3	0	0	0	0	0.00	0.00	0
Mahanadi	50.0	50.0	0	0	0	0	0.00	0.00	0
Godavari	76.3	76.3	0	0	0	0	0.00	0.00	0
Krishna	58.0	58.0	0	0	0	0	0.00	0.00	0
Pennar	4.6	4.6	0	0	0	0	1.69	1.69	0
Cauvery	16.1	16.1	0	0	0	0	2.89	2.89	0
Tapi	11.4	11.4	0	0	0	0	3.07	3.07	0
Narmada	34.5	34.5	0	0	0	0	0.00	0.00	0
Mahi	3.1	3.1	0	0	0	0	0.00	0.00	0
Sabarmati	1.9	1.9	0	0	0	0	0.00	0.00	0
West flowing rivers 1	12.0	12.0	0	0	0	0	2.98	2.98	0
West flowing rivers 2	36.2	36.2	0	0	0	0	0.00	0.00	0
East flowing rivers 1	13.1	13.1	0	0	0	0	0.00	0.00	0
East flowing rivers 2	12.1	12.1	0	0	0	0	4.44	4.44	0
India	476.0	476.0	0	O	0	0	15.10	15.10	0

[3] Minimum flow requirement of only few Indian River basins are more than the than the un-utilizable part of the surface runoff.

Annex table 8b. Environmental water requirements of Chinese river basins

River Basins	Environmental water requirements								
	Minimum flow requirement			Other requirements			Environmental flow to be met from the potentially utilizable water resources[4]		
	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates
	Km^3	Km^3	%	Km^3	Km^3	%	Km^3	Km^3	%
Songliaohe	39	39	0	0	0	0	0	0	0
Haihe	12	12	0	9	9	0	9	9	0
Huaihe	31	31	0	8	8	0	8	8	0
Yellow river	23	23	0	23	23	0	23	23	0
Yangtze river	289	289	0	0	0	0	0	0	0
Pearl river	139	139	0	0	0	0	0	0	0
Southeast	77	77	0	0	0	0	0	0	0
Southwest	173	173	0	0	0	0	0	0	0
Inland	26	26	0	40	40	0	40	40	0
China	808	808	0	80.0	80.0	0	80.0	80.0	0

Annex table 9a. Total water requirement for Agriculture, Domestic and Industrial sectors of Indian river basins

River Basins	Total water withdrawals								
	Surface water			Groundwater			Total		
	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates
	Km^3	Km^3	%	Km^3	Km^3	%	Km^3	Km^3	%
Indus	49.3	44.1	-0.37	32.5	33.6	0.12	81.8	77.8	-0.17
Ganga	139.6	156.8	0.39	125.3	159.9	0.82	264.9	316.8	0.60
Bramhaputra	8.6	14.9	1.86	1.1	2.5	2.81	9.7	17.4	1.98
Barak & Others	2.1	4.5	2.58	0.3	0.9	4.40	2.4	5.5	2.83
Subernarekha	4.2	5.2	0.75	2.1	3.1	1.31	6.3	8.3	0.95
Brahmani-Baitarni	4.9	6.0	0.69	3.8	5.2	1.12	8.6	11.2	0.88
Mahanadi	14.2	17.5	0.71	5.5	7.9	1.22	19.7	25.5	0.86
Godavari	23.9	29.7	0.73	16.7	22.7	1.04	40.6	52.4	0.86
Krishna	27.3	33.7	0.70	13.4	18.6	1.10	40.8	52.3	0.83
Pennar	8.4	8.0	-0.18	5.5	5.9	0.25	13.9	13.8	-0.01
Cauvery	10.0	11.2	0.38	7.7	9.7	0.76	17.7	20.9	0.55
Tapi	3.5	4.2	0.61	4.3	5.5	0.77	7.8	9.6	0.70
Narmada	8.2	11.5	1.13	4.1	6.3	1.47	12.3	17.9	1.25
Mahi	2.3	2.9	0.83	3.0	4.1	1.12	5.2	7.0	0.99
Sabarmati	0.9	1.6	1.94	3.5	4.0	0.44	4.4	5.6	0.80
West flowing rivers 1	3.9	5.9	1.38	36.5	35.2	-0.13	40.4	41.1	0.05
West flowing rivers 2	6.7	10.4	1.48	8.0	13.0	1.62	14.7	23.4	1.56
East flowing rivers 1	13.6	15.5	0.44	4.8	6.4	0.96	18.4	21.9	0.58
East flowing rivers 2	20.1	21.5	0.23	11.3	13.8	0.65	31.5	35.3	0.39
India	351.5	405.0	0.47	289.4	358.5	0.72	640.0	763.7	0.59

[4] Minimum flow requirement for all basins are less than the un-utilizable part of surface runoff.

Annex table 9b. Total water requirement for Agriculture, Domestic and Industrial sectors of Chinese river basins

River Basins	Total water withdrawals								
	Surface water			Groundwater			Total		
	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates
	Km^3	Km^3	%	Km^3	Km^3	%	Km^3	Km^3	%
Songliaohe	32.0	26.4	-0.77	27.0	29.2	0.32	59.0	55.6	-0.24
Haihe	15.1	13.4	-0.45	27.2	31.8	0.62	42.3	45.3	0.27
Huaihe	46.4	41.7	-0.42	26.4	30.1	0.53	72.7	71.8	-0.05
Yellow river	20.6	19.9	-0.14	13.1	19.3	1.56	33.7	39.2	0.60
Yangtze river	174.7	180.9	0.14	6.3	16.9	4.02	181.0	197.7	0.36
Pearl river	66.7	73.4	0.39	1.9	6.1	4.77	68.6	79.5	0.59
Southeast	33.3	30.8	-0.30	0.7	1.7	3.65	33.9	32.5	-0.17
Southwest	9.7	10.2	0.20	0.2	0.4	3.34	9.9	10.6	0.28
Inland	30.0	29.0	-0.14	12.0	14.2	0.67	42.0	43.2	0.11
China	428.5	425.8	-0.02	114.7	149.6	1.07	543.2	575.4	0.23

Annex table 10a. Utilizable water resources of Indian river basins

River Basins	Utilizable water resources								
	Surface and Groundwater			Net water transfers in			Available water resources		
	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates
	Km^3	Km^3	%	Km^3	Km^3	%	Km^3	Km^3	%
Indus	60	60	0	0	0	0	60.3	60.3	0
Ganga	386	386	0	0	0	0	386.5	386.5	0
Bramhaputra	48	48	0	0	0	0	48.0	48.0	0
Barak & Others	10	10	0	0	0	0	10.2	10.2	0
Subernarekha	8	8	0	0	0	0	8.5	8.5	0
Brahmani-Baitarni	22	22	0	0	0	0	21.7	21.7	0
Mahanadi	64	64	0	0	0	0	63.6	63.6	0
Godavari	110	110	0	0	0	0	109.8	109.8	0
Krishna	78	78	0	0	0	0	77.9	77.9	0
Pennar	10	10	0	0	0	0	8.6	8.6	0
Cauvery	28	28	0	0	0	0	24.9	24.9	0
Tapi	21	21	0	0	0	0	18.1	18.1	0
Narmada	44	44	0	0	0	0	43.9	43.9	0
Mahi	7	7	0	0	0	0	6.6	6.6	0
Sabarmati	5	5	0	0	0	0	4.8	4.8	0
West flowing rivers 1	24	24	0	0	0	0	21.1	21.1	0
West flowing rivers 2	52	52	0	0	0	0	51.8	51.8	0
East flowing rivers 1	26	26	0	0	0	0	25.9	25.9	0
East flowing rivers 2	29	29	0	0	0	0	24.7	24.7	0
India	1032	1032	0	0	0	0	1017	1017	0

Annex table 10b. Total water requirement for Agriculture, Domestic and Industrial sectors of Chinese river basins

River Basins	Utilizable water resources								
	Surface and Groundwater			Net water transfers in			Available water resources		
	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates	1995	2025 Default scenario	Annual growth rates
	Km^3	Km^3	%	Km^3	Km^3	%	Km^3	Km^3	%
Songliaohe	95	95	0	0.0	0.0	0	95	95	0
Haihe	30	30	0	3.9	3.9	0	34	34	0
Huaihe	65	65	0	9.9	9.9	0	75	75	0
Yellow river	48	48	0	-7.2	-7.2	0	41	41	0
Yangtze river	360	360	0	-6.8	-6.8	0	353	353	0
Pearl river	130	130	0	0.1	0.1	0	130	130	0
Southeast	50	50	0	0.0	0.0	0	50	50	0
Southwest	30	30	0	0.0	0.0	0	30	30	0
Inland	65	65	0	0.1	0.1	0	65	65	0
China	873	873	0	0	0	0	873	873	0

Annex 4

CPSP Workshop-Background, Objectives and Key Issues for Scenario Development

David Molden, International Water Management Institute

Workshop Background

- 2000 World Water Forum in the Hague
- Vision for Water for Food and Rural Development
- Vision for Water and Nature
- Podium model – how much more water?
- CPSP – follow up in India and China
- Further development of Podium for India and China
- Basin and country work in India and China

Workshop Objectives

- Share CPSP Outputs
- Introduce Podium and Scenario Development – participants should become more familiar with these tools
- Dialogue – is it possible to overcome controversy and reach consensus over issues of water, food and environment?

The Program

- Today morning – presentations on CPSP
- This afternoon – beginning scenario development
- Evening - reception
- Saturday morning – report back
- Saturday morning and afternoon – development of Water, food, environment scenario
- Saturday afternoon - wrapup

Water, Food and Environment: Key Drivers and Scenario Development

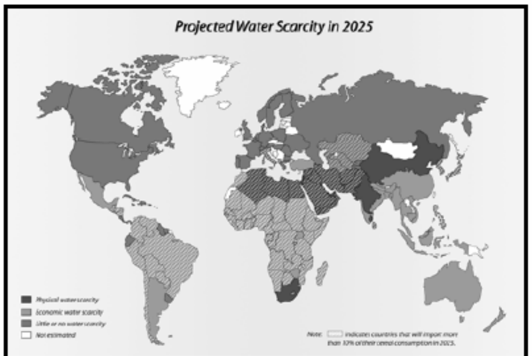
David Molden

Water-Food Equations

- More people, more food, more water
- Increased access to water – a proven ingredient to fight poverty
- More water for cities and industries
- Maintain enough water for ecosystems

- Balancing these equations depends on consumption, and where and how food is grown. What are the options?

Environmental Water Stress



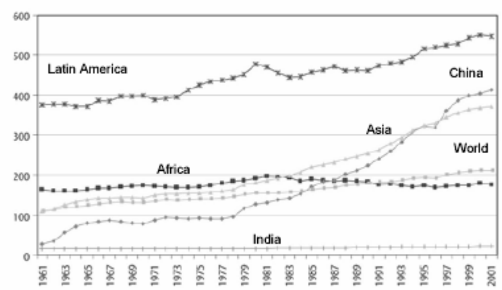
Important water-food-livelihoods-environment Choices

- Diets/population
- Trade
- Prices
- Improving irrigation efficiency
- Increasing water productivity
- Infrastructure for new water
- Upgrading rain-fed systems

Will influencing diets save water?

- Vegetarian Diet – 2000 liters per day
- Grain fed meat diet – 5000 liters per day
- Urban consumption patterns drive rural agricultural practices
- Changing diets could save water
- Another positive trend – increase in income, better diets in developing world

Calories provided by meat



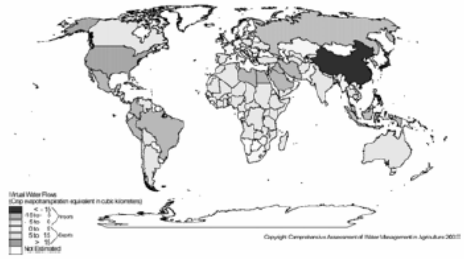
Diets ?

- Curtail unsustainable consumption patterns
- Much of the world the trend is for better diets, and thus more water

Trade in Virtual Water

- Presently with trade 11% of irrigation water depletion is “saved”
- Forecast up to 19% with increasing trade

Virtual Water Flows - 1995



Virtual Water Flows & Food Security

- Only about 25% of trade is from water abundant to water short countries – people trade for other non-water reasons
- What about countries with high rural poverty?
  - Money required for trade
  - Roads and markets to get food to people
  - Too risky to ensure food security with trade
- Overall trade remains important, but not so significant to countries with rural poverty

Prices

Prices

- Low food prices benefit consumer – has a poverty impact
- But makes life difficult for producers
- Do subsidies in the west keep prices down for producers?
- Would higher grain prices lead to more production and productivity by producers?

Irrigation Efficiency

- Common perception: Irrigation wastes a lot of water, thus saving water in irrigation would go a long way to solving water problems.
- In closed basins with a lot of reuse, scope for savings smaller than perceived (Yellow river, Egypt's Nile, much of Indus, Gediz, Turkey)
- Scope less than thought – but every effort should be made to curtail wasteful use

Improving Water Productivity

- Grow more food with less water
- More value per drop from livestock, fish, crops, ecosystem services
- For poor increasing WP can raise incomes
- Huge differences across regions implies huge scope – not just climate
  Wheat ranges from 0.2 liters to kg/1000 liters

Water Productivity – cont'd

- Field and farm practices – crop breeding, soil fertility, soil-water management
- Supplemental irrigation, precise practices
- Livestock and fisheries
- Water allocation and distribution – to facilitate practices and enhance values
- Policies – prices, subsidies, access to markets, reduction of risks
- Ecological consequences? More nutrients and an incentive to deplete more water

Expanding irrigated or rainfed?

- To improve irrigation – increase water productivity
- Investments in new water – how much and what type?
  - Small or large
  - Irrigation or rainfed
  - Green or blue
  - For food production or income and livelihoods
  - Are these the right divisions?

How much more irrigation?

Source	Total irrigation withdrawals km³		
	1995	2025	% increase 1995 2025
Shiklomanov	2488	3097	24%
IWMI	2469	2915	18%
FAO**	2128	2420	14%
IFPRI			4%*

Irrigation or Rainfed

- Expand irrigated area
- Increase yield on irrigated area
- Expand rainfed areas
- Improve yield on rainfed areas
- Is the irrigated – rainfed dichotomy the right one?

Irrigation

- Concentrate on yield and water productivity gains – how much is feasible?
- More irrigation
- Plus side –
  - Storage reduces risk
  - Irrigation has anit-poverty impacts
- Downside
  - Equity – not everyone can have irrigation
  - Environmental risks

Rainfed

- Pluses
  - Many rural poor live in rainfed areas
  - Seems possible to improve low yields
  - With supplemental irrigation, may be possible to spread benefits of water
  - Less aquatic ecosystem concern?
- Minuses
  - Can yield gains be achieved? Trying for a long time.
  - Riskier – depends on climate change
  - Aquatic and terrestrial ecosystem concerns

Is this rainfed or irrigated?

Upgrading Rainfed Systems

- Water harvesting and/or supplemental irrigation of primarily rainfed land
- $50 investment in drip or treadle pumps can yield $100 to $200
- What are ecological consequences of large upscaling?

Groundwater Irrigation

Groundwater

- Pluses
  - Reliable supply, can be conjunctively used with irrigation or rain
  - Where accessible, can be an important sources for poor
- Minuses
  - Groundwater pollution and depletion
  - How much more is left
  - If the water runs out do we have to replace it with surface supplies?

Interbasin Transfers

- Abundant to scarce areas
- What are impacts
- Are there other options

Investing in Institutions

- Good governance, IWRM, irrigation management transfer, river basin institutions, water pricing, dialogues
- How much success is there? Are new approaches needed?
- Non water policies and investments – markets, roads – extremely important

Scenarios

- Scenarios – explore plausible futures
- Not a projection of what will happen
- Allows exploration of consequences of polices we make now
- Procedure
- Step 1 – develop story line, concentrating on drivers
- Step 2 – Quantitatively and qualitatively analyze

Your Task – develop scenarios

- Go through key drivers one by one, and make your assumption on how these should change in the future
- Discuss possible impacts on poverty, environment, household and national food security
- We will make a Podium run with your scenarios tonight

Groupwork

- Today – we will go through the key drivers and variables with you one by one – you discuss how they should change
- Tomorrow – try to develop a scenario that will balance food, poverty, environmental needs
- Output – report on scenarios and their consequences, posted on CA website
- input into scenario development work of CA
- Recommendations on how to carry this work forward

Annex 5

Application of CPSP Hydrological Model in Qiantang River Basin

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ABSTRACT

CPSP hydrological model was used in this paper to simulate the water balance and analyze the impact of land and water use and climate changes on resources in Qiantangjiang River Basin. The model was run on monthly basis and calibrated by comparing the calculated and observed monthly outflow, total groundwater recharge and withdrawal, the withdrawal for irrigation, and the total withdrawal for irrigation and D & I at present (2000) and applied to simulate the past (1980) conditions and for all the future scenarios that were developed to analyze effects of water policies and sectoral demands of water. It showed from the result that CPSP model is a very useful tool for basin-level water assessment, especially for humid areas. As Qiantangjiang is a water rich river basin in China, there is even no groundwater withdrawal for irrigation so far. Therefore, the potentials of groundwater for both agricultural and D & I uses should be excavated. However, with the increased proportion of groundwater return, groundwater quality also faces huge challenges. How to manage the water and land well is inevitably a subject to us.
Key words: CPSP model, land and water use, scenarios

INTRODUCTION

Qiantang River Basin, which lies between Longitude 118º East to 121º East and Latitude 28º North to 31º North, extends across Zhejiang, Anhui, Jiangxi, Fujian and Shanghai five provinces/municipalities with a total of 55558 Km^2 of catchment area. The catchment area involved in this report is 35500 Km^2 in the upstream of Hangzhou Gate within the boundaries of Zhejiang Province that are under the jurisdiction of Hangzhou, Quzhou, Jinhua, Shaoxing and Lishui five municipalities/prefectures totally 27 counties/cities/districts (hereinafter the scope of Qiantang River Basin). It borders on Xianxia Mountain and spreads into Min River of Fujian Province in the south, Huaiyu Mountain and Le'an River and Xin River, water system of Poyang Lake of Jiangxi Province in the southwest, Huang Mountain and Tianmu Mountain and Qingyi River of Anhui Province and Taihu Lake of Zhejiang Province in the north, Bay of Hangzhou in the northeast, Siming Mountain and Yong River and Tiantai Mountain and Jiao River in the east, and Xianxia Mountain and Ou River in the southeast.

According to the statistical data in 2000, the total population in Qiantang Basin is 10.67 million (accounting for 24% of the total of Zhejiang Province) and cultivated area 0.4240 Mha (accounting for 11.9% of the total land area in Qiantang Basin and 31% of the total cultivated area of Zhejiang Province), including 0.3604 Mha of paddy field and 0.0636 Mha of upland. The per capita cultivated area in this river basin is 0.04 ha and garden plot 0.1309 Mha, accounting for 3.7% of the total land area.

Qiantang River Basin comes under subtropical monsoon climate with well-marked four seasons. The average annual precipitation is between 1200 mm and 2200 mm and evaporation between 800 mm and 1000 mm. The total water resources in Qiantang River Basin (upstream of Hangzhou Gate) is 38.64 billion m^3, including 7.71 billion m^3 of unconfined groundwater resources, accounting for 20% of the total amount.

Qiantang River Basin has favorable natural conditions and rich agricultural resources. Intensive cultivation and combination between agriculture and husbandry etc., traditional agriculture have been formed in its long history of development. It also has great potentialities in the development

of forestry and fishery and is always an important area for the all-round development in agriculture, forestry, sideline and fishery in Zhejiang Province and Anhui Province. Its cultivated area in 2000 is 0.4240 Mha, accounting for 11.9% of the total land area and the per capita cultivated area 0.04 ha, garden plot 0.1309 Mha, accounting for 3.7% of the total land area. The main land uses in Qiantang Basin is shown in Table 1.

Table 1. Main land uses in Qiantang Basin in 2000

Land use(Million ha)	Upstream	Downstream
Total land area	2.520	1.030
Available cultivated area	0.2888	0.1352
Gross cropped area	0.5776	0.2704
Farmland irrigated area	0.2679	0.1254
Fruit irrigated area	0.1052	0.0256
Forest area	0.9673	0.4527

Paddy rice, wheat, barley, maize, soybean and potato are the staple crops in this river basin as well as tea, rape, cotton, sugarcane and medical materials etc., cash crops and tea-oil tree, orange, bayberry, grape, persimmon and loquat etc., cash trees. Jinqu Basin is the second commodity grain base where the production of cotton occupies a pivotal position in Zhejiang Province. With the development of town/township enterprises in recent years, the economy here develops rapidly. In 2000, the gross value of agricultural and industrial output is RMB 258 billion (US$31.1 billion), accounting for 17% of the total and Jinqu has become one of the economic development regions with much potentiality in Zhejiang Province.

The model was calibrated for the present conditions and applied to derive responses corresponding to past and future scenarios using monthly time steps. Studies were done at the sub basin level. The basin was divided into two sub basins which are third-level zones to allow segregation of areas having similar hydrologic and water use attributes. The two sub basins studied are:

SB1 : Upstream of Fuchunjiang Reservoir
SB2 : Downstream of Fuchunjiang Reservoir

The present (year 2000) socio-economic conditions, including population, cultivated area, orchard area and equivalent sheep in the two SBs are shown in Table 2.

Table 2 . Socio-economic Conditions of SBs in Qiantang Basin

SB	Population (million)			Cultivated area (Km^2)			Orchard (Km^2)	Equivalent sheep (million)
	Urban	Rural	Subtotal	Paddy	Upland	Subtotal		
SB1	2.41	4.93	7.33	2403.52	484.82	2888.34	1052.59	9.00
SB2	1.15	2.19	3.34	1200.66	151.21	1351.87	256.08	2.82
Total	3.56	7.11	10.67	3604.18	636.03	4240.21	1308.67	11.82

The SB1 comprises around two thirds of the surface storages and land area. The soil moisture capacity was varied for each type of land use, and values consistent with the likely root zone depths and field capacities were used.

The water storage and water supply capacities of various projects for the present conditions, which are the key factors to check the rationalities of surface storage filling and depletion and area under reservoir, are detailed in Table 3.

Table 3 Water Supply Capacities of Various Projects for the Present Conditions

(Million m^3)

SB	Liver storage of medium and large reservoirs	Live storage of small reservoirs	Water supply capacity of water withdrawal projects	Water supply capacity of groundwater projects	Total live storage
SB1	1142.56	690.57	1169.51	212.16	1833.13
SB2	81.3	195.89	729.39	72.89	277.19
Total	1223.86	886.46	1898.9	285.05	2110.32

LAND USE TYPES

From Table 2 it can be seen that paddy rice is the major crop in this basin, accounting for 85% of the total cultivated area. Fruit and rapeseed etc., cash crops are also very common, the cropping area of rapeseed in 2000 is 733 Km, amounting to 12% of the total cropping area. Following fourteen standard land-use types were used in the model. It should be specially noted that the area under reservoirs (including ponds and swamps) is nearly closed to the total cultivated area because these reservoirs also take the functions of flood control and power generation besides irrigation and D & I water supply. Moreover, with the rapid socio-economic development and adjustment of cropping pattern, more and more farmlands were converted into ponds for fisheries since 1980 when the reform and opening-up policies were carried out broadly. Table 4 gives land categories used in the model.

SCENARIOS STUDIED

The various scenarios studied are showed in table 5. Table 6 provides a clear benchmark in various scenarios. The land use data used in different scenarios depicted in Figure 4.1.

Table 4. Land categories used in the model

P1	Forest and miscellaneous trees
P2	Permanent pastures
P3	Land not available for cultivation, waste, & fallow
P4	Land under reservoirs
P5	Rain-fed soybean and wheat
P6	Rain-fed fruit
P7	N/E
P8	N/E
P9	N/E
P10	N/E
P11	Irrigated double cropping of rice
P12	Irrigated early rice and autumn maize
P13	Irrigated single cropping of rice and rapeseed/vegetable
P14	Irrigated t sugarcane and barley
P15	Irrigated cotton and wheat
P16	Irrigated sweet potato and vegetable
P17	Irrigated vegetable
P18	Irrigated fruit

The model was run on monthly basis, for average rainfall and ET_0 conditions for the past, present and future scenarios.

Table 5. Description of scenarios

Sr. No.	Abbreviation	Explanatory notes
1.	Past (1980)	The social economy developed quickly since the implementation of the reform and opening-up policies after 1980.
2.	Present (2000)	To date.
3.	Future I (2025) B as U	Business as Usual. With increased water infrastructure (and small import), Irrigation expansion with cropping pattern same as at present. Proportion of surface & groundwater irrigation same as at present
4.	Future II (2025)	With no expansion of water infrastructure (and small import), shift in cropping pattern, better water management
5.	Future III (2025)	With increased water infrastructure (and small import) and irrigation expansion, shift in cropping pattern, more groundwater use and better water management
6.	Future IV (2025)	With increased water infrastructure (and small import), no irrigation expansion, shift in cropping pattern, more industries, more groundwater use, export water and better water management
7.	Future V (2025), agri. seasonal shift	With increased water infrastructure (and small import), no expansion of irrigation, more industries, more GW use, better water management

Table 6. Future Scenario Comparison in CPSP Model

Future Scenario	Additional water infrastructure	More irrigation area	Industry	Water management
FI (BAU)	Yes	Yes +No shift in CP	Normal	As usual
FII	No	No expansion + Shif in CP	Normal	Better
FIII	Yes	Yes + Shift in CP	Normal	Better + More GW use
FIV	Yes	No expansion +Shift in CP	More	Better + More GW use +Export
FV	No	No expansion + Shift in CP	Normal	Better + More GW use

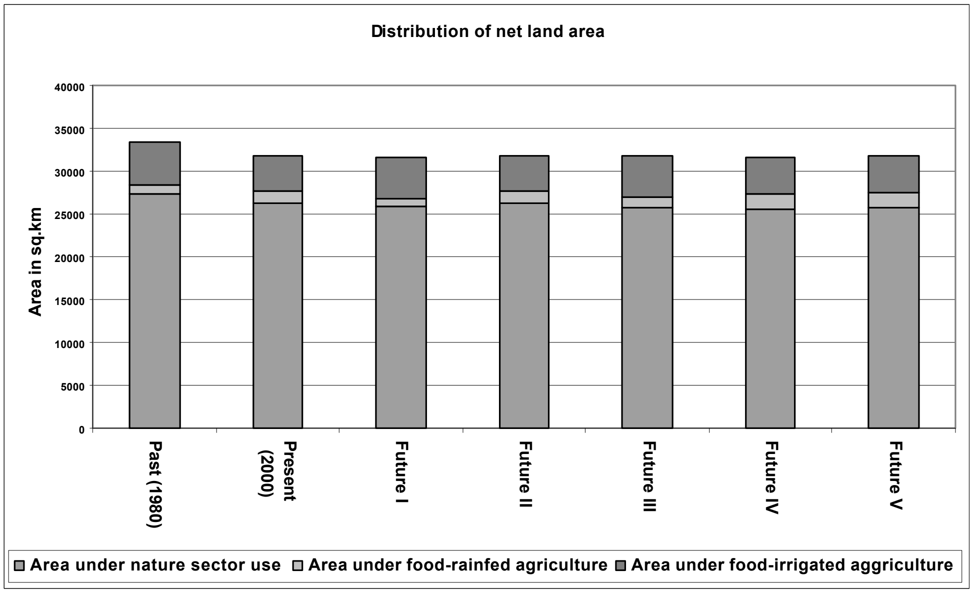

Figure 4.1. Distribution of the net land area in Qiantang Basin

MODEL CALIBRATION

Because Qiantang Basin is an area with abundant water resources, surface water resources are the major water source for agriculture, domestic and industry, while groundwater resources have not been used in irrigation so far, except a little in D & I use. Consequently, there are no observed groundwater fluctuation data in this basin. The model was calibrated and validated by adopting the following steps with the available data computed by the model and estimated by Qiantang Basin Management Bureau for the present conditions.

1. Comparing the total monthly outflow (surface runoff plus base flow) of SB1 and SB2 with the observed monthly runoff.
2. Comparing the natural recharge to groundwater as in the model, as a percentage of rainfall, and to compare this percentage with the generally adopted norms.
3. Comparing the total groundwater recharge and withdrawal, as computed by the model, with the estimates of the Qiantang Basin Management Bureau.
4. Comparing the withdrawal for irrigation, and total withdrawal for irrigation and D & I, as computed by the model, with the estimates of the Qiantang Basin Management Bureau.

As the boundaries of this river basin are dictated by the administrative units (municipalities) but not hydrologic units, therefore there could be natural inflows from outside the study area to the study area and similarly there would be some flows from the study areas which did not go to the sea to pass to other administrative units. In the assessment as made, this point has already been considered by using only the proportioned flow as generated from the study area.

In terms of monthly outflow to sea, this model has a very good match for the present conditions, where the difference between the total outflows computed by the model and observed by local hydrological stations is only around 0.5%. Figure 2 shows the computed and observed average monthly values.

Regarding total recharge to groundwater and total withdrawals for irrigation and D & I, the differences between the computed and estimated also are not very high, which are only 14.18%

and 8.2% respectively. Therefore, generally speaking, this model has a comparatively good match in the humid area. The main computed and estimated results for the present conditions are shown in Table 7.

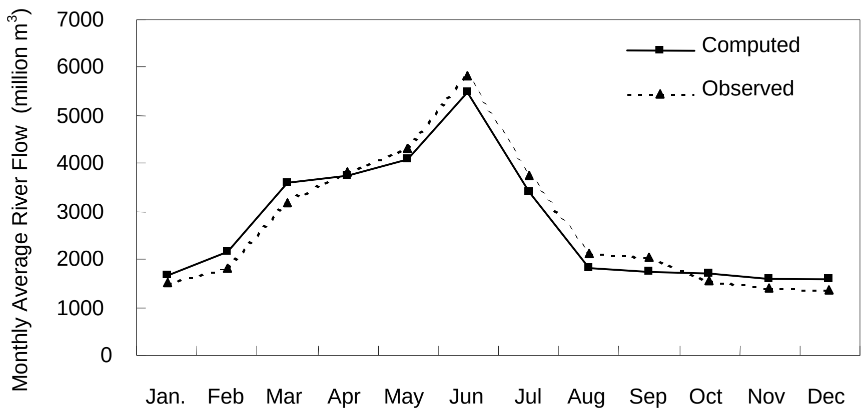

Figure 2. Comparison of Computed and Observed Average River Flow

With the above calibration, the general validation of the model was accepted with the following values of main parameters:

1. Soil moisture storage capacity: varies with soil type and land use: 200 mm for forests, 100 mm for pastures and fruit, 75mm for agricultural lands (but 150 mm for paddies) and 40 mm for bare lands or land put to other uses. Higher capacity values would lead to higher evapo-transpiration and lower flows after rainfall has ceased, thus giving a better calibration but values higher than these were not tried as such capacities were unlikely to be available.

Table 7. Comparison of Computed and Observed Resultsfor the Present Conditions (million m^3)

Items	Computed by the model	Estimated	Difference (%)
Percentage of groundwater recharge from rainfall	9	8	10.92
Total Recharge to groundwater	7451	6525	14.18
Groundwater fluctuation within the year	2451	NA	
Total outflow to sea	32542	32703	-0.5
Withdrawal for irrigation	4497	5028.8	-10.6
Withdrawal for irrigation and D&I	5909	6436.0	-8.2

2. The excess water was divided assuming that 85 percent yields to surface and sub surface (or quick runoff) flow and the rest 15 percent yield to groundwater. With this assumption, reasonable annual recharge was realized.

3. The exponential index, depicting the reduction of evapo-transpiration rate with reducing availability of soil moisture in the relationship was kept at 0.6.
4. A groundwater recession coefficient of 0.27 allowed the persistence of good base flows. As there is no much groundwater withdrawals in this river basin, the base flows both in the prototype and in the model are very high, particularly from May to November.
5. Qiantang Basin is a humid area in the south of China; therefore soil moisture capacity is used as the initial soil moisture of the first month –January for each land parcel.

SIMULATION OF PAST AND FUTURE CONDITIONS

The model was applied to simulate the past (1980) conditions and for all the future scenarios enumerated above with average rainfall and ET_0.

The inputs and outputs of this hydrologic model are all in million cubic meters. The abstracted results are presented in the following Tables 8 and Table 9 give the surface and ground water balances at the basin level.

Table 8. Annual water balance for surface water resource system - Qiantang basin (Steady state, average rainfall)

(Million m^3)

	Past (1980)	Present (2000)	Future I (2025) B as U, with increased irrigation infrastructure	Future II (2025), no expansion of irrigation infrastructure, better water management	Future III (2025) same as FII, with more groundwater use and better water management	Future IV (2025), more industries, more groundwater use, export water and better water management	Future V (2025) , No expansion of irrigation, more GW use, better water management
Inputs							
Quick runoff from rainfall	29679	29522	28572	28676	28525	28579	28847
Base flow	7980	7341	7387	6550	6242	5999	6603
Returns to surface from surface irrigation	1210	972	1068	881	810	694	792
Returns to surface from GW irrigation	0	0	0	0	26	22	24
Returns to surface from D&I withdrawals	311	507	990	990	990	1363	1363
Sub-total, returns to surface	1521	1479	2058	1871	1826	2079	2179
Imports	0	0	56	56	56	56	56
Total inputs	39180	38341	38073	37152	36649	36713	37685
Outputs							
Surface withdrawals for irrigation in the basin	5370	4497	4701	3218	2960	2477	3573
Surface withdrawals for D&I in the basin	820	1302	2511	2511	2511	3448	3448
Total surface withdrawals, for use in the basin	6190	5799	7212	5729	5471	5925	7021
Natural and induced recharge from river to GW	0	0	0	0	0	0	0
Outflow to sea	32990	32542	30861	31423	31178	30518	30664
Export	0	0	0	0	0	270	0
Total output	39180	38341	38073	37152	36649	36713	37685

Table 9. Annual water balance for groundwater - Qiantang basin (Steady state, average rainfall)(million m^3)

	Past (1980)	Present (2000)	Future I	Future II	Future III	Future IV	Future V
Inputs							
Natural recharge from rainfall	5182	5143	4966	4984	4958	4967	5015
Returns to GW from surface irrigation	2824	2268	2491	1636	1505	1289	1848
Returns to GW from GW irrigation	0	0	0	0	491	422	457
Returns to GW from D&I withdrawals	14	40	40	40	40	77	77
Sub-total, returns to GW	2838	2308	2531	1676	2036	1788	2382
Natural and induced recharge from river to GW	0	0	0	0	0	0	0
GW flow from other basins	0	0	0	0	0	0	0
Total inputs	8020	7451	7497	6660	6994	6756	7397
Outputs							
GW irrigation withdrawals, including GW pumping to surface canals	0	0	0	0	641	537	574
GW withdrawals for D&I use	40	110	110	110	110	220	220
Sub-total GW withdrawals	40	110	110	110	751	757	794
Base flow to rivers	7980	7341	7387	6550	6242	5999	6603
GW flow to other basins	0	0	0	0	0	0	0
Direct GW flow to sea	0	0	0	0	0	0	0
Total outputs	8020	7451	7497	6660	6994	6756	7397

DISCUSSION OF RESULTS

Based on the present conditions and average rainfall & the modified model response for sustainable water use conditions is briefly described below.

a) The model indicates that the present average flows are as follows:

SB1: 23308 million cubic meters
SB2: 9234 million cubic meters
Total basin: 32542 million cubic meters

The total flow computed from the model is somewhat less than the observed one, which is 32703 million cubic meters.

b) For the present conditions, the withdrawal required for sustaining agricultural (irrigation) uses, which is all from surface water is 4497 million m^3, and the withdrawals for D&I uses are 1302 million m^3 from surface water & 110 million m^3 from groundwater respectively. Therefore, there are huge potentials in groundwater development in this basin. To sustain these current withdrawals, the surface storage filling and depletion of 7680 million m^3 contributes considerably.

c) The current total natural recharge from rainfall for the basin computed by the model is 5143 million cubic meters, which is about 8.9 percent of average annual rainfall of 57958 million cubic meters. As there is no groundwater use in irrigation in this basin so far, exploiting groundwater for both agricultural and D & I uses inevitably is an priority plan for local Integrated Water Resources Development and Management (IWRDM) so as to achieve the sustainable development and use of water resources. Therefore, in Future III, Future IV and Future V scenarios, 20 percent of groundwater is planed to be abstracted. Moreover, export water, which is 180 million cubic meters in the upstream and 90 million cubic meters in the downstream, together with better water management is also adopted in Future IV to excavate the potentials for water resources use, even though up to now, there is no plan for water export in this area.

Consumptive use of water

For the current condition, the total consumptive use is 23519 million m^3, which comprises 17130 million m^3 of nature sector, 5551 million m^3 of agricultural sector and 838 million m^3 of people sector (D&I). The agricultural use is made up of ET in rain-fed lands (beneficial and inadvertent) as well as irrigated lands, additional ET met from irrigation and reservoir evaporation. The beneficial consumptive use of nature sector in the future five scenarios increased remarkably due to the expansion of forest area (the coverage rate of forest is increased from 36.4% in 1980 to 40% in 2000 and 50% in 2025), but the non-beneficial ET is reduced due to the decrease of waste and fallow land area.

The Scenario Future IV has been attempted to get the maximum practicable expansion, including more groundwater use, better management, export water and more industries. Even though the river flow is reduced slightly from 32542 million cubic meters to 30518 million cubic meters comparing with the BAU Scenario, the total consumptive use is 26610 million cubic meters, closed to the value of BAU Scenario 26537 million cubic meters. Table 10 summarizes the composition of sector consumptive use under different scenarios.

The consumptive use of agricultural sector can be further classified by the status of the land (rain-fed or irrigated). Part of the consumptive use from irrigated land is met either from rainfall or from irrigation waters. Non-beneficial consumption would be from reservoirs, waterlogged areas, or from land without crops in particular season.

Table 10. Consumptive use (evapo-transpiration) by sector (million m^3)

	Past (1980)	Present (2000)	Future I	Future II	Future III	Future IV	Future V
Nature sector beneficial	10126	11128	13908	13910	13910	13910	13126
non beneficial	7102	6003	4075	4241	3936	3850	4435
Subtotal	17228	17130	17983	18151	17846	17760	17561
Rainfed Agriculture sector beneficial	815	872	533	872	832	1280	1209
non-beneficial	17	15	11	15	13	16	16
Subtotal	832	887	544	887	845	1295	1224
D&I (People sector)	535	838	1591	1591	1591	2228	2228
Total for all sectors	18595	18855	20118	20629	20282	21283	21014

Surface water

From 1980 to date, surface water is all along the major water source in Qiantang Basin. Particularly for agriculture, 100 percent of irrigation withdrawal is from surface water. For D&I uses, only 5 percent of D&I withdrawal is from surface water in the past and 7 percent in the present conditions. In terms of total water withdrawal for agriculture and D&I, only 0.6 percent is from surface water in the past and 1.8 percent at present. Therefore, the abundant surface water resources here create superior conditions for local socio-economic development.

For the present conditions, as from the model, the withdrawal of surface water was 10 percent of the total inputs, and return flow contributed only 2.5 percent of inputs, the base flow was 7341 million cubic meters, 12.6 percent of the total inputs available in all the months. In the current situation, with average rainfall, total return flows contribute 6.5 percent of total inputs and total withdrawals are equal to 10 percent of the inputs.

In the future scenarios with average rainfall, even with more water consumption for agriculture and D&I, the maximum withdrawals was only 13.5 percent of the total inputs while the maximum return flows constituted 8 percent of the total inputs. Therefore, the sustainability of water resources in this area can be guaranteed.

Groundwater

A little groundwater, which is only 0.2 per cent of total inputs, has been exploited for D&I use in the current situation, return flow, natural & human together, constitutes only 4 percent of the inputs. Therefore, more groundwater use had been adopted in future three scenarios. At the same time, the abundant surface and groundwater resources also provide a scenario for export water. In Future IV scenario, 20 per cent of ground water is planned to be used and totally 270 million cubic meters of water is planned to be exported to other water short basins. But even then, the total withdrawal from groundwater is only 1.3 percent of the total inputs and the return flow would constitute about 3 percent of the inputs. The potentials for groundwater development are very huge in this basin.

The withdrawals of both surface and ground water for different purposes and for different scenarios are shown in Figure 3. Because paddy is the biggest water consumers and still the

major crop in this basin, surface water withdrawal for irrigation was reduced remarkably due to the cutting down of rice in the last four scenarios. However, with the rapid growth of population and quick development of industrialization and urbanization, the withdrawal for D&I use is nearly doubled in Future I, II & III scenarios and increased by 160 percent in Future IV & V scenarios. The ratio of irrigation withdrawal to total withdrawal is reduced from 86 percent in the past to 76 percent at present and even to 45 percent in Future IV scenario.

GW pumping & induced recharge

The agriculture and D & I water demand are met both from surface water and ground waters. When the surface water was not available, additional pumping from ground water to the surface canals was required to be done to fulfill the demands. Similarly, because of the heavy ground water withdrawals, the sustainability of the ground water storage, under the average recharge conditions was disturbed. This required the assumption of natural & induced recharge from surface to ground waters. As the abundant surface water resources in this river basin is high enough to meet local water demand as well as the base flow even in dry seasons, GW pumping into canals to meet the deficits in SW is not used. Meanwhile, as no much GW has been developed, natural & induced recharge to balance ground water table also is unnecessary.

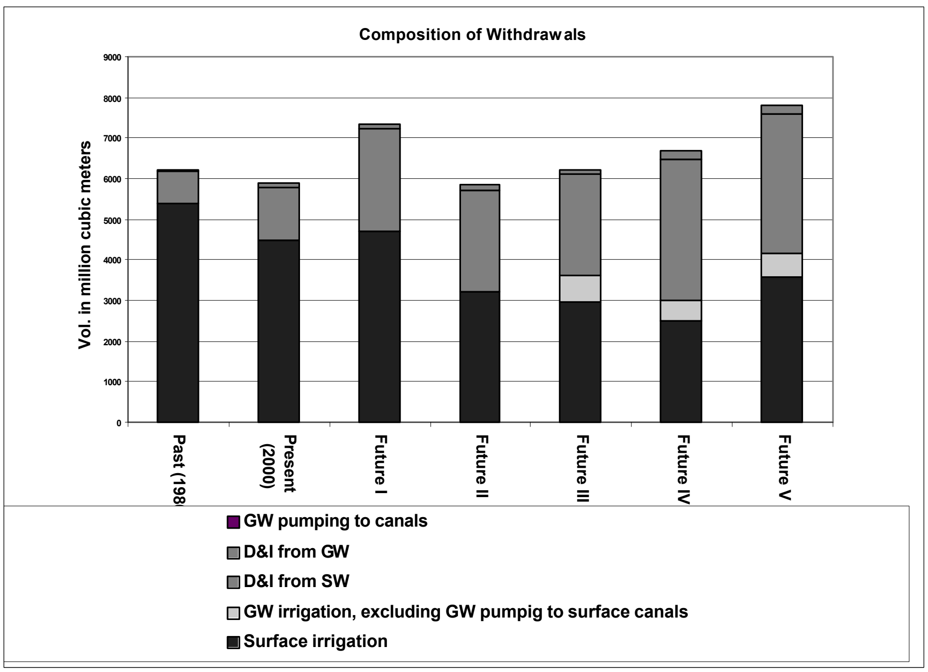

Figure 3. Composition of withdrawals in Qiantang Basin

Water situation indicators

In CPSP Model, four water situation indicators, viz. indicator 1 – total SW withdrawal to total SW inputs, indicator 2 – total returns to SW to total SW inputs, indicator 3 – total GW withdrawals to total GW inputs and indicator 4 – total returns to GW to total GW inputs have been proposed to depict the level of water use (withdrawals) and potential of hazard (due to return flow) to water quality. Values of these indicators for Qiantang Basin are given in Table 10:

Table 10. Water situation indicators

	Past (1980)	Present (2000)	Future I	Future II	Future III	Future IV	Future V
Indicator 1	0.16	0.15	0.19	0.15	0.15	0.16	0.19
Indicator 2	0.04	0.04	0.05	0.05	0.05	0.06	0.06
Indicator 3	0.005	0.01	0.01	0.02	0.11	0.11	0.11
Indicator 4	0.35	0.31	0.34	0.25	0.29	0.26	0.32

It can be seen from the above table that surface water withdrawals is only a small part of the total surface water inputs. Even in the future scenarios, indicator 1 varied from between 0.15 and 0.19, still less than 0.20. In groundwater withdrawal, the ratio varies from 0.005 in the past to 0.01 at present and to 0.11 in the three future scenarios, even with more GW use. However, it should be specially noted that GW return flows is very high in all the studied scenarios, even it was slightly reduced in future II to IV scenarios due to better water management. Therefore, efforts should be made to reduce this indicator to lighten the threat to groundwater quality.

Annex 6

Application of CPSP Hydrological Model in Jiaodong Peninsula Basin,China

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ABSTRACT

CPSP model, a watershed scale hydrological model, was used to simulate the impacts of land and water use on hydrological cycle in Jiaodong peninsula basin, Shandong province, China. The model was calibrated by using past (1980) and present (2000) condition, including the comparison of calculated and observed annual outflow, recharge to groundwater and groundwater fluctuation, and applied to derive responses corresponding to future scenarios using monthly time steps. The results showed that different land types have a large impact on consumptive use, thus influences the total hydrological cycle, especially the land shift between barren land and forestland. The outflow to sea, base flow to surface water and recharge to groundwater decreased from past to present. If not adopting effective management measures, this case would be worse in the future. The groundwater at present has highly been stressed, indicating the unsustainable groundwater balance. With the reduced groundwater use, especially in Yantai where the proportion of groundwater irrigation taking up total irrigation decrease to 0.3 or less, the groundwater would basically reach an approximate balance state. Along with the increase of water use and change of water use pattern, the return flows to input ratio in the surface water system would increase inevitably in the future, signifying more pollution risk for surface water resources, especially downstream water body. Therefore, the related water prevention measures must be adopted to reduce the pollution as soon as possible.

Key words: CPSP model, land use, surface water, groundwater, scenarios

INTRODUCTION

China is the most populous developing country in the world, and its food security is essential to the stability of Chinese as well as global food market. China is also a big irrigation country, where irrigation plays a key role in guaranteeing food production and sustainable agricultural development. However, the water resources per capita in China are less, meanwhile it distributes unevenly both spatially and temporally. How to rationally allocate the limited water resources and guaranteeing the state’s food security and the rapid economic development is an important issue in formulating the related water policies.

In recent years, the water demand for food and people sectors are mounting with continued growth of population. The consumptive requirement of the former far outweighs that of the latter. However, with the acceleration of the process of industrialization and cities, the water requirement for industry and domestic (people sector) would increase largely, inevitably occupying the agricultural water uses. The agriculture was confronting more serious water shortage. While claiming water shortages for food and people, little attempt has been done to evaluate basin-wise needs for nature sector in the past. The traditional development pattern, which aims only to pursue a fast economic growth and consume excessively resources and sacrifice environment, has made people' s basic subsisting condition threatened. Therefore, the coordinated development of population, resources and environment has become a major strategy problem commonly concerned by international society.

CPSP model was designed to specifically address future water scenario for food and rural development, water for people as well as for nature, in order to achieve sustainable development and use of the water resources. The model was already applied to Sabarmati and Brahmani

basins of India, and acquired a good application results. The objectives of the study were (1) to evaluate the performance of model in simulating the components of hydrological cycle in Jiaodong peninsula basin, Shandong province, China; (2) Using this model to predict the impacts of future scenarios on the basin hydrology, in regard to land and water use; (3) Proposing the related measures highlighted by the study.

OVERVIEW OF CPSP MODEL

CPSP model, a watershed scale hydrologic model, was developed to account for the whole land phase of the hydrologic sector, including the consideration of hydrologic changes due to changes in the land use and agriculture use the impact of sector policies on water supplies and demand. And the model was capable of depicting surface and groundwater balances separately and allowing depiction of interaction between them as well as impacts of storage and depletion through withdrawals. The model was designed to have the characteristics of simplicity, flexibility and capability. On the premise that precipitation constitutes the primary resource, the evapo-transpiration management to increase the flows in rivers/aquifers is considered as a potential development strategy that could be changed through policy intervention.

Water requirements are studied at the basin scale by water use categories. The direct water use by forest and other non-agriculture lands through rain and soil moisture is calculated as actual evapo-transpiration (ET), within the model based on land use statistics, reference ET and values of crop parameter. Options in ET management, such as de-weeding of barren lands to limit its root zone moisture capacity, could be tried in the model. Agricultural water requirements are assessed as potential ET needs of crops that are met through rain and on-field/root zone storage in case of non-irrigated crops. The crop area statistics were used to separate the rain-fed land from irrigated land in the basin and segregate both in agricultural parcels.

The main inputs in the model include hydrological data, crop parameters, land use and land parcel areas, soil moisture capacity for each type of land parcel, irrigation system efficiencies, coefficients for return flow accounts, changes in reservoir storages etc. The model was run on the monthly basis. Maximum 5 sub-basins and 25 land parcels in each sub-basin can be divided and studied by now.

BASIN DESCRIPTION

The Jiaodong peninsula, Yantai and Weihai cities, is in the east part of China, and faces the Huanghai sea and Bohai sea on the east, south and north (called Jiaodong basin below), seeing figure 1. It is a water deficit basin having intensive agriculture and industrial development, and large population density. Based on the previous study dated from 1956 to1999, total water resources volume in Jiaodong basin is 4394 million m^3 per year, in which Yantai City is 2865 million m^3, Weihai city 1529 million m^3. For the current population of 8.929 million, the annual water volume per capita in Jiaodong basin is only 492 m^3, belonging to serious water deficit area. The annual water volume per hectare is 7125m^3, only amounting to one fourth of average value of whole country. The inadequate water resources in Jiaodong basin are a major reason to cause the contradiction between water demand and water supply. The basin has a large irrigation development. The farmland-irrigated area in 2000 is 0.401 million ha, taking up 65% of cultivated area. It is estimated that the farmland-irrigated area in 2025 will reach 0.4603 million ha, increasing 15 percent, whereas the fruit-irrigated area will increase 21 percent in 2025 than in 2000. The major part of the irrigated agriculture is supported by groundwater development at present. The groundwater withdrawal for irrigation accounts for about 67 percent of total irrigation water use Some areas already occur the overexploitation.

The available cultivated area in Yantai and Weihai cities take up separately 32.3 and 31.6 percent of total land area and the farmland irrigated area amounts to separately 63.4 and 69.6 percent of the cultivated area. According to previous statistical data, the cultivated area decreases year by

year. The main reason is that non-agricultural land and fruit area increase gradually. The gross cropped area also cuts down, especially grain-crops area. However, the cash-crops area goes up the ratio of grain-crops and cash-crops decreases. The general tendency of cropping intensity variation rises gradually. There are the similar crop patterns in Yantai and Weihai cities. Main crops are wheat, maize, and groundnut. The rotation pattern of winter wheat and summer maize dominates a large part of area in the basin. In the past years, the area for vegetable and melon were on the increase, but the area for grains has been decreasing.

Considering administrative division, similar hydrologic and water use attributes, and available data, two sub-basins in this study are divided and studied; they are Yantai city and Weihai city.

SCENARIOS DESCRIPTION

The various scenarios studied are shown in Table 1. The land use, irrigated area, water use pattern around 1980 year represent the past state, and these terms around 2000 year are the representative of present (2000) condition. The past and present conditions indicate the actual state that ever happened in the basin. The model was run on monthly basis and annual average rainfall conditions for all scenarios studied.

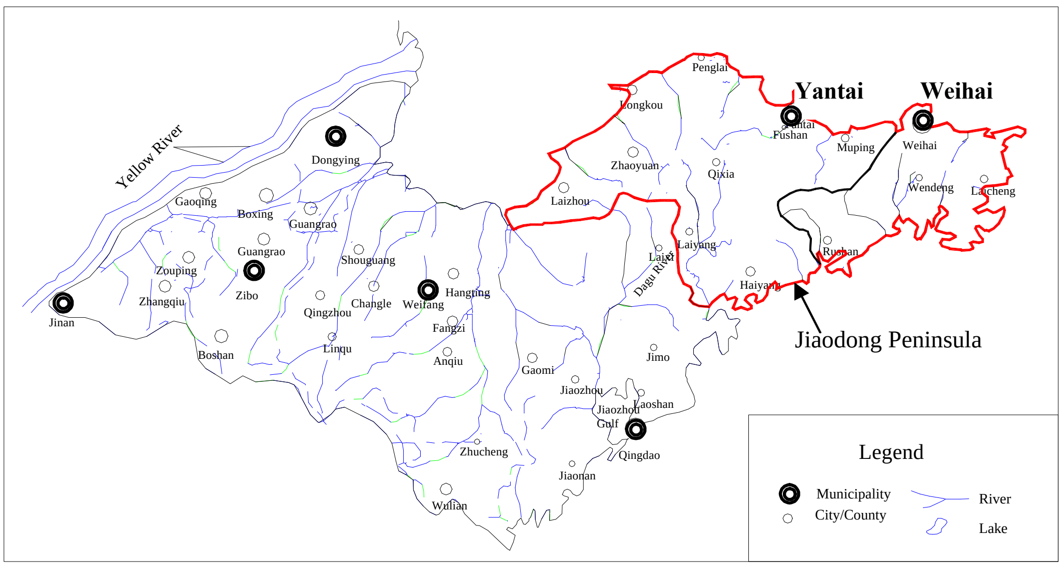

Figure 1. Map of Jiaodong peninsula basin

Table 1. Description of scenarios

Sr. No.	Sr.Studied	Abbreviation	Description
1	Past(1980)	Around 1980	The land uses, irrigated area, water use pattern represent the past conditions around year 1980
2	Present(2000)	Up to date	The land uses, irrigated area, water consumption volume, water use pattern represent 2000's year state.
3	Future I(2025)	B. as U.	Irrigation expansion is based on local planning, the proportion of surface and groundwater irrigation same as at present,the covering rate of forest increases to 40% based on present development speed,and import of about 97 million m3 in Yantai and 50 million m3 water in Weihai.
4	Future II(2025)	B. as U.without expansion of forest	Same as Furture I, but the covering rate of forest area maintains the available level
5	Future III(2025)	Better system mgt and reduced GW use	Same as future II, but the ratio of surface irrigation to total irrigation increased from 0.3 at present to 0.5 in Yantai
6	Future IV(2025)	Same as future III with drip irrigation	Same as future III,but with drip irrigation
7	Future V(2025)	Same as III,soil mgt, import more water and further reduced GW use	Same as future III, soil management in the barren lands,import 300 million m3 water, and further reduced groundwater irrigation ratio from 0.5 to 0.3.

MODEL EVALUATION

The model was calibrated by using past (1980) and present (2000) condition, and applied to derive responses corresponding to future scenarios. Based on the available data, the calibration in two sub-basins was limited to match with the following situation.

1. Comparing the annual outflow with the observed runoff.
2. Comparing the annual total recharge to groundwater computed by the model with the estimations made by local agency.
3. Comparing the groundwater fluctuation within an average year with the observed groundwater fluctuation.
4. Comparing agricultural water use with actual water use observed by local agency.

The approximate comparison for above-mentioned 1, 2 and 3 section between calculated and observed values is shown in table 2. It can be seen from table 2 that the results calculated by model match the observed values well. The outflow and recharge to groundwater at present has a marked reduction than that at past. The main reason might be the change of land uses. The covering rate of forest area in the past and present conditions have a large difference, in which the covering rate of forest area has gone up from 20 percent at past to 30 percent at present. Therefore, the consumption water from nature sector will be increased.

The calculated groundwater storage change within the years was mostly underestimated compared to observed values. Due to missing data, the proportion of groundwater withdrawal given in the model was assumed the same for every month, and equal to the proportion of available yearly groundwater withdrawal. However, the actual proportion of groundwater withdrawal is different between months. During the dry season and high peak of crop water demand, the groundwater withdrawal would contribute a large part of water use. This might be

main reason of the difference between calculated and observed groundwater storage change, whereas the rigid matching in the modeling was not tried.

Table 2. Comparison of calculated and observed results for past and present conditions

Condition	Items		Calculated by model	Observed	Difference(%)
Past(1980)	Annual outflow(million m^3)	Yantai	1528	1710	-10.6
		Weihai	1155	1100	5.0
		Total	2683	2810	-4.5
	Annual recharge to groundwater(million m^3)	Yantai	858	895	-4.12
		Weihai	403	399	1.0
		Total	1261	1294	-2.53
	GW flunctuation within the years(mm)	Yantai	362	401.4	-9.81
		Weihai	199	222.9	-10.59
Present(2000)	Annual outflow(million m^3)	Yantai	1136	1165	-2.5
		Weihai	947	912	3.8
		Total	2082	2077	0.3
	Annual recharge to groundwater(million m^3)	Yantai	668	NA	
		Weihai	341	NA	
		Total	1010		
	GW flunctuation within the years(mm)	Yantai	307	375.3	-18.1
		Weihai	169	141.9	18.9

Given reference ET and crop coefficient under the known land uses and crop pattern, the calculated and actual irrigation water use were compared in table 3. It can be seen from table 3 that the calculated irrigation water use was underestimated, especially the larger difference in Yantai occurred. The difference might be that the actual ET be overestimated because the calculation time-step was based on monthly basis, therefore, the effective rainfall might be overestimated. Generally, the calculated results by model are acceptable, and the results show that the selected crop parameters are suitable for local condition.

Through the above calibration, the results shows that the model responses the hydrological features of Jiaodong peninsula well, and can be used for predicting future hydrological cycle and water use situations.

Table 3. Comparison of calculated and actual irrigation water use for past and present condition (million m^3)

Items		Calculated by model	Actual water withdrawal	Difference(%)
Past(1980)	Yantai	767	955	-19.6
	Weihai	237	251	-5.4
	Total	1005	1205	-16.6
Present (2000)	Yantai	687	827	-17.0
	Weihai	232	226	2.6
	Total	919	1054	-12.8

RESULTS AND DISCUSSION

General

Compared to past condition, the outflow to sea and recharge to groundwater at present reduce largely, in which the former has decreased by 22 percent and the latter by 20 percent. The withdrawal of groundwater accounts for 44 percent of total groundwater inputs at past, and 86 percent at present, thus base flow reduce to a great extent.

The model indicates that the total recharge to groundwater at past is 1261 million m^3, which is about 9 percent of average annual rainfall of 13748 million m^3. These values appear reasonable, and match the estimations made by local agency.

The model displays the extreme sensitivity for land use change, especially the shift between barren lands (or other unused lands) and forest area. Under the same irrigation expansion, when the covering rate of forest area is extended from 30 percent to 40 percent, the nature consumption has a marked rise, and the surface water reduces obviously.

In the present condition, the actual irrigated area takes up only 68 percent of command-irrigated area, and the actual water withdrawal for irrigation computed by model is 919 million m^3, which was a little lower than observed values. With the expansion of irrigation in the future scenarios, the command-irrigated area would be 1.16 times as large as that of present condition. The water requirement for agriculture under planned development condition (future I) would reach 1307 million m^3, increasing 42 percent of water withdrawal over the available actual water use. While the proportion of surface irrigation to total irrigation keeps the available level, the water requirement for agriculture, D & I is 1074 million m^3 from surface water and 1440 million m^3 from groundwater. The capacity of surface water supply for future scenarios (2025) will reach 1611 million m^3, completely meeting the demand of surface water withdrawal, but the groundwater withdrawal would far exceed the total inputs. Therefore, various water management measures should be adopted, such as changing water use pattern of surface water and groundwater, improving further the efficiency of water use, import more water, natural &induced recharge from river to groundwater or pumping water from groundwater to river to maintain the river and groundwater balance.

Consumptive use of water

For the current condition, the total consumptive use is 11821 million m^3, including nature sector of 6114 million m^3, agricultural sector of 5429 million m^3 and people sector (D and I) of 277 million m^3. In the total consumptive use, non-beneficial ET is 2291 million m^3 in the nature and 711 million m^3 in the agricultural sectors. The beneficial ET in the nature sector changes obviously with the expansion of forest area or without. Corresponding to 20, 30 and 40 percent of forest covering rate for past, present and scenario future I, the beneficial ET in the nature sector is 2473, 3823 and 4946 million m^3 respectively, non-beneficial ET decreases accordingly. Total ET in the nature sector has increased by 12 percent over the past condition. If the covering rate of forest area continues to expand on the basis of available development speed, total ET in the nature sector would be on the increase and continues to increase by 8 percent in future (2025) over the present condition.

In the agricultural sector, the non-beneficial ET at present takes up 13.2 percent. With the expansion of irrigated area and increase of cropping intensity for future scenarios the proportion of non-beneficial ET reduces to 10—11.3 percent. To reduce the non-beneficial ET in the agricultural sector, the soil and water management in the fallow lands can lead to an improvement ET, such as scenario V including better soil management in the barren land, non beneficial consumption from irrigated land would reduce to10.1 percent.

Compared to present condition, the command-irrigated area in the future scenarios increase by 16 percent. Owing to the adoption of water-saving measures, the increase of irrigation water use is not so large that the agricultural consumptive use rises less, especially for future V with the increase of 2 percent. Table 4 summaries the composition of sector's consumptive use under different scenarios.

Table 4. Consumptive use (evapo-transpiration) by sectors (Million m^3)

	Past(1980)	Present(2000)	Future I (2025), B.as U.	Future II, B as U without expansion of forest	Future III, with better system mgt and reduced GW use	Future IV, same as future III,drip irrigation	Future V, same as III, more drip and soil mgt,import
Nature sector							
Beneficial	2473	3823	4946	3823	3823	3823	3823
Non beneficial	2986	2291	1656	2416	2416	2416	2416
Agriculture sector							
Beneficial	4690	4718	4985	4985	4977	4975	4990
Non beneficial	671	711	637	637	637	637	559
D&I (People sector)	136	277	500	500	500	500	500
Total all sectors	10956	11821	12723	12361	12353	12352	12289

Surface water

The withdrawal of surface water at past and present was the similar and equal to 22 percent of total inputs, but the return flows contribute 6 percent of total inputs at past and 10 percent at present. Thus more risk for pollution of downstream water was caused at present than at past. Also, the base flow availability reduced significantly at present.

In the future scenarios, the water requirement in the command-irrigated area is far larger than available actual irrigation water use, and the predicted water use for D&I go up much too. The withdrawal of surface water reaches 33—41 percent of total inputs. With reduced groundwater use in Yantai, the withdrawal to input ratio for scenario future III and IV reaches about 41 and 40 percent respectively, and return flows to input ratio approaches all 19 percent. With further reduced groundwater withdrawal and more import water, scenarios future V have 41 percent of surface withdrawal to total inputs, and the return flows to input ratio is a little lower than that of other future scenarios.

In all future scenarios, the base flow and river outflow are affected by the pattern of development, and reaches the smallest for scenario future I. The total river flows (after providing the natural & induced recharge from river to ground water) and its monthly distribution are shown in Figure 2. From scenario future I to future V, the total river flows increased gradually. The outflow to sea for scenario future V approaches the available level and only 4 percent lower than that of present condition.

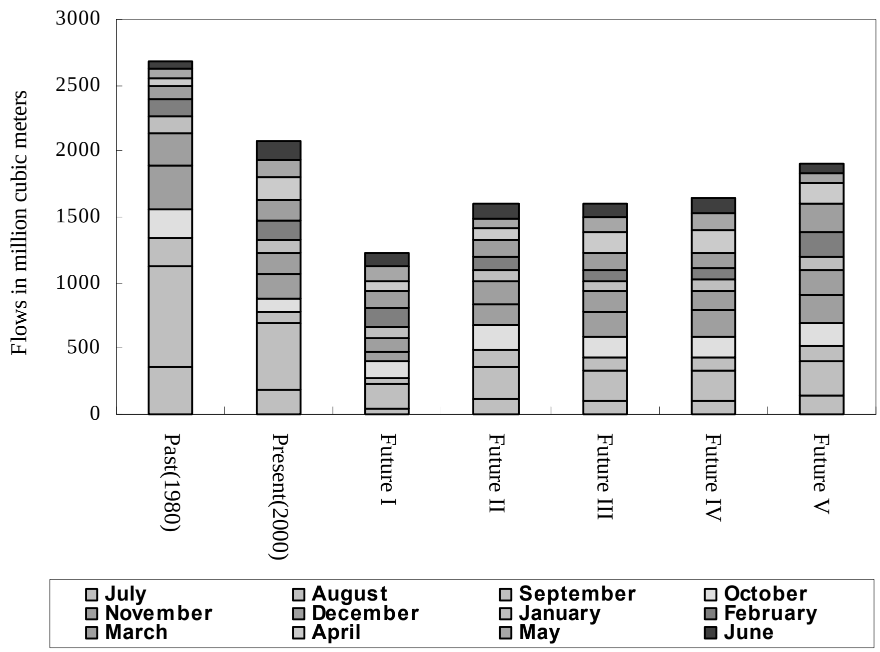

Figure 2. Monthly river flows in Jiaodong basin

Groundwater

The extensive groundwater use in the basin has been practiced. In the past condition (1980), the withdrawal of groundwater constitutes only 44 percent of the inputs, whereas the return flow is 32 percent of the inputs. In the present condition, the withdrawal of groundwater accounts for 86 percent of the inputs, indicating the unsustainable groundwater balance. For scenario future I with business as usual, the withdrawal of groundwater contributes still 87 percent of the inputs even though 600 million m^3 of induced recharge from river to groundwater, but the return flows to input ratio decreases.

In order to maintain the groundwater balance, the proportion of groundwater withdrawal should be reduced, especially for Yantai. When the proportion of surface irrigation to total irrigation in Yantai for scenario future III increased to 50 percent from available 30 percent, the withdrawal maintains the similar ratio compared to future II but with 300 million m^3 of induced recharge. With more drip irrigation (future IV), further reduced groundwater use (future V), the withdrawals would constitute 78 and 76 percent of the inputs respectively, whereas the induced recharge for future V decreased to 100 million m^3, the return flow to input ratio increases a little, and future V reaches an approximate balance state. The withdrawals of both surface water and groundwater for different scenarios are shown in Figure 3.

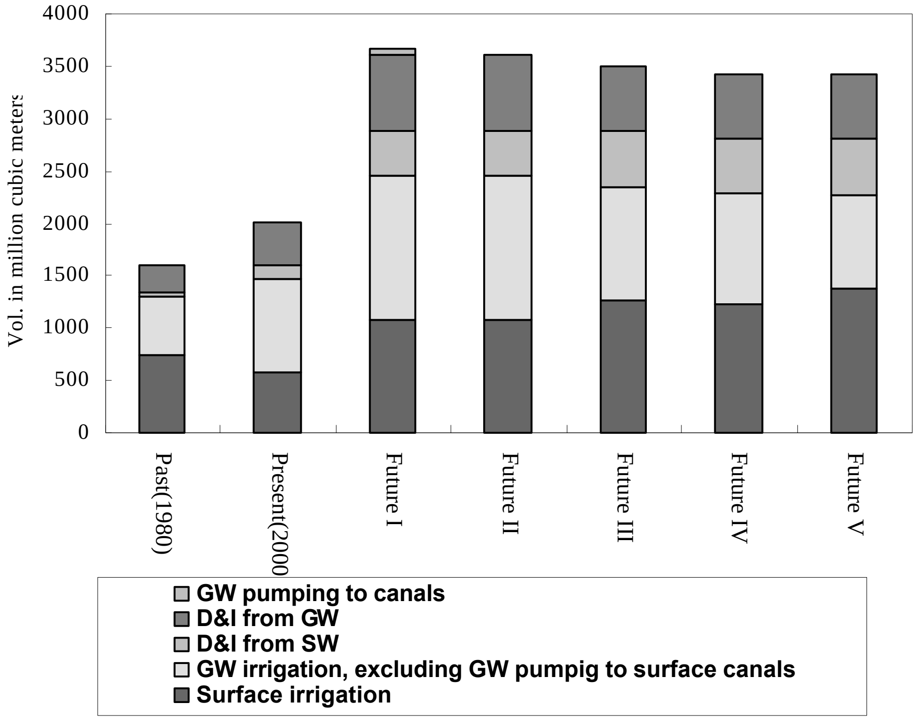

Figure 3 Composition of withdrawals in Jiaodong basin

GW pumping & induced recharge

The withdrawals from surface and ground water would be met from the available surface and groundwater waters. When the surface water was not available, additional pumping from ground water to the surface canals was required to fulfill the surface water demands. Similarly, due to heavy groundwater withdrawals, the sustainability of the groundwater storage under the average recharge conditions would be disturbed, and the assumption of natural and induced recharge from surface to groundwater would be required. The demands for groundwater pumping into canals and natural & induced recharge for all scenarios are given in table 5. The groundwater pumping to canals is often at the time when the river flow is low and the water requirement for crops is high. Whereas the natural & induced recharge from river to GW is mostly in the high flow months. Obviously, if maintaining available 30 percent proportion of surface irrigation to total irrigation, more natural & induced recharge from river to groundwater for scenarios future I and II was needed because the groundwater was overexploited. While the proportion of surface irrigation to total irrigation in Yantai increases to 50 percent such as scenario future III and IV, the natural & induced recharge could be reduced, but the groundwater withdrawal approaches or exceeds the exploitation rate, and the groundwater balance would confront crisis. If the proportion of surface irrigation to total irrigation in Yantai further increases to 70 percent and import more water, the groundwater withdrawal to input ratio maintains the similar level and the natural & induced recharge could be reduced, the groundwater could maintain an approximate balance for a long time. Given surface storage filling and depletion for all future scenarios, the groundwater pumping to surface canals for meeting shortages in surface irrigation would be zero except future I in which 58 million m^3 water is needed to meet the filling of surface storage. If the other water sources such as saline water, sewage reuse and seawater use could be developed to meet the shortages; the surface water and groundwater situation could be improved further.

Table 5 Requirements of groundwater pumping into canals and Natural and/or induced recharge from river to groundwater for all scenarios

(Million m^3)

Description	Past	Present	Future I	Future II	Future III	Future IV	Future V
Natural & induced recharge from river to GW for balancing the GW	0	0	600	600	300	300	100
GW pumping to surface canals for meeting shortages in surface irrigation	0	0	58	0	0	0	0

Water situation indicators

The four water situation indicators were proposed to depict the level of water use (withdrawals) and potential of hazard (due to return flow) to water quality. Table 6 presents the values of these indicators. Indicator 1 and 2 represent respectively the proportion of surface withdrawal and return flows taking up total surface inputs. Indicators 3 and 4 represent respectively the proportion of groundwater withdrawal and return flows taking up total groundwater inputs. It can be seen that the groundwater withdrawal in Jiaodong peninsula basin was highly stressed than past condition, and groundwater quality was under moderate threat. With the increase of surface water use, the return flows to input ratio would increase largely compared to past and present conditions, indicating more risk of pollution for surface water resources, especially downstream water. Therefore, the related water prevention measures must be adopted to lighten the pollution pressure as soon as possible along with the change of water use pattern.

Table 6. Water situation indicators

	Past	Present	Future I	Future II	Future III	Future IV	Future V
Indicator 1	0.217	0.218	0.358	0.327	0.398	0.386	0.406
Indicator 2	0.062	0.103	0.218	0.189	0.193	0.191	0.182
Indicator 3	0.439	0.858	0.867	0.781	0.788	0.780	0.761
Indicator 4	0.324	0.336	0.306	0.288	0.300	0.292	0.340

CONCLUSIONS

The model outputs show that the outflow to sea and recharge to groundwater were on the decrease from past to present, in which the annual outflow to sea reaches 2683 million m^3 in the past condition, and 2082 million m^3 in the present condition, the annual total recharge to groundwater is 1261 million m^3 in the past condition, and 1010 million m^3 in the present condition that match the observed results made by local agency. For scenario future I with business as usual, the river outflow reaches the smallest in all scenarios. Through adopting different measures, from scenario future I to future V, the total river flows increased gradually. The outflow to sea for scenario future V approaches the available level with 4 percent lower than that of present condition.

The different land types have a large impact on consumptive use, thus influences the total hydrological cycle, especially the land shift between barren land and forestland. Corresponding to 20, 30 and 40 percent covering rate of forest area at past, present and future scenario I, the consumptive use from the nature sector would be respectively 5459, 6114 and 6601 million m^3. Total ET in the nature sector at present has increased by 12 percent over the past condition and

increased by 8 in future I (2025) over the present condition. Therefore, the expansion of the forest area should be in consistent with local water resources and agricultural development.

The base flow from groundwater to river is decreasing from 592 million m^3 per year at past to 292 million m^3 per year at present, this indicates a decreasing groundwater storage, thus signifying the crisis of the groundwater deterioration. The groundwater withdrawal has higher stress than past condition. In order to sustain the groundwater balance, the groundwater withdrawal should be reduced, especially for Yantai. While the proportion of surface irrigation to total irrigation increases to 70 percent in Yantai and better water and soil management was adopted, the groundwater withdrawal for future V would decrease to 901 million m^3.

With the increase of water use, the ratio of return flows taking up input would increase inevitably in the future, indicating more pollution risk for surface water resources, especially downstream water body. Therefore, the related water prevention measures must be adopted to reduce the pollution as soon as possible along with the change of water use pattern.

With the increase of Industry and domestic water use, the agriculture would confront more serious water shortage. It is necessary to implement the optimal allocation and combined regulation of multi-water sources, increase the water reuse and water use efficiency, build the complete water engineering to increase the guarantee rate of water supply and enhance the prevention of water resources.

Annex 7

Long Term Demand Projections for India- A Note

Yoginder K. Alagh

Introduction

While chairing the IFFPRI meeting session on water demand modeling in China and India the present author had argued that the projections for India are grossly underestimated as compared to those for other countries. Methodologically they need improvement and also show no awareness of excellent work done in India by modeling groups. Further discussions in the WWF at Kyoto, etc., confirms this. The present note outlines this position

The Planning Commission of India has correctly projected that the net area sown or arable land of the country will remain constant at 141 million hectares. Growth in net area sown at around 1% annual in the early period of planning fell to around 0.6% and then to 0.3% in subsequent decades and is now not growing at all. It is reasonable to assume that the geographical area of the country or the extensive land frontier for exploitation has reached its limits. This is an important issue, the implications of which are not being realized with the urgency they deserve, since at a basic level resource constraints of a more severe kind faced by certain East Asian economies are now being approached in India. Organizations, communities, households and individuals will have to grasp this fact and live with it.

The intensive frontier for land use, however, remains. It has been known for example, as noted by Chaddha, et. al., that cropping intensity depends on irrigation. Thus gross cropped area or harvested area has been shown in the past to be strongly determined statistically, in an econometric sense, by net irrigated area and irrigation intensity. Irrigation permits the possibility of multiple cropping by bringing additional land under cultivation and the same land to be used more than once. Also the application of new technologies in the past was related to assured water supply. The new technology, on account of its photo insensitivity properties, permits shorter duration crops, which also is associated with increase in cropping intensity. (For details of this relationship in agricultural planning and policy models, see Alagh, ESCAP, 1983). The use of this relationship has been used in Indian agricultural policy and plan models, since the mid-Seventies when the first agricultural sub-model of Indian planning was formulated for grain self reliance (See Alagh, et. al., Planning Commission, 1979). The parameters used in different plans were as follows;

Sr. No.	Plan Irrigation Utilisation	Additional Cropped Area (mn. hec.)	Additional GCA w.r.t. GIA (mn. hec.)	Elasticity of
1.	Fifth	9.11	6.04	0.20
2.	Sixth	13.80	11.74	0.26
3.	Seventh(O)	10.90	10.00	0.31
4.	Seventh®	9.50	7.60	0.24

In the Nineties as we noted arable area has stopped growing and so the land constraint is far more severe. Growth will now have to be sourced from double cropping and yields.

This fundamental relationship can be used to project the intensive resource base of the economy. Table 1 shows that by the end of the decade India would have used up most of its balance water reserves, with the irrigated area reaching around 114 million hectares by 2010. (See Alagh, 1995, p. 395 and table). The projections for 2020 are a requirement of irrigation of 122 million hectares for irrigation (K. Chopra and B. Golder, Table 2.6)

Table 1. Land and Water resources perspective

Sl No	Variable	1991/2	1996/7	2001/2	2006/7
1.	Population (millions)				
	a. Planning Commission 🎬	856	938	1016✎	1099
	b. UN (Unrevised)	874✎	955	1042	1130✎
2.	Net Area Sown (mn. hec.)				
	a. Planning Commission estimate	140	141	141	141
	b. Revised		141	141	141
3.	Gross area sown (mn. hec.)				
	a. Planning Commission estimate	182	191	197	203
	b. Revised	183	191	197	205
4.	Gross Irrigated Area (mn. hec.)				
	a. Planning Commission estimate	76	89	102	114
	b. Revised	64	78	92	107
5.	Cropping Intensity				
	a. Planning Commission estimate	1.30	1.35	1.40	1.44
	b. Revised	1.30	1.35	1.40	1.45
6.	Gross Irrigated Area as % of Gross Area Sown				
	a. Planning Commission estimate	41.5	46.9	51.7	56.1
	b. Revised	35.0	41	46	51

Source: Perspective Planning Division, Planning Commission FAO, Agriculture Towards 2010, Rome (Revised projections are tentative and are by the author.

Note: ✎ Interpolated or extrapolated from implied trends.
🎬 Planning Commission estimates

Source: Uma Lele, et.al.. World Bank, 2001, Annex table by Y.K.Alagh

The projections assume a vastly improved performance on the land and water management frontiers. It needs to be remembered that the balance ground water reserves are now more limited. A very dramatic effort will be needed to harvest and carefully use the available water. Otherwise, the projected increase in cropping intensity will simply not take place. Cropping intensity increased from around 1.18 at the beginning of the Seventies to around 1.3 in the early Nineties. In the next two decades, this effort needs to be considerably strengthened, so that cropping intensity can increase from 1.3 to 1.5. Harvesting of rainwater, recycling water from agricultural drainage systems, more judicious use of water for cropping, will all be required. Non-agricultural use of water will have to be far more economical. The detailed exercise done for this study requires that in the sustainable scenario 35.83 BCM of water are saved by conjunctive use of surface and groundwater and 142 BCM through harvesting of runoff. (Chopra and Golder, Table 2.6)

Another way of looking at the severe land constraint is to see that a net area sown per person will go down from around 0.17 hectare to around 0.10 hectares. Gross area sown per person currently around 0.2 hectares will even, if cropping intensity increases very rapidly, go down to around 0.15 - 0.18 hectares.

Table II given below summarizes the findings on water requirements and water availability under alternative scenarios. Extrapolations of demand from different sectors show that if business as usual continues, quantitative shortages of water are likely to emerge. Declining water use efficiency in agriculture, increasing urbanization and unregulated industrialization pose significant challenges for the water sector in the future. Shortages, either of ground or surface water or both are likely to be pronounced in the states of Andhra Pradesh, Gujarat, Haryana, Punjab, Tamil Nadu and Maharashtra.

Table 2: Water Requirements: Different Scenarios (in BCMs in 2020)

	BAU	HG	SS (%)
Households	67.52	67.52	45.01 (4.66)
Power	8.19	12.29	5.00 (0.5)
Industry	27.91	41.58	27.72 (2.87)
Agriculture	677.30	804.20	768.37 (79.69)
Evaporation	42.00	42.00	42.00 (4.33)
Ecological	78.00	78.00	78.00 (8.09)
TOTAL	920.92	1005.59	964.09

Even with this a shortfall of irrigated land to the magnitude of 10 million hectares may arise. If this shortfall is made up for as in the HG scenario, a water shortage or deficit of 22% arises. The manner in which this translates into groundwater or surface water shortages in particular regions depends on policies pursued. The HG scenario also increases demands of the industry and power sectors, resulting in an overall increase in water requirement.

The sustainable scenario identifies interventions on the demand management and supply augmentation sides that can ensure that total water requirement is 964.09 BCMs in 2020. Of this, 79% shall come from the agricultural sector. In percentage terms, this is a decrease from current levels since requirements for non-agricultural sectors rise with industrialization and urbanization. Only 4.66% of total requirement comes from the household sector and another 3.37% from industry and power sector. This study provides additionally for a requirement of 78 BCM to maintain base non-seasonal flow in rivers and 42 BCMs for evaporation losses. With total supply from ground and surface water at 1110.566 BCMs, one can argue that the position at the aggregate level shall be manageable. Such a presumptions, assumes however that interventions suggested to achieve improved water use efficiency shall be undertaken and shall be successful. In frozen water use efficiency in agriculture scenario, acute shortages may arise even at the aggregate level.

By 2020, Chopra and Goldar estimate a BAU Scenario:

"In such a scenario, overall water shortage or deficit is only of 2%. This is accompanied by an under utilisation of surface water capacity of 21% (due to low water use efficiency) and an over-extraction of ground water of 25%. Such an unbalanced growth shall itself be the source of a considerable amount of unsustainability.

The second interpretation of the BAU scenario is motivated by the need to estimate regional shortages or surpluses. The BAUST or the business-as usual with the state level estimates is made by assuming that surface and ground water development follow the trend extrapolated from the past.[3] The regional analysis reveals that over-extraction of groundwater shall emerge in eight states. In addition to Gujarat, Haryana, Punjab and parts of Uttar Pradesh which are characterized as areas with over-use of ground-water, Andhra Pradesh, Maharashtra and Tamil Nadu are also expected to be subject to over-extraction. Surface water shortages may start emerging in some states such as Gujarat, Bihar, Maharashtra and Orissa. "and again taking population projections and the energy models as developed by the AITD urbanization study and suitable assumptions they estimate:

"The total requirement for households, power and industry is 103.62 BCMs in the BAU scenario. Adding evaporation loss and ecological requirement we obtain a total requirement of 223.62 BCMs for requirements other than agriculture."

[3] Following such a methodology implies that the two estimates should not be compared. The BAUST estimate is motivated by the need to identify regional shortages or surpluses of water, while the BAU estimates determine the impact of food security objectives on water demand.

Chopra and Goldar also estimate a high growth scenario. Then:

"The high growth scenario at the national level implies a rate of growth of agriculture of 4.98% per annum with the food grain sector growing at 2 to 2.4% p.a. and the non-food grain sector at 7.69 to 9.22% p.a. Irrigated land requirement increases to 122 million hectares. With present levels of water use efficiency, water requirement increases to 804.2 BCMs. This implies a shortfall/water deficit of 22%. The manner in which this translates into over-extraction of groundwater or other indices of un-sustainability depend on policies pursued and cannot be ascertained. It is, however, clear that both the high growth and BAU scenarios are likely to result in unsustainable demand for water of one kind or the other in the absence of specific investments and policies directed at improvement of water-use efficiency and other sustainability promoting measures.

The requirements of the households, power and industry sectors likewise add up to 120.57 BCMs in the HG scenario as against 103.62 BCMs in the BAU scenario.

Regarding the quality of water they say

"An important issue which our analysis brings out is that at present levels of urban wastewater and effluent treatment, water quality will deteriorate significantly, impacting availability as well in certain areas. The reduction in water availability due to quality problems is expected to be substantial.[4] We use this evidence to underscore the need for and the corresponding benefit from "sustainability investments".

Chopra and Godar then develop a sustainable policy scenario:

"It is clear from the above analysis that, in order to achieve sustainable water development, consistent with sectoral requirements arising from a sustained 7 to 8 % annual growth in GDP and other accompanying changes in the economy, a large number of interventions shall be required. These interventions could be technological, institutional, or supply augmenting possibilities. Table I list some interventions for sustainability we suggest, including watershed management, drip irrigation, and institutional arrangements, such as water users' associations, that help in more efficient use of water. Some of these have been experimented with in different contexts and we estimate (on the basis of existing studies) the extent to which they can be expected to spread over the next twenty years. Corresponding costs are also worked out. These are, in other words, the costs to be borne for ensuring sustainable use of water. Other interventions suggested involve costs which are either difficult to measure, involve uncertainty or are not only economic costs but also perhaps political in nature. Further, interventions are also classified according to whether they are to be undertaken on presently irrigated land which is privately owned, or consist of interventions on land (possibly under private, common or government ownership) to be brought under irrigation."

Table 3. Nature of Interventions under Sustainable Scenario

Nature of interventions	Sector	Water Saving/Addition (in BCMs)
Demand management/ Recycling technology	Households	22.51
	Power sector	7.29
	Industry	13.86
	Agriculture	35.83
Supply Supplementing	Additional Runoff Capture	142.00
Total Water Saving/ Augmentation		221.49

[4] See Das and Dipankar (2000) Using a more stringent standard for irrigation water, this study estimates that in some areas with a high level of urbanisation, only 54% of the groundwater in underlying aquifers shall be fit for use for irrigation. This study was commissioned by IEG as part of the current UNU study.

Much the same kind of approaches and projections have been made by the National Commission on Perspectives for Water Development as shown below:

Table 4. Water Requirement for Different Uses

S. No	Uses/year	Year 2010			Year 2025			Year 2050		
		Low	High		Low	High		Low	High	
		Km^3	Km^3	%	Km^3	Km^3	%	Km^3	Km^3	%
	Surface Water									
1.	Irrigation	382	391	53	360	389	46	375	463	39
2.	Domestic	23	24	3	30	36	4	48	65	6
3.	Industries	26	26	4	47	47	6	57	57	5
4.	Power	14	15	2	25	26	3	50	56	5
5.	Inland Navigation-in additional for ecological need	7	7	1	10	10	1	15	15	1
6.	Environment (2) Ecology	5	5	1	10	10	1	20	20	2
7.	Evaporation	42	42	6	50	50	6	76	76	6
	Total	499	510.1	70	532	588.3	67	641.1	751.7	64
	Ground Water									
1.	Irrigation	184	188	26	211	229	27	253	344	29
2.	Domestic & Municipal	19	19	3	25	28	3	42	46	4
3.	Industries	11	11	2	20	20	2	24	24	2
4.	Lower	4	4	1	6	7	1	19	14	1
	Total	217.7	221.9	30	262.3	281.7	33	331.9	428.3	36
	Grand Total	717	732	100	794	850	100	973	1180	100

Source: Government Of India, National Commission on Perspectives for Water Development

While some of the interventions suggested are well known, others involve fresh thinking, hence we discuss them in some detail, with theoretical and experience based analysis. The technology interface is important, both for land and water management and for cropping and non-crop farm systems that are optimal, in this class of issues. While a lot of research has been done and is available, (Alagh, FAO/ UNESCO, 2002) the real issues are policy rules for fast replicability of existing knowledge and success stories. Community institutions have to be at the heart of this process. The projects examined have varied considerably. Watershed development, for settled agriculture alternately tree crops, reclamation of saline lands, farmers run lower level irrigation systems, aquifer management in difficult situations, like coastal aquifers, tribal irrigation cooperatives, tank irrigation have all been reported as success stories and studied. Chaddha has generalized from them. The question is replicability on a larger scale. We have (YK Alagh,2003) tried to set out some policy rules which we argued if applied in functioning policies may reverse the tide .

It is interesting that in recent global meetings the same strategy is being advocated. India is playing a strong role in such advocacy. For example the Expert Round Table organized by India and the UN to operationalize the new initiatives required at the Johannesberg Meeting on RIO PLUS 10 said the following:

- *Improve* investment processes in developing countries and countries with economies in transition to facilitate access to credit lines as well as to preferential terms of financing and of providing funds for collateral support systems and sharing of investment risk. In this context, provide securities for local institutions involved in infrastructure development and specific knowledge based activities to support sustainable economic growth, through, for example, creation of collaterals, interest differentials and trading of financial papers. These processes should be targeted, amongst others, to artisan and producer groups linked with local and global markets, local government agencies providing social and economic infrastructure, and farming and rural communities.

  - *Improve* coordination among international financial institutions and redirect funds to sustainable development projects.
  - *Develop* new or *strengthen* existing mechanisms such as the Clean Development Mechanism (CDM), to finance or re-finance community projects in rural areas aimed at land and water development, agricultural diversification and agro-processing, development of infrastructure, trade, and rural energy supply.
  - *Study* for the purpose of replication, existing models for providing access of rural communities to ICTs in order to enhance the level of information in rural communities on productions, crops, markets, prices and technologies .

  India has raised this issue in the WTO negotiations also as the following draft of the Special Committee of Agriculture under the chair of Stuart Harbinson on support to Farmers and Producer s and Cooperatives in rural development infrastructure showed. The opportunities in the Harbinson Draft are as follows:

"Attachment 9

Article 6.2 of the Agreement on Agriculture

- ***Possible amendments for further consideration (changes in italics)***
- In accordance with the Mid-Term Review Agreement that government measures of assistance, whether direct or indirect, to encourage agricultural and rural development are an integral part of the development programs of developing countries, *and in accordance with paragraph 13 of the Doha Ministerial Declaration the following measures* in developing country Members shall be exempt from domestic support reduction commitments *to the extent that these commitments* would otherwise be applicable to such measures:

  1. investment subsidies which are generally available to agriculture
  2. agricultural input subsidies generally available to low-income or resource-poor producers
  3. domestic support to producers to encourage diversification from growing illicit narcotic crops *or those whose non-edible or non-drinkable products, being lawful, are recognized [by WHO] as harmful for human health*
  4. *subsidies for concessional loans through established credit institutions or for the establishment of regional and community credit cooperatives*
  5. *transportation subsidies for agricultural products and farm inputs to remote areas*
  6. *on-farm employment subsidies for families of low-income and resource-poor producers*
  7. *government assistance for conservation measures*
  8. *marketing support programs and programs aimed at compliance with quality and sanitary and phytosanitary regulations*

9. *capacity building measures with the objective of enhancing the competitiveness and marketing of low-income and resource-poor producers*

10. *government assistance for the establishment and operation of agricultural cooperatives*

11. *government assistance for risk management of agricultural producers and savings instruments to reduce year-to-year variations in farm incomes*

12. *Domestic support meeting the criteria of this paragraph shall not be required to be included in a Member's calculation of its Current Total AMS"*

It has been shown recently that such work is important in sustainable development policies for the subcontinent (Y.K.Alagh,2004)

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Annex 8

A note by V.M. Ranade

1.0 Water for nature

Terrestrial ecosystems viz., natural (rain forest, deciduous forest, grass lands etc.) and man-made (rainfed and irrigated agriculture), exercise first charge on the Water Resource that we get in the form of precipitation. These ecosystems take their share of water resource first, leaving the balance water to flow as 'blue water' through streams and groundwater aquifers. On the watersheds and on the land under cultivation, some measures are usually taken by humans to augment groundwater recharge or to prevent surface evaporation, in order to improve soil moisture availability. But as far as water demand for the natural terrestrial ecosystems is concerned, man can upgrade it qualitatively and/or quantitatively to increase its water demand or degrade it resulting in reduction in water demand. No other measures are necessary to reserve / allocate their share of water.

Balance 'blue water', flowing through streams and rivers traditionally supports the riverine ecosystems. In the central and peninsular India, despite the non snow-fed rivers, seasonal monsoon, tropical climate and hard rock geology, there used to be substantial fair-weather base flow in the rivers upto mid 20th century, because of the extensive forest cover (to hold the water and release it in fair weather) and lack of groundwater extraction. Dwindling of fairwater flow in the later half of the 20^{th} century, is clearly attributable to the sizeable reduction in forest cover, coupled with indiscriminate groundwater abstractions, facilitated by the extensive energisation of wells. This fact is rarely understood and recognised even by the experts.

Man-made reservoirs provide surface irrigation in monsoon & winter season, and because of its poor water-application efficiency it results in deep percolation of applied water to recharge groundwater and to augment base flow of rivers. 45,000 large reservoirs constructed the world over during later half of the 20th century, have increased land under irrigation and have enhanced land productivity manifolds, to meet food demand for rising population. Without these reservoirs, all land under forest would have had to be brought under plough, to meet rising food demand. Is it not a significant contribution of these large reservoirs by preventing the terrestrial ecosystems from denudation & destruction due to onslaught of agriculture? But still large dams are portrayed to be responsible for usurping water from the terrestrial & riverine ecosystems and are being treated as a 'whipping boy.'

Proposal of releasing water from reservoirs during fair weather, to maintain riverine ecosystem would have no logic because, without the reservoirs, there would not have been any fair-weather flow in the rivers due to loss of forest cover & high groundwater abstractions in the central & peninsular Indian rivers. Secondly, even if the costly stored water is released to support natural flora & fauna of the riverine ecosystems, such water would be lifted by the species 'Homo Sapiens' – human beings, to grow cash crops in fair weather, to the detriment of flora & fauna in the ecosystem which would wither, defeating the very purpose of such releases.

We need not be sentimental while acting for the good cause, but have to be practical & should have due regards to the ground realities. Policies suitable for snow fed rivers, temperate climate, extensive forest cover and less groundwater abstractions, which is observed in many developed countries, certainly cannot be applied for the Indian subcontinent. Hence I do not subscribe to the idea of releasing any water from reservoirs during fair weather, just to invigorate the presently non-existing riverine ecosystems.

Following, however, could be a workable solution in this case. Fair-weather flow in most of the rivers in India (and perhaps in most of the developing countries of the world) consists of domestic effluent from cities/towns and industrial effluent and there is no practically base flow in the rivers to dilute the effluent. There is dire need of taking strict measures to treat the effluent and release

it into the rivers only then, so that it would meet the demand of riverine ecosystems qualitatively and quantitatively. Otherwise such streams containing nitrates, phosphates and organic matter would cause eutrophication of the man-made lakes into which they drain. Pathogens from domestic effluent & toxic chemicals / heavy metals from industrial effluent would be a serious health hazard. Hence treatment of all effluent and releasing it through streams & rivers would be the environment friendly way to rejuvenate the riverine ecosystems.

2.0 Observations on Scenario Developments by Podiumsum model

2.10 From the demographic projections it is seen that, population of China may stabilize by the year 2025-2035 or so. Hence scenario development for China would be acceptable for the projected population of the year 2025.

But it is apprehended that population of India would stabilize by 2050 to a figure lying between about 150 crores (optimistic estimate) and 180 crores (pessimistic estimate), projection of UNO being 164 crores. Hence the scenario development of India would have to be done to cater to the water requirement for that projected population of the year 2050 and not 2025. Correct import of the probable situation for the expected stabilized population cannot be understood by the study made for 2025 population. This is a serious lacuna in the present study because 2025 projections would indicate the interim stage and not the final steady stage.

Secondly, the scenario development should not be for the median value of the projected population. It should be carried out for both upper & lower values of projected population, in order to be more realistic. Such study would bring forth the grave situation the country would have to face, if the policy makers do not take initiative and firm actions to control the population. Such a forewarning, as a result of this study, would culminate into reduction in the water demand as a result of control of population, if appropriate actions are taken right earnestly.

2.20 Basic assumptions to initiate the study,

It was proposed by environmentalists during discussions that, the present water consumption should be considered as constant and without any augmentation of water availability by any new human infrastructure, we should carryout the exercise so that projected demands for people, food & nature by 2025 would be fully met with.

Let us see what are the ground realities, which are going to influence the water demand for the country.

- Population of India, is projected to increase to about 130-150 crores by the year 2025 & to 150-180 crores by the year 2050.
- Trend of urbanization is going to increase and percentage of urban population would increase appreciably from 46% in the year 1995, to 60% by 2030 and to 70% by 2050.
- With the increase in standard of living, per day per capita consumption of 550 grams of food-grains in the year 2000, would increase to about 800 – 1000 grams by 2050 (Present consumption of China is about 950 grams per capita per day)
- Industrialisation would substantially increase, to meet needs of the people.

With these ground realities; it is not difficult to workout requirement of water for people (domestic & industrial use) in the year 2050. Requirement of nature should be taken as same as at present or may even be increased due to upgradation of terrestrial ecosystems. Water demand for food sector be worked out, assuring realistic projections upto the year 2050, in respect of increased land productivity due to biotechnology, tissue culture, cultural practices, improved seeds, micro irrigation systems etc. Exercise should then be carried out to assess the need of water supply enhancement by human interventions.

All these would be the logical steps, instead of going round the other way by assuming no need of human interventions to augment the supply.

Scenario Development would be more realistic if carried out in this manner.

3.0 Watershed Development works

Large reservoirs are constructed on major rivers and the area commanded by them is located on both banks of river, where lands are generally level, fertile & soil & are deep & retentive. Without irrigation, monsoon crop is assured on such land and there is possibility of even a rainfed winter crop if the monsoon is good. Major projects provide irrigation facilities to such lands to grow perennial & cash crops. But watersheds located in the upper reaches of river valleys, are generally rainfed, lands are sloping, soils are light, shallow & non retentive and hence even one monsoon crop is not certain in such watersheds. These cultivators are the neglected, disadvantaged section the society, normally bypassed by all the surface irrigation schemes. Hence watershed development works, which provide them some protective irrigation, needs to be given priority even if it may reduce runoff of some existing irrigation projects. Value of irrigation water is much more to these rained cultivators because it is the only sustainable development alternative available to them. For poverty alleviation and on the principles of social justice & equity, watershed development works should be given priority.

Annex 9

A note by B.P.Das

A comprehensive assessment of the water availability both current and in future (2025) in two representative basins of India along with the projected need has been undertaken utilising the holistic BHIWA model.

By expanding the analysis from the food and people sectors to include the nature sector, precipitation was recognised as a primary input and stream flow (inclusive of ground water flow through regeneration) as output showed interesting results. Forests which constitute the majority of nature sector that cover 35 to 40% in both Sabarmati and Brahmani basins consume 35% of overall water in Sabarmati and 65% in Brahmani, where as the agriculture sector consume 33% in Brahmani and 65% in Sabarmati. With D and I use constituting a maximum of 7% even in the future scenario, the overriding need of the terrestrial or aquatic ecosystem for which concern is expressed by environmentalist will not be in deficit.

Even with gross irrigation coverage in the future increasing by 50% in Sabarmati and a staggering 200% in Brahmani (from 252,000 ha currently to 670,000 ha in 2025) from food security consideration, consumptive use in nature sector will not have a shortfall of even 6%. With larger irrigation coverage in the future with surface or ground water a very large return flow (through regeneration of groundwater particularly in Brahmani) would sustain the net outflow (River) under average condition. Where as in Brahmani it will reduce to a minimum of 15000 Mm^3 against the current level of 20,000 Mm^3, in Sabarmati it will be maintained at 4,600 Mm^3 with Narmada import. An important consideration has been to ensure a crop production growth of 3 to 4% in the next 25 years to provide adequate calorie input to the incremental population in 2025 coming significantly from irrigated agriculture.

However, both Brahmani (in particular) and Sabarmati have been experiencing highly erratic monsoon rainfall in the range of 600 mm in worst drought years (against 1200 mm normal for Brahmani) and 500 mm in Sabarmati against normal of 750 mm. This calls for concerted and well planned efforts to implement satisfactory and dependable supplementation measures for rainfed agriculture in the form of deficit irrigation in September-October. Mere water harvesting structures will not be adequate in Brahmani where daily monsoon storm rainfall exceeds 200 mm almost every year. Creating storages in valleys with people's participation is a must, as 60% of agriculture would remain rainfed in 2025.

Rengali dam intercepting 25,500 Km^2 (65% of basin) has been getting low flows of 8,000 Mm^3 against 15,000 Mm^3 assumed as 75% dependable flow at design stage. This calls for integrated basin approach as non-monsoon flow of 26% that the dam provides is sustaining the aquatic ecosystem in Bhitarkanika.

The accelerated agricultural growth proposed by China to raise the total production of grains from the current level of 400 Million MT to 600 Million MT in 2025 has to recognise water availability and utilisation in the proper context. It has been reported by the Financial Times an International Economic Newspaper (July 27, 2004) that huge subterranean holes now gape beneath cities in Northern China as aquifers are depleted and deserts covering 18% of China's land area expand by hundreds and thousands of sq. km every year. Earth Policy Institute President Lester Braun says as grain stock is being drowned down (9 Million Ton imported in past several moths) China may need to import 30, 40, 50 Million Ton of grain the next 2/3 years. This calls for conservation/ diversion of surplus water in southern China to the North nor only for food security but environmental protection.

Annex 10

CPSP Water Resources Assessment Model and Its Application

A.D.Mohile, B.P.Das and L.N.Gupta, IAH-ICID Study Team

International Commission On Irrigation And Drainage

CPSP WATER RESOURCE ASSESSMENT MODEL AND ITS APPLICATION by IAH-ICID TEAM

PRESENTATION AT IWMI - ICID WORKSHOP

3rd - 4th September, 2004

Moscow, Russia

Part 1
CPSP Basin Assessment Model - An Introduction

A.D. Mohile
Study Team Leader
Retd. Chairman, Central Water Commission and Indian National Committee (INCID), New Delhi, India

Country Policy Support Programme (CPSP) Of the Interanational Commission on Irrigation and Drainage (ICID) Agencies Involved

CINCID - Chinese National Committee on Irrigation and Drainage

INCID - Indian National Committee on Irrigation and Drainage

Subsequently, national committees of Egypt, Mexico and Pakistan would be involved.

Other agencies

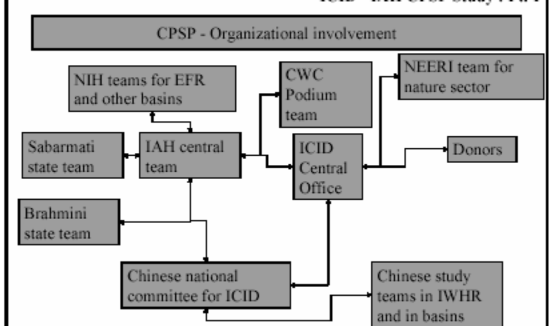
IAH - Indian Association of Hydrologists

NIH - National Institute of Hydrology, Roorkee, India.

NEERI - National Environmental Engineering Research Institute, Nagpur, India.

IWHR - International Water And Hydro Research, Beijing, China.

Field teams for basins in China and India



Water Resource Assessment

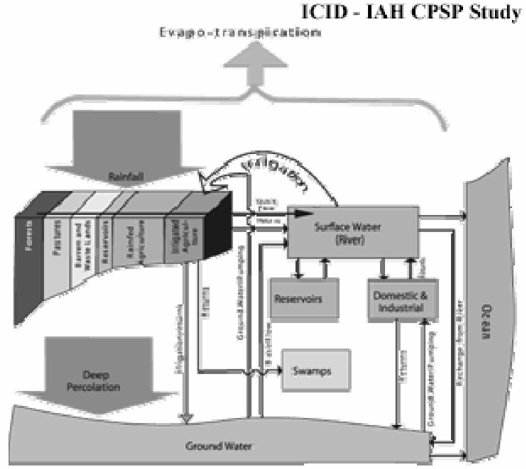
Scope
- Basin/Regional/Country/Global scale
- Whether integrated and holistic
- Assessment and integration of sectoral demands of water including EFRs
- Impact of land and water use and climate changes on resources
- Development and analysis of scenarios to evaluate effects of water policies
- Linkages with socio-economic and environmental aspects

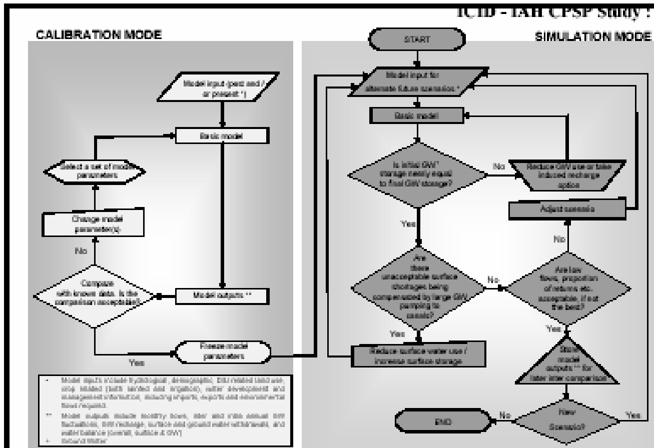
Purpose
- Understanding resources and needs
- Analyze development and management options
- Creating and improving knowledge base for meaningful and transparent dialogue

The Selected Water Assessment Model

The model has the following attributes :

- Simplicity, in concept.
- Capability to deal with the entire land phase of the hydrologic cycle, from precipitation to evapo-transpiration and outflow to sea including withdrawals & returns
- Flexibility, to allow depiction of changes in land use, as also human interventions through water infrastructure development, irrigation expansion, changes in domestic and industrial withdrawals and consumption, changes in water use efficiencies and in the paths of the return flows.
- Capability to depict surface and groundwater balances separately, interaction between them, as also impacts of storage and depletion through withdrawals
- Capability to consider changing environmental flow requirements
- Capability to consider gradual changes in rainfall and evapo-transpiration (climatic changes)





CPSP Model : Logical Sequence

THE RATIONALE

The need for depicting the entire land phase, stems from basic hydrologic premise (our view) that precipitation (and not river flow/ aquifer recharge) constitutes the primary resource, and evapotranspiration management to increase the flows in rivers/ aquifers is a potential development strategy which could be encouraged through policy intervention, either for improving river flows or the traditional resource

The Modules in the Model

- The natural module
- The module depicting hydrologic impacts due to anthropogenic influences.
- Modules for withdrawals, consumptive uses and returns for irrigation and D&I sectors.
- Module for accounting evapo-transpiration by "use sectors".
- Modules for separate and combined balances for river waters, ground waters and total sub-basin / basin.

CPSP - INDIA Model

Capabilities

- Quantification and integration of sectoral needs
- Water Balances for Surface and Ground Water systems and for the overall basin
- Interaction between surface and Ground water system
- Effects of land use changes on supplies
- Impact of sectoral policies
- Maintenance of prescribed Environmental flows (EFR)

Limitations

- Not a distributed hydrologic model
- Not a basin planning tool
- Need for additional modules to evaluate socio-economic impacts

CPSP Model - Main Data Requirements

- Hydrological - Monthly data on Rainfall, Reference Evapotranspiration, Runoff data at locations near subbasin outlets, Groundwater information on recharge, fluctuation etc.
- Land Use - Areas of forests, grasslands, barren and fallow lands, reservoirs and agricultural lands.
- Crops Statistics - Gross and net areas under agriculture and irrigated agriculture. Crop wise compositions of both. Cropping calendars. Source wise composition of irrigated area.
- Agronomic Data - Soil moisture capacities, K factors (crop coefficients).
- Information about withdrawals and returns for irrigation use and D&I use.
- Demographic information including growth rates.
- Water Development related - Surface storage changes, Imports and exports
- Data about environmental flow requirements (EFR)

CPSP Model - Main parameters

- Hydrological - Soil Moisture Capacities for all land parcels. Proportion of excess flow to surface. Index for soil moisture balance. Recession coefficients of linear GW reservoir.
- Water Use related - Irrigation System Efficiencies for surface and GW. Distribution of return flows to swamp evaporation, surface and GW

CPSP Model - Information for building alternate future scenario

- Engineering possibilities for in basin development, and inter basin imports and exports, efficiency improvements etc.
- Population and demand projections.
- Land development potentials.
- Ecological and environmental considerations regarding land use changes, low flow regimes and water quality.
- Agronomic possibilities in diversification, productivity improvements, changes in verities etc.
- Possibilities and desirability's of industrial development.
- Possibilities and desirability of rain water harvesting, watershed management and insitu water conservation

Part 2

Introduction to Sabarmati and Bramhini basins in India

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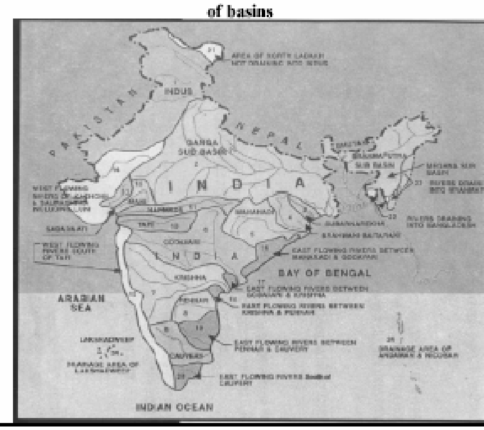
Orissa Team Leader
Retd. Engineer in Chief,
Water Resource Department,
Government of Orissa

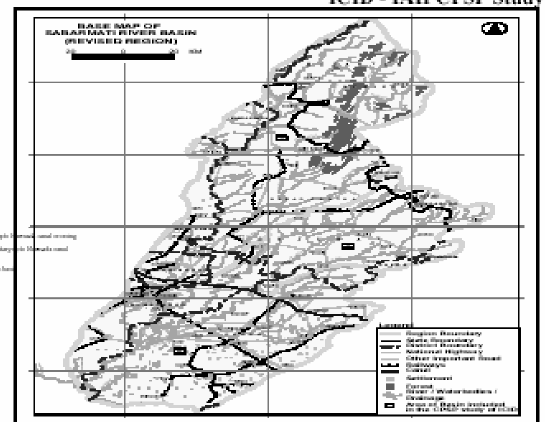
Application of CPSP Model to selected basins in India – Location of basins



Assessment for Sabarmati basin – Salient Features

Sabarmati is a water deficit basin having intensive agriculture and industrial development and large population density

Catchment Area –	About 21,600 km²
Current Population (Yr. 1995) – rainfall -	11.4 million (about 52 per cent urban) Average annual 750 mm
Renewable water resources –	48.5 million m³ per year including groundwater
	413 m³ per person per year (lowest among Indian river basins).
Current Gross Cropped Area –	About 1.5 million ha
Current Gross Irrigated Area –	About 0.8 million ha, with predominance of groundwater irrigation
Inter-basin water transfer –	Currently about 1580 million m³ from the adjacent Mahi river and there is a plan to import upto 2138 million m³ of Narmada river waters.
Major Industries -	Textile, Chemical, Dairy, Thermal power

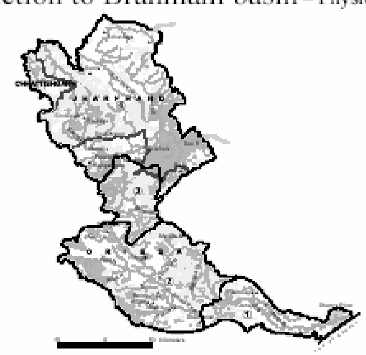


Map of Sabarmati Basin

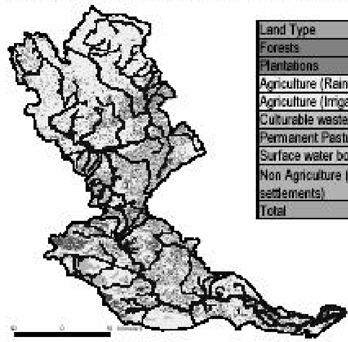
Assessment for Sabarmati basin – Subdivision of River basin

SB1	:	Main stem upto Narmada canal crossing
SB2	:	Watrak tributary upto Narmada canal crossing
SB3	:	Downstream basin.

Introduction to Brahmani basin – Physical features



Introduction to Brahmani basin – Land use



Land Type	Area (Sq.km)
Forests	14152
Plantations	949
Agriculture (Rainfed)	9899
Agriculture (Irrigated)	2533
Culturable waste/ fallow	9373
Permanent Pasture	1323
Surface water bodies	607
Non Agriculture (mining, settlements)	432
Total	39268

Introduction to Brahmani basin – Population

- About 8.4 million people live in the basin at present
- Rural population: 7.21 million
- Urban Population: 1.2 million
- The projected population in the basin in 2025 would be 11.4 million with 7.4 million rural & 4.0 million urban population

Introduction to Brahmani basin – Agriculture and Irrigation

Scenario	Divisions	Crop Land (Rainfed)	Crop land (Irrigated)	Fallow land	Total Agrl Land
Current	Orissa	3860	1897	5068	10825
	Jharkhand & Chatisgarh	6039	636	4305	10980
	Total	**9899**	**2533**	**9373**	**21805**
2025 BaU	Orissa	2729	4050	3900	10679
	Jharkhand & Chatisgarh	4741	2650	3500	10891
	Total	**7470**	**6700**	**7400**	**21570**

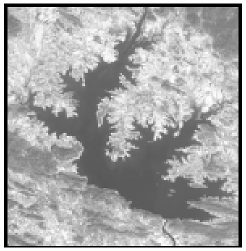
All area in Sq.km

Introduction to Brahmani basin – Agriculture and Irrigation

- At present there are 14 major/ medium projects in the basin with a live storage of about 5000 MCuM (including Rengali project) providing irrigation to about 250 thousand Ha of agriculture land (including minor/lift and other sources).
- 14 more major/medium projects are under progress to create additional storage of about 350 MCuM. This shall bring additional 400 thousand hectares (including benefits of Rengali) of agriculture land under irrigation.
- 18 more major/medium projects, with a storage of about 1250 MCuM are proposed in the basin to benefit about 130 thousand Ha of agriculture land.

Introduction to Brahmani basin – Agriculture and Irrigation

Rengali multipurpose dam project

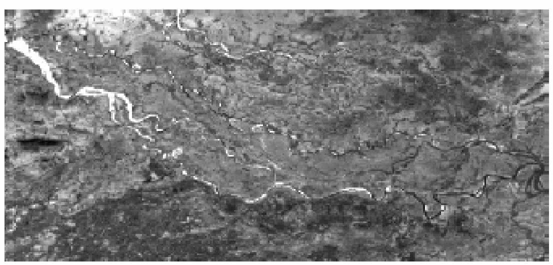


- Catchment Area:25250 km^2
- Gross Storage: 4400 Million m^3
- Live Storage: 3412 Million m^3
- CCA: 259100 Ha
- GCA: 336400 Ha
- Installed Capacity: 5 x 50 MW
- Flood Control of delta

Introduction to Brahmani basin – Industry

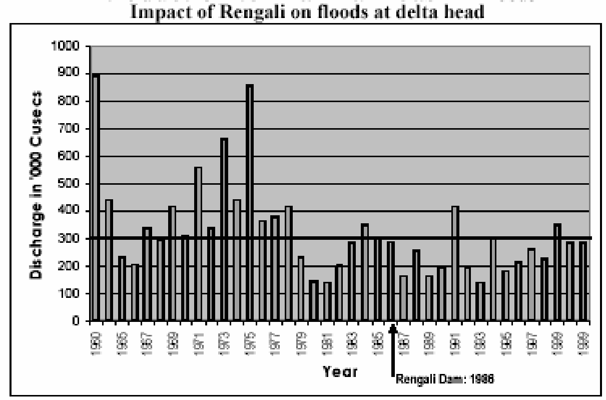
- Brahmani Basin is rich with minerals such as iron, coal, manganese, chromite, etc.
- A number of large industrial units have come up in the basin due to abundance of mineral reserves and cheap availability of thermal power (due to availability of coal).
- Angul-Talcher industrial complex (in sub-basin 2) has housed more than 10 large industries and 10 collieries
- Rourkela industrial complex (in SB 4) and Duburi Complex (in SB2) also house large industrial units

Assessment for Brahmani basin – Flood Plains in Brahmani Delta

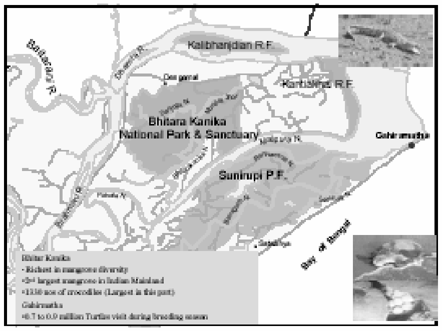


Introduction to Brahmani basin – Floods

Impact of Rengali on floods at delta head



Introduction to Brahmani basin – Estuarine Environment



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Introduction to Brahmani basin – Estuarine Environment

- *Crocodylus Porosus* (Schneider) (The Estuarine or the saltwater crocodile) (Baula Kumbhira)
- Endangered as per Red Data Book categories of IUCN;
- The estuarine or the salt water crocodile (*Crocodylus porosus*) is known to be the largest (7 mt.) among all species of the living crocodiles in the world.

Part 3
Assessment, Results and Findings - Sabarmati

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Study Team Leader
Retd. Chairman, Central Water Commission and Indian National Committee (INCID), New Delhi, India

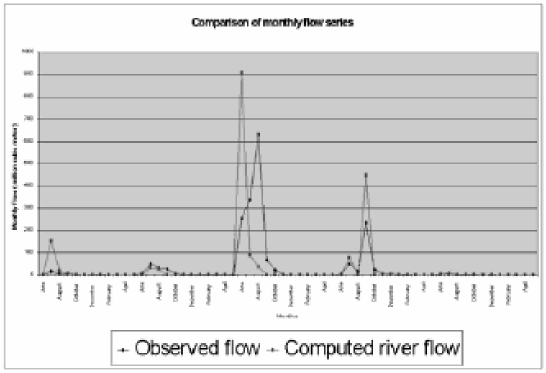
Assessment for Sabarmati basin – Model Calibration

- Rigorous calibration not necessary since model is meant to study relative impacts on basin hydrology. This was done by comparing the following :
- Annual and monthly river flows
- Natural recharge to groundwater as a percent of rainfall.
- Groundwater fluctuations
- Withdrawals from surface and ground waters

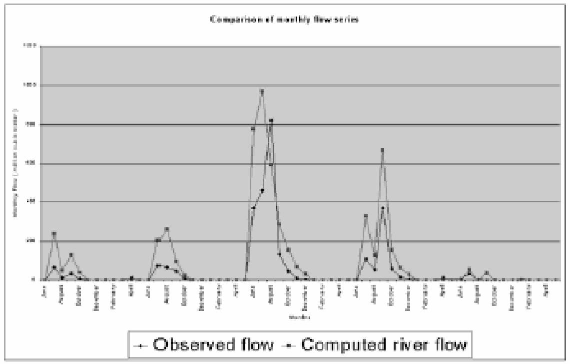
Comparison of annual average flow based on five year sequential run (1995-1996 to 1999-2000)

Sub-Basin/ Basin	Average flow computed by the model ($10^6 m^3$/yr)	Observed average flow ($10^6 m^3$/rec)
SB 1	359	373
SB 2	1075	590
Total basin	1933	1711

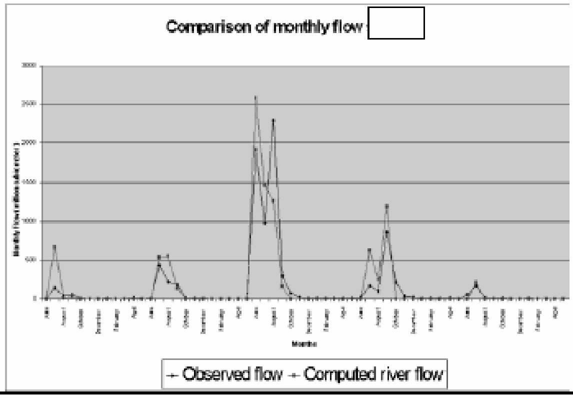
Assessment for Sabarmati basin – Model Calibration



Assessment for Sabarmati basin – Model Calibration



Assessment for Sabarmati basin – Model Calibration



Assessment for Sabarmati basin – Scenarios studied

Sr. No.	Name	Year	Abbreviation	Explanatory Notes
1	Past	1960	-	No water development
2	Present	1995	-	Considerable storage, groundwater and surface irrigation, and imports
3	Future I	2025	B AS U	Irrigation expansion with similar composition Additional Narmada Import
4	Future II	2025	B AS U , without Narmada Import	-
5	Future III	2025	Gujarat Plan	Larger imports and exports, pumping imported water in upper reservoirs
6	Future IV	2025	Less Imports and Exports	-
7	Future V	2025	Seasonal shift	Irrigation expansion mostly in wet season
8	Future VI	2025	-	Similar to Future V but groundwater irrigation reduced. Reduced pumping to reservoirs
9	Future VII	2025	-	Groundwater irrigation further reduced. Less irrigation expansion. Improved water management and more drip irrigation
10	Future VIII	2025	-	Smaller Seasonal Shift and improvements in water management

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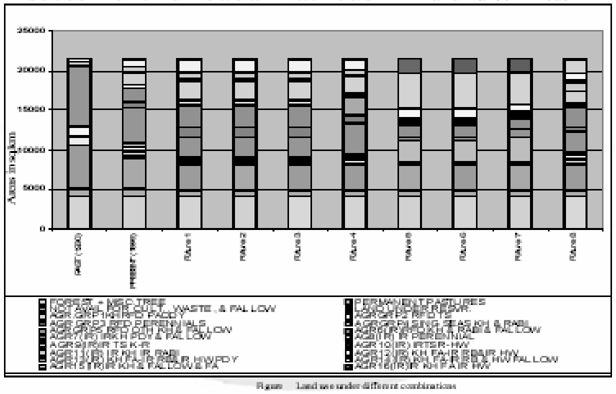
Assessment for Sabarmati basin – Land Parcel Areas km²



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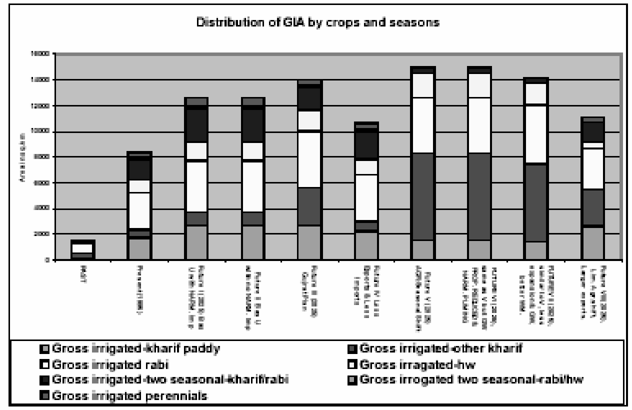
Assessment for Sabarmati basin – Distribution of GIA



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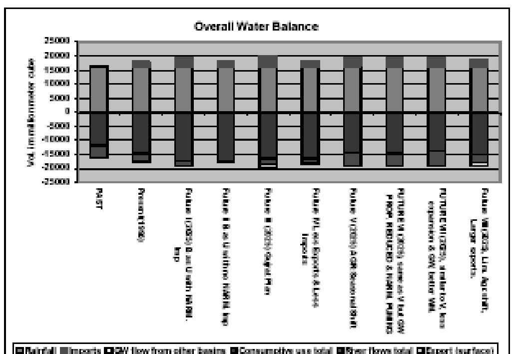
Assessment for Sabarmati basin – Overall basin annual water balance



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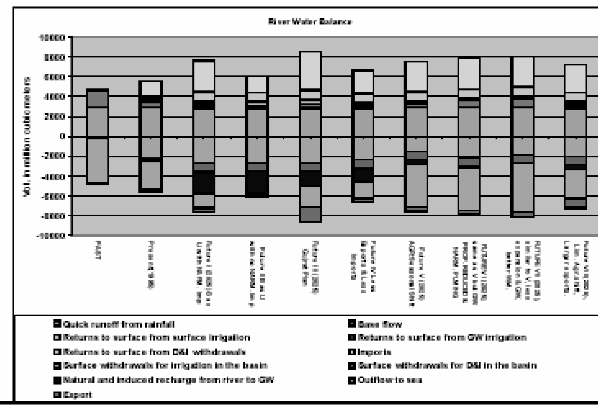
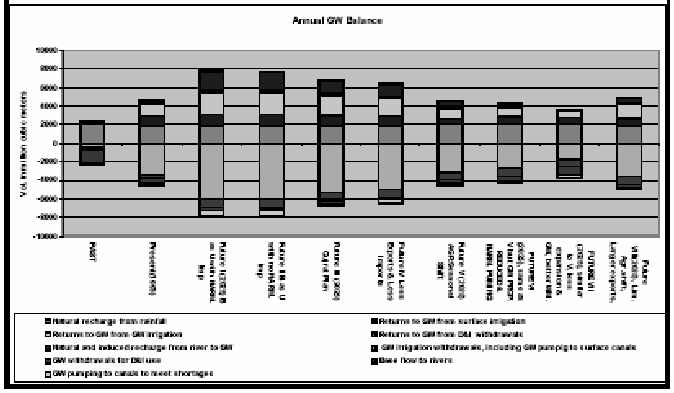
Assessment for Sabarmati basin –Annual river water balance



Assessment for Sabarmati basin – Annual ground water balance



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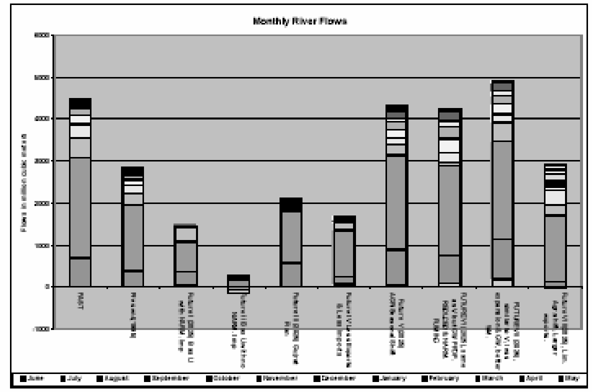
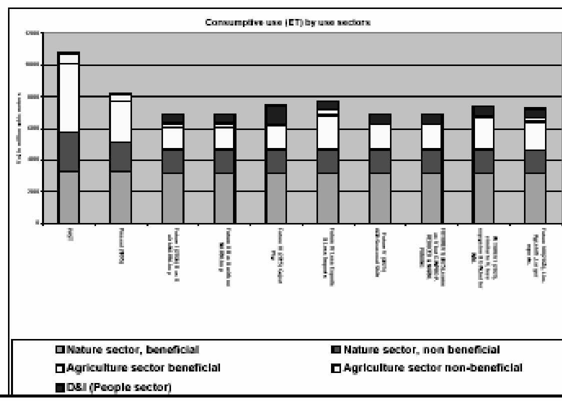
Assessment for Sabarmati basin – River flow (Steady state/sustainable condition)



ICID - IAH CPSP Study : Pt. 3

Assessment for Sabarmati basin – Consumptive use by sector



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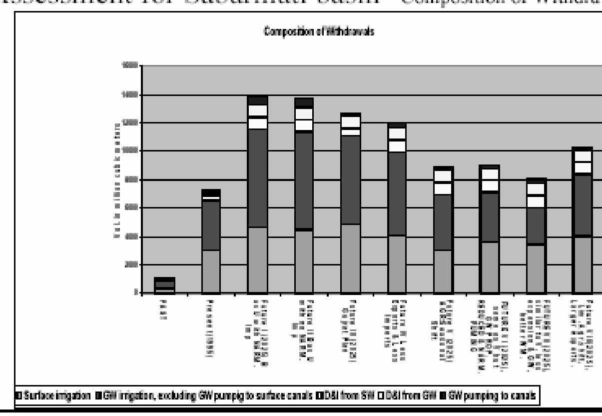
Assessment for Sabarmati basin – Composition of Withdrawals



Assessment for Sabarmati basin – Main Findings

- Non-beneficial ET in the nature and agriculture sectors exceeds quantum of annual river flow. *Reduction of non-beneficial ET through rain harvesting, soil and agriculture management is a potential strategy for improved water management*
- Import of Narmada water is necessary to sustain the present withdrawals and meet future needs, *including that for improvement of low flows.*
- Present ground water use is unsustainable. While the situation would improve slightly in future due to large additional Narmada imports, composition of return flow indicates much higher risk of ground water pollution

Part 4

Assessment, Results and Findings - Bramhani

L.N. GUPTA
Central Team Leader
Formerly Executive Director, Water and Power Consultancy Services (India) Limited, New Delhi, India

Assessment, Results and Findings- Brahmani Basin – An Overview

- Introduction
- Methodology : Assessment based on CPSP Model
- Model Calibration: Based on data for present conditions of land use and water resource development
- Formulation and Analysis of Scenarios
- Aggregated Results
- Main Findings

Assessment for Brahmani basin – Salient features

Brahmani is a water rich basin having large industrial development and less agriculture

Catchment Area –	About 39,268 km^2
Current Population (Yr. 2000) –	8.46 million, about 15 per cent urban
Average annual rainfall –	1304 mm
Renewable water resources –	About 20,350 million m^3 per year.
	2405 m^3 per person per year
Current Gross Cropped Area –	About 1.48 million ha
Current Gross Irrigated Area –	About 0.36 million ha, largely through surface water
Major Industries –	Coal, Steel, Aluminum, Thermal Power, Fertilizer

Assessment for Brahmani basin – Location map

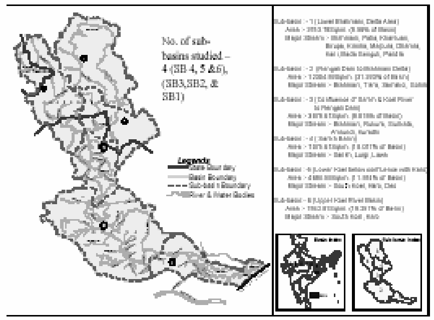


Figure 3. Brahmani River Basin

Assessment for Brahmani basin – Subdivisions of Brahmani basin

Sub-basin	Drainage Area, km²
• SB4, 5, 6 : Combined Sankh, Koel – Karo river subbasins below confluence with Karo	19330
• SB3 : Brahmani from confluence of Sankh and Koel rivers above Rengali reservoir	3880
• SB2 : Brahmani sub-basin from Rengali (including Rengali reservoir) upto head of delta at Jenapur	12303
• SB1 : Lower Brahmani delta below Jenapur	3754

Assessment for Brahmani basin – Model Calibration

- Comparison of river flows based on three years (1998-2000) data used in verification.

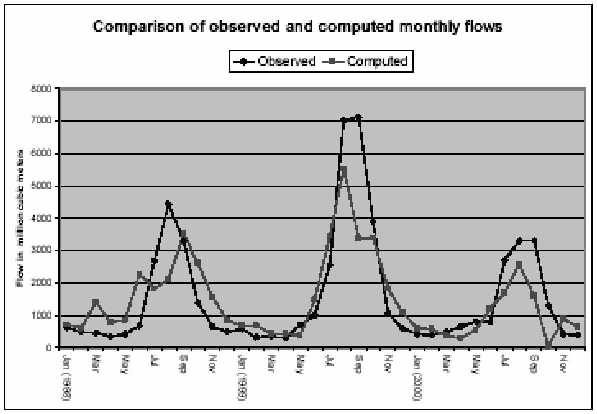
Comparison of annual flows at head of delta (million m^3)		
Year	Observed	Computed
1998	15951	19092
1999	25492	22733
2000	14989	11083
Mean	18811	17636

Contd...

Assessment for Brahmani basin – Model Calibration

Comparison of time series of monthly flows at head of delta (million m^3)			
	Observed	Computed	
Mean	1568	1470	
Standard deviation	1765	1192	
Root mean square error			*1020*

- Groundwater recharge from rainfall, 3 years average, 6375 million m3. This is about 11.7% of rainfall.This is considered reasonable and compares well with general estimates available for the basi



ICID - IAH CPSP Study : Pt. 4

Assessment for Brahmani basin – Scenarios Studied

- Past: 1960
- Current: 2000
- Future: 2025 (Business as Usual)
- Future 1: 2025 (with larger expansion of agriculture & irrigation)
- Future 2: 2025 (with more industrialization)
- Future 3: 2025 (with less agriculture & industry)

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Assessment for Brahmani Basin - Land Use

Total basin area: 39,268 sq.km

Scenario	Forest land	Grass land	Land not available for cultivation	Reservoir	Net area under cultivation			Gross irrigated area	Gross crop area
					Rainfed	Irrigated	Total		
PAST	14659	1348	14223	63	8575	400	8975	400	9375
Current	15101	1323	9605	607	9899	2533	12432	2582	14316
Future B as U	14979	1293	7946	880	7470	6700	14170	7035	17595
F1	14979	1293	6301	945	7960	7790	15750	8180	19700
F2	14979	1293	7728	890	7523	6855	14378	7208	17879
F3	14979	1293	9686	880	6914	5516	12430	5630	15602

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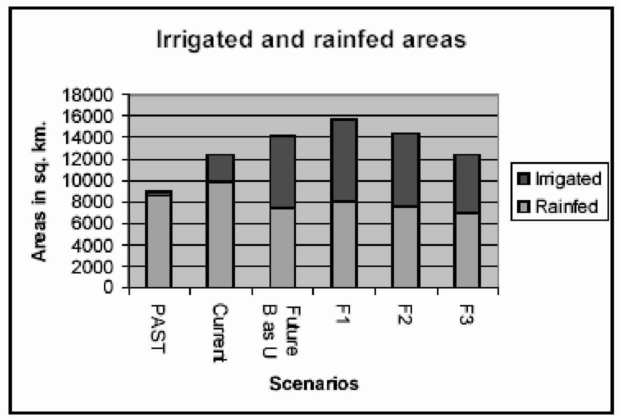
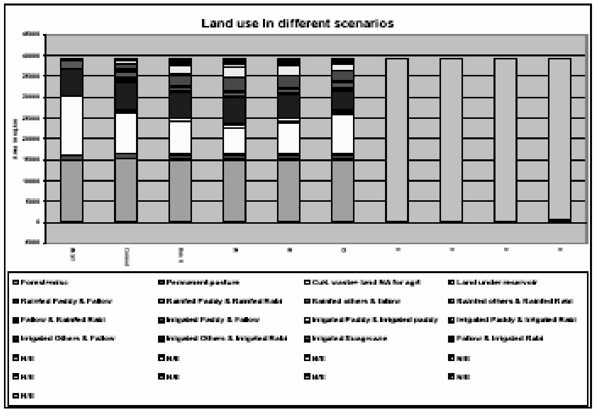


Assessment for Brahmani basin – Land Parcel Areas km²



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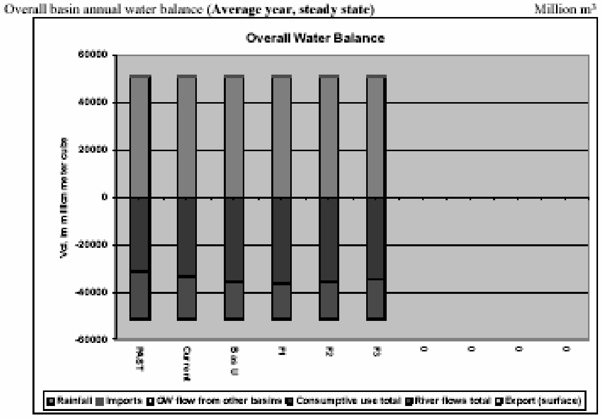
Assessment for Brahmani basin – Aggregated Results

Overall basin annual water balance (**Average year, steady state**) Million m³



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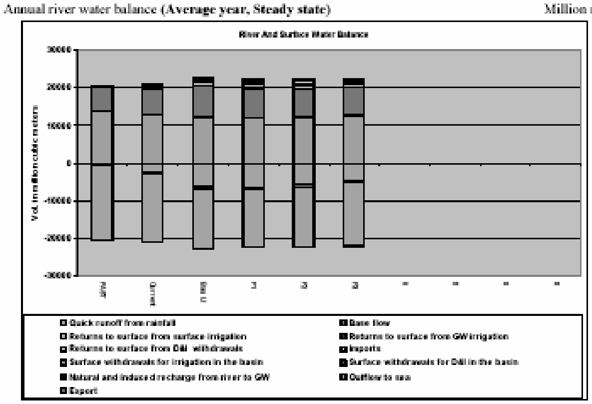
Assessment for Brahmani basin – Aggregated Results

Annual river water balance (**Average year, Steady state**) Million m³



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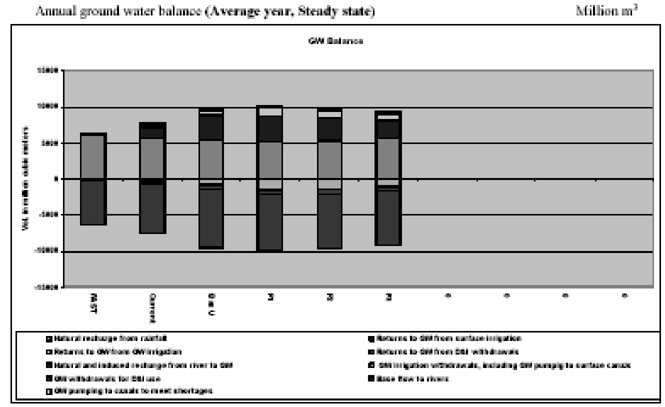
Assessment for Brahmani basin – Aggregated Results

Annual ground water balance (**Average year, Steady state**) Million m³



Assessment for Brahmani basin – Aggregated Results

Consumptive use by sector

Million m³

Component	PAST	Current	B as U	F1	F2	F3
Nature sector, beneficial	15512	15925	15778	15778	15778	15781
Nature sector, non beneficial	8362	5764	4651	3678	4505	5694
Nature sector, total	**23873**	**21690**	**20429**	**19456**	**20283**	**21475**
Agriculture sector, beneficial	5781	7852	9354	10470	9533	7964
Agriculture sector, non-beneficial	1735	3813	5571	6089	5536	4845
Agriculture sector, total	**7516**	**11666**	**14925**	**16559**	**15069**	**12809**
D&I (People sector) Total	**72**	**207**	**333**	**333**	**423**	**319**
Grand Total	***62850***	***66917***	***71041***	***72363***	***71128***	***68886***

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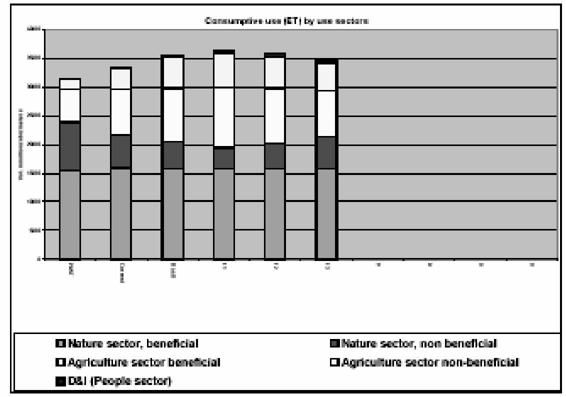
Assessment for Brahmani basin – Consumptive use by Sector



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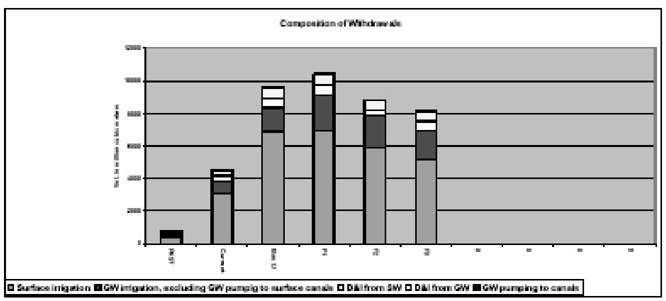
Assessment for Brahmani basin – Composition of Withdrawals



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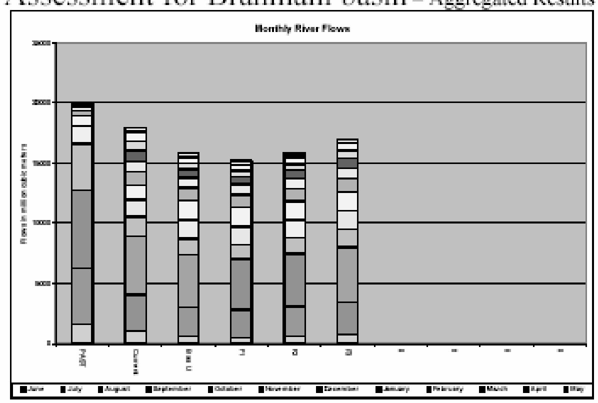
Assessment for Brahmani basin – Aggregated Results



River flows (Steady state)

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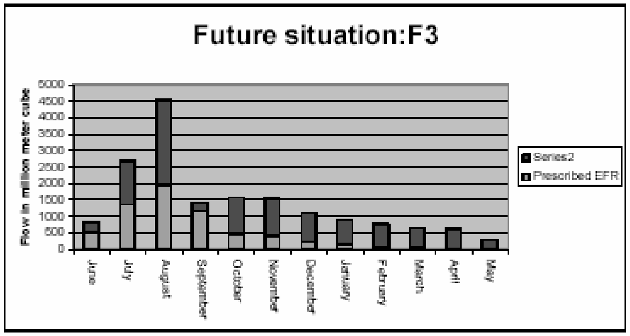
Assessment for Brahmani basin – Comparison of flows and EFR's as prescribed to the model

Scenario - F3 Total basin river flows



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Assessment for Brahmani basin – Main Findings

- ✓ Nature sector is by far the largest consumer of water.
- ✓ Contribution of groundwater to base flow is increasing, indicating risk of water logging
- ✓ Future withdrawal requirements would need full use of Rengali storage as well as creation of additional storage
- ✓ Considerable land would remain rainfed, and productivity increase may require watershed management of uplands.
- ✓ Basin would not have overall water shortages even in the projected scenario for increased agricultural and industrial use

ICID - IAH CPSP Study Pt. 5

Part 5
Extrapolation to other basins in India

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ICID - IAH CPSP Study : Pt. 5

Extrapolation to other basins in India

- Introduction
- Selection of indicators
- Data base and computation of indicators for other basins
- Grouping of basins by comparison
- Findings of extrapolation
- Limitations of extrapolation

Selection of Indicators: Water stress indicators used in international literature

- **Alcamo (2002) –**

  WSI= Withdrawal/MAR

  where MAR denotes the mean annual runoff for the pseudo natural conditions

- **Smakhtin (2002)-**

  WSI=Withdrawal/(MAR-EWR)

  where EWR represents the environmental water requirements for the aquatic system

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Selection of Indicators- Some Considerations

- Large **ground water use** in India, hence giving rise to the need for indicators for both sources

- WSI proposed by Alcamo based on **withdrawals** out of which a substantial part may return. Indicator to be based therefore either on **net withdrawal(or consumptive use) or the denominator (pseudo- natural runoff MAR) corrected to reflect returns**.

- Smakhtin presupposes overriding priority for **environmental water** requirement which may not be appropriate specially for the many water deficit basins.

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Suggested Indicators

In CPSP ICID-IAH Study framework following four indicators have been proposed to describe the state of water resources

Indicator 1: Withdrawals/total input to surface water
Indicator 2: Returns/total input to surface water
Indicator 3: Withdrawals/total recharge to ground water
Indicator 4: Returns/total recharge to ground water

Indicators 1&3- depict quantitative stress due to withdrawals and Indicators 2&4 depict hazard to water quality

ICID - IAH CPSP Study : Pt. 5

Computations of Indicators

- For Surface Water

S. No	Basin	Total input $10^9 m^3$	Total returns $10^9 m^3$	Total with-drawal $10^9 m^3$	Withdrawal/ Input (I_1)	Returns/ Input (I_2)
1	Indus	185	3	42	0.23	0.02
2	Ganga	525	19	146	0.28	0.04
3	Brahmaputra	633	1	12	0.02	0
4	Subarnarekha	12	--	4	0.33	0
5	Mahanadi	50	1	13	0.26	0.02
6	Godavari	126	3	21	0.17	0.02
7	Krishna	99	3	26	0.26	0.03
8	Pennar	7	1	7	1	0.14
9	Cauvery	28	2	19	0.68	0.07
10	Tapi	18	1	4	0.22	0.06
11	Narmada	51	1	7	0.14	0.02
12	Mahi	13	0	2	0.15	0
13	Sabarmati	7	0.7	2	0.4	0.09
14	Brahmani	17	0.6	2	0.14	0.04

Computations of Indicators

- For Ground Water

S. No	Basin	Total input 10^9m^3	Total return 10^9m^3	Total withdrawal 10^9m^3	Withdrawal/ input (I_3)	Return / input (I_4)
1	Indus	48	33	29	0.6	0.69
2	Ganga	251	115	118	0.47	0.46
3	Brahmaputra	33	7	2	0.06	0.21
4	Subarnarekha	4	3	2	0.5	0.75
5	Mahanadi	23	9	6	0.26	0.39
6	Godavari	49	15	12	0.24	0.31
7	Krishna	37	17	10	0.27	0.46
8	Pennar	9	5	2	0.22	0.56
9	Cauvery	22	13	8	0.36	0.59
10	Tapi	9	3	3	0.33	0.33
11	Narmada	15	4	4	0.27	0.27
12	Mahi	9	2	2	0.22	0.22
13	Sabarmati	5	2	4	0.87	0.54
14	Brahmani	6	1.5	1	0.11	0.3

Basin grouping by selected indicators

	Class description		Range	Basin
a)	Surface withdrawals	very high stress	Indicator 1>0.8	Pennar
b)		high stress	0.4 < Indicator 1<0.8	Cauvery, Sabarmati
c)		moderate stress	0.2 < Indicator 1<0.4	Indus, Ganga, Subarnarekha, Mahanadi, Tapi
d)		low stress	Indicator 1<0.2	Brahmaputra, Godavari, Brahmani
e)	Surface water quality	low or no threat	Indicator 2 < 0.05	All basins other than those listed next
f)		moderate threat	0.05 < Indicator 2 < 0.1	Cauvery, Tapi, Sabarmati, Pennar
g)	Groundwater withdrawals	very high stress	Indicator 3>0.8	Sabarmati
h)		high stress	0.4<Indicator3<0.8	Indus, Ganga, Subarnarekha
i)		moderate stress	0.2>Indicator3<0.4	Mahanadi, Godavari, Krishna, Pennar, Cauvery, Tapi, Narmada, Mahi
		low stress	0.2>Indicator 3	All other rivers including Bramhini
j)	Groundwater quality	very high threat	Indicator 4>0.8	None
k)		high threat	0.4<Indicator 4<0.8	Indus, Ganga, Subarnarekha, Krishna, Pennar, Cauvery, Sabarmati
l)		moderate threat	0.2>Indicator 4<0.4	Brahmaputra, Mahanadi, Godavari, Tapi, Narmada, Mahi, Brahmani

Findings of Extrapolation

- Inferences drawn from Sabarmati assessments are of much relevance to Pennar, Cauvery, Indus, Ganga, Subarnarekha, Mahanadi and Tapi in regard to surface water
- Ground water problems of Indus, Ganga, Subarnarekha, Krishna, Pennar and Cauvery have similarity with Sabarmati
- Problems of Brahmani resulting out of the high flows and low use of ground water have similar implications for Brahmaputra and Godavari

Limitations of Extrapolation

- Secondary data from CWC do not account for *imports and exports*. e.g.- Pennar basin
- Large and heterogeneous basins are treated as *single entities.There is a need for considering effects of spatial scales on indicators*
- Grouping of basins reflects present conditions. Significant differences could arise when drawing inferences for future scenarios due to disparities in several parameters like *physical limits of land and water availability, and water infrastructure; differential growth in population and industry , resource development and management*

Part 6

Possible Policy Interventions based on selected basin studies

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The policy related issues highlighted by the studies

- Shift in the concept of "Water Resources"
- Accounting water use by the sector, and integration
- Proper accounting of return flows, since these constitute a major resource and can depict hazard potential
- Consumptive use (evapotranspiration) management
- Watershed Management and water harvesting
- Integrating surface water and groundwater use in irrigation
- Integrated management of land and water resources
- Integrating livelihoods in land and water planning
- Water for people: Dimensions of priority.
- Water allocation by uses
- Estimating water use and requirement of 'Nature' sector

Shift in the concept of "Water Resources"

Considering rainfall (and not runoff/GW recharge) as the primary resource will allow consideration of strategies which involve management of evapotranspiraton, water shed management, effects of land use changes etc. to be studied

Total modelling of the land phase will allow accounting for evapotranspiration by uses, accounting of returns and base flows etc.

Accounting water use by the sector, and integration

Consumptive use for terrestrial ecosystem (forests,grasslands and lands not under agricultural use), agricultural lands including irrigated lands etc. needs to be accounted for separately. In each, beneficial and non-beneficial uses can be segregated. Consumptive use of the "People" sector also needs to be kept separate.

The unconsumed residual water would be available for the riverine ecosystem. (The residual water would normally equal or exceed the specified EFR.)

Watershed Management and Water Harvesting

Watershed management option, which changes the distribution of excess water, between surface and groundwater is again a policy option. The effects of such developments on the downstream require a holistic study.

Watershed management often involves harvesting (use) of the rainwater, at (or in immediate vicinity) the place of its occurrence. Watershed management can conserve only a part of the rainfall

a) When planning storage schemes, the possibilities of watershed development, upstream, need to be projected.

b) In catchments of projects in which problem of non-filling of reservoirs is experienced, watershed development and use needs to be discouraged.

Integrating surface water and groundwater use in irrigation

I) Subsidise GW exploitation in such areas and increase SW prices.

II) Charge the WUA with responsibilities for groundwater monitoring and management. If GW levels increase, reduce surface supplies. If GW levels decline, mount awareness about non sustainable practices.

III) Under-design distribution system: In planning and design exercises, purposefully.

Integrated management of land and water resources

The land parcel based working, and the flexibility it allows has highlighted the need for integrating the land and water resources in planning. The land use will affect water consumption through evaporation, and hence the need for integrated planning.

Irrigation planning needs to account for the existence of rainfed crops in the command. The production of land put to other uses is often ignored. Similarly, reduction in waste land is not integrated in irrigation planning.

Integrating livelihoods in land and water planning

I) In low rainfall plain areas with sizable population densities, the carrying capacity of the area, in terms of rural livelihoods, is severely constrained by local water availability.

II) Water from outside, either from wetter part of the basin or other basins would have to be applied to the land to increase this carrying capacity.

III) Even if self sufficiency in food is not targeted, food would have to be produced for generating local incomes, and for avoiding migrations.

IV) Integration of water, land and livelihoods is essential at this stage of Indian development.

Integrating livelihoods in land and water planning

Water balance of a typical 1 km² low rainfall rural area in India					
Land use	*Portion*	*Rainfall*	*ET*	*Runoff*	
	Ha	*mm/yr*	*mm/yr*	*mm/yr*	*m³/yr*
Forests	10	750	650	100	10000
Barren	30	750	500	250	75000
Agricultural (Rainfed)	60	750	600	150	90000
Total	**100**				**175000**

Irrigation would require additional ET of 300 mm. Use of local runoff from agricultural land, of say 45000 m³/yr. may be possible. This will irrigate 15 ha. Runoff from adjoining non-agricultural lands is 85000 m³/yr.. Using part of this through small irrigation will add another 15 ha, providing irrigation for 30 ha at most.

The broad estimate of the per capita income of agriculture dependent rural population in such typical area is shown below

Integrating livelihoods in land and water planning (contd.)

Estimate of per capita income from typical 1 km² low rainfall rural area in India										
		Rainfed area (ha.)	*Irrigation Intensity*	*Net irrigated area (ha.)*	*Production (t)*	*Farm gate price (Rs.)*	*Net farm income (Rs./yr.)*	*Net farm income per capita (Rs./yr.)*	*Net total income (Rs./yr.)*	*Net total income (US $/day)*
Alternate 1	*Rainfed*	60	1.0	0	75	525000	315000	3000	3600	0.22
Alternate 2	*Rain water harvesting*	45	1.0	15	101	708750	425250	4050	4860	0.30
Alternate 3	*Small irrigation with local water*	30	1.0	30	128	892500	535500	5100	6120	0.37
Alternate 4	*Full irrigation with outside water*	0	1.3	60	234	1638000	982800	9360	11232	0.68

Assumptions	
Rural population density per km²..	150
% dependent on agriculture	70
Rainfed yield, t/ha..	1.25
Irrigated yield, t/ha..	3
Farm gate price Rs./kg	7
Net farm income as % of production value	0.6
Additional income from alld activities as % of net farm income	20
Conversion (Rs./US$)	45

Thus, the poverty due to high densities beyond the normal carrying capacities of the land can be slightly alleviated through rainwater harvesting and local small irrigation and significantly alleviated through large irrigation.

Water for people: Dimensions of priority.

1) **A core demand for drinking, cooking and essential health and hygiene, at about 50 lit/day needs to attract the highest priority. Non core municipal demands can be on a somewhat lower priority.**

2) **The priority needs to be defined as a) the first charge on available water in a management situation b) the most reliable water, when considering time variability in availability, during planning and c) the best quality of raw water, where alternative raw water source are available, even if this requires re-allocation amongst sources and uses.**

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Part – 7

Possible model improvements - EFR related and others

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Background to EFR

- World Water Vision presented at WWF2 in The Hague recognized three main components of water use, namely water for food, water for people and water for nature and stressed on their integration
- At Third Word Water Forum (March 2003) the need for integration of requirements of the three sectors was re-emphasized.
- GWP also emphasizes integrated development and management of water resources taking into account the *vital needs of the ecosystems*
- *CPSP aims at furthering above objectives*

EFR - Definition and Scope

- EFR refers to water that is needed for maintaining an aquatic system (mainly river and the ecosystem dependent on it) in good health i.e. to PROTECT HYDROLOGIC INTEGRITY of the natural environment and CONSERVE ITS BIO-DIVERSITY.
- As currently defined, EFR does not include use of water by terrestrial or land based natural eco-systems which are met mostly from rain and soil moisture.
- Historically EFRs have been referred as MINIMUM or MANDATORY flows for downstream uses including drinking water, navigation,fisheries as well as maintenance of trans-boundary flow requirements
- Scope of EFR has been expanded recently to cover socio-economic and cultural values associated with use of river waters

Methodologies for determining EFRs

Broadly these are classified into four categories

- **Look-up tables** - Rules of thumb based on simple indices, mostly hydrological for setting EF targets.
- **Desk top analysis** - Methods use existing data on river flows and or data on fisheries, based on hydrological analysis or hydraulic rating methods to provide indices of habitat at a given discharge. Some others methods in this category use statistical techniques to correlate river flow variables to biotic dependent variables.
- **Functional analysis** - These methods attempt to build links between hydrology and ecology of river system through participation of experts, eg. Building Block Methodology (BBM).
- **Habitat modelling** - Use data on habitat for target species to determine EFs by deriving functional relationship between flow and physical habitat, eg. PHABSIM of US Fish and Wildlife Service.

Approaches to integration of EFRs - Overseas

South Africa : Derived from the the **National Water Act** (No. 36 of 1998) which provides for two water rights- The Human Right to safe accessible water and The Environmental Right of water for aquatic eco-systems to ensure sustainable use.

Starting with simple hydrological and hydraulic-habitat simulation a range of methodologies have been tested and applied the most recent of which are the DRIFT (Downstream Response to Imposed Flow Transformations) and the BUILDING BLOCK Methodology (BBM).

Some examples of application

- Olifant's river - to assess the effects of imposing ecological reserve on the availability of water.
- Lesotho Highland River Project- to assess the implication of flow change for fish species.
- Limbombo Waterways Programme-Pongolapoort Dam to negotiate releases from the existing dams to avoid detrimental effects of impoundment and downstream ecology and peoples livelihood.
- Koekedouw river, Western Cape Province to monitor flow releases to meet the desired in-stream flow requirements.

Approaches to integration of EFRs - Overseas

Australia

- Functional analysis methods and the South African Building Block Methodology are increasingly deployed with participation of multi-disciplinary team of experts (expert team approach). Another technique, BENCHMARKING has been developed to study the impact of flows required to sustain ecological processes and diversity of riverine ecosystems. Methodology has found application in the water resources planning process in small river basins of Queensland state (e.g. Burnett Basin).
- AN ADAPTIVE MANAGEMENT APPROACH, with participation from the scientific, technical and management and stakeholder communities, has also been used as part of initiatives in the direction of setting objectives for environmental flows for the heavily regulated River Murray.
- Council of Australian Government formally agreed in 1995 to a package of measures, including the *recognition of the environment as the legitimate user of water.*

Approaches to integration of EFRs - Overseas

United Kingdom

- Minimum flow concept has been in use since the 60s (1963 Water Act) primarily to protect the right of downstream users, including the water abstraction and navigation.
- Simple hydrological indices have been used for not permitting abstractions below a critical level called the *hands-off flow* (usually Q_{95}). In a few cases impact of the abstraction has been studied through modelling approaches (e.g. habitat model of key fish species, such as trout) using the PHABSIM. A scenario based approach is used for conflict resolution.

France

French fresh water fishing law of 1984 requires that flows remaining in the river in bypass sections of rivers must be minimum of 1/40 of the mean flow for existing schemes and 1/10 of the mean flow for new schemes.

Approaches to integration of EFRs - Overseas

Others

- Work done by University of Kassel: WaterGAP Model, scenario approach, use of "criticality ratio" (CR) to compare the level of water scarcity in different river basins.
- Work being done by IUCN: Benchmarking fresh water bio diversity for better design of sustainable water management strategies.
- Modeling approach used for Global Water Demand and Supply Projections by Ximing Cai and Mark W Rosegrant (June 2002) :
- Approach suggested by Smakhtin et.al. (2002) for incorporating requirements of fresh water ecosystem in global water assessment perspective

Approaches to integration of EFRs - India

NCIWRD (1999) has considered two types of water requirement under environment and ecology head while assessing total water demands

(A) for afforestation and tree planting and

(B) for abatement of water pollution and managing water quality in the rivers.

- No provision is made for type A requirement as these are considered temporary and are expected to be met from rain and moisture.
- Some adhoc provisions for type B are made for maintenance of quality to keep the BOD level of treated effluents to safe limits through dilution.

Approach used in CPSP

- Water for nature includes needs of both the terrestrial as well as aquatic systems and eco. systems dependent on them. This requires water accounting from rain.
- EFRs require to be recognized as part of water for nature sector and a legitimate user of water.
- Most overseas methodologies and modeling approaches for EFR estimation are AREA, and PROBLEM or PROJECT specific. An acceptable and simpler methodology for a broad basin level assessment of EFR need to be developed and included within the model. This methodology may have to be country specific, since there would be subjectivity about what is acceptable.
- In the present CPSP Basin Assessment Modeling Framework a provision exists to incorporate minimum flow requirements from environmental (or any other consideration) of the downstream as a separate demand on total water (river as well as groundwater). Such flows however require to be determined outside the model and prescribed at the sub-basin/basin outlet. The model adjusts the surface and groundwater withdrawals to meet the prescribed EFRs, as far as possible.

Other possible model improvements

CPSP model has to further address

- ✓ The problems of excess water namely floods, surface and sub-surface drainage and water quality.
- ✓ Target for water requirements at country/basin level for food , people and nature from on socio-economic, environment and other considerations.

In particular the following modules may need to be added to ICID-IAH's CPSP Model :

- At present, the land areas under terrestrial eco systems (Forests, grasslands etc.) are to be externally specified. If these could be estimated through the analysis of the goods and services provided, better scenarios would result.
- Production module for calculation of food and non-food products of agriculture from both rainfed and irrigated lands.
- Rural income module for the population dependent on land using data about land holdings etc., the income distribution and the incidence of poverty could also be estimated.
- National level water needs for food security-Utilizing nationally acceptably policy norms about food imports, and considering changes in income and diets, the module would estimate the requirements of food.

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Part – 8

Initiation of discussions on Phase II of CPSP

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CPSP Main Conclusions

- CPSP modeling framework allows a DYNAMIC, HOLISTIC and INTEGRATED approach to water resource assessments. It considers **terrestrial rainfall** as the primary resource
- CPSP model considers physical constraints of land and water including water resource development infrastructure constraints.
- It prepares source wise and composite water balances, and water accounting by sectoral use and classifies it in beneficial and non beneficial.
- Easy analysis of scenarios, including large scale changes in land use allows insight into desirable water policy interventions.
- Much of the fresh water may often be consumed by the nature sector. **Agriculture (including rainfed farming) may not be the main consumer of freshwater. Both would have beneficial and non beneficial components. Reducing non beneficial consumption needs to be an important strategy.**

A Possible Menu for CPSP Phase II

1. Improving model by adding new modules.
2. Extending water assessment in India and China
3. Trial application of CPSP or similar models to other countries, by national committees and national experts
4. Possible integration of CPSP modelling philosophy with WATER-SIM of IWMI and IFPRI
5. Pilot testing of WATER-SIM in India and China and in particular in basins selected for CPSP
6. Co-ordination, training and assistance to other countries by ICID Central Office

Future needs for country level assessments

- Need for study of additional sample basins to include snowfed rivers
- Developing modules for –
  - o nature sector needs
  - o quick estimation of EFR using an acceptable criteria
  - o production module
  - o national level water needs for food security
- Quick assessment for all basins in the country using CPSP Model
- Need for review of total renewable water resources (TRWR) estimates based on application of CPSP Model to individual basins/sub-basins

Future needs for country level assessments (contd.)

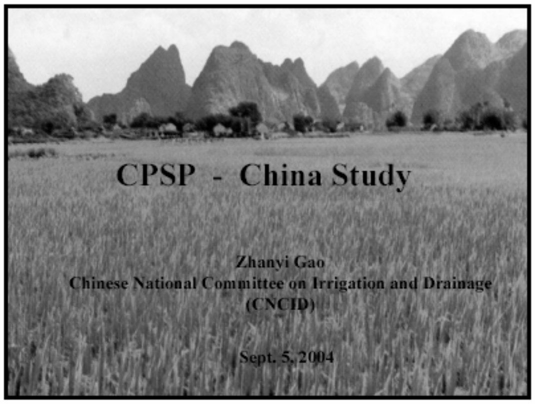
- Need for updating and review of potentially utilisable water resources (PUWR) estimates considering the following :

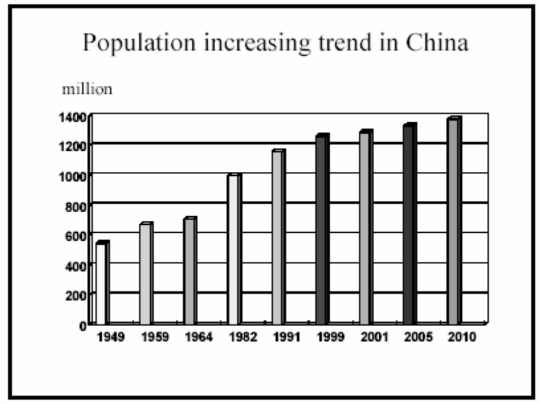
i. Overlap between surface and ground water
ii. constraints of cultivable land, water supply and water infrastructure (storages and diversion capacities, etc.)
iii. Flow to sinks
iv. Instream flow requirements for environment, navigation etc.
v. Possibilities of conjunctive use of surface and groundwater resources
vi. Interbasin transfers
vii. Recycling and reuse

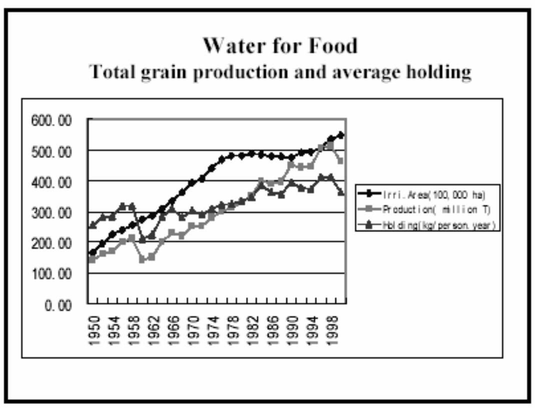
Annex 11

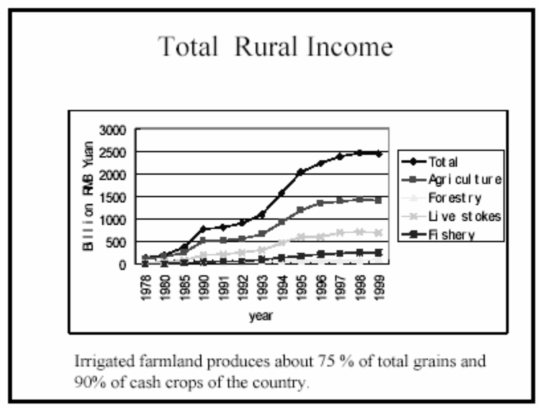
CPSP China Study

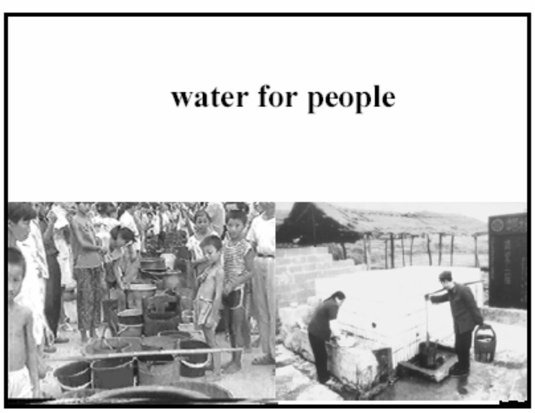
Zhanyi Gao, Chinese National Committee on Irrigation and Drainage

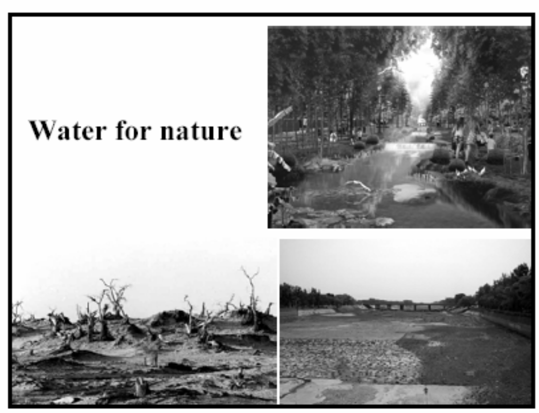




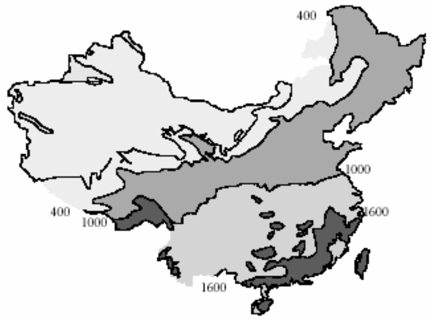




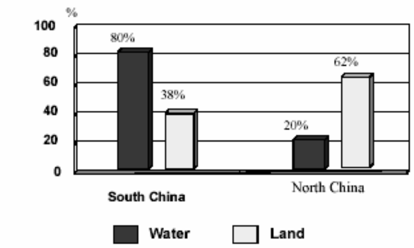




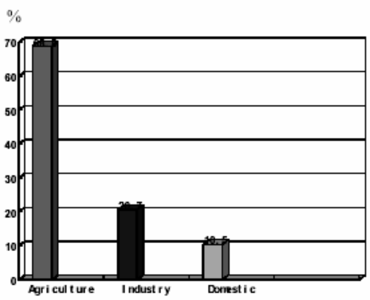
Precipitation Distribute Unevenly in Space



Unmatched Water and Land Resources Distribution



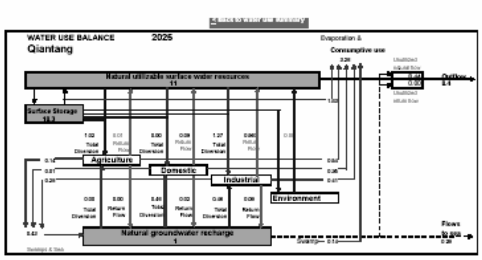
The total water consumption in 2000 was 549.8 billion m^3



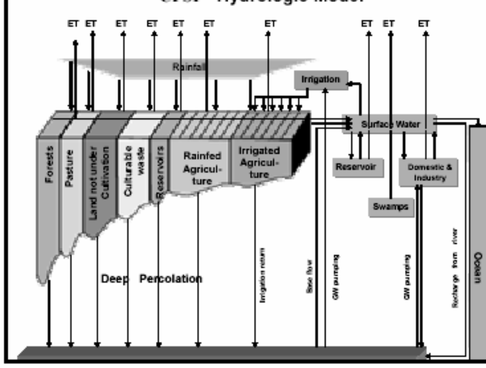
River Basins in China

River Basin Map of China

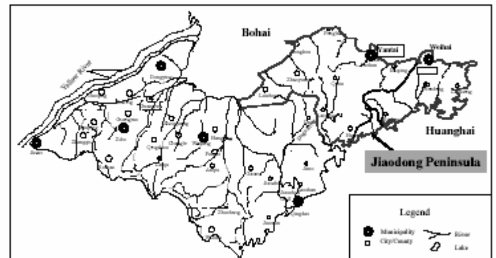
PODIUM Model



CPSP Hydrologic Model



Shandong Peninsula

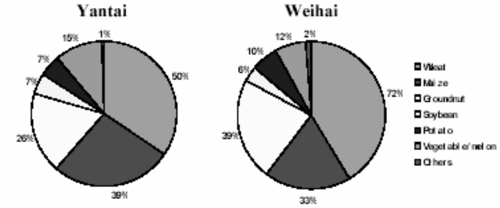


- **Climate: Semi-arid, temperate, monsoon**
- **Land area: 19182 km², two municipality, Yantai and Weihai**
- **Ave. rainfall: 700 mm, Weihai has higher rainfall**
- **Rivers: >2000 km² Wulong, Dagujia and (Dagu river) in Yantai, >1000 km² Muzhu river in Weihai**

Considering administrative division, similar hydrologic and water use attributes, and available data, two sub-basins, Yantai and Weihai cities, are divided and studied;

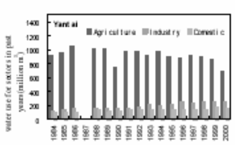
In 2000

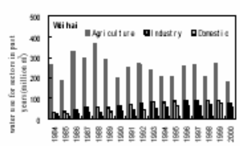
Main features		Yantai	Weihai	Total
Ave. annual rainfall (mm)		688.3	788.5	
Land area (Km²)		13746	5436	19182
Population (Million)	Urban	3.0369	1.2912	4.328(48%)
	Rural	3.4212	1.1783	4.600 (52%)
	Total	6.4581	2.4695	8.928
Available cultivated area (Million ha)		0.4439	0.1722	0.616
Gross cropped area (Million ha)		0.6552	0.2993	0.9545
Command-irrigated area (Million ha)	Farmland	0.2815	0.1199	0.4014
	Fruit tree	0.0687	0.0228	0.0915
	Total	0.3502	0.1427	0.4929
Forest area (Million ha)		0.4373	0.1560	0.5933
Main crops		Wheat, maize, groundnut		



Planting ratio of crops in 2000

Water use for Agri., I &D sectors in the past year





Agriculture:75%
Industry:15%
Domestic:10%

Agriculture:68%
Industry:19%
Domestic:13%

Calibration of model

The data for past (1980) and present (2000) conditions was used for calibration. The model was run on monthly basis and annual average rainfall conditions

- **Past(1980):** The land uses, irrigated area, water use pattern represent the past conditions around year 1980
- **Present(2000):** The land uses, irrigated area, water consumption volume, water use pattern represent the present conditions around year 2000

Comparison of calculated and observed results

Condition	Items		Calculated by model	Observed	Difference(%)
Past(1980)	Annual outflow(million m^3)	Yantai	1528	1710	-10.6
		Weihai	1155	1100	5.0
		Total	2683	2810	-4.5
	Annual recharge to groundwater(million m^3)	Yantai	858	895	-4.12
		Weihai	403	399	1.0
		Total	1261	1294	-2.53
	GW flunctuation within the years(mm)	Yantai	362	401.4	-9.81
		Weihai	199	222.9	-10.59
Present(2000)	Annual outflow(million m^3)	Yantai	1136	1165	-2.5
		Weihai	947	912	3.8
		Total	2082	2077	0.3
	Annual recharge to groundwater(million m^3)	Yantai	668	NA	
		Weihai	341	NA	
		Total	1010		
	GW flunctuation within the years(mm)	Yantai	307	375.3	-18.1
		Weihai	169	141.9	18.9

Comparison of calculated and actual irrigation water use

Items		Calculated by model	Actual water withdrawal	Difference(%)
Past(1980)	Yantai	767	955	-19.6
	Weihai	237	251	-5.4
	Total	1005	1205	-16.6
Present (2000)	Yantai	687	827	-17.0
	Weihai	232	226	2.6
	Total	919	1054	-12.8

Simulation for future scenarios

Scenarios and description

Sr.Studied	Abbreviation	Description
Future I(2025)	B. as U.	Irrigation expansion is based on local planning, the proportion of surface and groundwater irrigation same as at present,the covering rate of forest increases to 40% based on present development speed,and import of about 97 million m3 in Yantai and 50 million m3 water in Weihai.
Future II(2025)	B. as U.without expansion of forest	Same as Furture I, but the covering rate of forest area maintains the available level
Future III(2025)	Better system mgt and reduced GW use	Same as future II, but the ratio of surface irrigation to total irrigation increased from 0.3 at present to 0.5 in Yantai
Future IV(2025)	Same as future III with drip irrigation	Same as future III,but with drip irrigation
Future V(2025)	Same as III,soil mgt, import more water and further reduced GW use	Same as future III, soil management in the barren lands,import 300 million m3 water, and further reduced groundwater withdrawal.

Scenarios and description

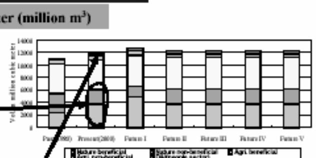
Sr. studied	Cover rate of forest(%)	Proportion of surface irrigation to total irrigation
Past(1980)	**20**	**0.6 in Yantai and 0.6 in Weihai**
Present(2000)	**30**	**0.3 in Yantai and 0.7 in Weihai**
Future I(2025)	**40**	**0.3 in Yantai and 0.7 in Weihai**
Future II(2025)	**30**	**0.3 in Yantai and 0.7 in Weihai**
Future III(2025)	**30**	**0.5 in Yantai and 0.7 in Weihai**
Future IV(2025)	**30**	**0.5 in Yantai and 0.7 in Weihai**
Future V(2025)	**30**	**0.7 in Yantai and 0.7 in Weihai**

➢**Simulation results**

Results and discussion

1. Consumptive use of water (million m^3)

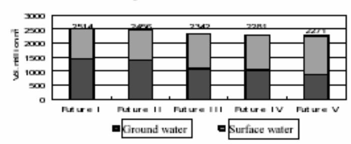
1. Total ET in the nature has increased by 12 percent over the past condition and would continue to increase by 8 percent in future I with the expansion of forest area, and non-beneficial ET decreases accordingly.



2. The non-beneficial ET in the agricultural sector will reduce from 13.2% at present to 10—11.3 % in the future with better mgt.

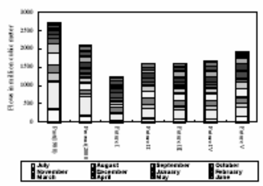
3. The command-irrigated area in the future rises 16 percent over the present condition. The agricultural consumptive use only increases about 3.5 percent or less by adopting better mgt

Total Water Use for Agriculture, Industry and Domestic under average annual condition(million m^3)



4. Total consumptive use from future I to future V was on the decrease with the decrease of total water use, the proportion of agricultural consumptive use taking up total consumption was also on the decrease with better water and soil management.

2. Surface water



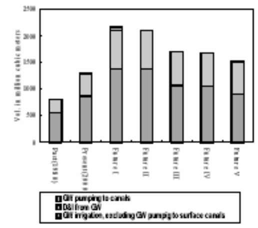
Monthly river flows

1. The river outflow are affected by the pattern of development

2. The river flows improved gradually from scenario future I to V. The outflow to sea for scenario future V approaches the available level and only 4 percent lower than that of present condition

3. The environmental water requirement to maintain the basic water demand in the river should be satisfied

3. Groundwater



Composition of GW withdrawals

1. The groundwater withdrawal at present has a striking rise than past, accounting for 86% of total inputs

2. For future I with B as U, the withdrawal of groundwater contributes still 87 percent of the inputs even though 600 million m^3 of induced recharge from river to groundwater

4. Water Situation Indicators(WSI)

Indicator 1 Withdrawals/Total runoff for surface water
Indicator 2 Returns/Total runoff for surface water
Indicator 3 Withdrawals/Total recharge for groundwater
Indicator 4 Returns/Total recharge for groundwater

	Past	Present	Future I	Future II	Future III	Future IV	Future V
Indicator 1	0.217	0.218	0.358	0.327	0.398	0.386	0.406
Indicator 2	0.062	0.103	0.218	0.189	0.193	0.191	0.182
Indicator 3	0.439	0.858	0.867	0.781	0.788	0.780	0.761
Indicator 4	0.324	0.336	0.306	0.288	0.300	0.292	0.340

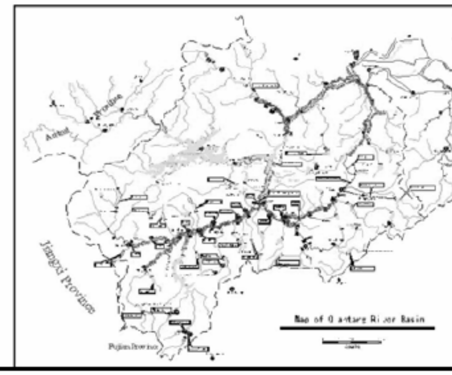
1. With the increase of water use and change of water use pattern, the ratio of surface withdrawal would increase, reaching 33—41 percent of total inputs, while the return flows to input ratio also increases, indicating more risk of pollution for surface water resources.

Conclusion and findings

- The model can successfully simulate the components of hydrological cycle
- The withdrawal of groundwater (GW) accounts for 86 percent of the inputs at present, highly stressed than that of past condition. The GW should be moderately exploited
- The groundwater reaches basically the sustainable balance for future V when the ratio of surface irrigation to total irrigation reaches 0.7 or more

- The irrigated area in the future would expand 1.16 times compared to the present condition. However, the water requirement for agriculture would increase 42 percent than available actual water use. With the increase of I&D water use, the agriculture would confront more serious water shortage
- The different land types have a large impact on consumptive use, especially the land shift between barren land and forestland. The expansion of the forest area should be consistent with local water resources, agricultural development

- The outflow to sea and recharge to groundwater was and will be decreasing from past to future. Through adopting different measures, the river outflow from scenario future I to V improved gradually. With more water imported and better soil management, the outflow to sea for future V approaches the available level with only 4 percent lower than that of present condition.
- With the increase of water use and change of water use pattern, the rate of return flows to surface water would increase. Thus, the related water prevention measures must be adopted to reduce the risk of pollution as soon as possible.



1. Description of the study basin

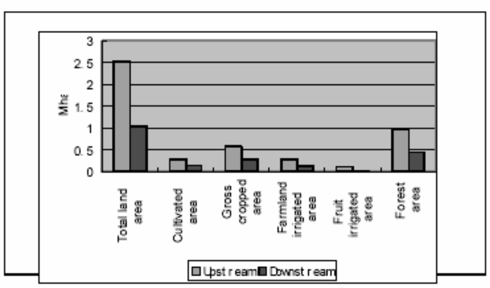
- **Location:** southeast of China, facing the East Sea in the east
- **Catchment area:** 55558Km², upstream of Hangzhou gate 41945Km², study 35500Km²
- **Length of main stream:** 477 km
- **Jurisdiction:** 5 municipalities and 27 counties/cities
- **Precipitation:** 1200mm–2200mm, average 1632mm
- **Forest coverage rate:** 30%–50%
- **Sub-basins:** SB1 Upstream of Fuchun Reservoir

  SB2 Downstream of Funchun Reservoir

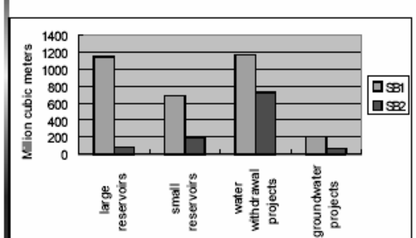
Main features in Qiantang Basin

Climate		Humid
Ave. annual rainfall (mm)		1632.6
Watershed area (Km²)		35500
Population (Million)	Urban	3.557(33%)
	Rural	7.113(67%)
	Total	10.67
Available cultivated area (Million ha)		0.424
Command-irrigated area (Million ha)	Farmland	0.3934
	Fruit tree	0.1309
	Total	0.5243
Forest area (Million ha)		1.420
Main crops		Rice

Main land use in Qiantang Basin by SBs



Water Supply Capacities of Various Projects for the Present Conditions (Million m³)



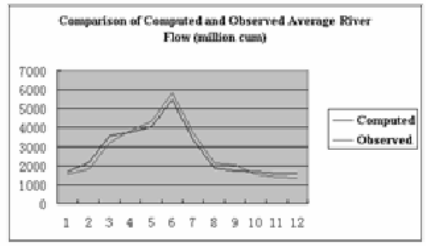
2. Scenarios studied

Future scenario comparison in CPSP Model

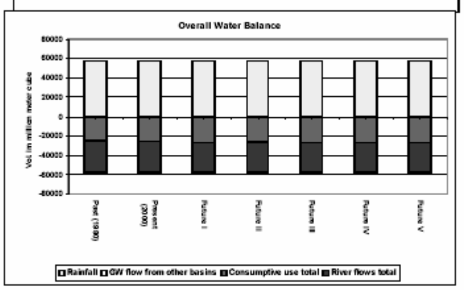
Future Scenario	Additional water infrastructure	More irrigation area	Industry	Water management
FI (BAU)	Yes	Yes +No shift in CP	Normal	As usual
FII	No	No expansion + Shif in CP	Normal	Better
FIII	Yes	Yes + Shift in CP	Normal	Better + More GW us
FIV	Yes	No expansion +Shift in CP	More	Better + More GW us +Export
FV	No	No expansion + Shift in CP	Normal	Better + More GW us

3. Model calibration

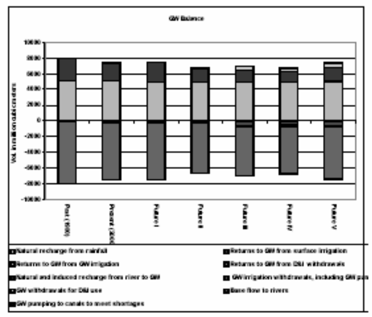
Comparison of Calculated and Observed Monthly River Flow (million m³)



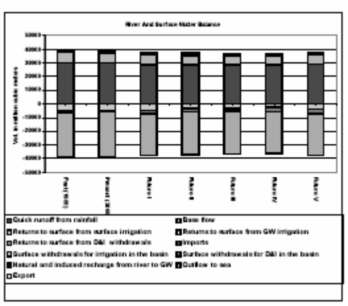
4. Simulation for future scenarios



Groundwater Balance

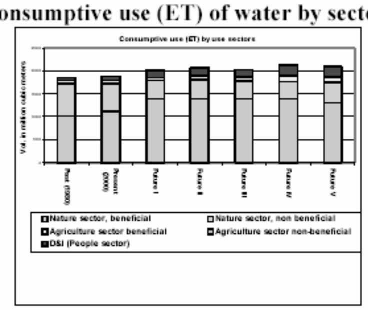


River and Surface Water Balance

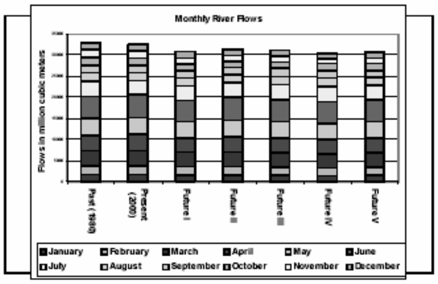


5. Results and Discussion

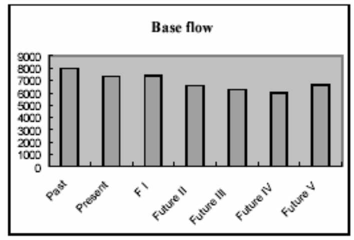
Consumptive use (ET) of water by sectors



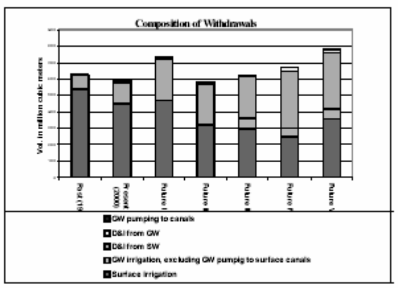
Surface water



Base Flow



Composition of Withdraws



5. Results and Discussion

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Indicator 3 Withdrawals/Total recharge for groundwater
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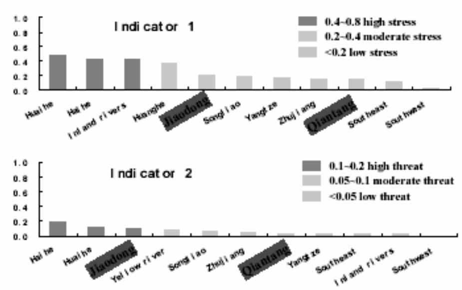
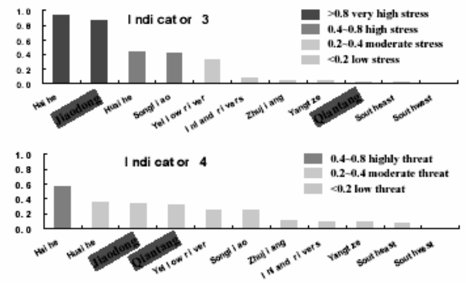
	Past (1980)	Present (2000)	Future I	Future II	Future III	Future IV	Future V
Indicator 1	0.16	0.15	0.19	0.15	0.15	0.16	0.19
Indicator 2	0.04	0.04	0.05	0.05	0.05	0.06	0.06
Indicator 3	0.005	0.01	0.01	0.02	0.11	0.11	0.11
Indicator 4	0.35	0.31	0.34	0.25	0.29	0.26	0.32

Extrapolation to Other Basins in China

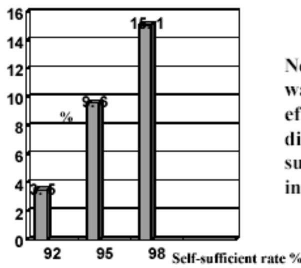
Basin Classification by water situation indicators for surface water



Basin Classification by water situation indicators for ground water



Solution 1. Increasing water using efficiency



Need for irrigation water using efficiency under different food self sufficient rate in 2010

Solution 2 Inter - Basin Water Transfer project

ICID 19th Congress and 56 IEC Meeting

Sept. 10-18, 2005 Beijing

BEIJING 2005

www.icid2005.org

Application of CPSP Model to Jiaodong Peninsular Basin

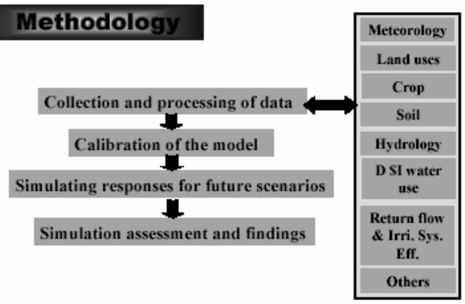
Shaoli Wang, China Institute of Water Resources and Hydropower Research

Application of CPSP Model to Jiaodong Peninsula Basin

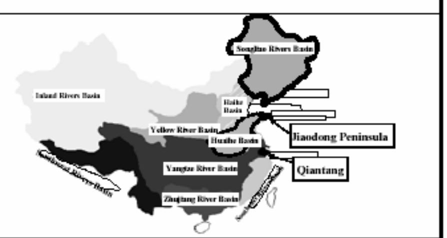
1 Objective

- To evaluate the performance of CPSP model in simulating the basin hydrological behavior
- Using CPSP model to predict and evaluate the impacts of future scenarios on the basin hydrology, in regard to land and water use

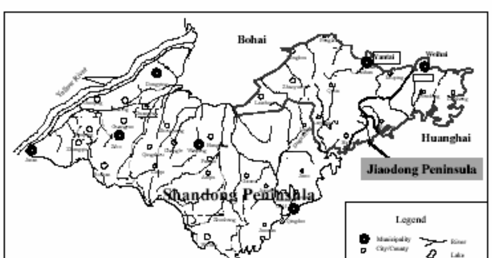
2 Methodology



3 Brief description of study basin



- **Location:** The Jiaodong peninsula is in the east of China. It belongs to Huaihe river basin, and faces the Huanghai sea and Bohai sea on the east, south and north



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- **Land area:** 19182 km^2, two municipality, Yantai and Weihai
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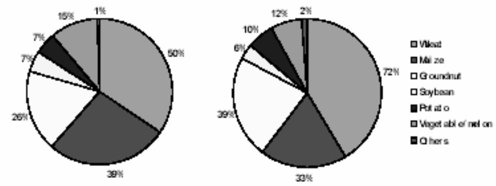
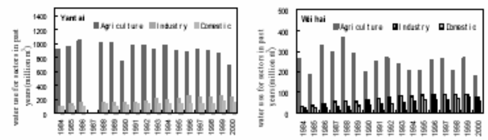
Main crops		Wheat, maize, groundnut		

Yantai **Weihai**



Planting ratio of crops in 2000

Water use for Agri., I &D sectors in the past year



Agriculture:75%
Industry:15%
Domestic:10%

Agriculture:68%
Industry:19%
Domestic:13%

4 Calibration of model

The data for past (1980) and present (2000) conditions was used for calibration. The model was run on monthly basis and annual average rainfall conditions

- **Past(1980):** The land uses, irrigated area, water use pattern represent the past conditions around year 1980
- **Present(2000):** The land uses, irrigated area, water consumption volume, water use pattern represent the present conditions around year 2000

The calibration (in Yantai and Weihai) was limited to match the following conditions between calculated and measured results.

- Comparing the annual outflow with the observed runoff
- Comparing the annual total recharge to groundwater with the estimations made by local agency
- Comparing the groundwater fluctuation within an average year with the observed groundwater fluctuation.
- Comparing agricultural water use with actual water use observed by local agency.

Comparison of calculated and observed results

Condition	Items		Calculated by model	Observed	Difference(%)
Past(1980)	Annual outflow(million m^3)	Yantai	1528	1710	-10.6
		Weihai	1155	1100	5.0
		Total	2683	2810	-4.5
	Annual recharge to groundwater(million m^3)	Yantai	858	895	-4.12
		Weihai	403	399	1.0
		Total	1261	1294	-2.53
	GW flunctuation within the years(mm)	Yantai	362	401.4	-9.81
		Weihai	199	222.9	-10.59
Present(2000)	Annual outflow(million m^3)	Yantai	1136	1165	-2.5
		Weihai	947	912	3.8
		Total	2082	2077	0.3
	Annual recharge to groundwater(million m^3)	Yantai	668	NA	
		Weihai	341	NA	
		Total	1010		
	GW flunctuation within the years(mm)	Yantai	307	375.3	-18.1
		Weihai	169	141.9	18.9

Comparison of calculated and actual irrigation water use

Items		Calculated by model	Actual water withdrawal	Difference(%)
Past(1980)	Yantai	767	955	-19.6
	Weihai	237	251	-5.4
	Total	1005	1205	-16.6
Present (2000)	Yantai	687	827	-17.0
	Weihai	232	226	2.6
	Total	919	1054	-12.8

5 Simulation for future scenarios

Scenarios and description

Sr.Studied	Abbreviation	Description
Future I(2025)	B. as U.	Irrigation expansion is based on local planning, the proportion of surface and groundwater irrigation same as at present,the covering rate of forest increases to 40% based on present development speed,and import of about 97 million m3 in Yantai and 50 million m3 water in Weihai.
Future II(2025)	B. as U.without expansion of forest	Same as Furture I, but the covering rate of forest area maintains the available level
Future III(2025)	Better system mgt and reduced GW use	Same as future II, but the ratio of surface irrigation to total irrigation increased from 0.3 at present to 0.5 in Yantai
Future IV(2025)	Same as future III with drip irrigation	Same as future III,but with drip irrigation
Future V(2025)	Same as III,soil mgt, import more water and further reduced GW use	Same as future III, soil management in the barren lands,import 300 million m3 water, and further reduced groundwater withdrawal.

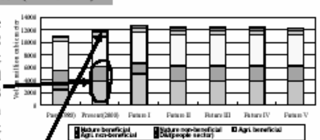
Scenarios and description

Sr. studied	Cover rate of forest(%)	Proportion of surface irrigation to total irrigation
Past(1980)	20	0.6 in Yantai and 0.6 in Weihai
Present(2000)	30	0.3 in Yantai and 0.7 in Weihai
Future I(2025)	40	0.3 in Yantai and 0.7 in Weihai
Future II(2025)	30	0.3 in Yantai and 0.7 in Weihai
Future III(2025)	30	0.5 in Yantai and 0.7 in Weihai
Future IV(2025)	30	0.5 in Yantai and 0.7 in Weihai
Future V(2025)	30	0.7 in Yantai and 0.7 in Weihai

➢Simulation results

6 Results and discussion

1. Consumptive use of water (million m³)

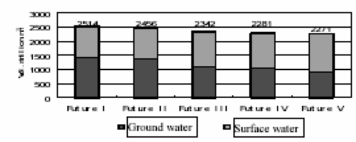


1. Total ET in the nature has increased by 12 percent over the past condition and would continue to increase by 8 percent in future I with the expansion of forest area, and non-beneficial ET decreases accordingly.

2. The non-beneficial ET in the agricultural sector will reduce from 13.2% at present to 10—11.3 % in the future with better mgt.

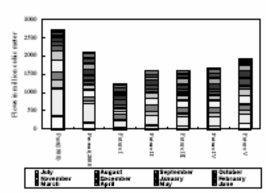
3. The command-irrigated area in the future rises 16 percent over the present condition. The agricultural consumptive use only increases about 3.5 percent or less by adopting better mgt

Total Water Use for Agriculture, Industry and Domestic under average annual condition(million m³)



4. Total consumptive use from future I to future V was on the decrease with the decrease of total water use, the proportion of agricultural consumptive use taking up total consumption was also on the decrease with better water and soil management.

2. Surface water



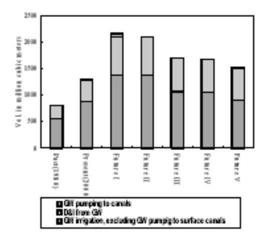
Monthly river flows

1. The river outflow are affected by the pattern of development

2. The river flows improved gradually from scenario future I to V. The outflow to sea for scenario future V approaches the available level and only 4 percent lower than that of present condition

3. The environmental water requirement to maintain the basic water demand in the river should be satisfied

3. Groundwater



Composition of GW withdrawals

1. The groundwater withdrawal at present has a striking rise than past, accounting for 86% of total inputs

2. For future I with B as U, the withdrawal of groundwater contributes still 87 percent of the inputs even though 600 million m³ of induced recharge from river to groundwater

4. Groundwater

Requirements of groundwater pumping into canals and Natural and/or induced recharge from river to groundwater

Description	Past	Present	Future I	Future II	Future III	Future IV	Future V
Natural & induced recharge from river to GW for balancing the GW	0	0	680	600	300	300	100
GW pumping to surface canals for meeting shortages in surface irrigation	0	0	50	0	0	0	0

1. More natural & induced recharge from river to groundwater for future I and II was needed if maintaining available water use pattern.

2. While reducing groundwater withdrawal (The ratio of GW withdrawal in Yantai decreases from 0.7 to 0.5), the natural & induced recharge from river to groundwater for future III and IV could be reduced.

3. The groundwater reaches basically the sustainable balance for future V when reducing GW withdrawal further.

5. Water Situation Indicators(WSI)

Indicator 1 Withdrawals/Total runoff for surface water
Indicator 2 Returns/Total runoff for surface water
Indicator 3 Withdrawals/Total recharge for groundwater
Indicator 4 Returns/Total recharge for groundwater

	Past	Present	Future I	Future II	Future III	Future IV	Future V
Indicator 1	0.217	0.218	0.358	0.327	0.398	0.386	0.406
Indicator 2	0.062	0.103	0.218	0.189	0.193	0.191	0.182
Indicator 3	0.439	0.858	0.867	0.781	0.788	0.780	0.761
Indicator 4	0.324	0.336	0.306	0.288	0.300	0.292	0.340

1. With the increase of water use and change of water use pattern, the ratio of surface withdrawal would increase, reaching 33—41 percent of total inputs, while the return flows to input ratio also increases, indicating more risk of pollution for surface water resources.

□. The groundwater should be moderately exploited. With the increase of water use and change of water use pattern, the ratio of surface withdrawal would increase, reaching 33—41 percent of total inputs, while the return flows to input ratio also increases, indicating more risk of pollution for surface water resources.

7 Conclusion and findings

- **The model can successfully simulate the components of hydrological cycle**
- **The withdrawal of groundwater (GW) accounts for 86 percent of the inputs at present, highly stressed than that of past condition. The GW should be moderately exploited**
- **The groundwater reaches basically the sustainable balance for future V when the ratio of surface irrigation to total irrigation reaches 0.7 or more**

- **The command-irrigated area in the future would expand 1.16 times compared to the present condition. However, the water requirement for agriculture would increase 42 percent than available actual water use. With the increase of I&D water use, the agriculture would confront more serious water shortage**
- **The different land types have a large impact on consumptive use, especially the land shift between barren land and forestland. The expansion of the forest area should be consistent with local water resources, agricultural development**

- **The outflow to sea and recharge to groundwater were on the decrease from past to future. Through adopting different measures, the river outflow from scenario future I to V improved gradually. With more water imported and better soil management, the outflow to sea for future V approaches the available level with only 4 percent lower than that of present condition.**
- **With the increase of water use and change of water use pattern, the rate of return flows to surface water would increase. Thus, the related water prevention measures must be adopted to reduce the risk of pollution as soon as possible.**

- **Rigorous calibration and the optimal scenarios was not attempted due to time and resource constraints. Further works, including model improvement and application, need to be done in the future**

Application of CPSP Model to Qiantang Basin

Jianxin Mu, ChinaNational Committee on Irrigation and Drainage

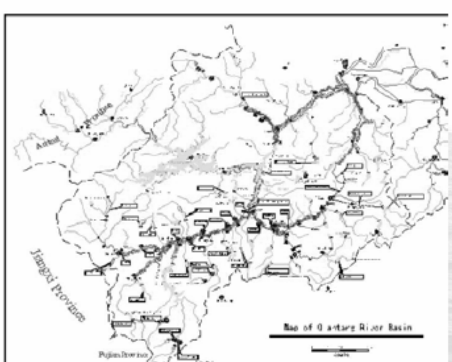
Application of CPSP Model to Qiantang Basin

September 3-4, 2004
Moscow, Russia

Contents

1. Description of the study basin

- **Location:** southeast of China, facing the East Sea in the east
- **Catchment area:** 55558Km², upstream of Hangzhou gate 41945Km², study 35500Km²
- **Length of main stream:** 477 km
- **Jurisdiction:** 5 municipalities and 27 counties/cities
- **Precipitation:** 1200mm 2200mm, average 1632mm
- **Forest coverage rate:** 30% 50%
- **Sub basins:** SB1 Upstream of Fuchun Reservoir
  SB2 Downstream of Funchun Reservoir



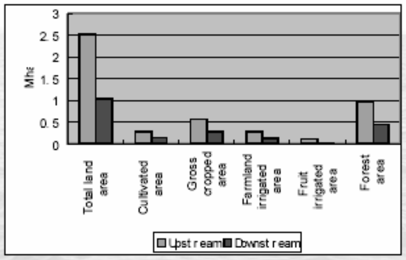
1. Description of the study basin

Main features in Qiantang Basin

Climate		Humid
Ave. annual rainfall (mm)		1632.6
Watershed area (Km²)		35500
Population (Million)	Urban	3.557(33%)
	Rural	7.113(67%)
	Total	10.67
Available cultivated area (Million ha)		0.424
Command-irrigated area (Million ha)	Farmland	0.3934
	Fruit tree	0.1309
	Total	0.5243
Forest area (Million ha)		1.420
Main crops		Rice

1. Description of the study basin

Main land use in Qiantang Basin by SBs



1. Description of the study basin

Comparison of main features in Qiantang Basin and Zhejiang Province in year 2000

Main features		Zhejiang Province	Qiantang Basin	Percentage
Land area (Km^2)		103200	35500	34%
Population		44.9	10.67	24%
Available cultivated area (Mha)		1.5904	0.424	27%
Farmland irrigated area (Mha)		1.403	0.393	28%
Forest area (Mha)		6.4	1.42	22%
Water resources (Mcm)		96367	32703	34%
Water supply (Mcm)		20327	7746	38%
Water withdrawals (Mcm)	Irrigation	11105	5029	38%
	Domestic & Industry	9010	1407	38%
	Total	20115	6436	32%
Outflow to sea (Mcm)		81681	29780	36%

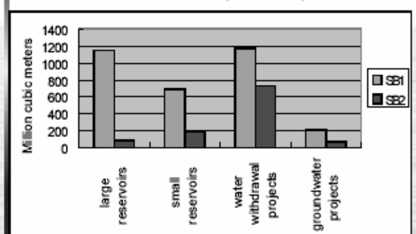
1. Description of the study basin

Socio economic Conditions of SBs in Qiantang Basin

SB	Population (million)			Cultivated area (Km^2)			Orchard (Km^2)	Equivalent sheep (million)
	Urban	Rural	Subtotal	Paddy	Upland	Subtotal		
SB1	2.41	4.93	7.33	2403.52	484.82	2888.34	1052.59	9.00
SB2	1.15	2.19	3.34	1200.66	151.21	1351.87	256.08	2.82
Total	3.56	7.11	10.67	3604.18	636.03	4240.21	1308.67	11.82

1. Description of the study basin

Water Supply Capacities of Various Projects for the Present Conditions (Million m^3)



2. Scenarios studied

Description of scenarios

Sr. No.	Abbreviation	Explanatory notes
1.	**Past** (1980)	The social economy developed quickly since the implementation the reform and opening-up policies after 1980.
2.	**Present** (2000)	To date.
3.	**Future I** (2025) B as U	Business as Usual. With increased water infrastructure (and small import), Irrigatic expansion with cropping pattern same as at present. Proportion surface & groundwater irrigation same as at present
4.	**Future II** (2025)	With no expansion of water infrastructure (and small import), shi in cropping pattern, better water management
5.	**Future III** (2025)	With increased water infrastructure (and small import) and irrigatic expansion, shift in cropping pattern, more groundwater use an better water management
6.	**Future IV** (2025)	With increased water infrastructure (and small import), no irrigatic expansion, shift in cropping pattern, more industries, mo groundwater use, export water and better water management
7.	**Future V** (2025), agri. seasonal shift	With increased water infrastructure (and small import), no expansic of irrigation, more industries, more GW use, better wat management

2. Scenarios studied

Future scenario comparison in CPSP Model

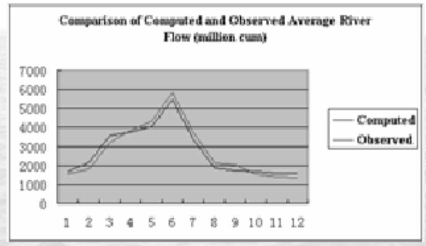
Future Scenario	Additional water infrastructure	More irrigation area	Industry	Water management
FI (BAU)	Yes	Yes +No shift in CP	Normal	As usual
FII	No	No expansion + Shif in CP	Normal	Better
FIII	Yes	Yes + Shift in CP	Normal	Better + More GW us
FIV	Yes	No expansion +Shift in CP	More	Better + More GW us +Export
FV	No	No expansion + Shift in CP	Normal	Better + More GW us

3. Model calibration

- Comparing the total monthly outflow (surface runoff plus base flow) of SB1 and SB2 with the observed monthly runoff.
- Comparing the total groundwater recharge and withdrawal, as computed by the model, with the estimates of the Qiantang Basin Management Bureau.
- Comparing the withdrawal for irrigation, and total withdrawal for irrigation and D & I, as computed by the model, with the estimates of the Qiantang Basin Management Bureau.

3. Model calibration

Comparison of Calculated and Observed Monthly River Flow (million m^3)

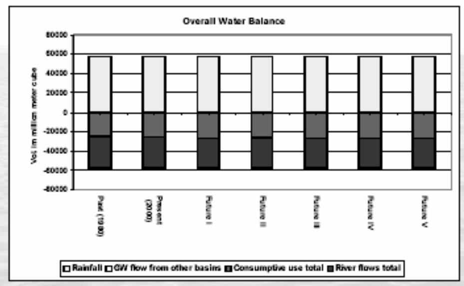


3. Model calibration

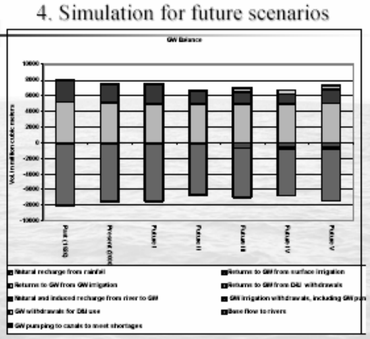
Comparison of Computed and Observed Results (Mcm)

Items	Computed by the model	Estimated	Difference (%)
Percentage of groundwater recharge from rainfall	9	8	10.92
Total Recharge to groundwater	7451	6525	14.18
Groundwater fluctuation within the year	2451	NA	
Total outflow to sea	32542	32703	-0.5
Withdrawal for irrigation	4497	5028.8	-10.6
Withdrawal for irrigation and D&I	5909	6436.0	-8.2

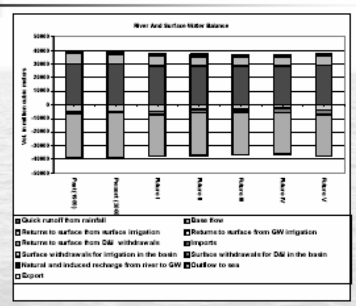
4. Simulation for future scenarios



4. Simulation for future scenarios



4. Simulation for future scenarios



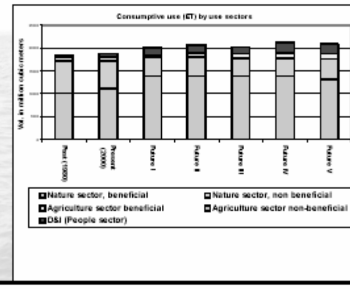
5. Results and Discussion

Consumptive use of water

	Past (1980)	Present (2000)	Future I	Future II	Future III	Future IV	Future V
Nature sector beneficial	10126	11128	13908	13910	13910	13910	13126
non beneficial	7102	6003	4075	4241	3936	3850	4435
Subtotal	17228	17130	17983	18151	17846	17760	17561
Agriculture sector beneficial	815	872	533	872	832	1280	1209
non-beneficial	17	15	11	15	13	16	16
Subtotal	832	887	544	887	845	1295	1224
D&I (People sector)	535	838	1591	1591	1591	2228	2228
Total for all sectors	**18595**	**18855**	**20118**	**20629**	**20282**	**21283**	**21014**

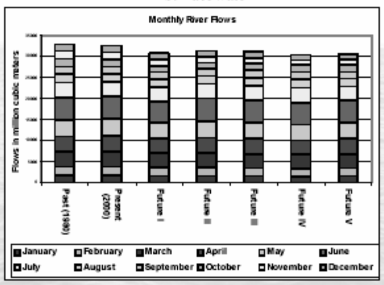
5. Results and Discussion

Consumptive use (ET) of water by sectors



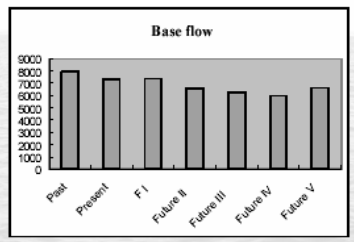
5. Results and Discussion

Surface water



5. Results and Discussion

Surface water



5. Results and Discussion

Surface water

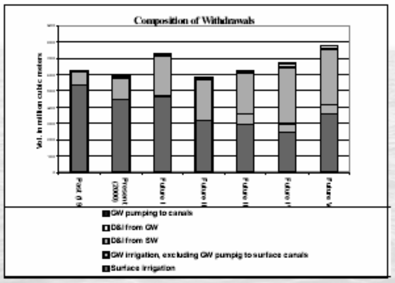
- From 1980 to date, surface water is all along the major water source in Qiantang Basin. Particularly for agriculture, 100 percent of irrigation withdrawal is from surface water. For D&I uses, only 5 percent of D&I withdrawal is from surface water in the past and 7 percent in the present conditions.
- In terms of total water withdrawal for agriculture and D&I, only 0.6 percent is from surface water in the past and 1.8 percent at present. Therefore, the abundant surface water resources here create superior conditions for local socio-economic development.

5. Results and Discussion

Groundwater

- A little groundwater, which is only 0.2 per cent of total inputs, has been exploited for D&I use in the current situation, return flow, natural & human together, constitutes only 4 percent of the inputs. Therefore, more groundwater use had been adopted in future three scenarios.
- In Future IV scenario, 20 per cent of ground water is planned to be used and totally 270 million cubic meters of water is planned to be exported to other water short basins. But even then, the total withdrawal from groundwater is only 1.3 percent of the total inputs and the return flow would constitute about 3 percent of the inputs. The potentials for groundwater development are very huge in this basin.

5. Results and Discussion



5. Results and Discussion

Water Situation Indicators(WSI)

Indicator 1 Withdrawals/Total runoff for surface water
Indicator 2 Returns/Total runoff for surface water
Indicator 3 Withdrawals/Total recharge for groundwater
Indicator 4 Returns/Total recharge for groundwater

	Past (1980)	Present (2000)	Future I	Future II	Future III	Future IV	Future V
Indicator 1	0.16	0.15	0.19	0.15	0.15	0.16	0.19
Indicator 2	0.04	0.04	0.05	0.05	0.05	0.06	0.06
Indicator 3	0.005	0.01	0.01	0.02	0.11	0.11	0.11
Indicator 4	0.35	0.31	0.34	0.25	0.29	0.26	0.32

Annex 12

Key Drivers of PODIUMSIM

Upali Amarasinghe, International Water Management Institute

IWMI/ICID Scenario Development workshop for India and China

Key Drivers – Consumption (National level)

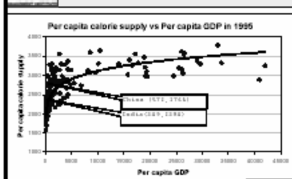
- Population growth
- Total calorie supply/person/day growth
- Change in calorie supply from grains
- Change in food grain consumption/person/day
- Calorie supply from animal products growth
- Change in feed grain consumption

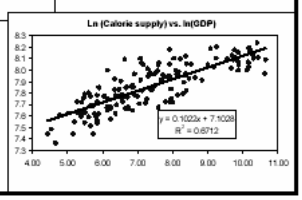
Population Projections

- Difference between UN Medium to UN Low projections is substantial

	India			China		
	UN Medium	UN LOW	Difference	UN Medium	UN Low	Difference
	Million	MIllion	Million	Million	Million	Million
1995	1221	1221	-	934	934	-
2000	1278	1276	2	1014	1008	6
2025	1329	1216	113	1480	1394	86
2050	1529	1216	313	1478	1250	228

Total Calorie supply





Calorie supply can increase substantially with income growth

Total Calorie supply

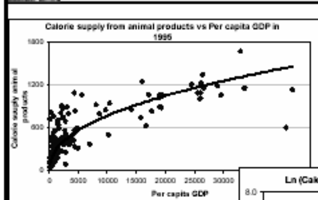
	Per capita calorie supply		
	1995	2025 Regression	2025 PODIUM
China	2766	3940	3311
India	2394	3013	2772

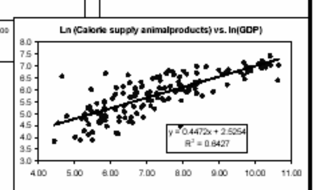
Grain consumption

- Food grain consumption decreases in China
- Food grain consumption increases in India

	Calorie supply from grain products		Food grain consumption	
	1995	2025 PODIUM	1995	2025 PODIUM
	%	%	g/day/pc	g/day/pc
China	59.6	51.6	551	534
India	67.4	61.0	490	509

Calorie supply from animal products





Calorie supply from animal products

Per capita calorie supply from animal products

	1995		2025 Regression		2025 PODIUM	
	#	% of total	#	% of total	#	% of total
China	461	16%	1318	33%	827	25%
India	173	7%	369	12%	332	12%

Grains for feeding animals

In China

- Meat contains 70 % of animal products.
- Maize for feed is high (80 MMT out of 110 MMT of grains).

In India

- Milk/butter/gee contains 70% of animal products.
- Grains for feed is low (only 3 MMt).

Key Drivers – Crop production side (Basin wise)

Key drivers - Production

- Net area growth
- Gross area (cropping intensity) growth
- Net irrigated area growth
- Gross irrigated area (irrigation intensity) growth
- Crop yield growth (irrigated and rainfed)
- Irrigated area of grain crops

Sown area growth

- No growth in net sown area in both India and China.
- Moderate growth in cropping intensity

Country	Net sown area		Gross Sown area	
	1995	2025 Podium	1995	2025 Podium
	MHa	MHa	MHa	Mha
China	**103.0**	**102.8**	**164.0 (159%)**	**165.9 (161%)**
India	**142.5**	**144.8**	**187.4 (132%)**	**197.5 (136%)**

Irrigated area Growth

- No growth in net sown area in both India and China.
- Moderate growth in cropping intensity

Country	Net irrigated area		Gross irrigated area (Cropping Intensity%)	
	1995	2025 Podium	1995	2025 Podium
	MHa	MHa	MHa	Mha
China	**53.5**	**56.2**	**85.7 (160%)**	**92.7 (165%)**
India	**52.6**	**63.8**	**70.1 (133%)**	**89.6 (140%)**

Irrigated area growth - Indian river basins

Country	Net irrigated area		Gross irrigated area (Cropping Intensity%)	
	1995	2025 Podium	1995	2025 Podium
	MHa	MHa	MHa	Mha
Indus	**5.5**	**5.5**	**9.7 (177%)**	**9.7 (177%)**
Ganga	**22.4**	**23.8**	**30.3 (135%)**	**40.5 (143%)**
Godhaw ari	**3.5**	**4.6**	**4.2 (120%)**	**6.1 (132%)**
Krishna	**3.2**	**4.0**	**4.7 (127%)**	**5.6 (138%)**
Others	**18.0**	**21.3**	**21.8 (121%)**	**27.6 (130%)**

Irrigated area growth - Chinese river basins

Country	Net irrigated area		Gross irrigated area (Cropping Intensity%)	
	1995	2025 Podium	1995	2025 Podium
	MHa	MHa	MHa	Mha
Yangtze	**14.9**	**15.7**	**28.8 (193%)**	**31.5 (200%)**
Huaihe	**8.9**	**9.3**	**16.6 (183%)**	**17.6 (189%)**
Haihe	**7.5**	**7.8**	**8.3 (112%)**	**9.2 (118%)**
Yellow	**5.1**	**5.3**	**6.8 (134%)**	**7.4 (140%)**
Others	**17.1**	**18.2**	**25.3 (148%)**	**27.0 (149%)**

Crop yield growth

- Irrigated yield growth in river basins – 1.0% to 1.1%
- Rainfed yield growth in river basin - 0.33%

Country	Irrigated area grain yield		Rainfed area grain yield	
	1995	2025 Podium	1995	2025 Podium
	(MT/ha)	(MT/Ha)	(MT/ha)	(MT/ha)
China	**4.60**	**6.02**	**3.31**	**3.65**
India	**2.35**	**3.09**	**0.99**	**1.10**

Irrigated area of grain crops - % of total irrigated area

Country	Irrigated area of grain crops - % of total irrigated area	
	1995	2025 Podium
	(%)	(%)
China	**63%**	**59%**
India	**69%**	**68%**

Key Drivers – Water withdrawals (Basin wise)

- Irrigation withdrawals
  - Groundwater irrigated area
  - Field scale irrigation efficiency
- Domestic withdrawals
  - Per capita domestic water supply
  - Urban population growth
- Industrial withdrawals

Groundwater irrigated area growth

Country	Groundwater irrigated area - % of total irrigated area	
	1995	2025 Podium
	(%)	(%)
China	**22%**	**23%**
India	**57%**	**61%**

Irrigation efficiency growth

Country	Surface water		Groundwater	
	1995	2025 Podium	1995	2025 Podium
	(%)	(%)	(%)	(%)
China	**46%**	**51%**	**60%**	**65%**
India	**38%**	**41%**	**65%**	**70%**

Per capita domestic water demand

Country	Urban		Rural	
	1995	2025 Podium	1995	2025 Podium
	(l/pc/day)	(l/pc/day)	(l/pc/day)	(l/pc/day)
China	**190**	**218**	**88**	**107**
India	**130**	**170**	**40**	**70**

Industrial water demand

Country	Industrial water demand	
	1995	2025 Podium (growth%)
	(km3)	(km3)
China	**114**	**175 (53%)**
India	**25**	**70 (80%)**

Water Supply drivers

- Water transfers in
- Water transfers out
- Environmental water demand

Water Supply drivers

Country	Minimum flow requirement		Other requirements		Environmental water demand from PUWR	
	1995	**2025**	**1995**	**2025**	**1995**	**2025**
	(Km^3)	(Km^3)	(Km^3)	(Km^3)	(Km^3)	(Km^3)
China	808	808	80	80	80	80
India	476	476	0	0	15	15

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Group on Storages for Water & Food Security

NEED FOR A HOLISTIC VIEWS ON IWRDM

– Net Sown Area has attained a plateau

- Increasing Cropping Intensity and achieving stable crop yield possible through Irrigation only

- Rainfed land should be classified as rainfed only when crop is exclusively grown on rainfall/ insitu moisture storage

HOLISTIC VIEWS ON IWRDM

- Globalise World economy by removing migration barriers along with trade barriers. Labour mobility. This will change demands for virtual water trade
- If not, try general self sufficiency for India;
- Reduce rural poverty by
  - Urbanisation
  - Services
  - Irrigation

PRODUCTION DRIVER

Present Situation in m. ha	Net Area	Gross Rabi+Hot weath	Kharif+2 Seasonal	Total
Irrigated	60	35	60	95
Rainfed	80	30	70	100
Total	140			195
2025 Situation				
Irrigated	80	50	80	130
Rainfed	60	20	80	100
Total	140			230

Drivers for Production - Contd..

Present Situation	Area (Mha)	Yield (T/Ha) I	Production (Million Tonnes)
Irrigated	95	1.5	142.5
Rainfed	100	0.7	70
Total			212.5
2025 Situation			
Irrigated	130.3	2.5	325
Rainfed	80	1.3	104
Total			429

Findings of India-Group 2 Deliberations

A.K.Alagh, Kamta Prasad, Vijay Pranjpey, Biksam Gujja, Malavika Cauhan,

Comments on BAU

- Sensitivity analysis Important sectors.
- Which is going to have more impact Demands
- NOs and parameters are already generated by Indian experts, look into it.
- Is it a three year average or one year??
- Thresholds on some critical sectors..
- Requirements of fisheries (all)??
- Domestic needs should revised to take into consideration of realistic animal needs

Comments on BAU nos..1

- Grain. 0.15 – closer 1.5 to 1.0 (ten times?)
- Oil crops- 1.04- it should be 2.5%
- Fruit and veg. (1.0) it should be 5.0%
- Eggs it should 7%
- Feed conversion is low- ??

BAU- Area..

- It should be less- 141 not 145 m.ha.
- Irrigation intensity – 140% ok
- Rain fed ok - but -may go down
- Rice – 0.5% may be more.. Close 1%
- Wheat may 1.0%??
- Sugar..may be more than 0.2%
- Cotton.. 0.8% low?

scenarios 1

- Best way to use water in local area
- Historical rights should be respected
- This may mean like in Mekong some large storage dams may be reduced somewhat
- Higher level Systems should be designed based on such needs
- Same considerations should apply for our regional countries as PM said in last SARCmeeting
- India will pass on the experiences of its reform process to SARC.
- First Priority to GW development, completing and modernising canal systems,water harvesting, watershed, local ponds as they suitable, needed.

scenarios 2

- River basin planning will back this scenario with increase in storage leading to conjunctive use
- Operational strategies will be developed for local level water management institutions community collateral for financing, news organisation designs.
- Highly stressed regions technology potential will be looked very seriously
- These are WTO compatibles, as at Geneva, but if progress is slow, alternative scenario's developed.

Scenario's- 3

- For each figure both high –low figure.
- Scenarios for the population stabilisation year around 2050
- Appropriation rights existing and new storages- are not on water but on function (land)Water saving should lead to greater equity.
- Policy on conjunctive use (watershed, upstream, storages..)
- Improving of existing canal systems.
- Minimum water flow should be 7 10%(gross storage) released in non monsoon.

Scenario's- 3

- Progressive water rates based on volumetric releases.
- Storages measurements should be made in Oct, and the deficit/ surplus should be shared by the all riparian water rights holders.
- Shift the investment allowcations 40:30:30- large, watershed, ground water

Annex 13

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