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UNDERGROUND TAMING OF FLOODS FOR IRRIGATION (UTFI) -

A NOVEL FORM OF CONJUNCTIVE WATER USE MANAGEMENT

V.K. Mishra | Chhedi Lal Verma | S.K. Jha | Navneet Sharma
Paul Pavelic | P.C. Sharma

ICAR- Central Soil Salinity Research Institute
Regional Research Station
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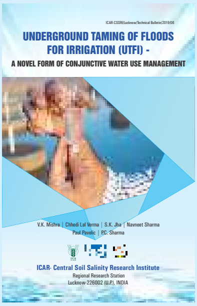

Cover photo: Recharged ground water sample

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Email : aaronmedia1@gmail.com

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INTRODUCTION

Climate induced extreme events such as floods and droughts are often disastrous in incidences and affects Indian economy. The global costs of floods are estimated to be in the order of US$ 16 billion per year whilst for drought (above-ground), it is US$ 3.5 billion per year (CRED, 2015). India is highly vulnerable to floods where flood prone area is about 40 million hectares (mha), out of the total geographical area of 329 million hectares. On an average every year, 75 lakh hectares of land is affected, 1600 lives are lost and the damage caused to crops, houses and public utilities is Rs.1805 crores due to floods (National Disaster Management Authority, 2008). It has been estimated that around 20 percent of the world's aquifers are over-abstracted and groundwater dependent ecosystems under threat (Connor, 2015). Groundwater use for irrigation is significant and increasing day by day. In general, it provides farmers with a reliable source of water that can be used in a flexible manner. Currently, in India, about 60 per cent of the cultivated area is irrigated by groundwater (Sikka et al., 2017). This indicates that as groundwater over-exploitation became severe, as a result the overall economic future of regions may become uncertain. The Indo-Gangetic Plain, Northwestern, Central and Western parts of India account for most intensive groundwater based irrigation. Among these, western India and the Indo-Gangetic Plain have more than 90% of the area irrigated by groundwater. Based on Central Ground Water Board (CGWB) data of nearly 5,900 wells which have long-term data (1996–2016), Mishra et al., (2018) reported that a majority of districts in India experienced significant depletion in groundwater storage. The districts with significant decrease in groundwater are mainly located in the Indo-Gangetic Plain, Northwest, and Central (Maharashtra) regions. Punjab has been witnessing a steep decline in groundwater table since 1996 with a declining rate of 91 cm per year. In northwestern India, the amount of groundwater extraction exceeds the total recharge, leading to groundwater depletion. As per National Water Mission (NWM, 2011), Out of 820 blocks in Uttar Pradesh, 111 blocks were under the overexploited category, 68 under critical, 82 semi-critical and 559 under the safe category. If groundwater is depleted and the region experiences drought for 2-3 years consecutively, there will be serious challenges with respect to availability for irrigation and drinking water. Natural recharge during monsoon may not help much if groundwater depletion becomes acute. Thus, there is a great potential for exploring various resource enhancing measures including conjunctive use of surface water and groundwater to meet rising demand in both rural and urban settings.

To address the dual problems of groundwater depletion and floods, a novel approach Underground Taming of Floods for Irrigation (UTFI) has been developed.

UTFI CONCEPT

UTFI a novel form of conjunctive water use management technology involves strategically recharging aquifers that have latent or depleted groundwater storage capacity with wet-season high flows, thus preventing flooding and adding to groundwater storage locally, as well as mitigating flooding in rural or urban areas. The concept is best reflected visually as illustrated in fig. 1. Capture and storage of high wet season flows that potentially pose a flood risk, take place through groundwater recharge structures (interventions) installed in upstream areas for the protection of highly valued assets (urban, industrial, cultural, etc.) locally and in downstream areas. This would then enable the recovery of water stored underground for productive use and livelihood enhancement. Therefore, in a sense, the impacts that would be felt across one part of the system could be offset to create opportunities in another part. UTFI is a specific and unique application of managed aquifer recharge (MAR). Recharge

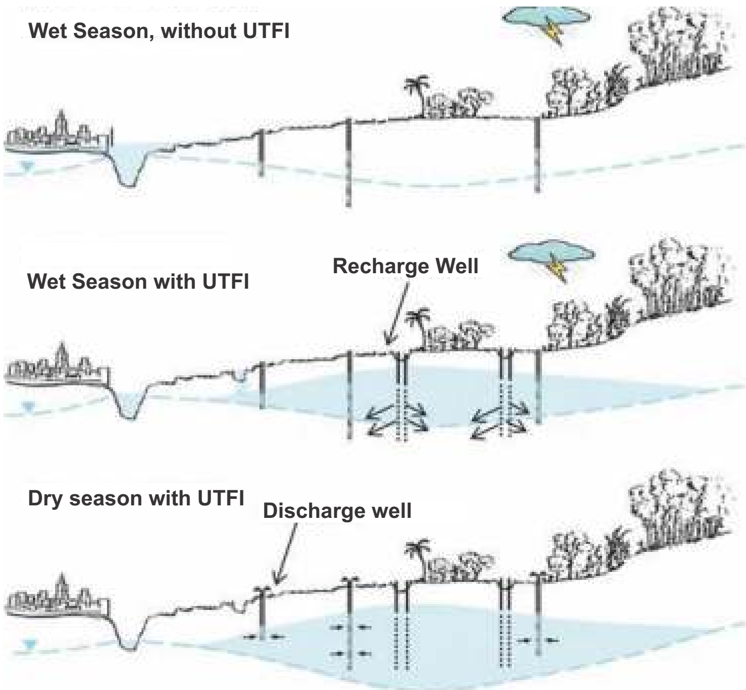

Fig. 1. The concept of UTFI

enhancing interventions across strategic parts of the basin to provide supplies to meet additional demand during the dry season, and for this water to be recovered via agricultural wells rather than allowing surface water to concentrate and be problematic in the flood plain areas.

SITE SELECTION CRITERIA

Selection was on the basis of a broad scale assessment of UTFI suitability covering the entire Ganges basin which revealed that much of the alluvial plains in the lower part of the basin are potentially well-suited (Brindha and Pavelic 2016). The favorable conditions for UTFI has been illustrated by Pavelic (2007) in table 1. In present pilot study, ten watersheds were selected from the Ram Ganga sub-basin situated in the Upper Ganga basin in Uttar Pradesh, India for field survey and subsequent ground-truth verification which helped to validate the mapping to some extent. Eleven villages within the Ram Ganga sub-basin were visited in April 2015, of which, 5 were short-listed and re-visited in May 2015. The details are presented in table 2. Based on all the desktop analysis and field visits, Jiwai Jadid village in Rampur district, Uttar Pradesh, India was chosen after the critical analysis of the suitability of the site from various considerations such as accessibility (approach road), ownership of pond, size of pond, distance from canal network, interest shown by the village community, decline in groundwater table and occurrence of flood and contamination of the pond with waste water.

Table 1. Favorable conditions to implementation of UTFI and key design considerations (Pavelic 2017)

Target aquifer	Typically, shallow depths< 50 m, under unconfined or semi-confined conditions
Site selection	Regular flood/drought occurrence and impact, fresh/transmissive aquifers, adequate depth to water table
Recharge method	Surface methods (basins, ponds etc.) for areas with permeable soils and unconfined areas or sub-surface methods (wells) for other areas
Design	Simple, low-cost technologies with adequate pretreatment of source water, manageable by local communities
Frequency of operation	Intended to capture excess flows, not necessarily in equal proportion in all the years
Operation and maintenance	Local communities working in partnership with the authorities

Table 2. UTFI first pilot trail site selection criteria.

Parameter	Jiwai Jadid	Aanga	Kesharpur	Bansipur Baknowri (site 1)	Bansipur Baknowri (site 2)
Flooding	X	X	X	-	X
Declining water table	X	X	X	X	XX
Nearness of canal/river	XXX	XXX	XXX	X	XXX
Number of ponds	2	1	1	2	2
Ease of access	XXX	XXX	XXX	XXX	XXX
Ownership of pond	Gram Panchayat	Private	Private	Gram Panchayat	Private
Ranking	2	1	3	5	4

LITHOLOGY OF STUDY AREA

The study of aquifer lithology is important as it facilitates identification of areas with favourable aquifer disposition, aquifers thickness and volume besides, aquifer boundaries and interconnectivity between adjacent aquifers. This information has implication in lateral groundwater movement, water exchange between adjacent aquifers, contaminant transport studies, and studies for artificial groundwater recharge (Tait et al., 2004; Srivastava, 2005; Samadder et al., 2007).The lithology of piezometers down to 24 and 30 m depth indicates (Fig.2) that the upper layer of soil around 3-4 m are clay in nature. The first aquifer which is lie below the top soil extend 5 to 8 m. This is most utilized and tapped aquifer for drinking water. Second aquifer is extending from 16 to 30 m and which is mainly utilized for irrigation by shallow tubewells .

UTFI STRUCTURE

(a) POND:

Jiwai Jadid village of Rampur District does not have a sewerage system and the wastewater from the household are disposed in three ponds located in the village. The wastewater from ~12 households was coming directly to the pond which was selected for UTFI piloting, and the water colour was blackish prior to setting up of trial. Alternate arrangements were made for the domestic wastewater and sewage in the form of lined drains so that it does not reach this pond and affect the quality of water being recharged. The top soil in the pond were clayey which was observed during the field visits and hence direct

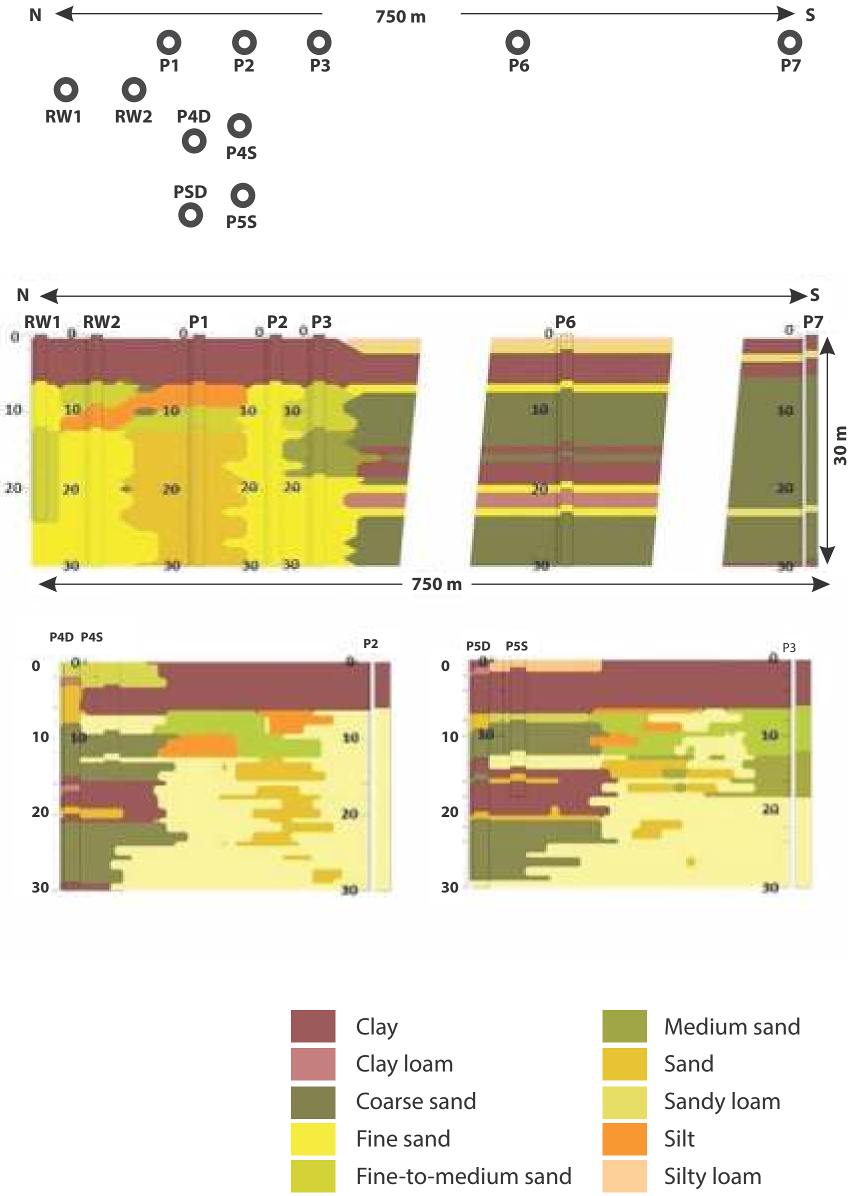

Fig. 2. Lithology of Piezometers site

infiltration of flood water from the pond will not be effective. This led to the inclusion of recharge wells in the UTFI design. The pond was dewatered and excavated upto the depth of 2 m with the base of the pond measuring an area of 2625 m^2 (75m x 35m). The excavated soil was used to dress the embankment and side slop of the pond. A cross-section of the pond is given in (Fig. 3). To avoid the wastewater that was entering the pond, it was diverted away from the pond through a drainage channel constructed specifically for this purpose. The modified pond is presented in Fig 4.

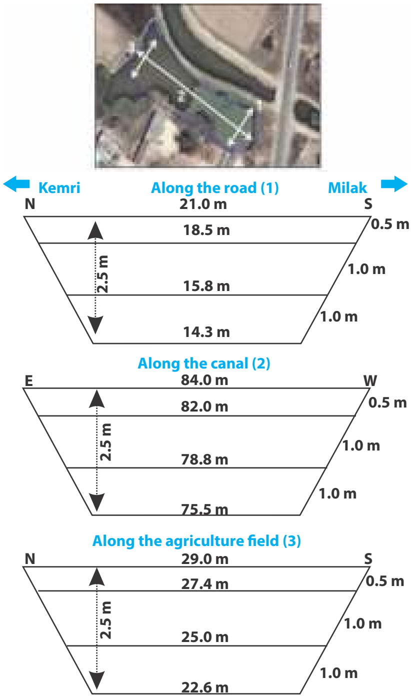

Fig. 3. Cross section of the pond along different traverses

Before UTFI After UTFI

Fig. 4. Pond selected for UTFI at Jiwai Jadid village, Rampur

(b). RECHARGE WELLS (RWs)

The diameter of the recharge well was 15 cm and the installation depth < 50m was considered for UTFI according to aquifer layer. Brick wall diameter of circular filter box was kept 1.5 m and 3.0 m. The height of the filter box above ground surface was 1.0 m which was taken as dead storage of the pond. Two variations of filter and depth of recharge were tested in order to ensure the prolonged functioning of the system. i) The depth of blind pipe was 6.0 m and corresponding depth of perforated pipe was 18.0 m with filter box diameter of 1.5 m. ii) The depth of blind pipe was 12.0 m with corresponding depth of perforated pipe was 18.0 m for filter box diameter of 3.0 m (Fig. 5)

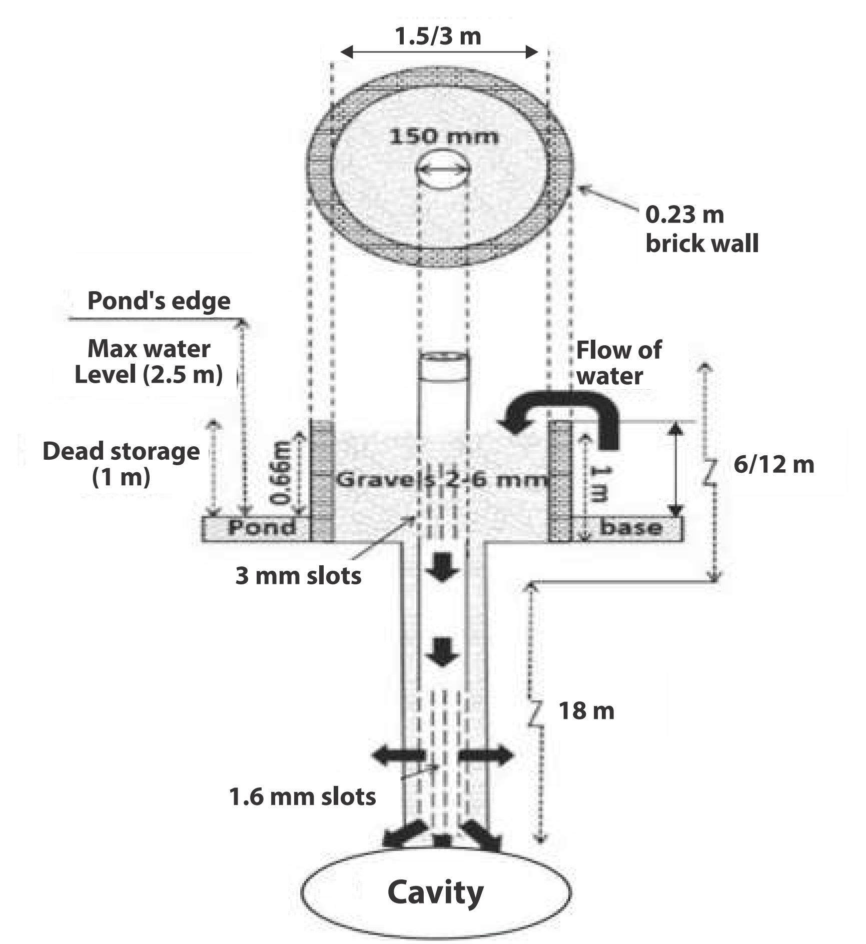

Fig. 5. Recharge wells design

Ten recharge wells were drilled and constructed in the pond. PVC pipe of 15 cm in diameter was installed in the center with gravel filters around them. The height of these structures from the bottom of the pond was 1 m and was packed with pea gravels to filter out suspended silts and ensure higher rates of groundwater recharge (Pavelic et al. 2015). Five of these recharge wells along with the well works (i.e. gravel filter chamber made of bricks) were of 3 m diameter and five other recharge wells were 1.5 m diameter. Comparison of various characteristics in these two wells are given in Table 3.

Table 3. Comparison of various features of the recharge wells

Characteristics	Specifications	
Filter diameter	1.5 m	3 m
PVC pipe diameter	150 mm	150 mm
Gravel packing diameter	1.5 m	3 m
Height of the gravel packing	1 m	1 m
Thickness of filter wall	0.23m	0.35 m
Length of PVC pipe	24 m	30 m
Length of pipe screen from bottom of pipe	18 m	18m

(c). RECHARGE FILTER

This is the most important element of a recharge system. It checks entry of silt and other foreign materials in to the recharge system. Media filters are being commonly used for recharge system. Two variants of brick walled circular filter boxes of 1.5 m and 3.0 m diameter were tested for prolonged recharge. The height of the filter box above ground surface was 1.0 m which was taken as dead storage of the pond. Pea gravel was filled inside the circular filter boxes (Fig 6).

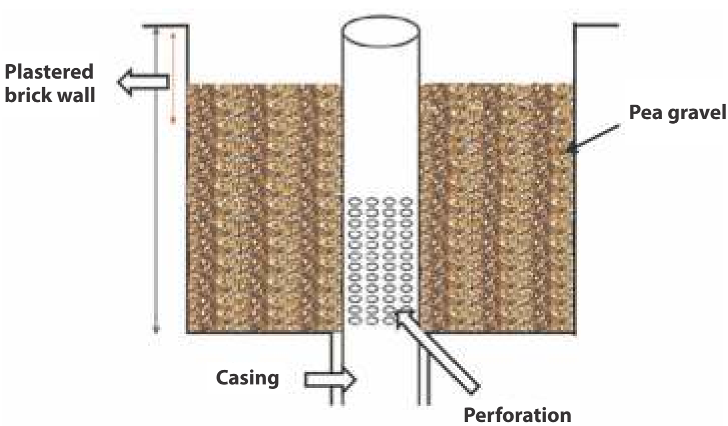

Fig. 6. Particle size distribution and gravel pack.

(d). MODIFIED RECHARGE WELL FOR MEASUREMENT OF WATER RECHARGE RATE

To measure the recharge rate of the wells, two wells (3 m and 1.5 diameter) were modified. These wells are termed 'modified' because the height of the brick wall surrounding the well was raised 1 meter extra. A hole was made in the wall for the water to enter inside (Fig.7). The hole can be closed after the well is filled with water. The fall of the water level in the modified well was measured over the time to estimate the recharge rate.

Fig. 7. Modified Recharge wells for measurement of water recharge rate

(e). DE-SILTING CHAMBER

Basic purpose of de-silting chamber is to remove silt and fine sand from recharge water in order to avoid its entry in the filter box and recharge well. The size of the de-silting chamber was decided based on the following assumption.

Assuming, a stream 30 liter/ sec is entering the de-silting chamber of 3.0 m x 2.0 m x 1.5 m size. The velocity of flow will become 0.01 m/sec [(30/1000) / (2.0 x 1.5)]. Desired length of de-silting chamber can be calculated by the water to travel in 150 sec. Therefore, the length can be calculated as 0.01 m/sec x 150 sec= 1.5 m. If 0.30 m is the flow stabilizing section at the entry and 0.30 m at the outlet of the de-silting chamber, the length will become 1.5 m + 0.30 m +0.30 m = 2.10 m. Since the water is in moving stage the settling efficiency will be low (settling efficiency =65-70%). The effective length of settling zone becomes 2.31 m (1.5 m/0.65=2.31 m). Thus, total length of the de-silting chamber becomes 2.31 m + 0.30 m + 0.30 m= 2.91 m i.e. 3.0 m. Based on computation, the silting chamber (3 x 2 x 1.5 m with 0.23 m wall thickness) was built at the point where the water enters into the pond (Fig. 8).

Fig. 8. De-silting chamber

(f). PIEZOMETERS

Monitoring wells were installed to monitor the impacts of recharge, groundwater levels and groundwater quality. For this, a groundwater model Visual Modflow V.4.6 was used to identify the groundwater flow direction and spatio-temporal changes. Based on the results, three piezometers (P1, P2 and P3) were installed initially near the pond (depth 30 m) along the direction of groundwater flow at 5, 10 and 15 m distance from the pond for monitoring the response of in water level due to recharge. Vertical cross-section of the piezometers is given in Fig.9. Six more piezometers were installed later in 2016

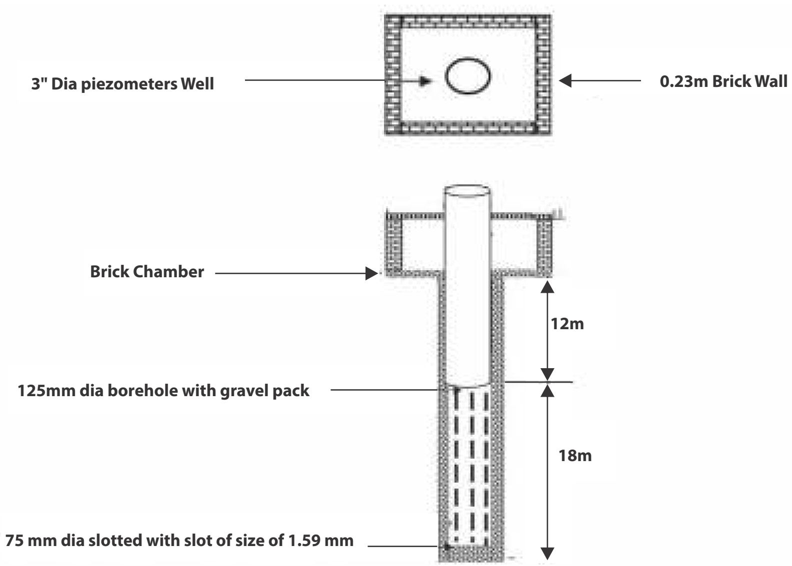

Fig. 9. Cross sectional view of piezometer

towards south direction of the pond. Out of the 6 piezometers, P4D and P4S were installed in the vicinity of the pond (6 m from the south edge of the pond) and aligned with the 4th row (located in the ~middle of the pond) of the recharge wells. Piezometers P5D and P5S are installed on 20 m south of P4D/P4S. The depth of the deep piezometers (P4D and P5D) and shallow piezometers (P4S and P5S) are 30 m and 12 m, respectively. At a distance of 100 m of the south edge of the pond, a piezometer (P6) was installed with a depth of 30 m. Finally, a control piezometer (P7) was installed at a distance of 700 m towards south of pond with a depth of 30 m.

RAINFALL PATTERN

Total rainfall was 857.9 mm and the numbers of rainy days were 23 during the recorded period of 25th June to 31st December, 2016 in Rampur district (Fig 10). During the recharge period total rainfall 736.5 mm was recorded, maximum

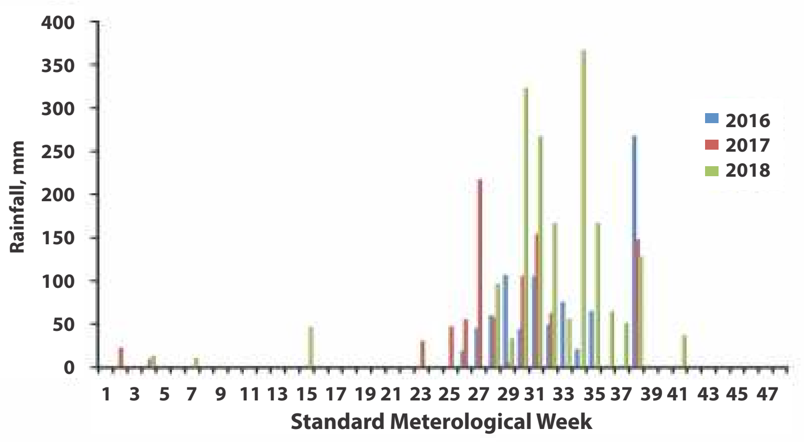

Fig. 10. Rainfall pattern of Rampur district

(266.7 mm) and minimum (5 mm) rainfall was on 22nd September and on 29th July respectively. Total 14 rainy days were observed during the whole recharge period from 15th July to 7th October 2016. In 2017, total rainfall was recorded 905.3 mm with 20 number of rainy days. During the recharge period from 17th July to 7th August, total rainfall 471.7 mm was measured with maximum 147 mm and minimum 5 mm on 22nd September and on 17th July, 2017 respectively. Total rainfall of the area was 1811.8 mm and the number of rainy days was 28 during the recorded period of 1st January to 31st November, 2018. During the recharge period, total rainfall of 992.4 mm was recorded with rainfall depth of maximum (269.7 mm) and minimum of (7.5 mm) were recorded on 25th August and on 28th July August respectively. Twelve rainy days was observed during recharge period of 6th August to 6th October 2018.

MEASUREMENT OF RECHARGE RATE OF THE WHOLE SYSTEM

To fill the water into the pond, excess canal water during rainy season was diverted by siphon pipe. At the time of measurement, the entry of water into the pond was stopped and the drop of water level in pond was recorded over the time. The volume of water present in pond against corresponding water depth in pond was calculated using incremental surface area of water surface against associated water depth in pond. A relationship between depth of water in pond and volume of water in pond was developed as under

$$V_{h_t} = 1164.8333 \times h_t + 133.6666 \times h_t^2 \qquad (1)$$

Where,

V_{ht} = Volume of water present in pond at time, t (m^3)

h_t = Depth of water in pond at time, t (m)

Recharge rate of pond as a unit was estimated by computing volumes of water against time t_i and time t_f for water depth drop from h_i to h_f using equation (2).

$$R_t = \frac{V_{hi} - V_{hf}}{t_f - t_i} \qquad (2)$$

R_t = Recharge rate at time, t

V_{hi} = Initial ($t=t_0$) volume of water in pond (m^3)

V_{hf} = final volume of water in pond at time, t=t (m^3)

t = Time, (day)

Total volume of water recharge was calculated using the equation (3)

$$V_R = \sum_{i=1}^{N} R_{ti} \Delta t_i \qquad (3)$$

V_R = Volume of water recharge, m^3

R_{ti} = Recharge rate at time t_i

$\Delta_{ti=}$ time interval = ($t_{i=1}$-t_i)

RECHARGE RATE AND VOLUME OF WATER RECHARGED BY WHOLE SYSTEM

The recharge rate of whole system and cumulative water recharge volume are shown in fig.11 &12. In recharge season 2016, the total recharge from the entire system was determined to be 40,067 m^3 or on average 471.4 m^3/day over 85 days of operation. Recharge rate started at 997 m^3/day and gradually declined to 220 m^3/day before

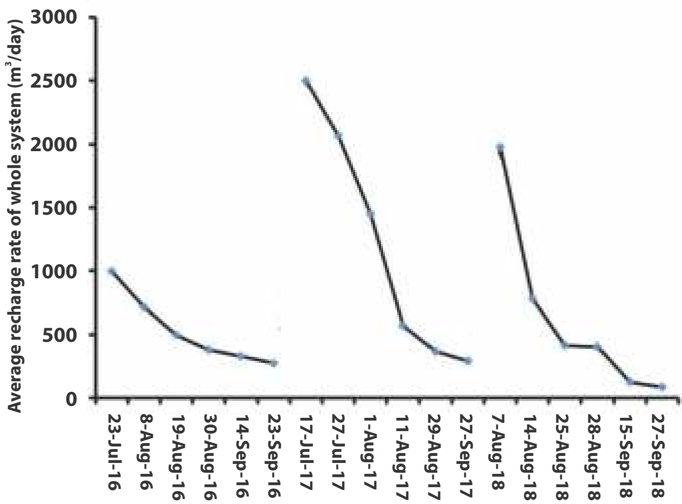

Fig.11. Recharge rate of whole system

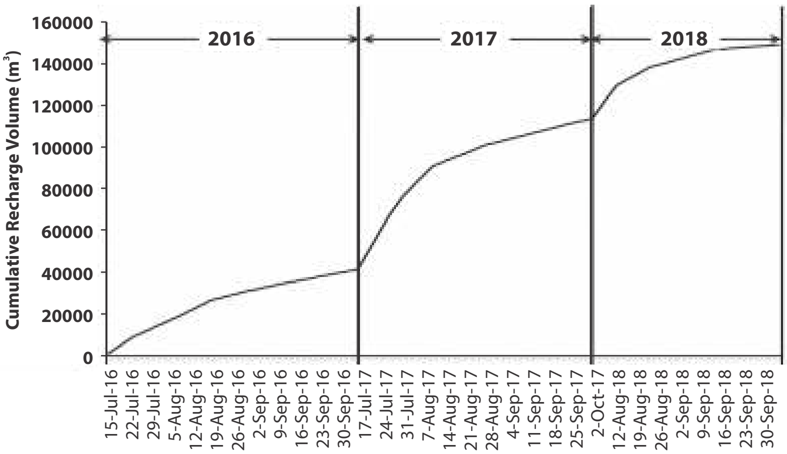

Fig. 12. Cumulative water recharge volume

the water level in the pond declined below the intake level for the recharge wells. These changes in recharge are typical of the anticipated patterns of recharge rate over the course of the system as a result of siltation due to the introduction of the recharge of turbid water. The pilot system could provide 500 mm of supplementary irrigation water in the dry season to irrigate about 8 ha of crop land.

In 2017, the total recharge from the entire system was determined to be 72426.51 m^3 or on average 1207.14 m^3/day over 78 days of operation. Rates of recharge started at 2499 m^3 /day and gradually declined to 289.44 m^3/day before the water level in the pond declined below the intake level for the recharge wells. These changes in recharge are typical of the anticipated patterns of recharge rate over the course of the system as a result of siltation due to the introduction of the recharge. The pilot system could provide 500 mm of supplementary irrigation water in the dry season to irrigate 29 ha of crop land .

In 2018 the total recharge from the entire system was determined to be 35253 m^3 or on average 568.60 m^3/day over 62 days of recharge period. Rates of recharge started at 1978 m^3/day and gradually declined to 85 m^3/day before the water level in the pond declined below the intake level for the recharge wells. The pilot system could provide 500 mm of supplementary irrigation water in the dry season to irrigate 14.10 ha of crop land.

GROUND WATER LEVEL

Ground water level in piezometers for the periods of 2016, 2017 and 2018 are presented in (Fig 13). Water level was lowest in all piezometers on 15th June 2016 (6.44 m bgl), 24th June, 2017 (6.58 mbgl) and 30th June 2018 (6.63 m bgl). Hence, it was treated as reference value for water table build up of respective year. The rise in groundwater levels was on an average 2.78, 2.84 and 4.43m in 2016. 2017 and 2018, respectively due to water recharge. Water table build up during the year 2018 was much higher compared to the water table build up during year 2016 and 2017 due to high rainfall, however, ground water level in the piezometers attained the same reference level in month of June.

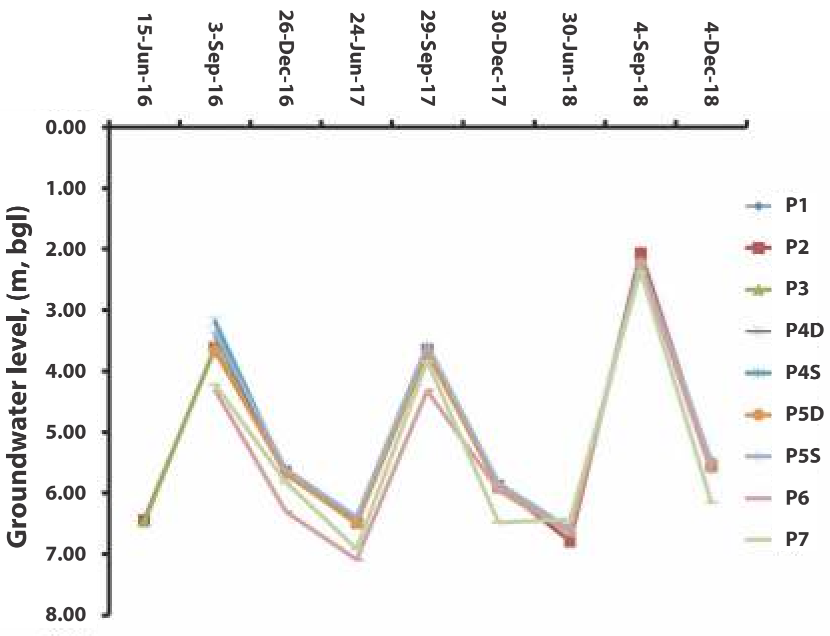

Fig.13. Ground water level

SILT LOAD IN UTFI SYSTEM

Silt load in canal water was measured by taking water samples at different time intervals during recharge period. Samples were analysed and total suspended sediment (TSS) load were worked out. The slit load deposition in pond bottom (75 m & 66 m length and 20 m & 12 m width) was measured by dividing the bottom area into 18 grids and silt samples were collected from each grid during summer season. Length of soil sampling grid at bottom of the pond is shown in fig 14. To avoid the erosion effect of embankments on silt load distribution, samples were collected from 1.0 m away from toe of the pond embankments. Silt load deposited in the bottom was vertically cut and depth of silt deposition was measured.

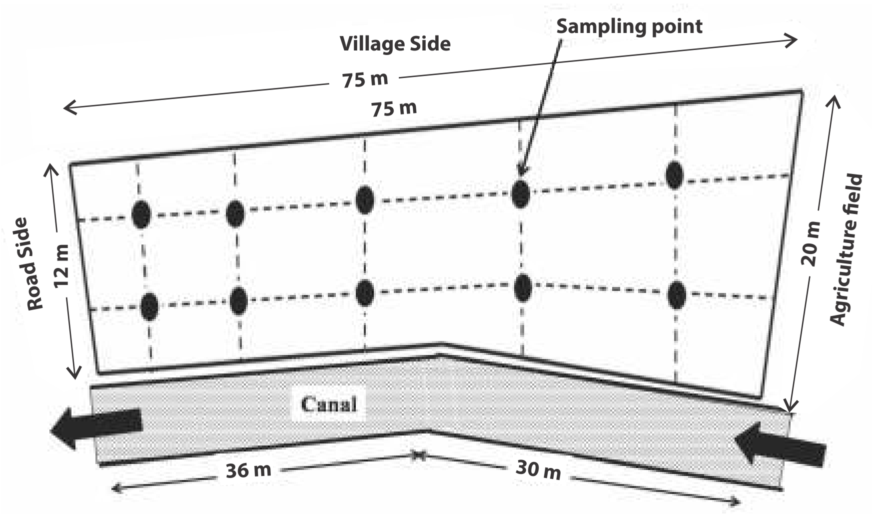

Fig.14. Pond base silt sampling locations points

Total silt load entered in pond through canal water was 13.18 and 22.50 tons during 2016 and 2017, respectively (Fig 15). Total accumulated silt load at pond bottom was recorded 12.18 tons and 21.17 tons during 2016 and 2017, respectively. The deference amount of total silt load entered in pond and deposited silt in pond bottom is supposed to be entered in recharge well and it was computed 1.27 ton 2016 and 1.33 ton in 2017.

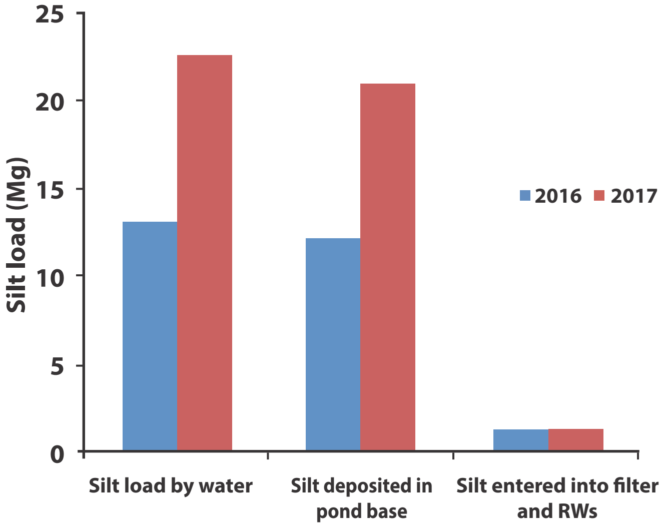

Fig.15. Silt load distribution

SILT LOAD IN GRAVEL FILTER

Gravel samples were collected at periphery and centre of filter box from surface to 0.60 m depth to assess the trapped silt within the filter medium. Sampling locations shown in fig.16 and 17. The silt distribution with depth at centre and periphery are shown in fig. 18 and19. The trapped silt percentage increase with depth in case of filter having 1.5 m diameter and decreased with depth in case of filter having 3.0 m diameter. Percent silt trapped at periphery were 5.37, 9.19, 9.40 and 9.29% and at centre 4.38, 7.30, 7.76 and 8.58% at corresponding gravel depth of 0-15, 15-30, 30-45 and 45-60 for the recharge filter with 1.5 m diameter. Similarly, percent silt trapped in filter box of 3.0 m diameter were 8.23, 7.18, 4.93 and 3.84% at periphery and 7.30, 6.95, 5.15 and 4.93% at centre at corresponding gravel depth of 0-15, 15-30, 30-45 and 45-60 cm, respectively.

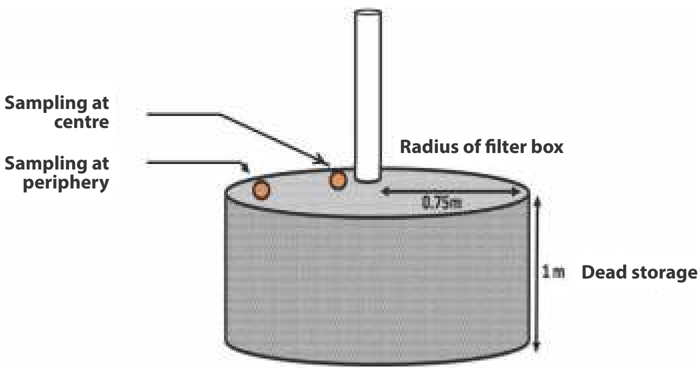

Fig.16. Filter gravel sampling locations structure with 1.5 m filter diameter

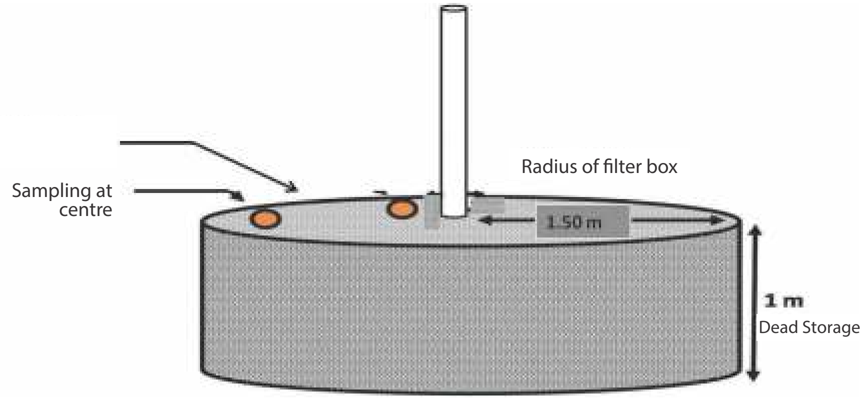

Fig.17. Filter gravel sampling locations structure with 3 m filter diameter

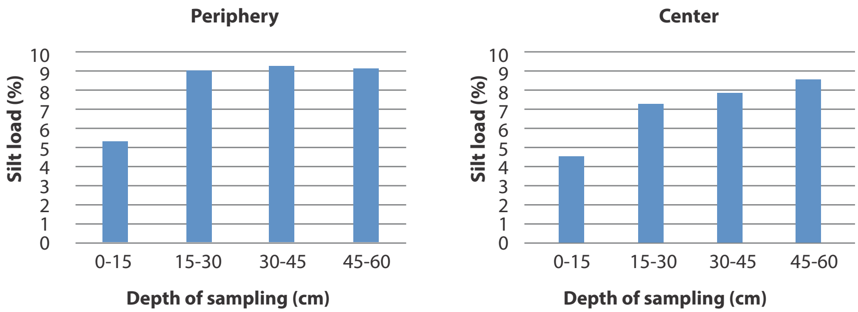

Fig.18. Percent of silt load trapped in pea-gravel structure with 1.5 m filter diameter

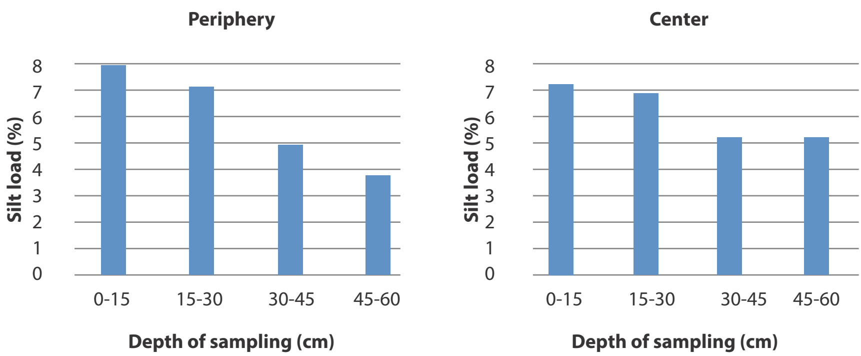

Fig. 19. Percent of silt load trapped in pea-gravel structure with 3 m filter diameter

CLEANING OF RECHARGE WELLS BY COMPRESSOR

The depth of the RWs was measured to estimate the silt depth accumulated in the wells just before cleaning of recharge wells by compressor. Mass of silt was calculated based on the density and volume of silt. The range of total silt deposited in the well prior to cleaning were 110.69 to 188.38 kg in recharge well of 1.5 m filter diameter and 73.02 to 142.42 kg in the recharge well of 3.0 m filter diameter (Table 4). Average silt deposition in large filter box was less compared to the silt deposition in recharge well of 1.5 m. The total silt deposit in recharge well was almost same as computed by the method of concentration of suspended particle in water.

Table 4. Details of recharge well cleaning through compressor

Wells ID	Silt load in pipe, kg	Silt removed from recharge well,kg	Extra silt removed, kg	Avg. cavity diameter, m
Recharge wells with filter box of 1.5 m diameter				
RW-1	156.75	2549.95	2393.20	0.816
RW-2	139.26	3946.04	3806.78	1.298
RW-3	142.43	1005.21	862.78	0.294
RW-4	188.38	1072.90	884.52	0.302
RW-5	110.69	533.32	422.63	0.144
Recharge wells with filter box of 3.0 m diameter				
RW-1	95.70	411.89	316.19	0.108
RW-2	142.42	1468.00	1325.58	0.452
RW-3	117.55	126.87	9.32	0.003
RW-4	88.16	168.01	79.85	0.027
RW-5	73.02	497.43	424.41	0.145

Cleaning of recharge well by compressor

Total silt removed from recharge wells ranged from 533.32 to 3446.04 kg and 126.87 to 1468 kg for recharge wells having filter diameters of 1.5 and 3.0 m, respectively. Extra silt removed from five recharge wells were 2393.20, 806.78, 862.78, 884.52 and 422.63 kg with 1.5 m dia filter box and 316.19, 1325.58, 9.32, 79.85 and 424.41 kg with 3 m dia filter box. Average cavity diameters were 0.816, 1.298, 0.294, 0.302 and 0.144 m and 0.108, 0.452, 0.003, 0.027 and 0.145 m for the recharge wells having 1.5 m and 3 m filter box respectively.

WATER QUALITY

The water quality was monitored periodically from nine piezometers, recharge wells, canal during pre-recharge (April), recharge (August-September) and post recharge periods (November).

The physico-chemical characteristics of overall water quality of canal are shown in (Table 5). The pH of the water was alkaline which varied from 7.69 to 8.40 and the electrical conductivity (EC) was low (0.51-0.62 dS m^{-1}). The water was dominated by Mg^{2+} ions which followed the dominance order as $Mg^{2+} > Ca^{2+}$.> Na+ > K+ while among the anions, HCO_3^- ion was dominant following the order as $HCO_3^- > Cl^- > SO_4^{2-} > CO_3^{2-}$. The total dissolved solid (TDS) in the canal water was within the maximum permissible limit of 2000 ppm (Fig.20), as prescribed by BIS (2012)., With respect to heavy metals contamination in the canal water, these were present within the permissible limit as laid down by World Health organization (WHO, 2008) except arsenic (As) which was slightly higher (19.0 ppb). However, it was found to be within permissible limit of 50 ppb, as prescribed by Bureau of Indian Standard (BIS, 2012), for the use in absence of alternate sources. This may be due to the contamination of river Pilakhar, a tributary of the Ramganga with heavy loads of industrial effluents discharged from cotton, chemicals, leather, furniture, paper, rubber, Plastic, steel fabrication, and various engineering units (CPCB, 2013; MSME, 2016-17). This led

Table 5: Physico-chemical characteristics of canal water

Parameter	Minimum	Maximum	Mean + SD
pH	7.69	8.40	8.06 ± 0.35
EC (dS m^{-1})	0.51	0.62	0.57 ± 0.05
Ca^{++} (meq l^{-1})	1.50	2.50	2.00 ± 0.41
Mg^{++} (meq l^{-1})	4.00	5.00	4.50 ± 0.41
Na^{+} (meq l^{-1})	0.42	0.61	0.51 ± 0.08
K (meq l^{-1})	0.07	0.15	0.12 ± 0.03
CO_3^{--} (meq l^{-1})	1.00	1.00	1.00 ± 0
HCO_3^- (meq l^{-1})	3.00	6.50	4.38 ± 0.55
Cl^- (meq l^{-1})	1.50	2.50	2.00 ± 0.41
SO_4-- (meq l^{-1})	0.30	2.40	1.48 ± 0.87

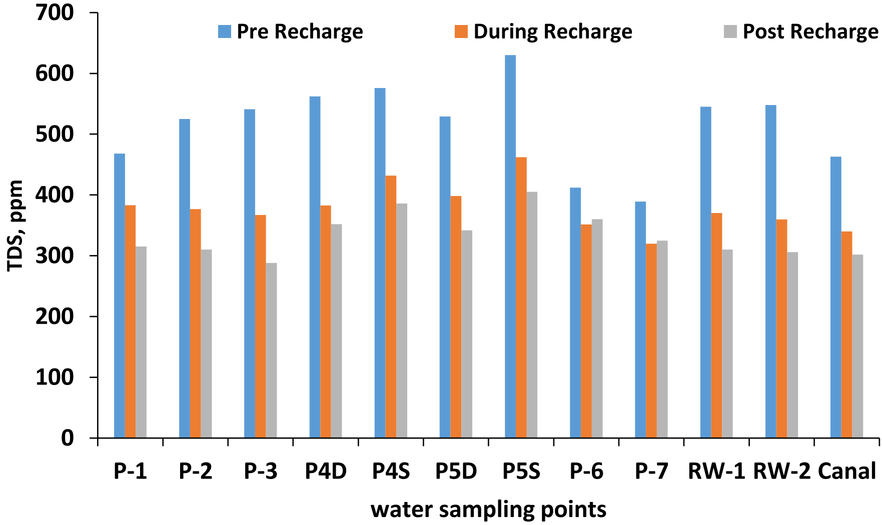

Fig. 20. Variation of total dissolved salts (TDS) in water at pre-recharge, during recharge and post recharge period

to the contamination of toxic heavy metals in the Pilakhar canal that runs through the recharge site. The fluoride concentration was also found to be in the range of 100-700 ppb, within the maximum permissible limit as laid down by both World Health Organization and Bureau of Indian Standards. The nitrate concentration in the canal water varied from 12600 to 17000 ppb with a mean value of 15200 ppb, which was within the permissible limit of 50,000 ppb as per WHO (2008). The mean ammonical nitrogen (NH4-N) was found to be 290 ppb.

The other chemical parameters such as soluble cations (Na^+, K^+, Ca_2^+, Mg_2^+) and anions CO_3^{2-}, HCO_3^-, Cl^-, SO_4^{2-}) were also monitored periodically (Table 6). The most of the water samples before the recharge operation fall in the field of Mg-HCO_3 which is dominant followed by mixed types of Ca-HCO_3 and Ca-Mg-Cl

Table 6: Descriptive statistics of overall water quality parameters of piezometers and recharge wells

Statistical parameter	pH	EC (dS m^{-1})	CO_3^{2-} (meq l^{-1})	HCO_3^- (meq l^{-1})	Cl^- (meq l^{-1})	SO_4^{2-} (meq l^{-1})	Na^+ (meq l^{-1})	K^+ (meq l^{-1})	Ca_2^+ (meq l^{-1})	Mg_2^+ (meq l^{-1})
Mean	7.61	0.72	0.67	3.21	2.22	1.41	1.08	0.16	2.14	4.10
S.E.	0.08	0.03	0.09	0.15	0.10	0.08	0.07	0.02	0.10	0.16
Median	7.58	0.73	1.00	3.25	2.50	1.45	0.99	0.13	2.00	4.00
Mode	8.11	0.78	1.00	2.00	2.50	1.50	1.90	0.08	2.50	4.00
S.D.	0.47	0.17	0.53	0.93	0.59	0.48	0.42	0.11	0.63	0.95
Min.	6.74	0.41	0.00	2.00	1.00	0.40	0.51	0.03	1.00	2.50
Max.	8.43	1.07	2.00	5.50	3.50	2.30	1.95	0.43	3.50	6.00
Confidence Level (95.0%)	0.16	0.06	0.18	0.31	0.20	0.16	0.14	0.04	0.21	0.32

types. During recharge operation, there was slight change in the dominance pattern of ions. About 87% of the water samples were found to be of $Mg^{-}HCO_3$ type, dominated predominantly by Mg^{2+} and HCO_3^- ions. Few water types were $Ca^{-}HCO_3$ & $Mg^{-}Cl$.

HEAVY METALS AND FLUORIDE IN GROUND WATER

The iron concentration in ground water before and after recharge was found to be almost same which implied that using canal water for recharging had no significant impact on the iron concentration in groundwater. Before recharge, its concentration was 228.04 ppb, ranging between 217 to 240 ppb whereas during post recharge period, maximum and minimum values were 247.10 and 207.50 ppb respectively. The zinc concentrations before recharge ranged from 19.70 to 35.40 ppb with a mean of 28.14 ppb. During recharge its value increased to 32.57 ppb while in post recharge, the value decreased to 11.45 ppb. The zinc concentration was found to be within the permissible limit as laid down by BIS (2012). The Manganese concentration in ground water was highest (27.81 ppb) during recharge. However, its value was lowest (17.63 ppb) after completion of recharging. The arsenic concentrations in the samples before recharge ranged from 8.1 to 20.1 ppb with a mean value of 12.06 ppb, which is above the permissible limits of World Health Organisation (WHO, 2008). The mean value of arsenic concentration was found to be increased (14.51 ppb) slightly after recharge which may be due to significantly higher loads of arsenic in the canal water. Although lead is one of the most abundant toxic metals in earth's crust, its mean concentration during pre recharge period in groundwater was 2.80 ppb, which was within the permissible limit. Post recharge indicated lower concentration of 2.39 ppb, may be due to the dilution effect. The presence of chromium, Cobalt and Nickel were present within the permissible limit during both pre and post recharge period as well as in canal water. The mean concentration of mercury in the canal and ground water during pre-recharge period was 3.84 and 1.88 ppb, respectively which decreased to 1.12 ppb during post recharge which is close to the permissible limit of 1.0 ppb, as laid down by Indian Standards (BIS, 2012).The mean fluoride concentration before recharge in groundwater of this area was 309.6 ppb whereas the canal water had fluoride content of 410 ppb. The post recharge fluoride content was found to be 277.04 ppb. The fluoride content was within the permissible limits of 1000 ppb, as laid down by Bureau of Indian Standards (BIS, 2012). The nitrate (NO_3), phosphate (PO4) and ammonical nitrogen (NH_4-N) in the canal as well as groundwater (pre recharge and post recharge period) was found to be within the permissible limit. The total dissolved solid (TDS) were found maximum in the piezometers with shallow depths (P5 and P7) and varied between 389 ppm to 630 ppm during pre-recharge period while the TDS of canal water was found to be 468 ppm only in this period (Fig 21). During recharge period, 2017 the TDS was low due to dilution factor. The TDS exceeded the desirable limit of 500 ppm as per Bureau of Indian Standards (WHO, 2008; BIS, 2012) in most of the samples during pre-recharge period while it was acceptable during recharge and post recharge periods.

The result suggested that there exists the prevalence of high heavy metals concentration in the groundwater of the area and the intervention of UTFI technique helped in reducing the toxicological exposure by diluting the concentration of the contaminants in groundwater.

HEAVY METALS IN FARMERS' TUBE WELLS

In our study, the heavy metal analysis in the waters of farmers' tube wells located in up-stream and down-streams to the recharge structure revealed higher arsenic, chromium, mercury and lead concentration than the acceptable limit prescribed by the Indian standards (BIS, 2012) as shown in Fig. 21 while nickel was nearly equal or little higher in two of the tube wells than the acceptable limits. The results suggested that there exists the prevalence of high heavy metals concentration in the groundwater of the area.

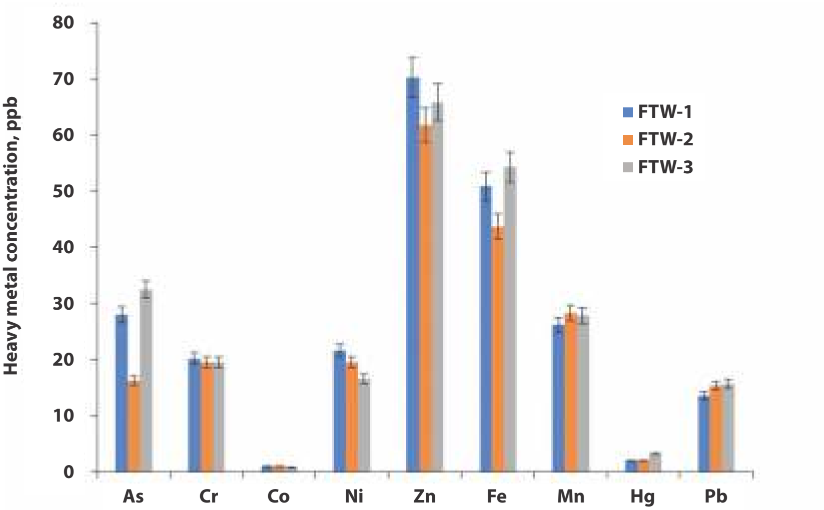

Fig. 21. Heavy metals content in farmers tube well water

COST OF UTFI SYSTEM

The cost of recharge system with an existing pond system was calculated component wise. Cost estimation of recharge well and a desilting chamber is presented in Table 7. The total cost of the one set of recharge unit (Five recharge wells + one desilting chamber) was estimated of Rs. 377500=00.

Table 7. Estimated cost of a recharge system with five recharge wells

Details	Quantity	No. of person require	Cost (using MNREGA)
Cost of digging and Dressing pond			
Renovation of existing pond (2500m^2)			25000
Total (A)			25000
Cost of the system with five recharge well and one desilting chamber			
Details	Charge Rs. per unit	Units	Cost (Rs)
Drilling (30 m)	21000	5	105000
Well development	4000	5	20000
PVC pipe 150 mm (pressure 6 kg/cm^2) and 30 m length	18000	5	90000
Brick filter box of 3 m dia & height 1.0 m	15000	5	75000
Pea gravels	7500	5	37500
De-silting chamber (3 m x 2 m x 1.5 m)	25000	1	25000
Total (B)			352500
Grand total (A+B)			377500

PRECAUTION DURING OPERATION OF UTFI

1. Recharge should only take place during the monsoon season when there are high flows in canal. It should not take place in the dry seasons even if there are flow available (as it competes water use for irrigation)

2. Avoid the diversion of water flows into the recharge structure at the very beginning of the season (i.e. for the first few rainfall spells) so that water with heavy silt load and contaminants does not enter into the recharge structure.

3. Recharge operations should be stopped whenever any abnormality is observed at the site or the de-silting chamber is filled/clogged, recharge shafts not functioning, embankments breach, breach of diversion channel etc.

During water recharge volume measurement, the diversion of water flow from canal to silting chamber by siphon should be stopped

MAINTENANCE OF THE UTFI SITE

Regular (annual) maintenance of site is required to maintain an uninterrupted flow of water in the recharge wells so that the benefits from UTFI are achieved. Following points should be taken care off during maintenance of UTFI.

1. Village wastewater diversion drain channel (if any) should be maintained and cleaned before the start of the monsoon season and collection of run-off water in pond should be avoided.

2. Grass planting on embankment slope is an essential for its stabilization.

UTFI structure

3. The de-silting chamber should be cleaned by removing the deposited silt and moving it away from site.

4. The accumulated silt at the base of the pond must also be removed to maintain the storage capacity of the pond and surface infiltration. The de-siltation of the pond bottom should be done when the thickness of the silt layer is greater than 30 cm.

5. All pea-gravels in the brick structures should cleaned either by removing and washing by hand or else by using high pressure clean water. Once cleaned, the gravels need to put back in the brick structures carefully so the recharge well does not get damaged in the process. In some practices, it is common to use high pressure water to clean the filter materials inside the brick structures, however, it is not recommend because this method will only remove the silt from first few layers of filter materials and washed silt will be accumulated in the subsequent layers which will reduce the filter/recharge capacity eventually.

6. The recharge wells need to be cleaned using a compressor to remove silt deposited silt inside the recharge wells and fine particles that have blocked the slits on the recharge well will be cleaned in this phase. Due to inaccessibility to the recharge sites in remote rural areas, a tractor mounted compressor is recommended, which will easy to install near the recharge well. The minimum capacity of the compressor is to generate 300 psi pressure to clean the recharge wells effectively. Before starting the cleaning

process, it is required to check the presence of enough water in the well otherwise external clean water is required to be put in the well. After putting both the pipes (one for to create pressure in well, with comparative less diameter and other to suck out silt etc. from well with a larger diameter) in the well until the end (accessible) of the well, the compressor can be operated. Once the cleaning operation starts, it may be required to put more clean water in the well from time to time. Over the time the silt accumulated in the well will come out with water and the both the pipes needed to be lowered in the well. The process should continue till the clean water started to come out from the well. For each well the process could take 2 to 3 hours and at least 2 persons is required to operate. If the cost of a compressor is too high, then to minimize the cost an electric powered submersible pump can be used to clean the wells. The pump (1 or 1.5 HP) will be lowered in the well and used till clean water comes out from the well.

CONCLUSION

In the present study, the UTFI intervention in the Ramganga basin of Indo-gangetic plain can recharge about 70000 cubic meters excess flow water each year which will be sufficient to irrigate an additional 20 to 30 hectares of land under dark zone areas. Although the added value from the individual pond scale is modest, when UTFI will be scaled up across the ground water stressed parts of the whole Ram Ganga basin, the benefits for water and food security may become more significant. The heavy metal contamination in the groundwater during the recharge is a major concern with respect to drinking water quality. The presence of heavy metal contamination above the permissible limits in the farmers' tube wells located up and down streams of the recharge site suggested an inherent heavy metals problem in the area. However, the result suggested that intervention of UTFI technique helped in reducing the toxicological exposure by diluting the concentration of the contaminants in groundwater.

REFERENCE

BIS (Bureau of Indian Standards). 2012. Specification for drinking water IS 10500: 2012, New Delhi, India.

Brindha, K., and Pavelic, P. 2016. Identifying priority watersheds to mitigate flood and drought impacts by novel conjunctive water use management. Environmental Earth Sciences, 75(5):1-17.

Central Pollution Control Board (CPCB). 2013. Ministry of Environment, Forest and Climate Change, Government of India, Pollution assessment: River Ganga. Delhi, India

Connor, R. 2015. The United Nations World Water Development Report (2015):

Water for a sustainable world. UNESCO Publishing, 122p.Available at: http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/wwdr/2015-water-for-a-sustainable-world/ (last accessed 16 May 2017).

CRED (Centre for Research on the Epidemiology of Disasters) 2015. EM-DAT: The international disaster database. Available at: http://www.emdat.be/database (last accessed30 November 2015).

Mishra, V., Asoka, A., Vatt, K. and Lall, U.2018. Groundwater depletion andassociated CO_2 emissions in India. Earth's Future,6, 1672–1681. https://doi.org/10.1029/

MSME, Ministry of Micro, Small and Medium Enterprises, (Annual Report 2016-17). Government of India, New Delhi, pp. 107.

National Disaster Management Authority (NDMA) 2008. Available at https://ndma.gov.in

NWM. 2011. National Water Mission, Vulnerable & Over Exploited Areas http://nwm.gov.in

Pavelic, P., Brindha, K., Amarnath, G., Eriyagama, N., Muthuwatta, L., Smakhtin, V., Gangopadhyay, P.K., Malik, R.P.S., Mishra, A., Sharma, B.R., Hanjra, M.A., Reddy, R.V., Mishra, V.K., Verma, C.L. and Kant, L. 2015. Controlling floods and droughts through underground storage: from concept to pilot implementation in the Ganges River Basin. Colombo, Sri Lanka: International Water Management Institute (IWMI), 34p., (IWMI Research Report 165). doi: 10.5337/2016.200.

Pavelic, P., Faiz Alam, M., Chinnasamy, P., Eriyagama, N., Gangopadhyay, P., Govindan, M., Jha, S.K., Kant, L., Karthikeyan, B., Mishra, V.K., Mutuwatte, L., Nair, N., Ratna, V.R., Sharma,B.R., Sharma, N., Sikka, A., Smakhtin, V., and Verma, C.L 2017. Underground Taming of Floods for Irrigation (UTFI):An innovativeapproach to manage the impacts of water variability, DRAFT Groundwater Solutions Initiative for Policy and Practice (GRIPP) Case Study Report, International Water Management Institute (IWMI), Colombo, Sri Lanka

Pavelic, P., Dillon, P.J., Barry, K.E., Vanderzalm, J.L., Correll, R.L. and Rinck-Pfeiffer, S.M. 2007. Water quality effects on clogging rates during reclaimed water ASR in a carbonate aquifer. Journal of Hydrology, 334:1-16.

Samadder , R. K., Kumar, S. and Gupta, R. P., 2007. Conjunctive Use of Well-log and Remote Sensing Data for Interpreting Shallow Aquifer Geometry in Ganga Plains, Journal of the Geological Society of India, 69, 925-932.

Sikka, A., Gangopadhyay, P. and Sharma, B. 2017. Stakeholders' involvement for main streaming UTFI in programs and policies. Proceedings of International Conference 3rd International Conference on the Status and Future of the World's Large Rivers 18-21 April 2017, New Delhi, India. pp 6 (02).

Srivastava, A. 2005. Aquifer Geometry, Basement-topography and Groundwater Quality around Ken Graben, India, Journal of Spatial Hydrology, 2(2), 1-7.

Tait, N. G., Davison, R. M., Whittaker, J. J., Leharne, S. A. and Lerner, D. N., 2004. Borehole Optimization System (BOS) - A GIS Based Risk Analysis Tool for Optimizing the Use of Urban Groundwater, Environmental Modeling and Software,19, 1111-1124.

WHO,1996. Guidelines for Drinking water Quality: 2nd edition World Health Organization, Geneva.

WHO, 2008. Guidelines for Drinking water Quality: incorporating the first and second addenda Volume 1 Recommendations, 3rd Eds., World Health Organization, Geneva.

Underground Taming of Floods for Irrigation (UTFI) -
A Novel Form of Conjunctive Water Use Management

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Regional Research Station

Lucknow-226002 (U.P.), INDIA