REPORT OF THE HIGH LEVEL EXPERT GROUP ON

WATER LOGGING IN PUNJAB

GOVERNMENT OF INDIA

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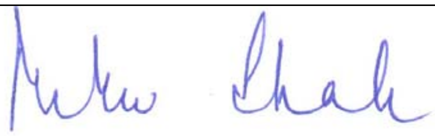

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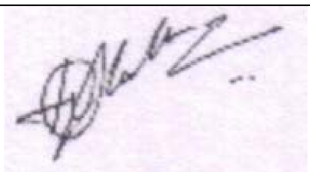
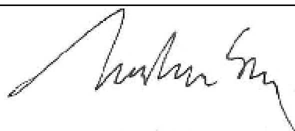
 Dr. Himanshu Kulkarni Executive Director Advanced Centre for Water Resources Development and Managemen (ACWADAM), Pashan Pune, Maharashtra	 Dr Tushaar Shah Sr. Fellow, International Water Management Institute (IWMI), Anand, Gujarat
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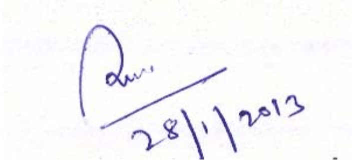
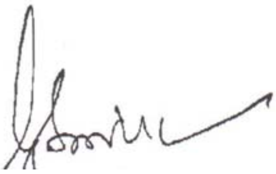
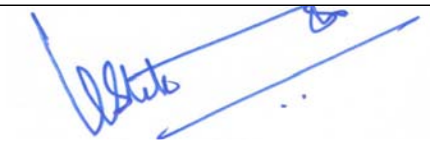
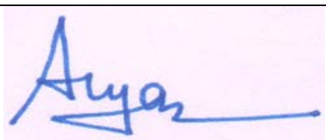
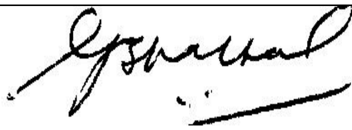
 Shri Rajesh Kumar Chairman, Central Water Commission & Member (Water Planning and Projects), CWC New Delhi	 Ms Savita Anand Joint Secretary, Department of Land Resources, Ministry of Rural Development, New Delhi
 Shri G.S. Jha Commissioner, Command Area Development and Water Management, Ministry of Water Resources, New Delhi	 Director, Ground Water Water Resources & Environment Irrigation Department, Government of Punjab, Chandigarh
 Prof. Dr. A.K.Jain HoD, Department of Soil & Water Engineering, Punjab Agricultural University, Ludhiana	 Chairman, Punjab State Farmers Commission, Mohali, Punjab

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January 2013

1. INTRODUCTION

The state of Punjab while occupying only 1.57% geographical area of India, contributes more than 50 % of the grain in the central grain pool. In particular, it contributes about 55% of wheat and 42% rice to the central pool. More than 83% of land in Punjab is under agriculture as compared to the national average of 40.38%. Three perennial rivers, namely the Sutlej, Beas and Ravi, flow through the state. In addition, the Ghaggar, which is almost a seasonal river, flows through the southwestern part of Punjab. The water from the rivers is utilised for irrigation through a network of canal systems (14,500 kms) such as Sirhind canal, Sirhind feeder, Eastern canal, Upper Bari Doab canal, Bhakra canal and Bist Doab canal. The state has experienced a phenomenal increase in agricultural production during the last three decades, mainly due to extensive adoption of rice-wheat cropping system with assured irrigation facilities, leading the country in achieving food-sufficiency. Cropping intensity has increased from 133% in 1971 to 190% in 2009.The state has 86% cropped area and 98% of this is under irrigation that uses nearly 84% of the state's water resources. Out of this, rice consumes 34%, wheat 30% and other crops 36% (Jain, 2012)[1]. The dominant cropping pattern of wheat and paddy rotation has led to a manifold increase in irrigation water demand. Injudicious surface water irrigation policies, excessive ground water pumpage due to free electricity coupled with irrational irrigation and agricultural practices have led to a situation wherein fresh ground water resources of the

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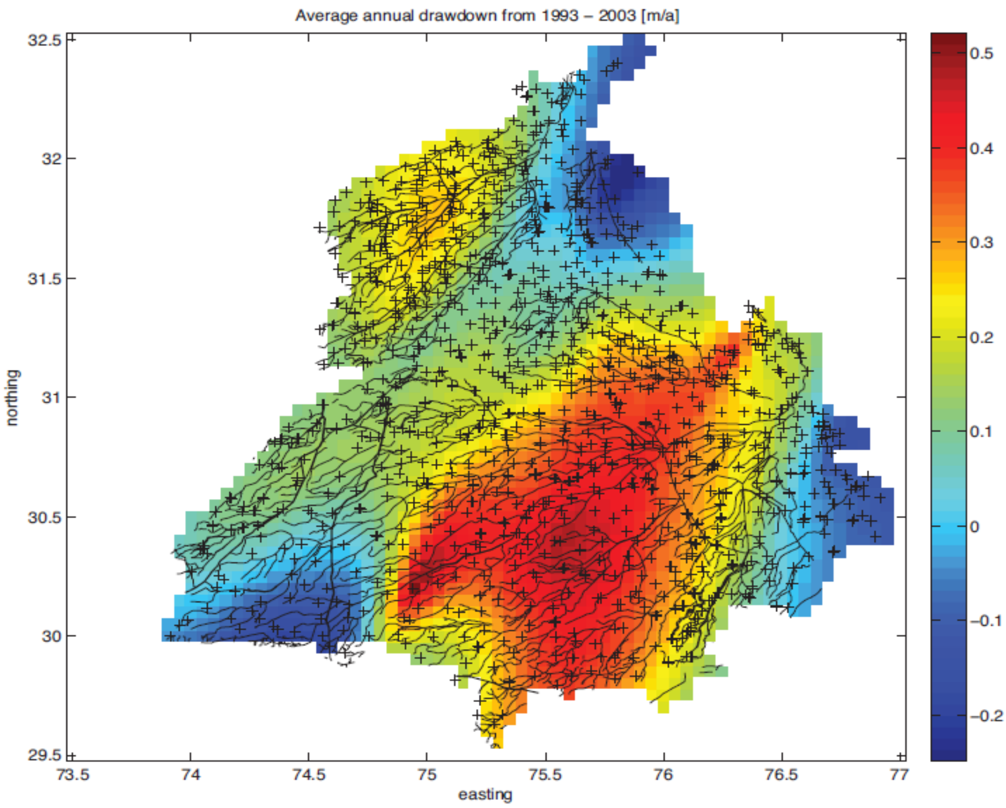
[1] Considering the Evapo-transpiration rate (ETR) method, rice on an area of about 2.8 million ha would be consuming about 44% , wheat for an area of 3.4 million ha about 34% and other crops the remaining 22%. However, in terms of water applied for irrigation, which also approximates the share of electricity used, the share of rice would come to be about 2/3rd (say 67%), wheat about 22% and other crops about 11%.

state have depleted at an alarming rate in most parts of the state. It is believed that the water table in the state is falling by up to one metre per year (Singh, 2004).[2]

While groundwater is declining at an alarming rate in fresh water regions, the south-western parts of Punjab are facing problems of severe water logging and salinization. The state can in fact be characterized by two distinct topographical and hydro-geological settings: high yielding fresh groundwater regions in northern and central districts and the saline groundwater regions in south western districts. Groundwater depletion on one side and water logging on the other, are perhaps two sides of the same coin; however, these two extreme scenarios in close proximity to one another are probably a unique case of extreme ecosystem vulnerabilities that require intensive, extensive and sustained solutions. The blue areas in Figure 1 below indicate the low lying pockets in southwestern districts of the state, facing a severe problem of water logging and resultant soil salinity. These include the districts of Muktsar, Fazilka, Bhatinda and Faridkot, irrigated by the Sirhind canal (with the Sirhind and Rajasthan feeders running North-South through this region). Lying in close proximity, are the areas experiencing groundwater overdraft. The red areas indicate the maximum drawdown. The state, therefore, requires a twin pronged strategy to manage its ground water resources i.e. arrest the declining trend in ground water in Northern and Central districts and combat water logging in South-West districts. However, much of this report will restrict itself to discussions regarding the water-logged regions of Southwestern Punjab.

Figure 1: Average annual drawdown over the last ten years [meter/year] in the state of Punjab.



Source: Restoring Groundwater in Punjab, India's Breadbasket: Finding Agricultural Solutions for Water Sustainability, Columbia Water Center White Paper, December 2011.

Before proceeding further, it would be useful to elucidate the concept of waterlogging and salinization. "An area is said to be waterlogged when the water table rises to such an extent that the soil pores in the root zone of a crop become saturated, resulting in restriction of normal circulation of air, decline in the level of oxygen and increase in the level of carbon dioxide. The harmful depth of water table would depend on the type of crop, type of soil and quality of water."

Water logging causes depletion of oxygen and increase of carbon dioxide in the root zone of crops which causes loss of plant nutrients and the loss of useful microorganisms at the expense of the growth of harmful ones. It also causes chemical degradation due to accumulation of salts at the soil surface leading to an ecological imbalance. It invariably becomes difficult to carry out agricultural activities in the areas affected by water logging. All these factors result in reduced or near zero productivity.

The Working Group of Ministry of Water Resources on “Water logging, Soil Salinity and Alkalinity (1991)” prescribed the norms for defining waterlogged, saline and alkaline areas. According to these norms, an area is said to be water logged (due to rise in water table) if the water table lies within 2 meters of land surface. An area is said to be potentially water logged if water table is between 2 and 3 meters of land surface. The area is taken as safe if the water table is below 3 meters of land surface. The norms for salinity and alkalinity were adopted as per classifications of soils done by US Salinity Laboratory (1954) are as below:

Table 1-Norms for Salinity and Alkalinity

Class	EC(dS/m)	ESP	PH
Saline Soils	>4	<15	<8.5
Saline-Alkali Soils	>4	>15	>8.5
Alkali Soils	<4	>15	>8.5

A. EC (Electrical Conductivity): The reciprocal of the electrical resistivity

B. ESP (Exchangeable Sodium Percentage) : The percentage of the cation exchange capacity of a soil occupied by sodium. It is expressed as follows:

ESP= (Exchangeable sodium/Cation-exchange capacity) x 100

C. PH: It is expressed as – log of (hydrogen ion concentration). PH of neutral water is 7

Waterlogging and salinization, which have emerged as a major impediment to the sustainability of irrigated lands and livelihoods of the farmers in South-West Punjab, are the result of a multitude of factors. These include seepage from unlined earthen canals system, inadequate provision of surface and subsurface drainage, poor water management practices, insufficient water supplies and use of poor quality groundwater for irrigation. Seventy per cent of the South-western regions of Punjab area are canal irrigated. The application of excess irrigation and recharge from irrigation distribution network in these regions causes gradual rise of ground water table and when the water table rises within 2m of the soil surface, the root zone available to plants becomes restricted and salts rise to the surface by capillary action. The resulting salinization renders the land unsuitable for cultivation.

The Government of Punjab has indicated that about 2 lakh hectares (Ha) of fertile agricultural land is water logged and there are certain patches where not even a single crop has been grown for more than a decade. Under the present circumstances more than 200,000 farmers have lost their primary income source from agriculture as their lands have become unproductive.The situation of farmers is further aggravated by a decrease in land holdings, heavy debt burden leading to suicides, crop failures, ground water pollution and agro-industrial sickness. The farmers whose fields have become waterlogged have limited sources of income and are forced to work as labourers. There is a serious threat of the region turning into a desert over the longer run, if appropriate actions are not taken now. Furthermore, the contamination of drinking water in the water logged area with Uranium, Arsenic and Heavy Metals etc. is posing a grave threat to the region.The situation is further aggravated by the fact that there are early indications that the saline water of South-West Punjab may be beginning to flow into the depleted sweet water aquifers of central Punjab, the heartland of the Green Revolution, on account of the hydraulic gradients induced by shallow water levels in Southwestern Punjab and deeper water levels in the Northern parts.

As we move into the 12th Plan period, India faces daunting challenges in the water sector, with conflicts across competing uses and users of water growing by the day. Dealing with these challenges requires a paradigm shift in the management of water resources in India, and this is what the 12th Plan proposes. The experience of Punjab deeply underscores the need for such a shift, given the diverse contrast in the nature of the water problem – that of excess versus scarcity, with associated contamination of water. A renewed focus on Command Area Development is the need of the hour in Punjab as is in the rest of the country. Given the groundwater situation in Punjab, the new Aquifer Mapping and Aquifer Management Programme of the 12th Plan should give high priority to the seriously affected areas of Punjab. There is a need to shift emphasis in large-scale irrigation from construction to management, with empowerment of water users, participatory irrigation management and improved water efficiency. Implementing appropriate policies to combat the twin menace of water logging and salinization in Punjab is an essential part of this strategy. This High Level Expert Group (HLEG) has been set up to address precisely these two problems. The Terms of Reference and Constitution of this HLEG are presented in Annexure 1.

The structure of the HLEG's report is as follows. Section 2 examines the water table behaviour in Punjab, identifying the areas where the water table is rising and where it is declining. Section 3 outlines the causes of waterlogging. Section 4 examines the extent of contamination of groundwater with uranium and heavy metals in the Malwa regions of Punjab. Section 5 discusses the status of soil in Punjab, in particular the status of organic carbon and available micronutrients in the surface soils of district Muktsar, available micronutrients in the soils of Faridkot and soil texture of Punjab soils. Section 6 provides a comprehensive master plan to combat the twin problems of waterlogging and salinization in South Western Punjab. In this section, we highlight the urgent need for crop diversification to move the state away from the rice-wheat cycle. Commercial dairy farming and aqua culture may also be taken up in the saline and water logged areas. Seepage from the Rajasthan Feeder and Sirhind feeder canals also needs to be stopped so that the problem of water logging does not aggravate further. In addition to traditional drainage systems i.e. surface and subsurface, bio-drainage through appropriate plantation such as eucalyptus should be undertaken. Section 7 outlines the best international practices adopted in Central Asia to combat waterlogging.

2. WATER TABLE BEHAVIOUR IN PUNJAB

There are three major perennial rivers, the Ravi, the Beas and the Sutlej, in Punjab and their waters are stored at the Ranjit Sagar Dam, Pong Dam and Bhakra Dam respectively. This water is supplied through a vast canal network of about 14500 kms including distributaries and minor canals to irrigate about 1.6 million hectares (m ha) of land. The canal water supply is more extensive in the South western zone of the State, which receives less rainfall and has a high salinity in soils and groundwater. This is the cotton-wheat dominant cropping belt and covers about 34 % of the cultivated area of the state.

Table 2 shows how the water table in Punjab has been declining at varying degrees over a large area. The riverbed region has 35 blocks, with each region (Majha, Doaba and Malwa) having 10 – 14 blocks. It is a rice growing area, though traditionally rice was grown more in the Majha and Doaba regions. The water table in the riverbed blocks has been declining only gradually. The central block consists of 50 blocks out of which 8 blocks are in Majha, 10 in Doaba and 32 in Malwa. Rice is intensively cultivated here. The water table here has been declining at varying degrees. The Foothill or Kandhi zone in the North / East side comprises 22 blocks and has a fluctuating water table and though the water is sweet, exploration is difficult. There is a belt of 9 blocks in the south west of Malwa Region where the water table has been rising.

In 1973, there were as many as 113 blocks where water table was less than 10 meters, 9 blocks where water table was 10 to 15 meters below ground level (bgl) and only 10 blocks with water table at more than 15 meters bgl (most of which were in the south west with water unfit for irrigation and these had rising water table). In contrast, in 2005-2006 there were 44 blocks with water table at more than 15 meters bgl, 39 blocks where the water table was 10 to 15 meters bgl and

13 blocks with water level of 5 meters bgl. These 13 blocks lie in the Malwa block where water table has been rising. The water table situation is becoming critical, especially in the Malwa region, which was traditionally not a rice growing area.

In two sub regions in the Malwa region, the water table has been rising, which is creating problems of waterlogging. In the 4 blocks of Abohar to Talwandi Sabo sub-region, the water table has gone up from more than 25 meters bgl in 1970s to 5–6 meters bgl in 2003 (Figure 2). Just above these blocks, in the 5 blocks from Khuyian Sarwar to Maur, water table rose from 17 meters bgl in 1970s to 5 meters bgl in 2003 (Figure 2). In both cases, the water table was 5 meters before monsoon. The water is saline and unfit for irrigation.

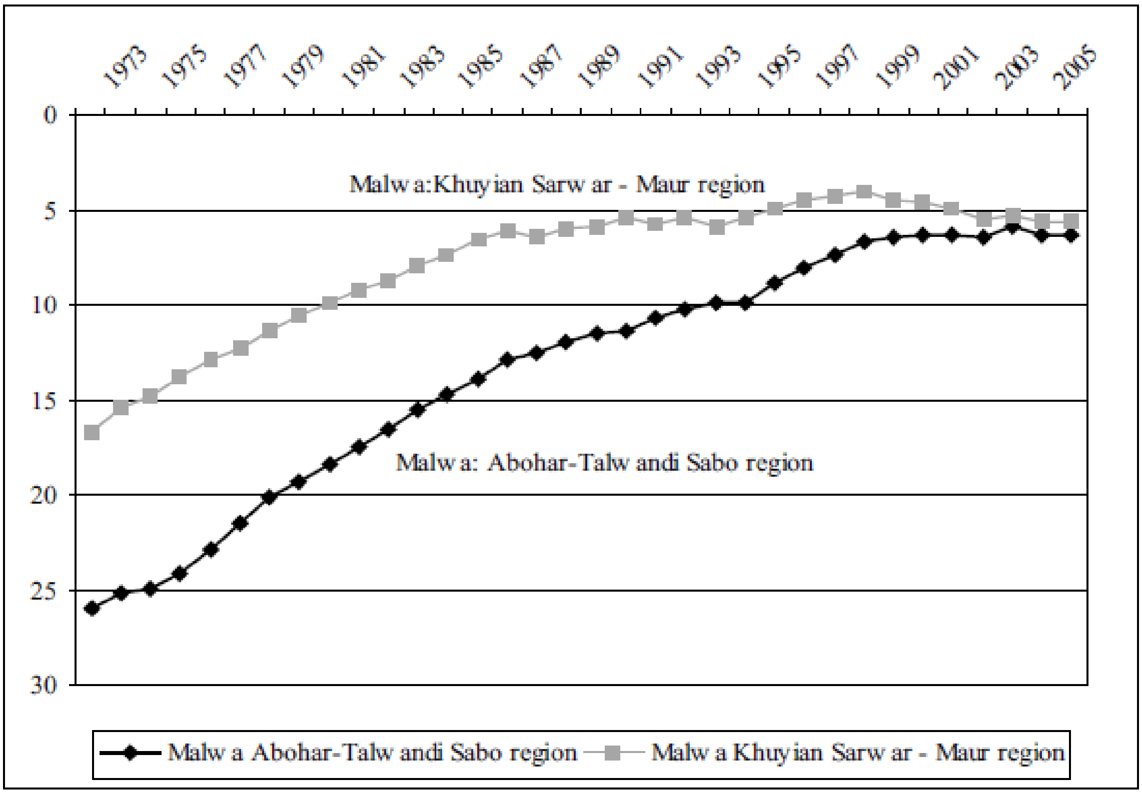
Table 2: Water Table Situation, region wise, Punjab, 1973 to 2006

Particulars	Majha	Doaba	Malwa	Total
	Number of Blocks			
Total	29	30	73	132
As river bed	11	14	10	35
Water Table behavior (No of Blocks)				
Rising	0	0	9	9
Static/Fluctuating	7	9	18	34
Declining	22	21	46	89
Rate of Decline				
Gradually	18	11	27	56
Severe: Around 10 metres or more	4	10	19	33
Severest: More than 15 metres	1	2	9	12
Water table level				

From 1973 to 2006 (in metres)				
Upto 5	12 → 1	6→1	29→11	47→13
5 to 10	14→12	20→7	32→17	66→36
10 to 15	2→11	4→7	3→21	9→39
15 to 20	1→1	0→10	4→17	5→31
Above 20	0→1	0→5	5→7	5→13
Water table behavior zones				
Rising	0	0	9	9
River Bed(Gradual Decline)	11	14	10	35
Central: Going Deep	10	6	13	31
Going deeper	1	1	13	16
Going deepest	0	0	6	6
Other: Fluctuating, generally static, declining lately	7	9	22	36

Source: Water Table Behaviour in Punjab: Issues and Policy Options, Karam Singh (2011)

Figure 2: Trend in water table in South-West Malwa sub region



Source: Water Table Behaviour in Punjab: Issues and Policy Options, Karam Singh (2011)

While discussing groundwater conditions in Southwestern Punjab, it is important to discuss rainfall patterns in this region (Table 3). The region shows a long-term rainfall range of 300 to 400 mm, with an average coefficient of variance of about 38%. Ferozpur and Muktsar receive normal rainfall of the order of 350 mm, clearly indicating a low-rainfall input on an annual basis. Southwestern Punjab is in fact a low-rainfall zone.

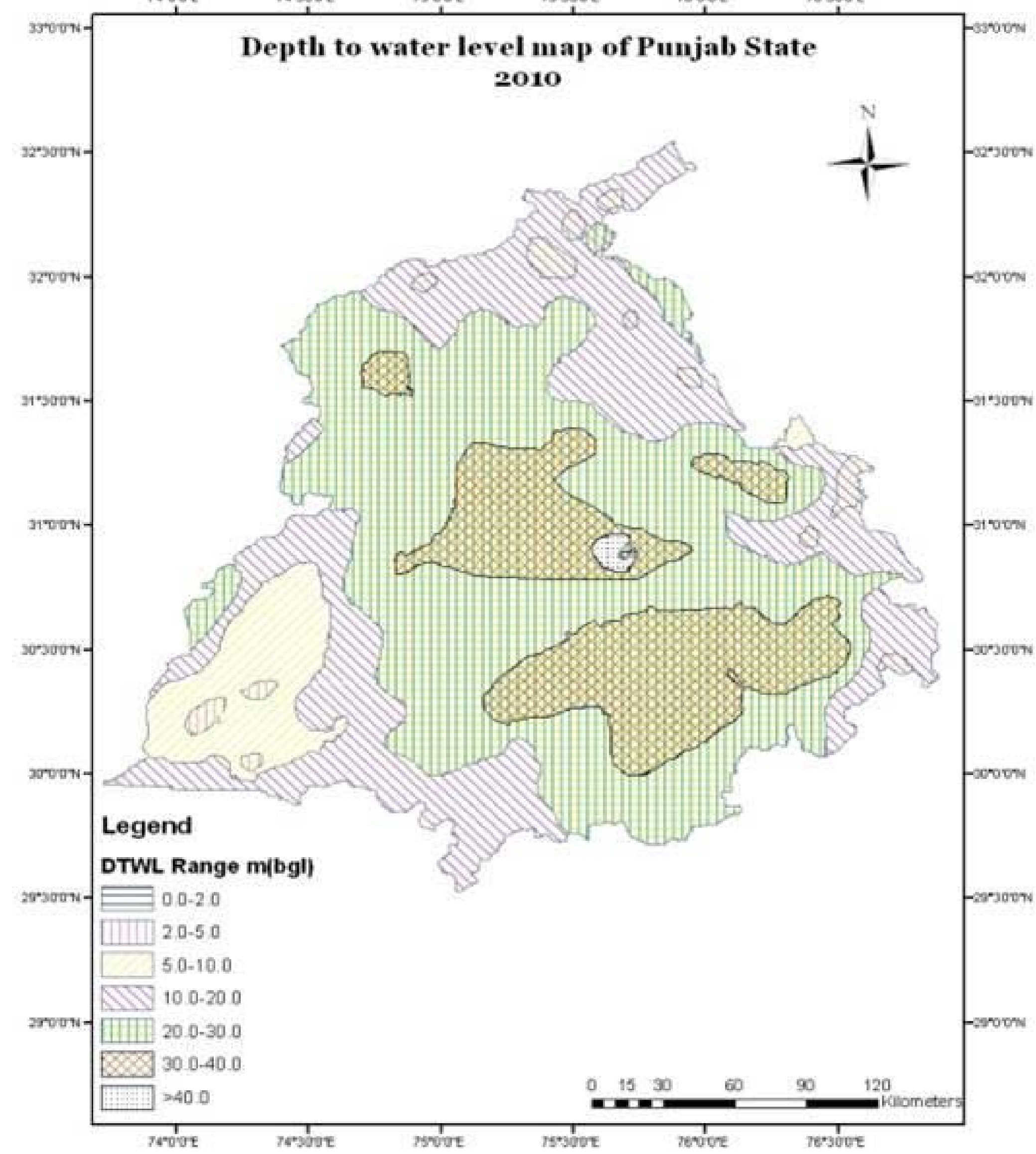
Table 3: Summary of rainfall statistics for four districts of Punjab State (MoES-IMD, 100 year rainfall data: 1901-2000)

District	Hundred year mean rainfall	Standard deviation	Coefficient of variance
Faridkot	474mm	160	34
Ferozpur	374mm	139	37
Muktsar	377mm	159	42
Bhatinda	406mm	160	40

Despite the limited rainfall, the hydrogeology of unconsolidated sediments – alluvial and aeolian – allows for large volumes of groundwater storage and transmission. Transmissivity of aquifer material is high primarily on account of the aquifer thickness; aquifer storage is substantial because of porous aquifer material, its thickness and extent. Most of Punjab shows evidence of a fall in the water level mainly in alluvial aquifers. Except for a thin strip running parallel to the border with Himachal Pradesh – Northeastern boundary of the State – and the Southwestern portion referred to in this report, decline in the water level the order of 20 to 40 cm per year, is not uncommon in other parts. As a matter of fact, the entire belt stretching from northwest of Amritsar, through the confluence of Sutlej and Beas Rivers, to the southeastern boundary of the State, shows evidence of water level decline. Southwestern Punjab, on the other hand, shows an evidence of groundwater level rise of various magnitudes. The water levels in this region, i.e. southwest Punjab, particularly in the areas that lie geographically west of the Sirhind and Rajasthan feeders show clear evidence of a shallow water table that has reportedly risen over a period of time.

At the same time, seasonal fluctuation in the groundwater levels also shows interesting variation across the State of Punjab. The depth-to-water maps for pre and post monsoon seasons from a single year show how, even in the southwestern waterlogged area, depth of water changes significantly and zones can be demarcated even on a seasonal basis. Moreover, with differing rainfall inputs, such as that in 2008, the extent and degree of water logging is complex and shows variation both on spatial and temporal scales.

Figure 3: Depth to water level, Punjab state, pre-monsoon 2010 (CGWB data)



Depth to water level map of Punjab State
2010
N
Legend
DTWL Range m(bgl)
0.0-2.0
2.0-5.0
5.0-10.0
10.0-20.0
20.0-30.0
30.0-40.0
>40.0
0 15 30 60 90 120
Kilometers

Figure 4: Depth to water level, Punjab state, monsoon 2010 (CGWB data)

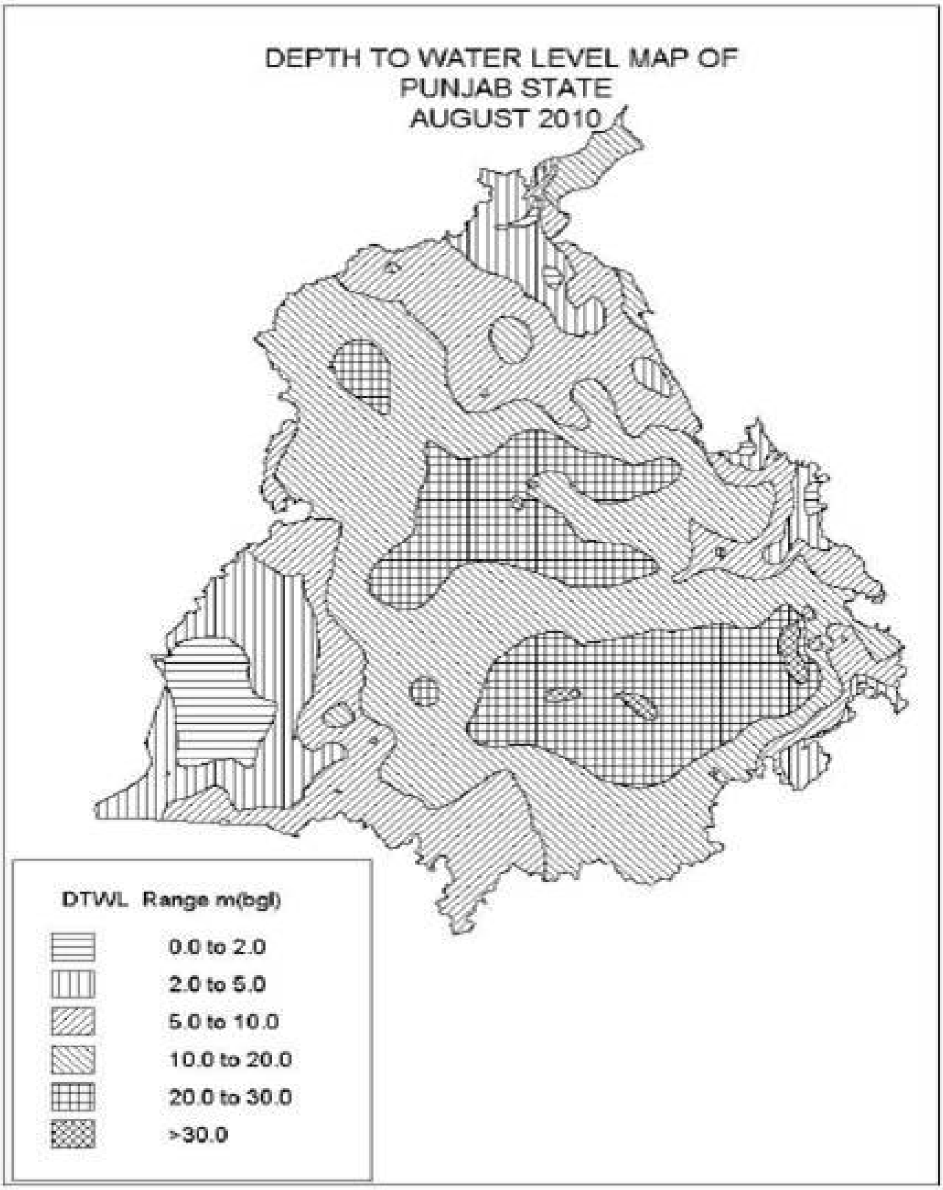


Table 4: District-wise Waterlogging in Punjab

Waterlogging in Punjab

Area in sq.km.

Sl. No.	Districts	2005-06	2008-09	Change
1	Muktsar	36.81	46.32	9.51
2	Firozpur	1.87	6.59	4.72
3	SAS Nagar	0.00	0.55	0.55
4	Ludhiana	1.26	1.47	0.21
5	Barnala	0.00	0.06	0.06
6	Rupnagar	2.02	2.07	0.05
7	Jalandhar	0.08	0.11	0.03
8	Tarn Taran	0.34	0.34	0.00
9	Patiala	0.08	0.08	0.00
10	Fatehgarh Sahib	0.00	0.00	0.00
11	Moga	0.00	0.00	0.00
12	Nawan shahr	0.02	0.02	0.00
13	Kapurthala	6.07	6.03	-0.04
14	Bathinda	0.04	0.00	-0.04
15	Sangrur	0.11	0.04	-0.07
16	Amritsar	2.86	2.53	-0.33
17	Mansa	1.14	0.72	-0.42
18	Faridkot	3.22	1.97	-1.25
19	Hoshiarpur	10.88	9.23	-1.65
20	Gurdaspur	45.60	40.07	-5.53
	Total	**112.40**	**118.19**	**5.79**

Source: Government of India, Department of Space, ISRO, National Remote Sensing Centre

It is important to note that the problem of waterlogging is observed across other states of India, too. The problem of improper drainage is especially serious in northern states like West Bengal, Haryana, Rajasthan and Uttar Pradesh. The problem in these states has originated due to floods in rivers and faulty irrigation methods. The states of Andhra Pradesh, Orissa, Kerala, Tamil Nadu, Karnataka, Jammu & Kashmir, Himachal Pradesh and Assam face problems of inundation in the rainy season. Generally, the southern plateau does not face serious drainage problem because of its undulating topography and the resultant tendency to surface drain the excess water. Interestingly, there is also an overriding geological correlation of the presence of alluvium in many water-logged areas. It is in the irrigated and low lying lands that this problem is serious. The states of Punjab and Haryana have the largest area affected by water logging. State-wise details of the extent of waterlogged areas are reported in the table below.

Table 5: State-wise Waterlogging (inundation) in India

Waterlogging in India

Area in sq.km.

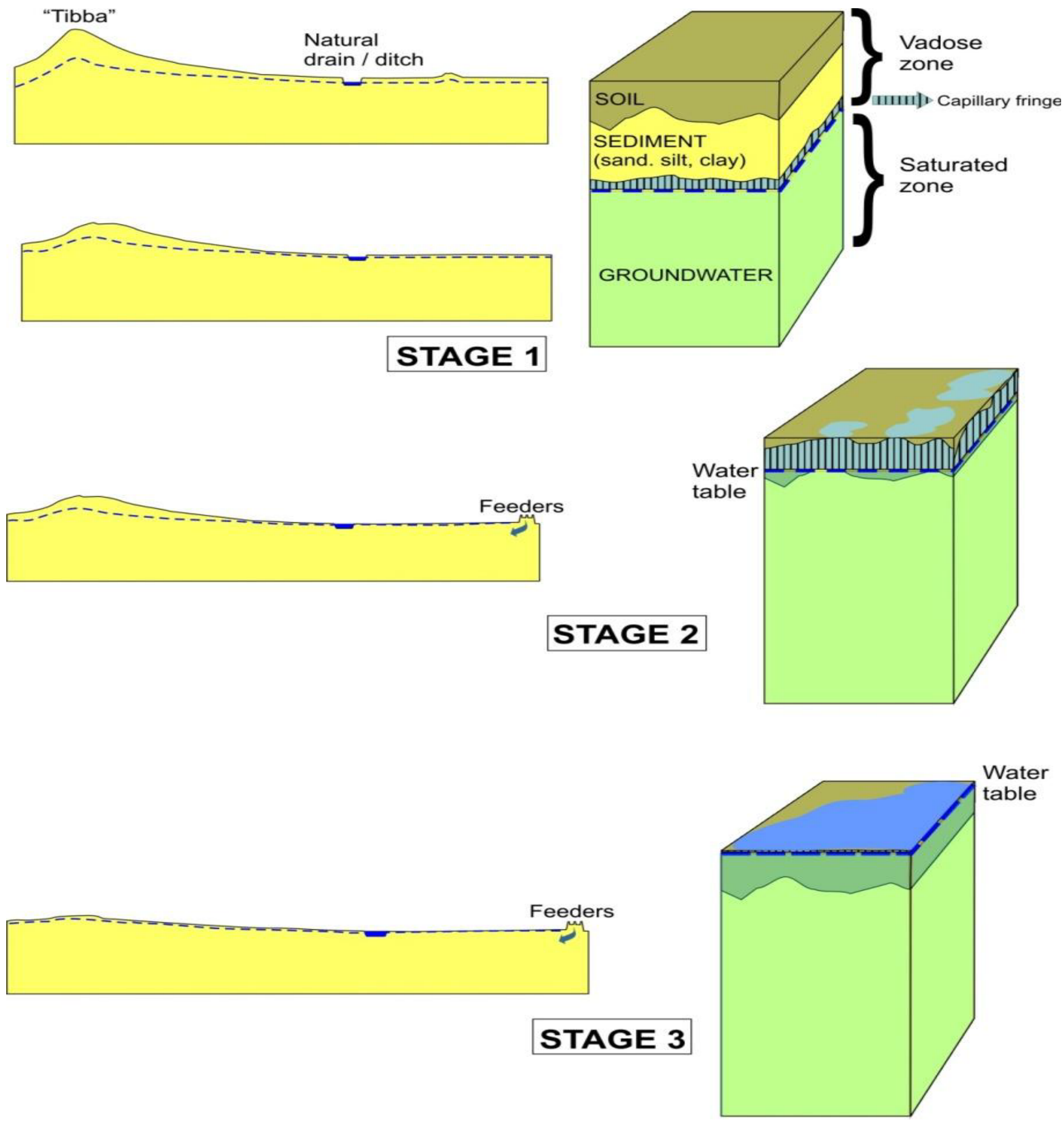
Sl. No.	States	2005-06	2008-09	Change
1	Bihar	1564.05	5737.75	4173.70
2	Jammu & Kashmir	75.52	85.73	10.21
3	Tripura	0.68	7.12	6.44
4	Punjab	112.40	118.19	5.79
5	Uttarakhand	0.00	1.92	1.92
6	Delhi	5.29	7.14	1.84
7	Arunachal Pradesh	0.00	1.75	1.75
8	Chattisgarh	0.00	0.74	0.74
9	Karnataka	17.86	18.54	0.68
10	Goa	52.27	52.79	0.51
11	Meghalaya	0.00	0.41	0.41
12	West Bengal	19.91	20.29	0.37
13	Jharkhand	0.36	0.72	0.36
14	Maharashtra	60.79	61.05	0.26
15	Nagaland	0.00	0.02	0.02
16	Madhya Pradesh	0.00	0.00	0.00
17	Manipur	0.00	0.00	0.00
18	Mizoram	0.00	0.00	0.00
19	Sikkim	0.00	0.00	0.00
20	Andhra Pradesh	109.07	108.23	-0.84
21	Union Territory	1.21	0.00	-1.21
22	Rajasthan	119.81	118.36	-1.46
23	Tamilnadu	123.55	119.33	-4.22
24	Himachal Pradesh	10.45	6.17	-4.28
25	Kerala	19.97	8.23	-11.75
26	Haryana	72.08	48.85	-23.23
27	Orissa	459.60	402.41	-57.19
28	Gujarat	83.98	23.88	-60.10
29	UttarPradesh	1097.66	865.73	-231.93
30	Assam	1520.15	888.06	-632.09
	Total	**5526.68**	**8703.39**	**3176.71**

Source: Government of India, Department of Space, ISRO, National Remote Sensing Centre

3. CAUSES OF WATERLOGGING

The twin problems of waterlogging and salinization in South-west Punjab are broadly attributed to the depressional location of the area coupled with the lack of proper drainage system, poor percolation because of impervious clay strata and constant seepage from Rajasthan Feeder Canal & Sirhind Feeder Canal. Moreover, intensity of irrigation and land-levelling leading to a major obliteration of the natural topography and drainage, coupled with major shifts in cropping patterns and practices (such as the periods of transplanting of paddy) have together undergone major changes during the last 50 to 60 years, all of which seem to have contributed and compounded the dual problem of water logging and salinity. Much of the unsaturated zone (vadose zone) in large parts of Southwestern Punjab has ‘thinned’ with the rise in groundwater levels. The capillary fringe now operates more actively in the soil-zone than in the sediment below, clearly giving rise to salinization and decreased hydraulic drainage of soils.

Figure 5 : Schematic showing how obliteration of – *tibbas (high grounds / dunes and ditches* – due to land-levelling and intensive irrigation and leakage from feeders led to the rise of groundwater levels, eventually closing out the vadose zone completely.



The field visits undertaken by the High Level Expert Group also provided key insights into the causes of waterlogging in different regions, although these visits were in the form of rapid appraisals involving limited observations and measurement. In Kuttianwali Village, Muktsar District, farmers indicated that there is no natural drainage as the terrain is flat and water is stored on the surface in the monsoon and inundates large areas. In the Rattakhera Village, Muktsar District where it was seen that a vast area of land had been affected by water logging and no crop had been grown on almost five to six thousand acres of land since 1996, the sub-surface drainage laid by the Government of Punjab had remained largely ineffective. This was attributed to the fact that the soil had been totally damaged due to salinization of sub soil water and did not allow any plant to grow. Also, the natural slope of the ground was from East to West direction whereas the alignment of Rajasthan feeder and Sirhind Feeder canals was towards river Sutlej. This resulted in concentration of water at this location. After the construction of Rajasthan canal in 1960, the ground water table had risen from 140 ft. in 1960 to the present level of about 3 feet. This seriously affected crop production in an area of 3,50,000 acres. Discussions with the State field officers suggested that if about 1800 cusecs of seepage from RF & SF (which had been scientifically measured by Directorate of Irrigation and Power Research Institute Punjab) could be controlled, then the crop output in this area would recover.

There is great cause for alarm of how the finer dynamics of canal seepage, water logging, soil salinity and groundwater dynamics is playing out at a local level – say at the village or panchayat level. In the absence of sufficient local level information on groundwater levels and the time-slot over which this rapid appraisal was undertaken, a quick representative monitoring of salinity – in canal water, so-called natural ponds, tube wells, soil-water and artificial drainage systems – was undertaken to understand the variability in salinity across two to three pockets of Southwestern Punjab. The table clearly shows that the salinity count is highly variable, with the maximum for the drains constructed to remove saline water from the water-logged root zone. The minimum, as would be expected, is for canal water which is sourced from the Harike headworks just after the confluence of Beas and Sutlej rivers. The salinity levels in groundwater also exceed the freshwater range, and mostly fall in the range of brackish waters.

Table 6 : Salinity count (October 2012) to random locations, for different sources in the Malout-Kuttianwali-Rattakheda locations

Source	Locations tested	Salinity in ppm	Specific observations, if

			any
Canal/distributary	Off Malout-Gidderbaha road; Rattakheda distributary	90 – 150 *FRESH WATER*	*FRESHWATER*
Natural ponds	Off Malout-Gidderbaha road	About 2000 *BRACKISH WATER*	*Natural ponds are the only visible vestiges of the original „natural□ system of drainage lines in the area; these have been influenced by the water-logging in adjoining areas but still bear a much lower level of salinity than in the artificial drains*
Soil water	Kuttianwali; Rattakheda	1370 to >10000 BRACKISH TO SALINE	Highly variable levels of salinity in soil water from place-to-place
Groundwater	Kuttianwali; Punjawa link Drain; TWs near *Tibba*	370(fringes) to 3000 FRESH TO BRACKISH WATER	Highly variable
Artificial drains	Malout; Kuttianwali and Rattakheda	1500 to >15000 BRACKISH TO SALINE	Highly variable

These field visits also revealed the various initiatives being taken in these villages to counter the problems of waterlogging and salinization. In the Sikhwala Village in Muktsar District, where no crop has been sown for the last 15 years due to water logging, a sub-surface drainage system is being installed for a low lying pocket of about 150 acres. Collector pipes have been laid along with 20% lateral pipes with the 'sub soil' being collected in sump wells. In Tappakhera village of Muktsar District, a Sub Surface Drainage System has been installed in low lying pockets of the village. Crop yield has been good and functioning of the drainage system appears satisfactory. In Shajrana village of Fazilka District (newly carved out of Firozepur District), more than 400 acres of agricultural land on the west of Bikaner Canal has been water logged for more than two decades. As a result no crop has been grown in the area during this period. As a remedial measure for draining this water, a new gravity drain has been sanctioned. In addition to this, the existing drain is to be widened. For low lying pockets where gravity flow is not technically feasible, a sub-surface drainage system has been proposed. Another possibility being explored in Fazilka is the development of saline water fisheries in PPP mode. Detailed solutions to combat the problem of waterlogging and salinization are presented in Section 6.

4. CONTAMINATION OF GROUNDWATER WITH URANIUM AND HEAVY METALS

A hazardous by-product of the problem of water logging in the state of Punjab has been the contamination of groundwater and drinking water with Uranium, Arsenic and Heavy Metals. The chemical analysis of heavy metals and of uranium has been carried out by NEERI and Bhabha Atomic Research Centre (BARC). The analysis of uranium carried out by BARC reported a concentration of uranium higher than the permissible limit in the ground water sample collected from shallow and deep tube wells. NEERI carried out chemical analysis of heavy metals including Arsenic. A brief description of the occurrence of Arsenic, Selenium and Uranium is given below.

Uranium

The occurrence of Uranium has recently been reported from Districts Bhatinda, Mansa, Ludhiana, Moga, Ferozepur, Muktsar and Faridkot. BARC examined 1686 ground water samples from all areas of Punjab to understand and report potable sources of ground water with particular reference to Uranium contamination. The presence of uranium in drinking water in rural areas has emerged as a serious problem with almost 70 per cent samples sent to BARC testing positive for presence of the radioactive material. The table below shows the summary of distribution of Uranium concentration in ground water above permissible limit.

Table 7: Distribution of Uranium in different districts of Punjab

S.No.	District	Total number of samples	Samples exceeding permissible limit(60 µg.l) of AERB	% samples exceeding permissible limit	Range of values(in µg.l)
1	Amritsar	45	0	0	<0.3 to 22.9
2	Barnala	106	71	66.98	<0.3 to 290
3	Bhatinda	49	14	28.57	0.6 to 205.8
4	Faridkot	11	3	27.27	2.8 to 208.4
5	Fatehgarh Sahib	26	0	0	5.03 to 45.46
6	Ferozepur	342	61	17.83	0.3 to 331.42
7	Gurdaspur	56	0	0	<0.3 to 28.8
8	Hoshiarpur	51	0	0	<0.3 to 39.2
9	Jalandhar	50	0	0	3.4 to 37.9
10	Kapurthala	25	0	0	<0.3 to 27.7
11	Ludhiana	280	16	5.71	<0.3 to 301.0
12	Mansa	26	1	3.84	0.3 to 350.3
13	Moga	232	77	33.18	4.4 to 346.7
14	Muktsar	8	0	0	<0.2 to 4.7
15	Nawashahr	25	0	0	<0.3 to 29.1

16	Pathankot	24	0	0	1.44 to 6.4
17	Patiala	88	1	1.13	<0.3 to 87.76
18	Roopnagar	24	0	0	1.24 to 16.2
19	Sangrur	140	14	0.1	8.6 to 116.6
20	Sas nagar	22	0	0	<0.3 to 29.3
21	Tarn Taran	56	3	5.35	0 to 68.4
	TOTAL	**1686**	**261**	**15.48**	

The groundwater samples were collected from different depth ranges to study the level of Uranium at different depth ranges. This is reported in table 8.

Table 8: Levels of Uranium in Drinking Water for 4 Districts (DWSS)

S.No	Name of the District	Total No. of samples	Depth (ft.)	No of water samples	Remarks
1.	Bhatinda	80	<100ft.	44	**50% of total samples showed above AERB permissible limits (>60ppb)**
			100-200ft	16	
			200-300ft	9	
			>300ft	7	
			Oft (canal water)	3	
			RO treated water	1	
2.	Mansa	80	<100ft.	42	**42.5% of samples above limit**
			100-200ft	16	
			200-300ft	6	
			>300ft	13	
			Oft (surface water)	2	

			RO treated water	1	
3.	Faridkot	30	<100ft.	20	**36.7% of samples above >60ppb limits**
			100-200ft	3	
			200-300ft	2	
			Oft (surface water)	5	
4.	Ferozepur	45	<100ft.	26	**31.1% of samples above >60ppb limits**
			100-300ft	9	
			>300ft	10	

The contamination of groundwater and drinking water with uranium in the Malwa region of Punjab has emerged as one of the worst examples of agriculture based pollution in the state. Uranium has been detected in districts where water level has fallen (Barnala, Moga) and where it has risen (Ferozepur, Faridkot). Studies indicate that agrochemical processes are responsible for producing chemicals in the region. Irrigation water percolating through soil dissolves carbon dioxide gas produced at high pressures from the plant root respiration and the microbial oxidation of the agricultural matter. The resulting carbonic acid reacts with the insoluble calcium carbonate to produce soluble bicarbonate, which leaches compounds of various metals including uranium from soils and adds it to the shallow ground water. The use of fertilizers also adds to the chemical contamination. It is imperative that government agencies plan uranium extraction from the ground water in the Malwa region (observed up to ~ 500 ppb level in ground water) using Reverse Osmosis (RO) equipment with special filters. Also, the use of chemical fertilizers and pesticides should be minimized.

Arsenic

High concentration of Arsenic (more than 50 µg/l) has been reported from Muktsar, Bhatinda, Mansa and Sangrur District (A.K Jain and Raj Kumar, 2007). Jain (2007) reported that Arsenic concentration exceeding the limit of 0.01mg/l was encountered at a few places in the districts of Amritsar, Gurdaspur, Hoshiarpur, Kapurthala and Ropar.

Figure 6: Arsenic in groundwater of Punjab

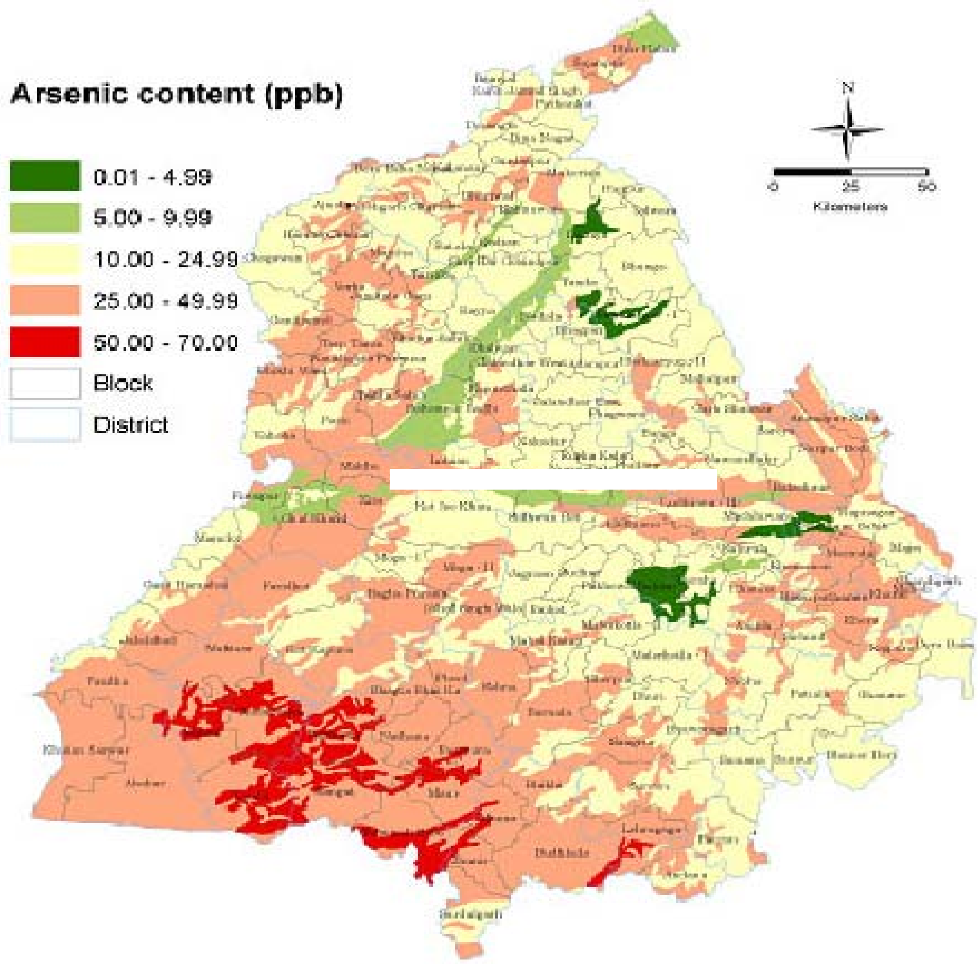


Fig 2 Arsenic in groundwater of Punjab

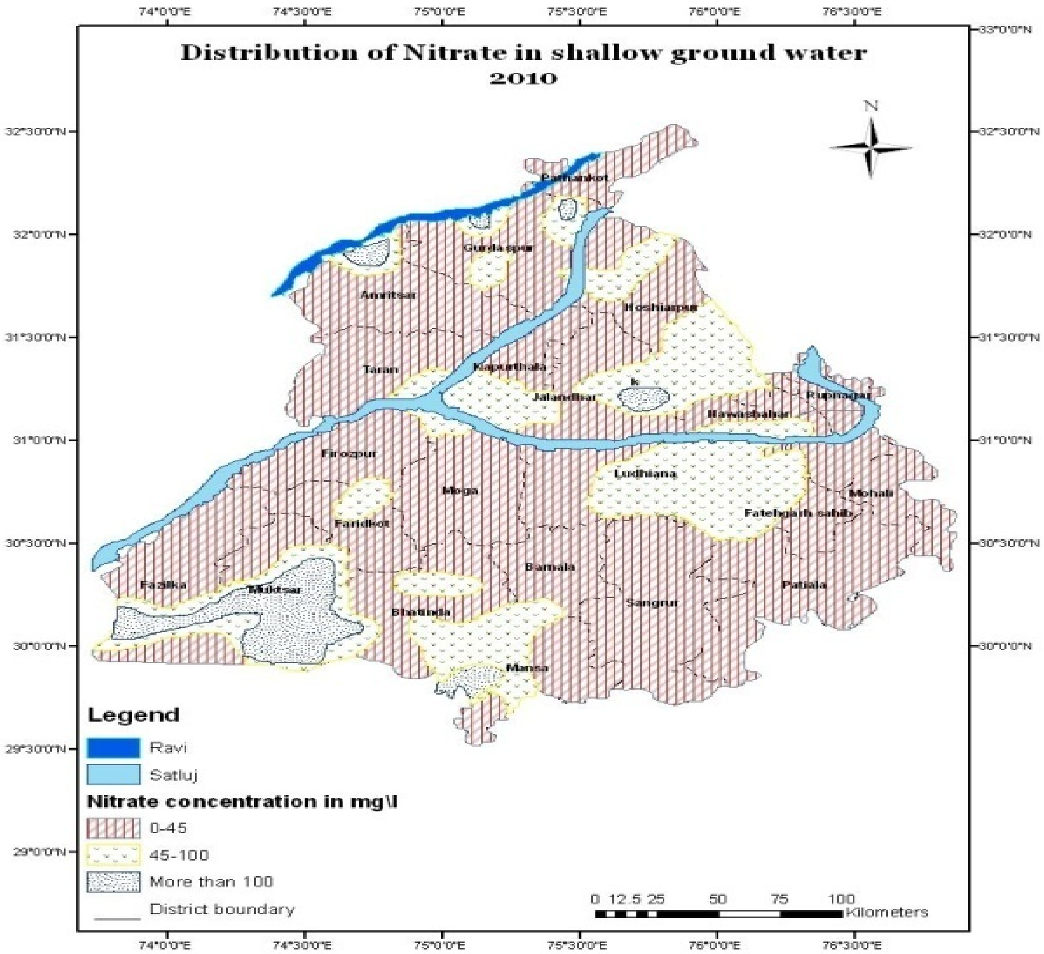
Selenium

Selenium in ground water is mainly observed in the Nawanshahar district. The concentration of selenium is observed to be more than 0.01 mg/l in 3 out of 20 samples collected from various depths in Nawanshahr district. Groundwater in few other districts was also found to be contaminated with selenium. In Fatehgarh sahib district, 3 of the 93 samples were found to be contaminated by selenium. In Hoshiarpur district, 1.12% of the 178 samples, in Ludhiana district 6% of the 83 samples and in Ropar 0.8% of the 234 samples were found to be selenium contaminated. The problem of selenium contamination was observed many years ago, but no worthwhile project using low cost technology or identification of the geometry of deep aquifers free from selenium and reduction of selenium concentration to permissible limits by rain water harvesting has been implemented for removal of selenium from ground water.

Nitrate

Occurrence of nitrate in ground water above 45 mg/l reflects contamination in drinking water. A considerable area of the southern and southwestern part of the state has nitrate concentration exceeding the critical level and this includes Faridkot, Muktsar, Bhatinda, Mansa, Ludhiana , Ferozpur, Nawanshahar, Hoshiarpur, Taran Taran, Kapurthala, Moga, Gurdaspur and Amritsar. Nitrate contamination in ground water has been attributed to excessive application of fertilizers, bacterial nitrification of organic nitrogen and seepage from animal and human wastes. The nitrate distribution in different districts of Punjab is given in the figure below. Nitrate concentration of more than 100ppm is mostly seen in the Muktsar area.

Figure 7: Distribution of Nitrate in shallow ground water

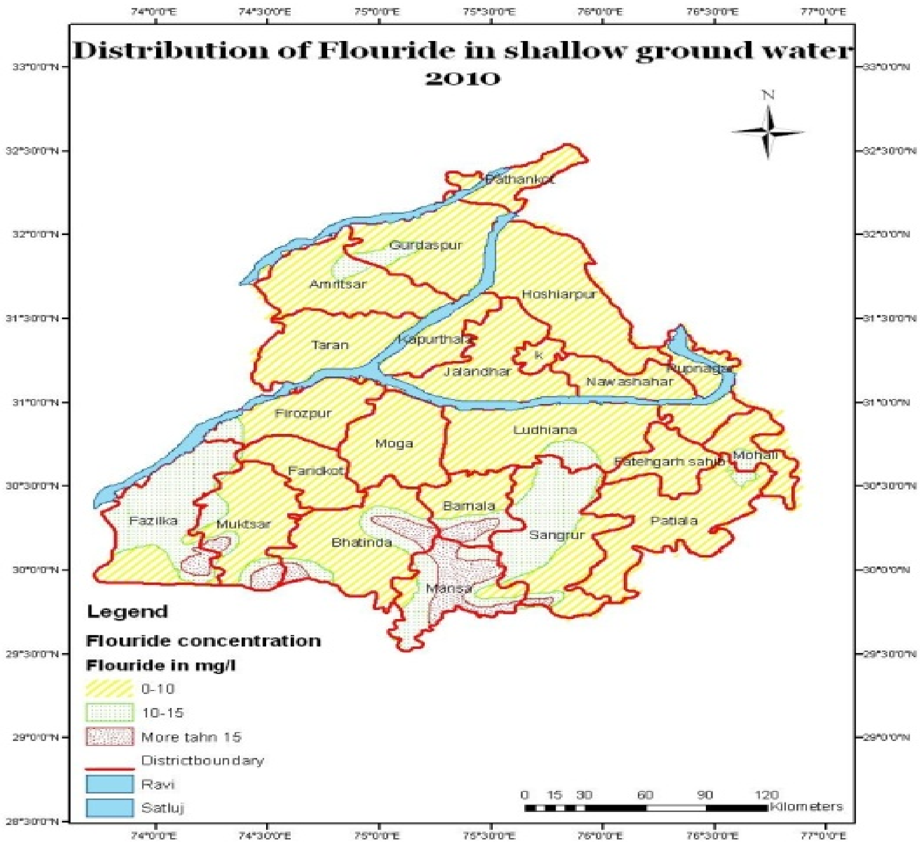


Fluoride

The Fluoride (F) content in ground water of the State is, in general, less than 1.0mg/l and covers about 85 % of the area. It ranges from 0.04 mg/l in Fatehgarh Sahib (district Fatehgarh Sahib) to 13.8 mg/l at Lambi (district Muktsar). High fluoride content i.e. more than 10mg/l is found in Fazilka, Muktsar, Bhatinda, Sangrur, Barnala and in parts of Gurdaspur, Amritsar and Mohali Districts (Figure

4). It is found that 78.4% samples have fluoride in desirable range, 10% in the permissible and the remaining 11.7% have fluoride above 1.5 mg/L.

Figure 8: Distribution of Fluoride in ground water



The distribution of Fluoride, Nitrate, Chloride and Electrical conductivity which shows the status of salinity and contamination of fluoride and Nitrate in different areas of Punjab is reported in the table below.

Table 9: Distribution of Ground Water in Different Classes of Drinking Water Suitability

Sr.	District	EC in 25^{0}C in µS/cm			Cl in mg/L			NO_3 in mg/L			F in mg/L		
		<750	750-3000	>3000	<250	250-1000	>1000	<45	45-100	>100	<1.0	1.0-1.5	>1.5
1	Amritsar	6	7	0	13	0	0	8	3	2	10	1	2
2	Bathinda	2	19	2	19	4	0	11	6	6	15	4	4
3	Faridkot	1	4	1	4	2	0	3	1	2	3	1	2
4	Fatehgarh Sahib	7	3	0	10	0	0	9	1	0	10	0	0
5	Ferozepur	2	13	5	15	4	1	15	0	5	10	5	5
6	Gurdaspur	17	7	1	24	1	0	18	3	4	24	1	0
7	Hoshiarpur	10	2	0	12	0	0	8	4	0	12	0	0
8	Jallandhar	9	5	0	13	1	0	10	4	0	12	1	1
9	Kapurthala	3	3	0	6	0	0	3	2	1	6	0	0
10	Ludhiana	12	4	0	16	0	0	3	13	0	14	1	1
11	Mansa	2	6	3	6	5	0	7	2	2	2	3	6
12	Moga	0	2	0	2	0	0	2	0	0	2	0	0
13	Muktsar	0	7	2	5	3	1	2	2	5	6	2	1
14	Nawanshahar	3	3	0	6	0	0	3	3	0	6	0	0
15	Patiala	5	17	0	3	19	0	19	3	0	18	1	3
16	Ropar	10	9	0	19	0	0	13	6	0	18	0	1
17	Sangrur	2	15	0	14	3	0	17	0	0	13	3	1
	Total 231	91	126	14	187	42	2	151	53	27	181	23	27

Source: CGWB (2010)

5. THE STATUS OF SOIL IN WATER LOGGED AREAS

Waterlogging has had an adverse effect on soil health, soil productivity, and led to rapid depletion of good quality aquifers in large areas in Southwestern Punjab. The following is a discussion on the soil texture of Punjab soils, status of organic carbon and available micronutrients in the surface soils of district Muktsar, available micronutrients in the soils of Faridkot and possible remedial measures.

Soil texture of Punjab soils

Soil texture of Punjab soils has been classified into eight different categories depending upon the varying content of sand, silt and clay. The table clearly indicates a preponderance of loam to loamy sand, indicating the dominance of sand in the overall soil distribution. Of course, it becomes difficult to presume that this distribution represents the status of in-situ soil characteristics. Large parts of the State have probably undergone major land-levelling activities as part of 'preparing lands' for agriculture, which in turn may have disturbed the in-situ nature of soils. Soil-sampling in such a situation has also become a rather impractical issue in understanding soils and soil distribution, although this is a hypothesis that requires further probing.

Table 10- Soil textures of Punjab soils

Soil Texture	Per cent area of state
Sand	0.20
Loamy sand	12.2
Sandy loam	47.3
Loam	16.0
Clay loam	0.10
Silt	1.40
Silt loam	22.3
Silty clay loam	0.50

Status of Organic carbon and available Micronutrients in soils of District Muktsar

Organic matter in the soil acts as a reservoir of plant nutrients that are essential for plant growth. Its' status in the soil depends upon the quantity that is periodically added, soil temperature and the rate of its decomposition. The organic carbon content of the soil varies from 0.09% to 0.74 % with a mean value of 0.53%. Soils of the Muktsar district are low to medium in organic carbon content. The high temperature prevailing in the area is responsible for the rapid decomposition of organic matter, resulting in low carbon content. Spatially 50569 ha area (19.2%) has low (<0.4%) organic carbon content, while, 212552 ha area (80.8%) has organic content in the medium range (0.4 to 0.75%). This means that there is little coverage by soils that have high organic carbon content in the district.

Intensive cropping and cultivation of fertilizer responsive high yielding crop varieties has resulted in the decline of available DTPA (diethylenetriamine pentaacetic acid) micronutrients in the soils affecting the crop growth. The Zinc (DTPA-Zn) content of the soils in the region vary between 0.11 to 4.7 mg/kg with a mean value of 1.13 mg/kg. As per spatial distribution, about 102090 ha (39%) area has deficiency (<0.6 mg/kg) in zinc content. The copper (DTPA-cu) content ranges from 0.08 to 3.16 mg/kg with a mean value of 0.92 mg/kg. Approximately 18479 ha (7 %) area is deficient in copper (according to critical limit of 0.2 mg/kg in soils). The iron (DTPA-Fe) content varies from 1.18 to 32.56 mg/kg with an average value of 10.93 mg/kg. Based on the critical limit of 4.5 mg/kg, nearly one third (89258 ha) area is affected by Fe deficiency. The Manganese (DTPA-Mn) content of the soil varies from 1.16 to 14.38 mg/kg with an average value of 7.07 mg/kg. Based on the threshold limit (3.5 mg/kg), about 241209 ha(92 %) area is sufficient in Mn and only 8% area has Mn content below the threshold value.

Available Micronutrients in soils of District Faridkot

DTPA-extractable Zn varies from 0.44 to 3.12 mg/kg with an average value of 1.83 mg/kg. Only 5 % samples are Zn deficient. DTPA-Cu varies from 0.16 to 1.74 mg/kg with an average value of 0.8 mg/kg. Only 1% samples are deficient in Cu. DTPA-Fe varies from 1.96 to 25.8 mg/kg with an average value of 13.13 mg/kg and only 8% samples deficient in Fe. DTPA-Mn varies from 0.84 to 9.6 mg/kg with an average value of 4.2 mg/kg and about 53 % samples deficient in Mn.

Remedial measures

In soils with low organic carbon content (less than 0.4 %), the dose of nitrogenous fertilizer should be increased by 25 per cent over the general recommended dose and in high organic carbon(more than 0.75 %) soils, the recommended dose be lowered by 25 per cent.

In Zinc deficient soils, Zinc sulphate has been found to be the most efficient and economical material to meet the zinc requirement of crops. Soil application of 10-25 kg zinc sulphate per acre is recommended depending upon the crop. In a cropping sequence, the application of zinc sulphate should preferably be made to kharif crop for getting maximum benefits. In zinc-deficient soils, application of 10 kg zinc sulphate heptahydrate per acre is recommended for cotton and maize. For rice, the application of 25 kg zinc sulphate heptahydrate per acre is recommended.

In rice-wheat crop rotation, manganese deficiency can be expected in wheat crop. In this situation, it is recommended to spray the wheat crop with 0.5% manganese sulphate solution (one kg manganese sulphate in 200 litres of water/acre). Generally, two to three sprays at weekly intervals are sufficient to correct its deficiency in wheat. It is also recommended to give one spray 2-4 days prior to first irrigation.

In iron deficient soils, it is desirable to ensure the supply of Iron (Fe) to crops through foliar application of iron sulphate to get the optimum crop yield. It is recommended to spray the crops with 1.0 per cent solution of ferrous sulphate at the appearance of deficiency symptoms. Generally, 2-3 sprays carried out at weekly intervals are sufficient. Green manuring also reduces the occurrence of iron deficiency in rice.

Furthermore, to provide assistance to farmers, soil from agriculture fields should be tested by the Government or private agencies. Ground water and Soil Health Cards should be issued to the farmers which describe the water quality and fertility condition of their soil and their deficiency of micro nutrients. Regional centers of Punjab Agriculture University, Ludhiana, with soil and water experts should be opened in the Malwa region to help the farmers.

6. COMBATTING WATER LOGGING AND SALINIZATION

A comprehensive anti-water logging program is clearly the need of the hour in the state of Punjab. To deal with the twin problems of water logging and salinization, the Expert Group has suggested the following short-term, medium-term and long-term solutions:

A) DIVERSIFICATION TO LOW-WATER REQUIRING CROPS IN PUNJAB

In the past half century, India has successfully transformed itself from a country of recurring famine to a grain surplus nation, in large measure through the rapid expansion of irrigation—irrigation that has increasingly come from groundwater. However, this success has come at a cost. Today the rapid depletion of groundwater across much of India threatens the success of the Green Revolution, hurts efforts to provide safe drinking water and contributes significantly to the instability of the nation's electrical grid, as well as to the poor fiscal condition of states that provide subsidized electricity for agricultural pumping. Punjab, the "breadbasket" of India, is at the heart of this crisis.

The early success of the Green Revolution in Punjab prompted the Government of India to target the state as a source of rice and wheat for the national food procurement and distribution system, at a guaranteed price. Subsequently, the state government of Punjab provided electricity for agricultural pumping at a fixed seasonal cost, irrespective of quantity used. These two factors led to the establishment of a rice-wheat annual crop rotation, which consumes much more water than the average annual rainfall and renewable supply in the region, leading to groundwater depletion. Therefore, for long term sustainability, agricultural diversification is imperative. It is necessary to divert significant area from paddy to other low water requiring crops, such as maize and cotton; develop varieties/hybrids of paddy which are of shorter duration with high yields and coincide with monsoon season; develop better-yielding basmati varieties (as it requires much less water than coarse paddy varieties) and increase area under their production. There is no dearth of other options like growing pulses and oilseeds which commanded significant areas under production at one time but were consequently replaced by rice due to better profitability considerations. Similarly, production of high-value alternatives like vegetables around the cities, sugarcane around the sugar mills, fruits like citrus/kinnow in Abohar, Fazilka and Kandi areas, which require less water than paddy but face many marketing constraints and price uncertainties, need to be encouraged. There is also a need to promote cultivation of salt-resistant plants in waterlogged areas. However, attempts to promote these alternative options demand the assured relative profitability vis-à-vis rice and wheat through a combination of state-backed infrastructure and incentives.

We shall now briefly discuss the possibility of crop diversification in the context of each of the above mentioned crops.

Maize:

For diversification of paddy to other crops, one of the major available choices is maize. The maximum area under maize was 567 thousand ha (in 1975-76), which was mostly in the Central region of the State. During the 1990s, the post-harvest prices of maize remained higher than that of paddy but the maize technology (gauged in terms of yield) was not as competitive as that of rice. The decline in the maize area also led its marketing system (place, investments and infrastructure) to become unimportant. But now, when high-yielding hybrids of maize have been developed, the marketing system has emerged as a dominant deterrent. Moreover, the MSP of maize, though fixed and announced, has become meaningless because there has never been any procurement even when the post-harvest market price was lower than the MSP. During the current decade, not only has the post-harvest price of maize been lower than that of paddy (for as many as three years) but farmers have also had to face many hardships due to lack of proper market space at the cost of paddy marketing. Thus, establishing special markets for maize with mechanical driers, plans for which are already afoot but moving forward slowly due to lack of funds, should be accorded priority. Appropriate price incentives for maize should also be assured.

Cotton:

In the case of cotton, the maximum area under cultivation was 758 thousand ha in 1988-89. This was mostly in South Western Punjab. This region was the most agro-ecologically suited to production of cotton as rainfall was low and irrigation was mainly by canals as the underground water in most parts of the belt was saline.

The three successively poor (rather failed) crops of cotton during 1997-98 to 1999-2000, brought down the area under its production. There was a pick-up in area under cotton production during the first half of this decade when the Bt varieties came on the scene, but again, it headed downwards during the second half of the decade due to inadequacies of proper market incentives. It is worth noting that the price incentive for rice made it certain that its price would never be lower than the previous year's even if there was a bumper crop output or the crop was damaged by rains. On the other hand, there were as many as 5-6 years during the last 20 years when the post-harvest price of cotton as well as that of maize was lower than the one in the previous year. The real farm harvest prices of paddy during the 1990s increased at the rate of 0.75 per cent while those of its substitutes like maize, groundnut and cotton desi decreased at the rate of 0.45, 2.79 and 0.44 per cent respectively. Also the index of variability in real prices in case of paddy was less than 4 per cent compared with 12 per cent for maize, 9 per cent for groundnut and 16 per cent for desi cotton. The American cotton prices increased at a lower rate than that of paddy and its index of variability was as high as 16 per cent (Singh, 2003). Price variability, especially a decline in prices over the previous year, is a strong deterrent in cotton production.

Pulses:

There is scope to shift to cultivation of pulses in certain pockets of the state such as Mansa-Bathinda-Muktsar belt. But, once again, the price to the farmer and marketing problems remain the determining factors besides the uncertain yields and cultivation constraints such as harvesting difficulties due to uneven maturity.

Research needs to be liberally funded in the long-term horizon to develop the high-yielding, uniformly-maturing varieties of pulses.

Fruits and vegetables:

Substitution of rice and wheat by high-value alternatives like vegetables around the cities, and fruits like citrus/kinnow in Abohar, Fazilka and Kandi areas which require less water than paddy face many marketing constraints and price uncertainties. Any attempt to promote these alternative options demands their assured relative profitability through a combination of incentives such as state-backed infrastructure to facilitate marketing. Exploring more domestic and export markets would also enable farmers to get better prices.

Salt Tolerant Species

There is also a need to encourage cultivation of salt-resistant plants such as barley, sugar beet, sunflower, banana, oats, safflower and corn particularly in water-logged areas. Salt-tolerant plants (halophytes) can tolerate high internal concentrations of salts and take up salt with water. Examples include saltbush (*Atriplex* species) and bluebush (*Maireana* species). However, salt-resistant plants (glycophytes) cannot tolerate salt internally and exist in saline environments by excluding salt at their roots. Most agricultural plants fall into the salt-resistant category of glycophytes. They can maintain growth in mildly saline soil by excluding salts at the roots. But, in extremely saline soils glycophytes are unable to both exclude salt and obtain sufficient water for maintenance (QDNR 1997).The impact of salinity varies with plant species, stage of growth, management practices, varieties and soil fertility. Selection of species itself will need a nuanced approach given that the extremely high salinity levels of soils in some parts may foreclose many options.

Policy initiatives:

The premise of shifting significant area from paddy to other low-water-requiring crops demands some concerted policy initiatives.

1. Though high yielding hybrids of maize are already available, they need to be provided the same facilities of assured price and marketing as given to paddy and wheat. The target for replacing paddy by maize in 4-5 years could be fixed as about 6-7 lac hectares.

2. Likewise, the incentives for cotton are needed to keep it continuously more competitive than paddy; the target should be to add another 2 lac ha thereby bringing the total area under cotton to exceed its earlier maximum level of 7.5 lac ha.

3. The product specific markets, especially maize markets with mechanical driers are needed to facilitate the handling of the produce and its aggregation for purchasers. This is very important so that farmers do not face physical inconvenience or undue price cuts while marketing maize. Maize and paddy come to the market almost at the same time but paddy with its support price and effective procurement mechanism in place gets preference while maize farmers are left to face many hardships. The state's plan to establish 20 specialized state-of-the-art maize markets with mechanical driers and storage infrastructure need be given top priority. A sum of about Rs 50 crores would be needed for each market; the GOI could assist the state with one time assistance of about Rs 1000 crores.

4. The procurement of maize needs to be regulated/supported, along with some more incentives, especially in lieu of the savings on electricity and thereby its subsidy.

5. It is also suggested that a market stabilization fund of Rs.1000 crores be established to compensate the farmers for the orderly marketing especially in case of gluts/crash in prices, not only of crops such as cotton and maize but also of other important crops like potatoes. A regular detailed procedure should also be set up for recouping the stabilization fund in the normal years. The GOI needs to contribute one-time only at 75% of the initial fund.

6. Along with the support and incentives for cotton, there is a need to rationalize the canal water supply to the South-Western zone, where the water logged area is abundant, vis-à-vis Central Punjab, where the water table has gone too deep thereby further constraining the scarce electricity power.
7. Research needs to be liberally funded in the long-term horizon to :
    i. Develop high-yielding basmati and short duration rice hybrids.
    ii. Improve the yield-potentials of maize-hybrids.
    iii. Develop high-yielding, uniformly-maturing varieties of pulses.

B) DAIRY DEVELOPMENT IN WATER LOGGED AREAS

There is scope to promote dairying in the state of Punjab. However, there are constraints in doing so, particularly, in the water logged areas of the state where groundwater is saline. These include scarcity of potable water for milch animals and inadequate availability and poor quality of green fodder. There are other problems in dairy development, common to other parts of the state too-inadequate and untimely delivery of services especially artificial insemination facilities for breeding buffaloes and a lack of awareness amongst farmers about latest techniques of dairy farming.

The following programmes are proposed to achieve the above objectives:

1. Provision of Water Trenches: Sub soil water in water logged villages of Muktsar and Fazilka districts is saline, heavy and not fit for human or animal consumption, especially milch animals. Unfortunately village ponds have either been put to other uses after leveling or are highly polluted, wherever they exist. Providing potable water to dairy animals is the top most priority. In the absence of potable drinking water, the dairy animals do not achieve optimum growth and health standards resulting in poor productivity and many health hazards.

In order to tide over this situation, it is proposed to make use of the canal water for the animals. There are 234 villages in Muktsar district. Canals/ distributors pass through 211 villages. Out of these, 98 villages are located up to a distance of ½ km from these water sources. Similarly out of 376 villages in Fazilka district, 170 are located up to ½ km distance from canals/distributors passing through the villages. Drinking canal water trenches of 35’x40’ size are proposed to be constructed along the canals in the villages to facilitate the dairy animals to drink potable water. Keeping in view the size of the village population of dairy animals, it is proposed to construct 200 water trenches in 98 villages of Muktsar district and 260 in 170 villages of Fazilka district. Each trench would cost about Rs.2.00 lac. Thus, about Rs.10 crore shall be required for this purpose.

2. Commercial Dairy Farming: Availability of fodder, shelter and potable water is essential for successful commercial dairy farming of cross bred cows. Those farmers who have some land still fit for production of green fodder in districts of Muktsar and Fazilka should be identified and assisted to produce green fodder especially maize for making silage. They can be trained to set up commercial dairy farms of 10-15 cross bred Holstein Friesian cows each yielding about 4000-4500 litres milk per lactation. Such farmers should be provided financial assistance to set up model cattle shed and silo towers and assisted in digging out tubewells for pumping out potable water which is supposed to be available at the depth of about 10’. Four centrifugal pumps can be inter-connected to pump out water which can be stored in a concrete tank to use for drinking of cows. It is proposed to provide financial assistance to farmers @ Rs.30000 or 50% of total cost of this water pumping unit. 100 such commercial dairy farms each in Muktsar and Fazilka districts should be set up every year. Funds to the tune of Rs.25 crore will be required during next 5 years for providing financial assistance to 200 farms every year. Interest subsidy on capital should be arranged for such units under the scheme of NABARD.

3. Improving milk productivity of Buffalo: Almost all farmers in the water logged region of Punjab keep one or two buffaloes to meet day to day expenses. However, the milk productivity of these buffaloes is very low because of lack of

knowledge and an inadequate infrastructure for delivering services of Artificial Insemination (AI) of buffaloes with semen of high quality bulls in this area. It is proposed to improve the milk productivity potential of the buffaloes by providing AI services at the door steps of the farmers by setting up Integrated Buffalo Development Centres in each cluster of 5-6 villages. The in-charge of the Centres shall be recruited from one of these villages and trained as Lay Inseminator. He shall be readily available to farmers even on odd hours and holidays.

At present 70 villages out of 234 in Muktsar district and 30 villages out of 372 villages in Fazilka district have been covered under a project being implemented by Milkfed Punjab, wherein 2 NGOs namely; J K trust and BAIF have set up Integrated Buffalo Development Centres (IBDCs) for providing services of AI to buffaloes. Semen of bulls having milk production potential of 4000 litres per lactation is being used for insemination. These centres are also providing services like de-worming of calves, vaccination etc.

The districts of Muktsar and Fazilka require about 90 IBDCs (30 in Muktsar district and 60 in Fazilka district). Rs.1.0 lac is required to set up one IBDC and an average of Rs.2.85 lac per annum is required to run these centres for 5 years. In all, about Rs.15 lac is required for setting up an IBDC and running it for 5 years. Funds to the tune of about Rs.15 crores would be required during the next 5 years.

4. Training of farmers: A special campaign should be launched in these district to disseminate know-how of latest techniques of dairy farming by organizing village level/ block level courses/workshops etc. All farmers intending to adopt commercial dairy farming should be given free training of 45 days at training centre ‘Abulkhurana’ set up by Dairy Development Department. The expenditure of training which is Rs.3000 per trainee should be borne by the government. Funds to the tune of Rs.40 lac are proposed to be allocated for this purpose for next five years starting with Rs.8 lac for year 2012-13.

In conclusion, to improve dairying in the water-logged South-Western districts of the state, it is important to make arrangements for drinking water, improve the availability of good quality fodders, extend veterinary services to the farmers at their doorsteps and disseminate the dairy technology to the farmers through training in dairy development.

C) MICRO -IRRIGATION SYSTEM WITH SOLAR ENERGY

In order to reverse the water-logging conditions, it is important to apply as little water as possible to many lands, preferably in the root zone. This would progressively bring under control the degree of capillary rise and salinity levels and help restore the vadose zone. Promoting drip irrigation energized by the solar pumping system could be widely promoted in Southwestern Punjab. Combining drip irrigation with solar power system saves about 40-60% water[3]. In a region like Southwest Punjab, it would help in bringing more area under high-value, low-water requiring crops, specifically (kinnow) orchards. Drip irrigation enables precision irrigation, i.e. applying only that much water which is enough for plants. Thus no water percolates down which brings soluble salts to the surface and causes salinity. The system also gets higher yields and better quality of fruits, lowers the annualized long-run cost of production and increases the farmers' incomes. This aspect is even more significant with the adoption of fertigation (application of fertilizers with the drip irrigation in split dozes).

A 2-3 hp pump with drip irrigation is sufficient for about 5 Ha orchard or about 2-3 Ha under vegetables / field crops. The total cost of solar pump based drip-irrigation system for a 2 Ha vegetable farm or a 3 Ha orchard farm would be about Rs.6 lac. The consumption of 10993 million units of electricity as reported by the PSPCL for 2011-12, gives an average of about 3700 units per Ha for 2.95 million Ha of tubewell irrigated area, i.e. more than 7000 units for a farm of 5 acres (2 Ha). Over the life span of 25 years at the least, the savings would sum up to more than 150,000 units of electricity, which would bring enough saving to the exchequer to justify a heavy subsidy on the system.

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[3] The water use efficiency of the drip, sprinkler and flood irrigation is 90, 70 and 40 % respectively (Report of Task Force on Micro Irrigation, GOI, Ministry of Agriculture, Department of Agriculture and Co-operation, pages 32 and 111, Table 4.2 , Table 4.10)

The government is already providing subsidy on drip irrigation system. There is subsidy of 75% for the farmers having land holdings of 2-5 Ha and 85% for the small and marginal farmers (0.4 to 2 Ha). The subsidies for micro irrigation are provided under NMMI. The 50% subsidy, with an upper limit of Rs. 1.2 lac for water storage tank of 20mX20mX2.5m size is available for the farmers having land up to 2 Ha. These subsidies are provided under NHM. The GoI subsidy on the solar system is 30%.

There is a need to increase the subsidy on the solar energy systems along with the drip irrigation. If 85% subsidy is provided, a 5 acre orchard farmer will still have to incur about Rs.70000. Similarly, a 5 acre vegetable farmer will have to incur about Rs.90000. The benefits to farmers include zero maintenance costs, freedom from electricity power cuts and load shedding, certainty of more efficiency during the high irrigation demand in summer months and long operating life of usually 20-25 years. The system is also non-polluting and eco-friendly for the society.

The Expenditure Finance Committee on “Development of Micro Irrigation through Public Private Partnership (PPP) under Command Area Development and water management (CADWM) Programme” is being processed for approval. All states including Punjab are eligible and will be able to avail during XII Plan for bringing efficiencies in water use.

D) DEVELOPMENT OF FISHERIES

In India about 2.54 mha of salt affected soils exist, which are unfit or marginally fit for agriculture. There are large tracts of salt affected land in the semi-arid and arid eco-regions of northern plains and Central High lands in the States of Haryana, Rajasthan, Uttar Pradesh and Gujarat with surface and sub-soil brackish water. These areas can be used for promoting brackish water aquaculture. Since the early eighties, development of brackish water fish culture has gained prominence. However, a suitable environmental method is required for the disposal of the saline water. In most situations, this water can be intercepted and pumped through a series of tanks or ponds in which marine finfish can be cultured. The farming of commercially important aquatic species is considered a better option than agriculture for utilising vast inland surface and subsurface saline water resources which are mainly distributed in semi-arid and arid regions of Rajasthan, Haryana, Punjab and Uttar Pradesh.

Experimental work on use of saline soil was initiated by the Central Institute of Fisheries Education, Mumbai at its Sultanpur and subsequently Rohtak Centres in Haryana. Based on the studies, growth and production of some of the candidate species have been identified. However, the inland saline water aquaculture is yet to be developed for large scale commercial utilisation in the country. There are several issues related to the subject that need attention of researchers, administrators and policy makers to harness the potential of inland saline water resources for sustainable growth of this sector. Before saline groundwater can be utilised for marine finfish culture, it must be tested for chemicals, pesticides and dissolved ions as high concentrations can be unsuitable for aquaculture or even lethal.

Candidate Species of Brackish water for Culture

Though many species can survive and grow in the brackish water, only a few can be cultivated viably. One of the main criteria for the viability of the aquaculture is demand both in the domestic and international markets for the species cultivated. In this context shrimps especially, the Tiger shrimp Penaeus monodon dominates others. Some of the other candidate species for farming in brackish water are Fenneropenaeus indicus (Indian White shrimp), Fenneropenaeus merguiencsis (Banana Shrimp), Macrobrachium rosenbergii (Scampi), Mud crabs (Scylla tranquebarica & Scylla serrata). The fin fish which can be economically cultured in India in brackish water are Asian Seabass Bhetki Lates caicarifer, Groupers (Epinephlus sp), Snappers (iutjanus sp), Rabbit fish , Milkfish (Chanos chanos), Grey Mullet (Mugii cephalus, Liza tade, Liza macrolepis, Liza parsia) and Pearl spot (Etroplus suratensis). Brine shrimp Artemia is yet another small crustacean suitable for culture and cyst production in high saline environment in Rajasthan. Though these species are euryhaline and can be cultured in saline freshwater conditions to conditions of higher salinities, their growth rate is relatively high in salinity range of 10-20 ppt. These species grow in the brackish water environment. Most of them depend on the sea conditions for maturation and spawning. The larvae and juvenile are drifted to the estuaries and backwaters and even areas of very low saline conditions and spend the growing phase in these environments.

Prospects of Brackish water Aquaculture in Inland saline water

Efforts made in the last two decades by various agencies (Central Institute of Fisheries Education (CIFE), Central Institute of Freshwater Aquaculture (CIFA)) as well as the National Agricultural Technology Project have shown culture of shrimps and fishes as a techno-economically viable proposition in the Inland brackish water areas.

Excellent growth of Grey Mullets (Mugil cephalus), to an extent of 600 gm within a period of 6 months has been recorded in Haryana saline farm. Milkfish (Chanos chanos) has also showed excellent growth rate in the saline ponds of Sultanpur, Rohtak and Hisar. Scampi (Macrobrachium rossenbergii) grow to marketable size within 5 months culture period in Bharatpur area saline ponds. The shrimp, Penaeus monodon, was found to thrive and grow in areas of moderate salinity and hardness. States like Haryana have already launched massive programme for Scampi culture using saline water. Presently, the major input seed has to be transported from coastal areas to these inland areas. This adds to the cost of input. The recent advancements made at ClFE Rohtak centre in completing the life cycle of Macrobrachiurn rosenbergii using inland ground saline water is a welcome trend in the maturation spawning and larvae rearing of some candidate species. Probably in the years to come attempts can be made on other species like Grey Mullets (Mugil cephalus) and Milk fish (Chanos chanos). Pearl spot (Etropius soratensis) introduction will help in the establishment of these species in inland area.

Technical feasibility

The species suitable for saline water aquaculture are basically tropical fishes. Many fish and shrimps may not be able to survive in water temperature less than 14- 15 degrees. However, the inland areas experience very low temperature during the months of October to February. In these months, the fish may die or not grow. Hence, all the culture programmes should be managed between March and September. However, the seeds in the coastal area are available only during May-June or November-December. There are hardly 3-5 months culture period available. So, technically the culture practice should be short-term oriented.

Roadblocks to be crossed

Some of the steps that need to be taken to address the roadblocks in promoting brackish water aquaculture include promotion of seed production activities in seed deficit States such as Punjab, Haryana, Rajasthan, Madhya Pradesh, Tamil Nadu; establishment of brood banks at the District level/State level and up-gradation of hatcheries for maintaining and holding the brood stock as well as seed; in situ production of seed for stocking of reservoirs and other large water bodies; mandatory accreditation and certification of hatchery and seed; import of technology for breeding of commercially important fishes, especially for species holding potential for mariculture; breeding and seed production of indigenous ornamental fishes and rearing of ornamental fishes; public private partnerships for fish seed production and marketing. It would be appropriate to once again reiterate the importance of (Fisheries and Aquaculture Development Agency) FADAs in ensuring promotion of seed production activities in the country.

In fact states like Punjab, Haryana and Andhra Pradesh with a high average productivity of 6094 kg/ha/yr, 4370 kg/ha/yr and 3740 kg/ha/yr respectively avail very little assistance under the Schemes of Govt. Many states have felt that the existing subsidy structure does not meet the realistic costs and therefore, needs revision.

Issues of concern

Developmental strategies for freshwater aquaculture will include both horizontal and vertical increase in production; utilization of new resources such as water logged, saline lands and irrigation canals; and diversification of species and intensification of culture practices including integration of aquaculture with agriculture/livestock/poultry. In addition, focus will be on region-specific aquaculture, public- private partnership for scientific aquaculture; fish health management and disease diagnostics and promotion of ornamental fisheries. Finally, the support of field level agencies is inevitable if the targets are to be achieved. There are vast sheets of inland saline water bodies lying unexploited in different states of the country, mainly in northern and central India. The inland area populations are not mainly fish consumers and preference to saline water fish will pick up slowly. Campaign for marketing of the products should be regularly conducted through awareness programmes.

In conclusion, by 2020 brackish water aquaculture production is expected to be around 350, 000 tonnes of shrimps, and 250,000 tonnes of fishes and 10,000 tonnes of non conventional groups from the coastal area. There exists salt affected soil to an extent of 4.6 million ha mainly in the states of Rajasthan, Haryana, Punjab, Uttar Pradesh and Gujarat. The surface and ground water in these areas are not usable for agriculture operations and salinised soil conditions also make it unsuitable for agriculture. Growing salt-water shrimps and fish in these areas is the only profitable venture. Brackish water Aquaculture may look highly remunerative and attractive owning to the high unit price fish shrimp fetch. But management involves constant involvement and vigil. Before taking up saline water aquaculture in inland areas on a large scale, more pilot scale demonstration should be conducted and the techno economic viability should be standardized with suitable management protocols.

E) LINING OF RAJASTHAN AND SIRHIND FEEDER CANAL

In a comprehensive assessment of water logging in South-western Punjab by Central Ground Water Board, one of the major causes of water logging in Muktsar, Faridkot and Ferozepur districts of Punjab is the continuous seepage from Rajasthan and Sirhind Feeder canals. In order to reduce the seepage of water from the canals and watercourse, lining of the irrigation network is imperative.

Project for relining of Sirhind Feeder (from RD 119700-447927) [AIBP(25:75)]

Proposed Outlay - Rs.5000.00 lakhs

The project for relining of Sirhind Feeder (from RD. 119700 to 447927) costing Rs. 489.165 crore has been approved by Government of India under AIBP. 25% grant assistance on the cost of project benefiting Punjab (Rs. 333.71 crore) and 90% grant assistance under AIBP on the cost of project benefiting Rajasthan (Rs. 155.46 crore) is payable by Government of India. The project was proposed to be taken up during March 2010. The project is proposed to be completed during the year 2013-14. After completion of the project, better irrigation facilities would be available to an area of 34548 acres in Punjab and Rajasthan. It shall also help in reclaiming 84800 hectare water logged area in Muktsar, Faridkot and Ferozepur Districts of Punjab. Though an amount of Rs. 38 core was provided for this project during 2010-11, it could not be started. Rs. 50 crore has been provided for this scheme during 2011-12. An outlay of Rs. 250 crore has been proposed for the 12^{th} plan.

Project for relining of Rajasthan Feeder (from RD 179000-496000) [AIBP (90:10)] (GoI: Rajasthan)

Proposed Outlay - Rs.120 crore

The project for relining of Rajasthan Feeder (from RD. 179000 to 496000) costing Rs. 952.100 crore has been approved by Government of India. As per the AIBP Guidelines, 90% grant assistance under AIBP on the cost of project is payable by Government of India and balance 10% is to be paid by Government of Rajasthan. The project is proposed to be taken up during March 2010 and would be completed by 2013-14. After completion of the project, better irrigation facilities would be available in an area of 93117 acres in Punjab and Rajasthan. It shall also help in reclaiming 84800 hectare water logged area in Muktsar, Faridkot and Ferozepur Districts of Punjab. Although an outlay of Rs. 234 crore was provided for this project in the Annual Plan 2010-11, the project could not be started. An outlay of Rs. 100 crore is provided for Annual Plan 2011-12. An outlay of Rs. 700 crore has been proposed for the 12^{th} plan. An outlay of Rs 120 crore is proposed for the Annual Plan 2012-13.

In addition to lining the Rajasthan & Sirhind Feeder canals, an immediate and urgent measure to combat waterlogging, it may also be useful to estimate the cycles of seepage from the canals into the adjoining aquifers – rates across the region may be variable, given the variability in the characteristics of underlying aquifer systems and the status of the groundwater level at different times of the year.

F) SURFACE AND SUB-SURFACE DRAINAGE

The lining of Sirhind and Rajasthan feeders is foreseen to reduce the flux of canal water to the vadose zone and the aquifers below. However, draining the sub-surface of excess water – mainly from the vadose zone as well as from the shallow aquifer below - is also an important measure that must not just been seen as an immediate response to the problem of water logging, but as a strategic medium-term measure in Southwestern Punjab. Soil drainage becomes essential when the soil is water logged and salinized. In such soils, aeration becomes a limiting factor and microbial activities get hindered. Reducing conditions prevail and the chemical and physical features of soil progressively undergo changes, often for the worse. Hence the removal of excess water from such water logged areas become very essential. An efficient drainage system needs to be provided in order to drain away the storm water as well as the excess irrigation water. A good drainage system consists of surface drains or sub-surface drains or combination of both, as per need. Bio-drainage, as discussed below, is evolving as a popular system of drainage, as it is less costly, more eco-friendly and does not need disposal of drained water.

Surface drainage is the removal of excess water with the help of open ditches, field drains, land grading and related structures suitable for the existing site conditions. Drainage of agricultural fields can be achieved by providing interceptor drains along the canals to divert the flood and seepage water thereby preventing seepage water induced waterlogging. Also vertical disposal drains (sumps) connecting the natural drains or nallas can be constructed to dispose off the excess water.

Sub-surface drainage in the form of horizontal, vertical or combination of both are required for soils with poor internal drainage capacity with a high water table. Although the implementation of this drainage system is expensive, it helps to avoid water logging very effectively and increase crop yields by draining the excess water and lowering the water table. However, as the sub-surface drains tend to get choked in due course, their proper maintenance should be ensured.

In this context, the project report prepared by the Chief Engineer, Drainage & Irrigation Works (Government of Punjab) envisages the construction of the following major components to tackle water logging in South Western Punjab:-

i) Surface Drain:-New surface drains have been proposed for this area, which cater to rainfall run-off as well as draining out ground water.

ii) Lift schemes:-The topographical area of south-western Punjab is basically riverine with depressions in the form of ponds, around which most of the villages are based. Lift schemes have been proposed to evacuate water from these pockets.

iii) Sub-Surface Drainage System:-A very large investment in sub-surface drainage systems needs to be made to support agricultural infrastructure in Punjab. In pockets of land where agricultural productivity is low due to water logging, laying sub-surface drainage system will not only increase productivity but also lower the sub-soil water level.

iv) Widening of drains:-After the initial construction of drainage network in 1997, a numbers of new lift schemes, sub-surface drainage systems and new surface drains have been added or are being added, thereby necessitating the widening of drains to cater to higher discharge.

v) Removal of overburden:-To ensure the smooth movement of machinery required to clear drains at regular interval, it is imperative to remove the overburden.

vi) Construction of bundhs in forced reaches:-Given the undulating topography of the land, where drains pass through lower area, the construction of bundhs has been proposed to avoid the flooding of adjoining arable land.

vii) Pucca Structures:-For ensuring proper water way, hydraulic structures which are obstructing smooth flow, need to be remodeled.

viii) Resectioning/cleaning of drains:-With the passage of time, weed growth & sloughing in drain is a regular feature. This has to be tackled by resectioning of drains at regular interval.

ix) Special treatment in sloughed reaches:-Sloughing is a regular feature which results in the deterioration of existing drains. To keep the drains in proper shape & size, special treatment is required to be done at the existing drains.

x) Intercepting Sub-Surface Drains:-To check seepage from the Rajasthan feeder & Sirhind feeder drains, the project proposes to lay perforated pipes along the Rajasthan & Sirhind Feeder.

The estimate of the above mentioned project amounts to Rs 960.62 crores and this has been submitted for approval and funding under Central Assistance.

The dewatering arrangements made by the drainage administration in the Muktsar district during the unprecedented rains of September 2011 are worth mentioning here. The devastation caused to the area during the rains was enormous and all the low lying pockets running through the village and agricultural land were filled with 2 to 6 feet deep flood water. The dewatering machinery worked day and night to bring the situation under control and it took a month and a half to bring normalcy in the affected area. For the first time, the network of drains carried flood water to the river Sutlej with a peak discharge of more than 1700 cusecs (measured by Irrigation and Power Research Institute, Amritsar, Punjab) continuously resulting in evacuation of 1.5 lakh acre feet (volume of water). These efforts of the drainage administration brought the situation under control in record time and made the affected cultivable land ready for the next crop, avoiding further financial loss to the farmers.

In addition to the above mentioned works, the HLEG recommends focusing on improvements in field drainage, including filters and conditioning the rate of groundwater movement. Sometimes variability in rate of groundwater flows can be a factor that influences the efficiency of drain pipes and filters. For instance, sump well W1 in Rattakheda, at its maximum drawdown (depth of about 5m) recovered by about 0.3 in 20 minutes, implying much lower rates of drainage than planned. This clearly indicates that the shallow aquifer being drained either has much lower hydraulic conductivities (clays may be dominating part of the sub-surface) that reduce the input of water from the sediment to the drain pipe network or the net (artificial) hydraulic gradients induced by pumping are lower than anticipated. Further, the shallowest drain pipe inlet was at 6 feet below ground level, whereas the main root zone of most crops would be above this level. In water logged conditions, the water table is also much shallower. Exploring possibilities of raising the uppermost drainpipes to shallow levels, at least in the future design of the artificial drain-pipe network below the ground could be attempted. Furthermore, an increased network density could also be tried out, especially in extreme conditions of water logging and soil salinisation such as pockets in Rattakheda village.

Installing shallow tube wells to pump out saline water from the aquifer into the drains, particularly when seepages from the feeders (fresh water) are operative could serve the dual purpose of quickly draining out saline water and providing the transient condition for assimilating fresh water recharge into the aquifer, in addition to the artificially piped, sub-surface drainage.

Improvement in the design of channels that drain an area into the adjoining rivers can also be considered, although the overall observation is that the drainage channels are certainly draining out water from the water logged areas. At the same time, prevention and mitigation of the silting of such channels also requires close attention for the channels to be effective. The possibilities of deeper channels, with stabilised banks (some locations show collapse of channel banks) could improve the effectiveness of the channels. This study, being limited by time, could not fully ascertain if the channel gradients were sufficient to allow for quick drainage, but visibly this seemed so, given that the rates of flows in some portions of the drainage channels were quite low. This aspect could be revisited by the Department to probe possibilities of increasing (even marginally so) the gradients of some of the drainage channels to accommodate larger fluxes of water from the water logged areas, at the same time ensuring that sloughing does not occur. However, details will need to be derived on the basis of accurate assessment of the drainage channel network, which could be taken up afresh to explore how such drainage networks could be significantly improved further.

G) DEVELOPMENT OF BIO-DRAINAGE FOR WATER LOGGED SOILS

For the reclamation of waterlogged saline soils, the conventional technique is sub-surface drainage which is relatively expensive and generates harmful drainage effluents. A viable alternative of the above technique could be bio-drainage, which is 'pumping of excess soil water by deep-rooted plants using bioenergy'. Bio-drainage system is a combined drainage-cum-disposal system, which makes use of the evapo-transpirative power of plants especially of trees for lowering the adjoining water table and hence the possibility of water logging. It is economically viable because it requires only an initial investment of afforestation and when established, could generate economic returns by means of fodder, fuel wood and timber. Various clones of Eucalyptus have shown promising results for reclamation of waterlogged soils through bio-drainage. *Atriplex amnicola* have been reported to produce good biomass on water logged soils as well as on waterlogged saline soils.

In India, bio-drainage is still in experimental stage. Guidelines for bio-drainage are yet not available. Studies for assessing potential of different plant species under various agro-climatic conditions of India, geometry of their effective plantations including spacing and synergy with the adjoining crops are being conducted. . The outcomes of these are likely to be available in two- three years to take up formulation of its guidelines. MOWR had sanctioned Research Schemes costing Rs. 216.39 lakhs in different regions of the country through various research institutes.

In order to develop sustainable technologies for the bio-drainage of water logged and saline soils using Eucalyptus and *Atriplex amnicola*, a technical programme comprising of the following needs to be put in place:

- Characterization of soils for water logging and soil salinity.
- Procurement of Eucalyptus clonal planting stock and *Atriplex amnicola* seeds (and rising of nursery) and testing their adaptation to local conditions.
- Mass multiplication and establishment of plantations with various densities of selected clones of Eucalyptus in block and boundary plantation for biodrainage.

- Number of Eucalyptus rows along canal side (on both sides of the canal) to reduce seepage into the soil will be standardized to minimize water movement through subsurface drainage.
- Various densities of planting of *Atriplex amnicola* to be tested for transpiration.
- Vertical (downward) and horizontal water movement to be measured in and around all experimental plantations established to access the effect of the treatments.
- Working out of the economics of Eucalypts and *Atriplex amnicola* plantations raised on waterlogged soils.

H) ON-FARM WATER MANAGEMENT

Adoption of proper water management practices at farm level is essential for sustainable production as well as productivity of crops. This calls for promotion of awareness among the farmers for optimal usage of irrigation water as well as construction of suitable irrigation structures for equitable distribution of irrigation water, which eventually reduces the possibility of occurrence of water logging. This can be achieved through closer participation of beneficiary farmers.

Implementation of Command Area Development and Water Management Programme (CADWM)

The objective of the CADWM Programme is to ensure equitable distribution of water to each farm holding in the command and promote efficient water management and agricultural practices for optimizing agricultural production and productivity. In order to achieve the objective, the programme envisages a number of activities like construction / lining of field channels for smooth supply of water from canal to the field, warabandi (fixation of farmers' turn) for equitable distribution of water, construction of drains for drainage of surplus water, reclamation of waterlogged areas, participatory irrigation management (PIM), training to functionaries and farmers, laying out of adaptive trials and demonstrations etc. A brief description of the activities that contribute to water efficiency are as under:

a) Construction / lining of field channels: Research studies conducted in the past have concluded that if selective lining is done in the vulnerable sections of field channels up to 20% of the channel length, reduction in seepage losses in the field channel can be achieved to the extent of 55%. Under CADWM Programme, central assistance for selective lining of field channels on this principle is being provided.

b) Enforcement of warabandi for equitable distribution of water: Warabandi is fixation of time and turn for supplying irrigation water to each farmer's field. Non-enforcement of warabandi in various States of the country except Punjab, Haryana, parts of Rajasthan and western Uttar Pradesh, is largely responsible for poor water management at farm level. As a result, the farmers in the head reach of the command generally use lion's share of water depriving the farmers of tail areas of their due share. In order to overcome this problem, warabandi or other similar methods prevalent in various parts of the country for equitable distribution of water need to be made mandatory all over the country for which the State Governments must take necessary administrative measures.

c) Participatory Irrigation Management (PIM): Recognising that farmers can play an effective role in the management of water resources, their participation in the management of irrigation systems has been incorporated as an important activity under the CADWM Programme. To facilitate the process of PIM, 15 States namely; Andhra Pradesh, Assam, Bihar, Chhattisgarh, Goa, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Sikkim, Tamil Nadu and Uttar Pradesh have enacted exclusive legislation for involvement of farmers in irrigation management. But operationalisation of the provisions of these acts by the respective State Governments needs to be done at a faster pace so as to empower the Water Users' Associations (WUAs) legally and financially to perform the task effectively.

d) Correction of system deficiencies: Many of the irrigation systems have become dilapidated due to silting of canal system, weed growth, damages to the canal sections and regulatory structures leading to low performance. With a view to help State Governments in ensuring O&M and improving efficiency of the systems, a provision for correction of system deficiencies upto distributaries of 4.25 cumec (150 cusec) capacity has also been made under CADWM Programme. Such works for the network of canals with discharge more than 150 cusecs are covered under extension, renovation and modernization (ERM) of old irrigation systems, which is a component of Accelerated Irrigation Benefit Programme (AIBP).

Distribution of Irrigation Water through Pipes

In the commands where topography is rolling or uneven, PVC pipes for conveyance of water from outlet of a minor to the farmers' field can also be used as substitute to the open field channels. In this way, considerable savings in seepage and evaporation losses can be achieved.

I) CONJUNCTIVE USE OF SURFACE AND GROUND WATER

Planned use of surface and groundwater (conjunctive use) serves the dual purpose of increasing the area under irrigation by utilizing the ground water on one hand and lowering the adjoining water table on the other, thereby reducing the possibility of water logging. Lift irrigation through tube-wells and dug-wells should, therefore, be emphasized along with surface flow irrigation, especially for areas prone to water logging.

Farmers using canal water for irrigation purposes should be encouraged to switch to the tube well wherever the water is of good quality (they should be supported in cash or kind). In fact, canal water supply may be cut in such fields. The exact ratio in which surface and ground water should be used can be determined after testing the available ground water. This will allow the two to be used in real conjunction.

J) CONTROL OF FLOODING

If a farm land is continuously submerged by floods as in North India in the Gangetic plains causing water logging, flood control measures such as flood control reservoirs and proper drainage arrangement are to be provided to minimize water logging.

Buddha NEER Project

A Hope for Use of Ecologically Corrected Water for Agriculture

Buddha Nallah is a seasonal water stream, which runs through the Malwa region of Punjab. After passing through the district of Ludhiana, it drains into the Sutlej River. Today it has become a major source of pollution, as it gets polluted after entering the highly populated and industrialized city of Ludhiana, turning it into an open drain. Also, since large areas in South-Western Punjab depend on canal water for irrigation, and water from Buddha Nallah enters various canals after Harike waterworks near Firozpur, it affects far-reaching areas such as Malout, Zira, upper Lambi. The areas being fed by the Sirhind feeder are the most affected by its pollution.

Research conducted by the Shrishti Eco-Research Institute (SERI) has indicated that Dissolved Oxygen (DO) of Buddha Stream becomes zero as it starts receiving industrial, CETP and domestic discharges while passing through Ludhiana. There is no aerobic life in the Buddha stream giving rise to proliferation of anaerobicity. There is decreasing trend of Chemical Oxygen Demand (COD) /Biochemical Oxygen Demand (BOD) in Buddha Nallah downstream of Balloke STP from about 1200 mg/L & 400 mg/L to 391 mg/L & 136 mg/L near the confluence with Sutlej river (Distance about 10 – 12 km). The Buddha stream hydrologic system contains solvents, toxic carcinogenic chemicals and heavy metals in excess in surface and ground waters. Radioactive Uranium is found to be 100 times that of prescribed standard limit of 0.003mg/L(USEPA). Volatile organics and fecal coliforms are noticed not only in surface waters of Buddha Nallah and Sutlej river but in groundwater samples also. It is a serious cause of concern for the health of the villagers.

Given the urgent need for restoration of the Buddha Nallah, the "Buddha NEER Project" (Buddha Nallah Ecological and Economic Restoration Project) by the Srishti Environment & Sustainability Society (SES) was finalized in February 2011. To bring down the pollution levels in Buddha Nullah, the Central Pollution Control Board (CPCB) approved the installation of a biological technology known as Green Bridge technology for cleaning the Nallah. The green bridge technology[4] is a horizontal eco-filtration system made from local materials like sand, soil and bacterial mixture. The ecological food chain is developed in this system. The pollutants become nutrients for bacteria and clean water flows out. This technology entails constructing small bridges alongside Buddha Nallah, where the bacteria are kept. The bacteria treat the chemicals in the water passing through these bridges and reduce its toxicity. The green bridge technology is based on a natural procedure and there is no need for electricity or any harmful chemicals for treating the water because the bacteria treat it automatically. According to CPCB, the project would help in utilizing the treated water of the drain for agriculture and reduce the toxicity in the water getting mixed with that of Sutlej, which is used for drinking purposes. The total cost of the project on the Buddha Nullah where flow of water is 600 million litres per day (MLD) is around Rs 22 crore.

[4] Sandeep Joshi, director, SERI, who has developed this technology and received a patent for it

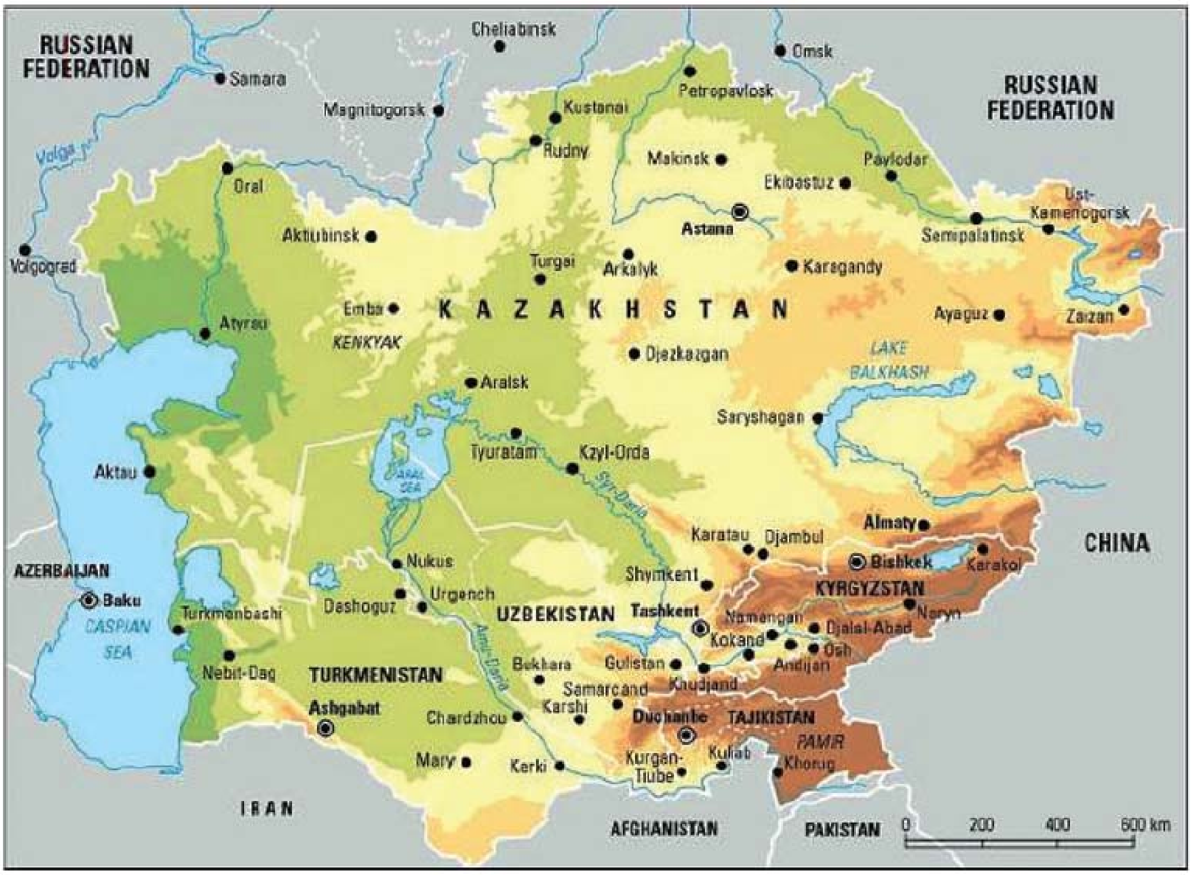
7. LEARNING FROM THE CENTRAL ASIAN EXPERIENCE[5]

Managing Waterlogging and Salinization in Irrigated Agricultural Lands

Expansion of irrigated agriculture in the Aral Sea Basin in the second half of the twentieth century led to the conversion of vast tracks of virgin land into productive agricultural systems resulting in significant increases in employment opportunities and income generation. The positive effects of the development of irrigated agriculture were replete with serious environmental implications. Excessive use of irrigation water coupled with inadequate drainage systems caused large scale land degradation and water quality deterioration in downstream parts of the basin, which is fed by two main rivers, the Amu-Darya and Syr-Darya. Recent estimates suggest that more than 50% of irrigated soils are salt-affected and/or waterlogged in Central Asia.

[5] This discussion is drawn from Rakhmatullaev et al (2010): "Groundwater resources use and management in Amu Darya River Basin (Central Asia)", Environmental Earth Science, 59: 1183-1193.

Figure 9-Map of Central Asia indicating the Aral Sea and five states—Kazkhstan, Kyrgyz Republic, Tajikistan, Turkmenistan and Uzbekistan



Since the 1970s, the level of salts in river water has increased steadily as a result of discharge from drains associated with irrigated schemes back into the river systems. Analysis of the salt inflow and outflow shows that salts accumulate at an annual rate of 0.6 to 10 t ha-1 in the middle and lower reaches of the Amu-Darya Basin, and this is being exacerbated by years of below-average rainfall. In the lower reaches of the basin, the rate of salt accumulation is estimated to be 8 t ha-1 yr-1, even in wet years. In the Syr-Darya Basin, salts accumulate at a rate of 5.3 t ha-1 yr-1. These amounts are 5 to 10 times higher than in other river basins. In addition to salt accumulation, about 30% of the irrigated land is affected by elevated levels of groundwater with implications for waterlogging. In the past, an extensive artificial drainage network (including horizontal or vertical subsurface drains) covering 5.7 million ha was developed to address the problem. The results of the practiced drainage measures are far from satisfactory on account of many reasons. The salinity of the natural water of the rivers, in the beginning of the century, used to be about 250 mg/l in the upper water shed and 1000 mg/l in the low lands. It has been progressively increasing everywhere. The major cause of this increase is the discharge of saline drainage water from irrigated lands into the rivers. The scenario of discharge of drainage water into the river thereby increasing river water salinity, then using greater volumes of saline river water for irrigation and again discharging back salts into the river results in a vicious cycle in which the demand for irrigation water keeps on growing and the salinity of river water keeps on increasing. The Aral Sea Basin, unfortunately, is caught in this vicious cycle. The drainage measures such as the horizontal sub-surface or open drains have therefore ended up exacerbating the problem.

Considering the limitation of traditional drainage measures, Central Asian states have turned their attention to biophysical measures for the management of the affected natural resources (salt-affected and waterlogged soils and saline waters) for improving agricultural productivity and environment conservation. Since there is no single biophysical solution to the complex problems of salt-induced soil degradation and waterlogging in Central Asia, approaches addressing the management of salt-affected and waterlogged environments need to be multidimensional and multidisciplinary. These approaches should take into account the biophysical and environmental conditions of the target area as well as livelihood aspects of the communities depending on them. There are several promising examples, which have the potential for large-scale adoption in Central Asian states under government or community-based programs aiming at improved productivity of a range of degraded soils, from abandoned areas due to extremely low or no productivity to those with low productivity of common agricultural crops.

Groundwater conditions in Amu and Syr Darya basins, along with the soil salinity problem has many similarities with the Southwestern Punjab scenario

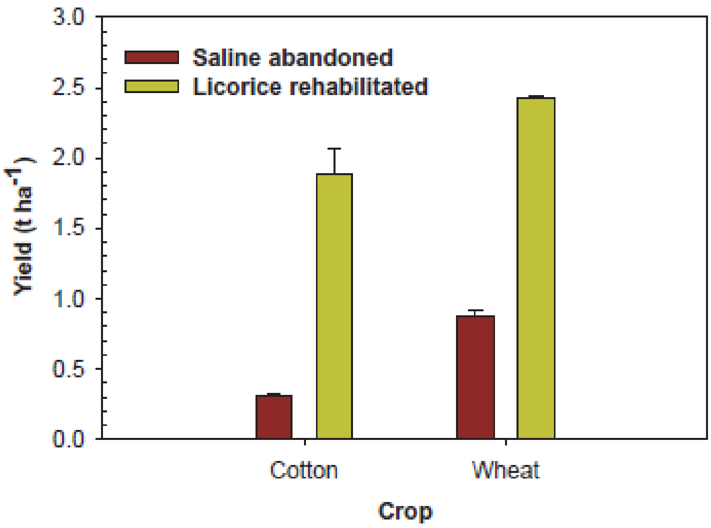
Rakhmatullaev et al, 2009 summarise this as follows: ‘While irrigation dependent cotton and wheat have been affected due to depletion in groundwater, the lack of water flowing downstream has contributed to the catastrophe of the Aral Sea Basin. The problem is so comprehensively and deeply entrenched that despite the inevitable need to use groundwater, better management strategies and co-operation between different partners involved has become necessary. However, groundwater has emerged as a transboundary issue for which joint utilization of groundwater resources in terms of regulation and institutions is almost imperative now’.

Research based interventions that have shown significant promise in addressing this impasse include:

i. **Rehabilitation of abandoned saline lands through crop-based interventions**

Rehabilitation of abandoned salt-affected soils through crop-based interventions is an attractive low-cost opportunity that can be undertaken by farmers. The introduction of halophyte species ‘licorice’ (*Glycyrrhiza glabra* L.) as a bioremediation crop for the reclamation of saline soils and subsequent restoration of irrigated cropping systems has been studied on abandoned land in the Hungry Steppes of Uzbekistan. After four years of cropping with licorice, the field was reverted back to a cotton-wheat rotation prevalent in the region (Figure 1). The yields of both crops were significantly higher than the crops grown on adjacent saline fields. Yields of wheat after licorice increased from 0.87 t ha-1 on saline fields to 2.42 t ha-1, revealing nearly a 3-fold increase. Similarly, cotton yields increased from 0.31 t ha-1 to 1.89 t ha-1 with a 6-fold increase due to the remediation effects of licorice. The yields of these crops from the bio-remediated fields clearly demonstrate the potential of licorice to increase the productivity of abandoned saline fields thereby increasing farm-level incomes and livelihoods of the associated communities.

Fig 10-Yields of cotton and wheat after four years of growing licorice compared to an adjacent saline field



The rehabilitation of the abandoned saline soils, and in certain cases saline-waterlogged soils, under licorice cultivation is attributed to the combined effect of (1) a decrease in the water table to below 2 m; (2) a decrease in the total salt content of the root zone and soil profile due to enhanced leaching of salts associated with improved soil hydraulic conductivity and infiltration rate; and (3) an increase in the soil organic carbon content because of the increased root activity and biomass over the 4-year period. This intervention has the potential to rehabilitate waterlogged saline soils in areas with drainage congestion problems.

ii. Productivity enhancement of high-magnesium soils through calcium supplement

The productivity of magnesium-affected soils can be enhanced by increasing Ca2+ on the cation exchange sites to mitigate the effects of excessive exchangeable Mg2+. As a major waste product of phosphorous fertilizer factories, phosphogypsum is a low-cost source of Ca^{2+} that can be used as an amendment for magnesium-affected soils. In addition to increasing the Ca^{2+} content of the soil, phosphogypsum supplies appreciable quantities of phosphorous to the soil. Other low-cost soil amendment supplying Ca^{2+} is mined gypsum ($CaSO_4·2H_2O$).

The results of a 4-year study conducted in Kazakhstan on magnesium-affected soils demonstrated the beneficial effects of applying a source of Ca^{2+} (phosphogypsum) to these soils in terms of improvement in soil quality and cotton yield. The irrigation water used at the study site was of marginal-quality with Mg^{2+} to Ca^{2+} ratio ranging from 1.30 to 1.66 during cotton growing season. There were three treatments: (1) control without phosphogypsum application; (2) soil application of phosphogypsum at the rate of 4.5 t ha^{-1}; and (3) soil application of phosphogypsum at the rate of 8.0 t ha^{-1}. The amendment was applied to the respective treatments once at the beginning of the study. Its application increased Ca^{2+} concentration in the soil and triggered the replacement of excess Mg^{2+} from the cation exchange sites. After harvesting the first crop, there was an 18% decrease in exchangeable magnesium percentage (EMP) in the upper 0.2 m soil depth over the pre-experiment level in plots where phosphogypsum was applied at 4.5 t ha^{-1}, and 25% decrease in EMP in plots treated with phosphogypsum at 8 t ha^{-1}. The additional beneficial effect of the amendment application resulted in an increase in the soil phosphorus content.

The highest cotton yields were obtained during the first year of the treatment application, which were 2.7 and 3.0 t ha^{-1}, respectively, from the treatments where phosphogypsum was applied at 4.5 and 8 t ha^{-1}. Cotton yield in the control plots (1.4 t ha^{-1}) was almost half the yield harvested from phosphogypsum treatments. There was a 93% increase in cotton yield from the phosphogypsum treatment (4.5 t ha^{-1}) over the control. In the case of the 8.0 t ha^{-1} treatment, cotton yield increased to 114% over that harvested from control plots. The 4-year average cotton yield with phosphogypsum application at 8 t ha^{-1} was 2.6 t ha^{-1}, while it was 2.4 t ha^{-1} when phosphogypsum was applied at 4.5 t ha^{-1}. The control plots yielded cotton at 1.4 t ha^{-1}.

The increase in cotton yield in phosphogypsum treatments was due to the increased levels of Ca^{2+} in soil solution and on cation exchange sites, thereby improving the ionic balance and physical properties of the soil. The increase in phosphorus levels from the amendment application also helped in improving the phosphorous nutrition of the plants. Since phosphogypsum was applied once at the beginning of the study, exchangeable Mg^{2+} levels tended to increase after four years of application, particularly in the treatment with 4.5 t ha^{-1} phosphogypsum. This necessitated the need for a booster dose of phosphogypsum to such soils after every 4–5 years to optimize the ionic balance and sustain higher levels of cotton production.

The economic benefits from the phosphogypsum treatments were almost twice that of the control. In the short term, the 'phosphogypsum' technology has the potential to improve the productivity of about 150,000 ha affected by magnesium-induced soil degradation in southern Kazakhstan. In the medium and long term, the use of Ca^{2+} supplying amendments can be expanded to other areas in the Central Asian states where growing evidence suggests a gradual increase in exchangeable Mg^{2+} levels in soils.

iii. Use of tree species as biological pumps to lower elevated groundwater levels

Near-horizontal subsurface drainage systems have been used in the Aral Sea Basin to address waterlogging and salinity problems. These systems consist of a combination of horizontal buried pipes and deep open drains. Previous experience had shown that these systems although having distinct advantages had negative implications such as the need for proper reuse or disposal of saline drainage water, high maintenance cost, and the fact that a portion of highly fertile land is taken out of production due to the presence of drains. In the case of reusing saline drainage effluent for irrigation without salinity management interventions, salts tend to redistribute in the landscape. The disposal of saline drainage effluent into river systems was reported to cause pollution of natural water bodies in a gradual manner. In addition, a substantial part of the installed drainage systems in Central Asia is partly or fully non-functional because of the lack of finance on the part of farmers and the government.

As a potential alternative to a cost-intensive horizontal drainage system, a plant-based approach 'bio-drainage' can be used to control elevated levels of groundwater in certain areas. Studies carried out on bio-drainage have shown promising results. Collaborative research of Center for Development Research, Germany and Uzbek Forestry Research Institute evaluated 10 native and exotic tree species for their transpiration rate and salinity resistance. The species included: apricot, black poplar black willow, Chinese cedar , Euphrates poplar, Russian olive, salt cedar, Siberian elm, swamp ash, and white mulberry. The transpiration rates per unit leaf area (LA) varied with time, i.e. months after planting (MaP) and followed the sequence: 18 MaP (late season) >16 MaP (mid growing season) >14 MaP (early season) >7 MaP (end of the first season), which were consistent with the mean air temperature and relative humidity during these periods.

Other studies on bio-drainage in the Syr-Darya province of Uzbekistan with the Uzbek Forestry Research Institute and the International Center for Agricultural Research in the Dry Areas (ICARDA) have addressed the efficacy of different ages of tree plantations in regulating the groundwater level. Tree plantations reducing evaporation from soil through their crown reduced capillary rise of saline groundwater to the upper soil depth. Salt accumulation was partially restricted, while higher evaporation rates from bare soil in control treatments brought soluble salts to within 0.3 m from the soil surface.

iv. Optimal use of fertilizers to manage effects of water and soil salinity

Optimal use of fertilizers, particularly those supplying nitrogen, can mitigate the adverse effects of soil or irrigation water salinity. Results of a 2-year study in Kazakhstan under farmers' field conditions reveal that the application of nitrogen at the rate of 140 kg ha-1 can increase cotton yields by a margin of 300 kg ha-1 over nitrogen application rates at 70 kg ha-1 when saline water was used for irrigation. The differences between the treatments were more pronounced when water of higher levels of salinity was used as a source of irrigation.

Studies conducted elsewhere reveal that split applications of nitrogen to salt-affected soils and/or while using saline waters for irrigation, minimizes the nitrogen losses such as ammonia volatilization from the fields. The use of three equal splits at 40 kg ha-1 of the recommended rate of nitrogen (120 kg ha-1) for rice and wheat was found to be an efficient practice on sodic soils of the Indo-Gangetic Basin. Considering the scope of increasing the reuse of saline drainage water from a mere 16% of the total volume produced in Central Asia, optimal use of fertilizers has the potential to improve water productivity over the long term.

v. Mulching of furrows under saline conditions to reduce evaporation

Reduction in evaporation losses under irrigated agriculture is particularly important to minimize salt accumulation in the root zone when saline water is used for irrigation. The results of a 3-year study undertaken in Syr-Darya district of Uzbekistan addressing the interactive effects of saline water irrigation and mulching of furrows demonstrated the beneficial effects of mulching in the form of a better crop response as well as management of root zone salinity. On average, mulched plots used 13 percent less water and produced 12 percent higher yields as compared to nonmulched plots. The significant increase in cotton yield in mulched plots was attributed to increased crop transpiration as a result of reduced salinity in the soil profile. The average root zone salinity was decreased by 13% as compared to non-mulched plots.

Long-term use of mulching has the potential to further improve soil organic matter content and nutrient availability status, with beneficial effects on crop yield and soil quality. With improved soil conditions, there would be a possibility of irrigating with water of relatively higher salt concentration in a cyclic mode with low-saline water, i.e. using low-saline water at the early stages of cotton development and highly-saline water for irrigation during the second half of the crop growing season, when plants are more tolerant to ambient levels of salinity in the root zone.

vi. Biomass and renewable energy production using multipurpose plant species

Abandoned salt-affected lands bear a larger potential for biomass and renewable energy production. A strategic move towards renewable energy generation on salt-affected soils and possibly with saline water resources could consider the establishment of plantations consisting of multipurpose tree and shrub species. Recent evidence reveals several plant species for renewable energy production on salt-affected environments. For example, in the Amu-Darya River Basin, multi-purpose tree plantations established on degraded land at 2300 stems ha-1 produced the energy equivalent of 6.4–10.3 t oil and 12.6–20.5 t coal ha-1 five years after planting. The performance of three tree species was in the order: *Populus euphratica* Oliv. > *Elaeagnus angustifolia* L. > *Ulmus pumila* L . These plantations provided wood, high quality leaf fodder, fruits and all together contributed to meeting requirements of rural households in the study area of Uzbekistan. The selected tree species used in these studies were representatives of the local flora, underlining that their promotion would not cause adulteration of the local plant biodiversity.

Other studies have shown that several plant species have the potential to produce renewable energy from salt affected environments. The cultivation of multipurpose plant species on salt-affected waste lands offers an opportunity to put otherwise unproductive land back into production, but ensures simultaneously that no natural ecosystems are converted into systems for renewable energy production. Also, such conversions may contribute to building up soil carbon stocks and reduce the impact of global warming.

vii. Complementary approaches facilitating soil and water management

Excessive drainage flows in Central Asian states are an inevitable consequence having off-site impacts. However, farming communities in Central Asia are not fully aware of the consequences of the inappropriate management of drainage flows. In addition, they have no economic incentive to consider the effects of the drainage flows on other areas and farmers, to minimize deep percolation, or to reuse or dispose of drainage flows safely. Under such conditions, it is likely that the bulk of the damage is borne by other farmers and other water users. There is, therefore, a need for appropriate regulatory policies and investments designed to aid the introduction of improved management practices and decisions. It is likely that a combination of different management instruments will be needed to reduce deep percolation losses and drainage flows, in order to protect surface and groundwater bodies, particularly in downstream areas. There is a need for collective action by different stakeholders to address such issues to minimize the development of secondary salinity and sodicity in the region.

The following aspects are expected to add value to the soil-based interventions: (1) preparation of datasets and maps of soil salinity, sodicity, and waterlogging (indicating their extent and intensity) to determine feasibility of the management options; (2) establishment of benchmark monitoring sites to evaluate changes in salt-affected and waterlogged soils through satellite imagery; (3) improvement in salt tolerance of the genotypes of major field crops such as wheat and cotton through selection, breeding, and molecular and biotechnological options; (4) conservation of potential genetic pools of halophytic plant communities for highly salt-affected environments; (5) introduction of salt-tolerant medicinal and aromatic plant species as income generating options from salt-affected soils; (6) retirement of lands to permanent vegetation where it is not economically feasible to use the degraded lands and/or highly saline waters for crop production; and (7) develop efficient water management measures and practices in the “problem solution area” upstream to reduce the impact on downstream end water farms (source reduction approach).

8. SUMMARY ACTION PLAN

As we move into the 12th Plan period, India is likely to face daunting challenges in the water sector, with conflicts across competing uses and users of water growing by the day. Dealing with these challenges requires a paradigm shift in the management of water resources in India, and this is what the 12th Plan places at its focus. There is a need to shift emphasis in large-scale irrigation from construction to management, with empowerment of water users and improved water efficiency. Implementing appropriate policies to combat the twin menace of water logging and salinization is an essential part of this strategy in the state of Punjab. Addressing this issue is imperative not just to ensure that fertile land is not laid waste, but also to optimize the use of surface water and to conserve and artificially recharge ground water, wherever possible. This could help provide water for irrigation in other parts of the state, and increase agricultural production.

As a part of the initiative for reforms in irrigation and enhanced water use efficiency, the HLEG was set up. It examined the extent and causes of water logging in the state of Punjab. Importantly, it provided a comprehensive anti-water logging action plan for South Western Punjab. A summary of this action plan is presented below:

A) DIVERSIFICATION TO LOW-WATER REQUIRING CROPS IN PUNJAB

For long term sustainability, it is necessary to divert significant area from paddy to other low water requiring crops. This demands some concerted policy initiatives.

1. Research needs to be liberally funded in the long-term horizon to:

- Develop high-yielding basmati and short duration rice hybrids.
- Improve the yield-potentials of maize-hybrids.
- Develop high-yielding, uniformly-maturing varieties of pulses.

2. Maize needs to be provided the same facilities of assured price and marketing as given to paddy and wheat. The target for replacing paddy by maize in 4-5 years could be fixed as about 6-7 lac hectares.

3. Likewise, incentives for cotton are needed to keep it continuously more competitive than paddy; the target should be to add another 2 lac ha thereby bringing the total area under cotton to exceed its earlier maximum level of 7.5 lac ha.

4. Product specific markets, especially maize markets with mechanical driers are needed to facilitate the handling of the produce and its aggregation for purchasers. The state's plan to establish 20 specialized state-of-the-art maize markets with mechanical driers and storage infrastructure need be given top priority. A sum of about Rs50 crores would be needed for each market; the GOI could assist the state with one time assistance of about Rs1000 crores.

5. Procurement of maize needs to be regulated/supported, along with some more incentives, especially in lieu of the savings on electricity and thereby its subsidy.

6. A market stabilization fund of Rs.1000 crores needs to be established to compensate the farmers in case of gluts/crash in prices. A regular detailed procedure should also be set up for recouping the stabilization fund in the normal years. The GOI needs to contribute one-time only at 75% of the initial fund.

B) DAIRY DEVELOPMENT IN WATER LOGGED AREAS

While recognizing the constraints in the development of dairying in the water logged areas, where the underground water is saline and unfit for crops and animals, the report presents a set of measures that could be taken to encourage dairy development:

1. Constructing water trenches to provide drinking water for animals
2. Improving the availability of good quality fodders
3. Extending the veterinary services to the farmers at their doorsteps
4. Disseminating the dairy technology to the farmers through training in dairy development.

C) MICRO-IRRIGATION SYATEM WITH SOLAR ENERGY

To reverse the water-logging conditions, it is important to promote drip irrigation especially energized by the solar pumping system. There is a need to increase the subsidy on the solar energy systems along with the drip irrigation.

D) DEVELOPMENT OF FISHERIES

The experimental work undertaken on use of saline soil for aquaculture identifies candidate species such as Chanos chanos (milk fish), mullet (Mugil cephalus), Etroplus suratensis (pearl spot) and tiger shrimp (P. monodon), which are ideal for growth and production in the saline and water logged areas of Haryana and Punjab.

Steps that need to be taken to address the roadblocks in promoting brackish water aquaculture include-- promotion of seed production activities in seed deficit States such as Punjab; establishment of brood banks at the District level/State level and up-gradation of hatcheries for maintaining and holding the brood stock as well as seed; in situ production of seed for stocking of reservoirs and other large water bodies; mandatory accreditation and certification of hatchery and seed; import of technology for breeding of commercially important fishes; public private partnerships for fish seed production and marketing.

E) LINING OF RAJASTHAN AND SIRHIND FEEDER CANAL

The project for relining of Sirhind Feeder has been approved by Government of India under AIBP. 25% grant assistance on the cost of project benefiting Punjab (Rs. 333.71 crore) and 90% grant assistance under AIBP on the cost of project benefiting Rajasthan (Rs. 155.46 crore) is payable by Government of India. An outlay of Rs. 50 crore is proposed for the Annual Plan 2012-13.

The project for relining of Rajasthan Feeder costing Rs. 952.100 crore has been approved by Government of India. As per the AIBP Guidelines 90% grant assistance under AIBP on the cost of project is payable by Government of India and balance 10% is to be paid by Government of Rajasthan. An outlay of Rs 120 crore is proposed for the Annual Plan 2012-13.

F) SURFACE AND SUB-SURFACE DRAINAGE

The project report prepared by the Chief Engineer, Drainage & Irrigation Works (Government of Punjab) envisages the construction of the following major components to tackle water logging in South Western Punjab:-

1. New surface drains have been proposed for this area, which cater to rainfall run-off as well as draining out ground water.

2. The topographical area of south-western Punjab is basically riverine with depressions in the form of ponds, around which most of the villages are based. Lift schemes have been proposed to evacuate water from these pockets.

3. A very large investment in sub-surface drainage systems needs to be made to support agricultural infrastructure in Punjab. In pockets of land where agricultural productivity is low due to water logging, laying sub-surface drainage system will not only increase productivity but also lower the sub-soil water level.

4. After the initial construction of drainage network in 1997, a numbers of new lift schemes, sub-surface drainage systems and new surface drains have been added or are being added, thereby necessitating the widening of drains to cater to higher discharge.

5. To ensure the smooth movement of machinery required to clear drains at regular interval, it is imperative to remove the overburden.

6. Given the undulating topography of the land, where drains pass through lower area, the construction of bundhs has been proposed to avoid the flooding of adjoining arable land.

7. For ensuring proper water way, hydraulic structures which are obstructing smooth flow, need to be remodeled.
8. With the passage of time, weed growth & sloughing in drain is a regular feature. This has to be tackled by resectioning of drains at regular interval.
9. Sloughing is a regular feature which results in the deterioration of existing drains. To keep the drains in proper shape & size, special treatment is required to be done at the existing drains.
10. To check seepage from the Rajasthan feeder & Sirhind feeder drains, the project proposes to lay perforated pipes along the Rajasthan & Sirhind Feeder.

The estimate of the above mentioned project amounts to Rs 960.62 crores and this has been submitted for approval and funding under Central Assistance.

G) DEVELOPMENT OF BIO-DRAINAGE FOR WATER LOGGED SOILS

In order to develop sustainable technologies for the biodrainage of water logged and saline soils using Eucalyptus and Atriplex amnicola, a technical programme needs to be put in place.

H) ON-FARM WATER MANAGEMENT

Adoption of proper water management practices at farm level is essential for sustainable production as well as productivity of crops. This calls for promotion of awareness among the farmers for optimal usage of irrigation water as well as construction of suitable irrigation structures for equitable distribution of irrigation water, which eventually reduces the possibility of occurrence of water logging. This can be achieved through closer participation of beneficiary farmers.

I) CONJUNCTIVE USE OF SURFACE AND GROUND WATER

Planned use of surface and groundwater (conjunctive use) serves the dual purpose of increasing the area under irrigation by utilizing the ground water on one hand and lowering the adjoining water table on the other, thereby reducing the possibility of water logging. Lift irrigation through tube-wells and dug-wells should, therefore, be emphasized along with surface flow irrigation, especially for areas prone to water logging. Farmers using canal water for irrigation purposes should be encouraged to switch to the tube well wherever the water is of good quality (they should be supported in cash or kind). In fact, canal water supply may be cut in such fields. The exact ratio in which surface and ground water should be used can be determined after testing the available ground water. This will allow the two to be used in real conjunction.

FINANCIAL OUTLAYS

The financial outlays for the various works proposed by the HLEG are presented in table 11 below. The total central assistance for the above-mentioned works is Rs 3056.75 crores. Of this, Rs 1975.62crores will flow from Central Schemes of various ministries, while Rs 1081.13crores will need to be provided as a Central Grant. The share of the state in this project will be Rs 489.97crores. The amount would be provided to address this problem over a period of 5 years.

Table 11: Financial Requirements over 2013-18 (Rs Crore)

S No.	Name of the component proposed for intervention	Assistance to be provided under	Central Share	State share/ Individual contribution	Special Central Assistance on 100% Grant basis	Total Central Assistance
1	**2**	**3**	**4**	**5**	**6**	**7 (Col. 4+Col.6)**
1	Lining of Rajasthanfeeder Canal	AIBP	856.80 (90%)	95.20(10%)	Nil	856.80
2	Lining of SirhindFeederCanal	AIBP	83.4275 (25%)	33.71(10% as State has requested not to share	216.57	299.99

S No.	Name of the component proposed for intervention	Assistance to be provided under	Central Share	State share/ Individual contribution	Special Central Assistance on 100% Grant basis	Total Central Assistance
1	**2**	**3**	**4**	**5**	**6**	**7 (Col. 4+Col.6)**
				beyond 10% which is at par with contribution made in Rajasthanfee derCanal project)		
3	Drainage works- Surface and Sub Surface works,	One time Grant	Nil	96.06 (10%)	864.56(90%)	864.56
4	Bio Drainage, On Farm Water Management	MGNREGA And Other RD schemes	270.00 (90%)	30.00(10%)	Nil	270.00
5	Diary development in waterlogged areas (i) Provision of Water Trenches (ii) Commercial Dairy Farming (iii) Improving milk productivity of Buffalo (iv) Training of farmers	NRLM	10.00 25.00 15.00 0.400 **50.40**	Nil	**NIL**	10.00 25.00 15.00 0.400 **50.40**

S No.	Name of the component proposed for intervention	Assistance to be provided under	Central Share	State share/ Individual contribution	Special Central Assistance on 100% Grant basis	Total Central Assistance
1	**2**	**3**	**4**	**5**	**6**	**7 (Col. 4+Col.6)**
	Total					
6	Micro Irrigation System with Solar Energy (24000 Ha)	National Mission on Sustainable Agriculture (NMSA) and Jawaharal Nehru National Solar Mission	(400 Crore) 85% for micro irrigation and 30% for Solar Pumps	(200 Crore) 15% for micro irrigation and 70% for solar pumps by individuals	NIL	**(400.00 cr)** Rs 6 lakh is estimated for 2 ha of vegetable farm or 3 ha of orchard farm
7	Development of Fisheries	National Fisheries Development Board (NFDB)	**315.00**	35	NIL	**315.00**
	Total Assistance Proposed		**1975.62**	**489.97**	**1081.13**	**3056.75**

THE BREAKUP OF YEAR WISE FINANCIAL OUTLAYS FROM 2013-14 TO 2017-18

S.No	Year	Components			
		Central Share	State share/ Individual contribution	Special Central Assistance on 100% Grant basis	Total Central Assistance
1	**2013-14**	197.562	48.997	108.113	305.675
2	**2014-15**	395.124	97.994	216.226	611.35
3	**2015-16**	395.124	97.994	216.226	611.35
4	**2016-17**	493.905	122.4925	270.2825	764.1875

5	**2017-18**	493.905	122.4925	270.2825	764.1875
	Total	**1975.62**	**489.97**	**1081.13**	**3056.75**

Moving forward, the HLEG proposes to set up a Steering Committee to facilitate, co-ordinate, support and provide technical assistance to all agencies implementing this Action Plan for controlling water logging and salinization in the state of Punjab. The Committee would also suggest corrective measures for scheme improvement and target achievement. It would also monitor the implementation and operation of programmes and projects to ensure timely completion.

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ANNEXURE 1: Terms of Reference and Constitution of High Level Expert Group

File No 22(199)/2012-WR
Government of India
Planning Commission
(Water Resources Division)

436 Yojana Bhawan,
Sansad Marg, New Delhi
Dated 08.06.2012

ORDER

Subject: High Level Expert Group for addressing the issues of Water Logging in Punjab.

*****

The XII Five Year Plan proposes a paradigm shift in water management in India wherein it has been decided to increase the water use efficiency by 20% in the XII Plan. In order to achieve this objective, Planning Commission has decided to set up a "**High Level Expert Group for addressing the issues of Water Logging in Punjab". The "High Level Expert Group" will** study the complex issue of water logging and recommend the way forward to address the problem in a holistic manner along with the related financial resource requirements.

The composition of the "**High Level Expert Group"** is as under:

Name	Position in the Expert Group
1. **Dr Mihir Shah, Member, Water Resources and Rural Development, Planning Commission, New Delhi.**	**Chairman**
2.Dr. A. Vaidyanathan, former Member, Planning Commission, Chennai	Member
3. Dr Tushaar Shah, Sr Fellow, International Water Management Institute, Anand, Gujarat.	Member
4 Dr. Himanshu Kulkarni, ACWADAM Pune	Member
5 Shri Karam Singh, Professor and Head, Department of Economics and Sociology, Punjab Agricultural University, Ludhiana	Member
6. Member (Water Planning and Projects), Central Water Commission, New Delhi	Member
7. Chairman, Central Ground Water	Member

Name	Position in the Expert Group
Board, Faridabad, Haryana.	
8. Commissioner (Command Area Development and Water Management), Ministry of Water Resources	Member
9. Representative of Department of Science and Technology –to be nominated by Secretary DST.	Member
10. Representative of the Department of Land Resources, Government of India, not below the rank of the Joint Secretary.	Member
11. Representative of the Government of Punjab – Director (Ground Water) Water Resources & Environment Irrigation Department, Government of Punjab, SCO 32-34, Top Floor, Sector 17-C Chandigarh – 160 017.	Member
12.Representattive of the Punjab Agriculture University, Ludhiana – To be nominated by the Vice Chancellor	Member
13. Chairman, Punjab State Farmers Commission, Plot No 52 Phase 2, SAS Nagar, Mohali-160055	Member
14. Representative of the Ministry of Agriculture, Government of India, not below the rank of the Joint Secretary.	Member
15. Shri Avinash Mishra, Joint Adviser, Water Resources Division , Planning Commission	Member Secretary

The Terms of Reference to the High Level Expert group will be:

1. To study the extent and nature and reasons for water logging in the State of Punjab in a holistic manner.

2. To study the performance of the existing remedial measures implemented (if any). To suggest innovative globally accepted remedial measures suited to local conditions.

3. To estimate the financial resource requirements for the implementation of the remedial measures and to identify the possibility of convergence with the existing programmes for augmenting resources.

4. To study the measures like Watershed Management, Crop/Agricultural Diversification to address the issue of water logging in the State.

5. Any other ToR to be decided by the Expert Group with the approval of Chairman.

The High Level Expert Group will devise its own procedure and may co-opt any other official/non official Member, if necessary.

The TA/DA would be paid by the respective Government Department/State Governments for the members nominated by them. For non-official members and the Professors of the University, the TA/DA would be paid by the Planning Commission as per the applicable norms in vogue. The Expert Group is empowered to constitute any sub groups and co-opt any official or non-official member, if necessary.

The High Level Expert Group will submit the report to the Planning Commission by 30th November 2012.

Undersigned is the Member Secretary of the "High Level Expert Group" (Telephone 011- 23096732) will be the nodal officer for this group and further correspondence / query may kindly be addressed to the undersigned.

08.06.1

(Avinash Mishra)
Joint Adviser (WR)
Telefax: 011-23096732

Copy To:

1. Chairman and all Members of the Expert Group.
2. PS to Deputy Chairman, Planning Commission
3. PS to all Members/Minister of State, Planning Commission
4. PPS to Secretary, Planning Commission
5. Adviser (Administration), Planning Commission.
6. Adviser (WR), Planning Commission.

ANNEXURE 2: Salinity tolerance in irrigated crops (NSW Department of Primary Industries: Agriculture)

Table 1. Vegetable crops water salinity tolerance (ECw)

This table indicates the yield reductions which could be expected when various vegetable crops are irrigated with saline water.

Vegetable crop	No reduction (dS/m)	10% reduction (dS/m)
Zucchini	3.1	3.8
Garden beet	2.7	3.4
Broccoli	1.9	2.6
Cucumber	1.7	2.2
Tomato	1.7	1.9
Cantaloupe/rockmelon	1.4	2.4
Watermelon	1.3	Na
Spinach	1.3	2.2
Cabbage	1.2	1.9
Celery	1.2	2.2
Broad bean	1.1	1.8
Potato	1.1	1.7

Sweet potato	1.0	1.6
Capsicum	1.0	1.5
Sweet corn	1.0	1.7
Lettuce	0.9	1.4
Onion	0.8	1.2
Eggplant	0.7	1.6
Carrot	0.7	1.2
Beans	0.7	1.0
Radish	0.7	0.9
Turnip	0.6	1.3

Note: The salinity tolerance of seedlings of most vegetable plants is likely to be less than the levels shown.

Table 2. Fruit and nut crops water salinity tolerance (ECw)

This table indicates the yield reductions which could be expected when various fruit and nut crops are irrigated with saline water.

Fruit and nut crop	**No reduction (dS/m)**	**10% reduction (dS/m)**
Date	2.7	4.5
Fig	2.7	NA

Olive	2.6	3.0
Grapefruit	1.2	1.6
Walnut	1.1	1.6
Orange	1.1	1.6
Peach	1.1	1.4
Apricot	1.1	1.3
Grape	1.0	1.7
Almond	1.0	1.4
Plum	1.0	1.4
Boysenberry	1.0	1.3
Avocado	0.8	1.0
Pear	0.7	na
Prune	0.7	na
Apple	0.7	1.0
Raspberry	0.7	1.0
Strawberry	0.7	0.9
Lemon	0.7	na

Note: Variety of rootstock may have a bearing on salinity tolerance of some fruit trees.

Table 3. Field crops water salinity tolerance (ECw)

This table indicates the yield reductions which could be expected when various field crops are irrigated with saline water.

Field crop	No reduction (dS/m)	10% reduction (dS/m)
Barley	5.3	6.7
Sugar beet	4.7	5.8
Canola	4.3	7.3
Safflower	4.3	NA
Wheat	4.0	4.9
Millet	4.0	4.8
Sunflower	3.6	3.9
Oats	3.3	4.2
Cotton	1.7	see note
Sesbania	1.5	2.5
Sugarcane	1.1	2.2
Faba bean	1.1	1.8

Linseed/flax	1.1	1.7
Maize	1.1	1.7
Peanut	1.1	1.4
Rice	1.0	1.3
Cowpea	10	1.7
Grain sorghum	1.0	1.4
Soybean	1.0	1.3
Beans (field)	0.7	1.0

Notes: During the early seedling stage of the most tolerant crops, ECw should not exceed 3.0 dS/m.

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