



**ORE THE HON'BLE NATIONAL GREEN TRIBUNAL,
PRINCIPAL BENCH AT NEW DELHI**

ORIGINAL APPLICATION NO. 148 OF 2025

IN THE MATTER OF:

Rohit Singh

.....Applicant

Versus

State of Himachal Pradesh and Ors.

...Respondent

INDEX

Sr. No.	Particulars	Page No.
1.	Rejoinder on behalf of the Applicant to the reply filed by the Respondent No. 1 along with an affidavit	343 - 357
2.	ANNEXURE: A/10 True Copy of Environmental Clearance of Bulk Drug Park in Polian Beet	358 - 368
3.	ANNEXURE: A/11 True Copy of Ground Water Information Booklet Una 2013	369 - 391
4.	ANNEXURE: A/12 True Copy of Aquifer Mapping and Management of Ground Water 2020	392 - 441
5.	ANNEXURE: A/13 True Copy of GEC Methodology 2015	442 - 583

Saurabh Ahluwalia

Petitioner

Through Counsel

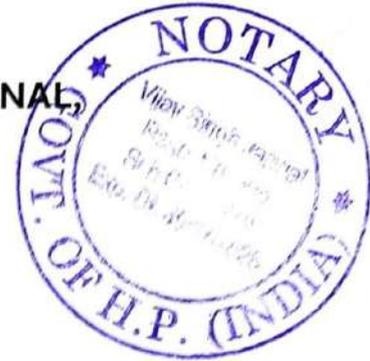
Saurabh Ahluwalia

Advocate

Dated: 27.11.2025

New Delhi

**BEFORE THE HON'BLE NATIONAL GREEN TRIBUNAL,
PRINCIPAL BENCH AT NEW DELHI
ORIGINAL APPLICATION NO. 148 OF 2025**



IN THE MATTER OF:

Rohit Singh

.....Applicant

Versus

State of Himachal Pradesh and Ors.

...Respondent

**REJOINDER AFFIDAVIT ON BEHALF OF THE APPLICANT IN
RESPONSE TO REPLY FILED BY RESPONDENT 1**

MOST RESPECTFULLY SHOWETH:

I, Rohit Singh, son of Sh. K.P. Singh, aged about 40 years, resident of 96, Basant Vihar, Near Rakkar Colony, District Una, Himachal Pradesh – 174303, do hereby solemnly affirm and declare as follows:

1. That I am the Applicant in the present Original Application and am thoroughly conversant with the facts and circumstances of the case.
2. That the present rejoinder is being filed in response to the reply filed by Respondent No. 1, Ministry of Environment, Forest and Climate Change (MoEF&CC), to the Original Application.
3. That at the very outset, the Applicant categorically denies each and every averment made in the reply of Respondent No. 1, except those that are matters of record and/or are explicitly admitted herein. It is clarified that there shall be no admission on the part of the Applicant for want of specific denial and/or traverse.

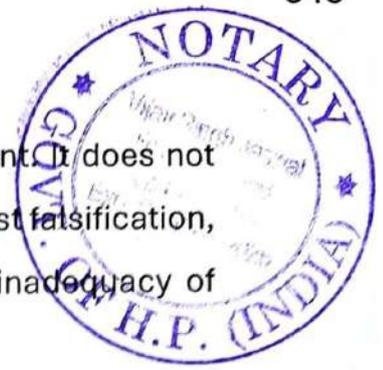


4. That all detailed submissions made by the Applicant in the Original Application may be read as part and parcel of the present rejoinder and are not being reiterated herein for the sake of brevity.
5. That the Applicant submits this rejoinder in firm dispute of the contentions raised by Respondent No. 1. It is respectfully submitted that the reply is marked by procedural narration of the EIA Notification, ToR grant, public hearing, and EAC meetings, but fails to address the substantive objections raised by the Applicant. The reply does not engage with the core issues of groundwater depletion, forest falsification, wildlife impacts, hazardous waste appraisal, or the inadequacy of public consultation.
6. That the reply further seeks to dismiss the Applicant's concerns as "premature" or "speculative," despite the fact that enabling works, borewell drilling, tenders, and tree enumeration have already been undertaken. The Applicant submits that such contradictions and omissions demonstrate abdication of statutory responsibility by Respondent No. 1. Further, the subsequent grant of Environmental Clearance dated 25.09.2025, while this matter was pending, underscores that the reply was overtaken by events and that clearance was issued in disregard of judicial process.
7. That the Applicant therefore files this rejoinder to place on record the deficiencies in Respondent No. 1's reply and to seek appropriate directions from this Hon'ble Tribunal.

PRELIMINARY SUBMISSIONS AND OBJECTIONS:

The reply filed by Respondent No. 1 is marked by procedural narration of the EIA Notification, ToR issuance, public hearing, and EAC meetings, but fails

to address the substantive objections raised by the Applicant. It does not engage with core issues such as groundwater depletion, forest falsification, wildlife displacement, hazardous waste appraisal, or the inadequacy of public consultation.



1. Environmental Clearance Granted During Pendency of Proceedings

The Environmental Clearance dated 25.09.2025 was granted while OA 148/2025 was pending before this Hon'ble Tribunal. This altered the nature of the litigation from a challenge to a proposed project into a challenge to a finalized clearance, thereby prejudicing the Applicant's case. The Ministry was duty-bound to await judicial directions before proceeding with clearance. The Ministry's own reply claimed the proposal was 'delisted' and under examination. Yet, clearance was granted on 25.09.2025 during pendency, contradicting their reply and rendering the clearance procedurally vitiated.

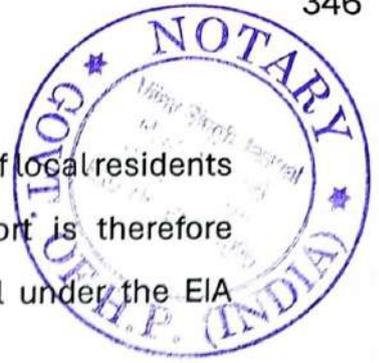
2. Failure to Suspend Appraisal Despite Formal Objections

The Applicant submitted detailed objections to the Deputy Commissioner, MoEF&CC, and other authorities (Annexure A/2 and A/3), including requests for a second public hearing and independent verification of forest boundaries. Despite this, no interim hold was placed on the appraisal or clearance process. This constitutes suppression of material facts and violates the participatory mandate of the EIA Notification, 2006.

3. Defective Site Visit and Non-Recording of Local Objections

The EAC Sub-Committee's site visit to Polian Reserve Forest in May 2025 was perfunctory. Members stayed in the Forest Rest House for

barely five minutes and refused to record objections of local residents who attempted to meet them. The site visit report is therefore unreliable and cannot be treated as valid appraisal under the EIA Notification.



4. Contradictions in Forest Classification and Tree Felling

The reply's assertion is contradicted by its own enumeration figures: Phase I authorizes felling of 21,702 trees, while Phase II lists only 146. This disproportionate phasing is unexplained and undermines the credibility of the appraisal. If Phase I requires such extensive felling, Phase II should reflect commensurate impacts; the stark mismatch suggests misrepresentation or incomplete disclosure of ecological loss.

Further, the Environmental Clearance dated 25.09.2025 was granted without prior approval of the Wildlife Conservation Plan, which was only "forwarded" to the Chief Wildlife Warden. Proceeding to permit tree felling and site development in the absence of an approved conservation plan is contrary to Section 29 of the Wildlife Protection Act, 1972, which requires prior sanction before activities that risk habitat disturbance. The omission of this mandatory safeguard renders the clearance procedurally vitiated and unsustainable in law.

5. Inadequate Public Hearing and Cross-Border Exclusion

The public hearing conducted on 20.11.2024 recorded only four objections and excluded affected villages in Tehsil Garhshankar, District Hoshiarpur, Punjab, located within 100 meters of the project boundary. The Applicant's request for a second public hearing was

ignored. This violates the principles of natural justice and participatory compliance under the EIA Notification.

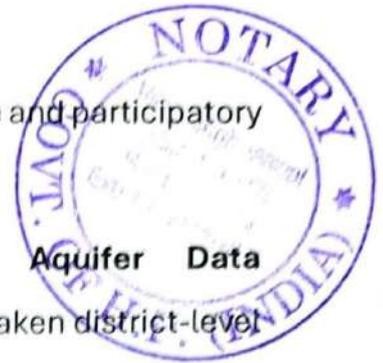
6. Suppression of Groundwater Stress and Aquifer Data

The Ministry's reply fails on two counts: first, it has taken district-level groundwater figures at face value without any independent verification, thereby masking the valley-specific "Critical" status documented by CGWB in 2011 and 2020; second, even on technical grounds, its reliance on static storage volumes while omitting recharge analysis, cumulative drawal modelling, and climate sensitivity directly violates the binding GEC-2015 methodology. This dual failure—accepting unverified aggregates and ignoring mandated hydrogeological parameters—renders the Environmental Clearance unsustainable in law.

7. Deferred Appraisal of TSDF and Pollution Control Infrastructure

The Environmental Clearance defers appraisal of the TSDF to a "separate clearance," despite its express inclusion in the project layout. This reveals a fundamental deficiency in the EIA Report itself, which failed to provide emissions modelling, leachate containment design, liner specifications, monitoring well grids, or a public hearing specific to the TSDF. Similarly, the CETP/ZLD claims are speculative, unsupported by performance data, OCEMS/CEMS integration, or third-party audits. These omissions mean that the EIA was incomplete at the time of appraisal and did not satisfy the requirements of the EIA Notification, 2006.

Even when the EC was subsequently granted on 25.09.2025, it remained procedurally invalid because Schedule 7(h) (Common





Effluent Treatment Plants) and Schedule 7(f) (Hazardous Waste Management facilities including TSDFs) require separate, prior appraisal and clearance. By granting EC without a full and lawful appraisal of these integral components, the Ministry effectively sanctioned the project in a piecemeal manner, contrary to binding precedent (*Lafarge Umiam Mining Pvt. Ltd. v. Union of India*, (2011) 7 SCC 338; *Tamil Nadu Pollution Control Board v. Sterlite Industries (India) Ltd.*, (2019) 19 SCC 479 : AIR 2019 SC 1074). The clearance is therefore vitiated in law and cannot be sustained.

8. Health Infrastructure Deficiency and Risk Preparedness

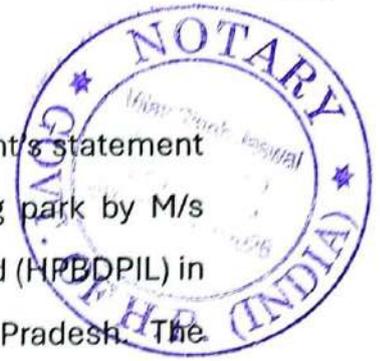
The reply fails to address the absence of toxicology units, burn care, and emergency response capacity in Una District. Reliance on distant tertiary facilities (PGIMER, AIIMS) is not a substitute for on-site readiness. No commissioning conditions tied to verified healthcare upgrades have been imposed.

9. Pattern of Evasion and Selective Disclosure

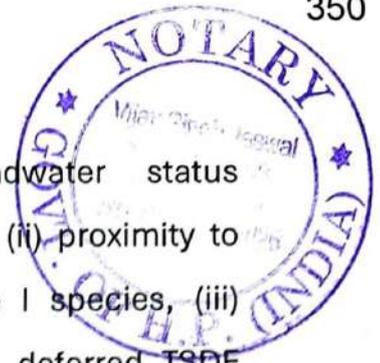
The reply dismisses the Applicant's concerns as "premature" or "speculative," even though enabling works, borewell drilling, tenders, and tree enumeration have already been undertaken. This pattern of evasion and selective disclosure underscores regulatory abdication and violates binding precedent.

REJOINDER TO THE REPLY OF RESPONDENT NO. 1 MoEF&CC

1. Para 1 is noted. The contents pertain to the deponent's authority and familiarity with the facts of the case based on official records. No specific reply is pressed.



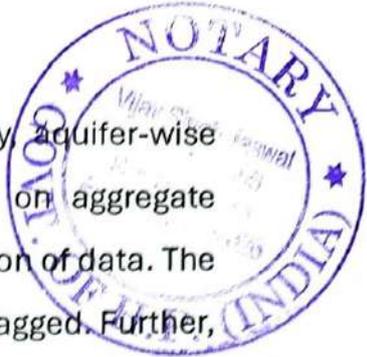
2. Para 2 is noted to the extent that it records the Applicant's statement regarding the proposed establishment of a bulk drug park by M/s Himachal Pradesh Bulk Drug Park Infrastructure Limited (HPBDPIL) in Polian Beet, Tehsil Haroli, District Una, Himachal Pradesh. The Respondent does not comment on the merits of the project at this stage, as the Environmental Clearance has been issued while matter is sub-judice in the Hon'ble NGT.
3. Para 3 is noted. The Applicant's invocation of constitutional provisions under Article 21 and Article 51A(g) is acknowledged. The Respondent submits that the Environmental Clearance process under the EIA Notification, 2006 is designed to uphold these constitutional principles through structured appraisal, public consultation, and enforceable safeguards.
4. Para 4 is noted. The Respondent does not offer any comment on the allegations at this stage, as they pertain to the Applicant's stated concerns and are subject to adjudication before the Hon'ble Tribunal.
- 5 – 8. Paras 5 to 8 are noted to the extent they reproduce the statutory framework of the Environment (Protection) Act, 1986 and the EIA Notification, 2006. The Applicant does not dispute the applicability of these provisions. However, the reply was filed prior to the grant of Environmental Clearance dated 25.09.2025 and does not engage with the substantive objections raised in the application. The Ministry has not demonstrated how the appraisal of the Bulk Drug Park was conducted in compliance with the precautionary principle, participatory mandate, and binding precedent. Specifically, while acknowledging that the project falls under Category 'A' as per Item 7(c) of the Schedule, the reply remains silent on whether the appraisal



considered (i) valley-specific “Critical” groundwater status documented by CGWB reports of 2013 and 2020, (ii) proximity to Polian Reserve Forest and presence of Schedule I species, (iii) hazardous waste generation of 700–800 TPD and deferred TSDF appraisal, and (iv) exclusion of cross-border stakeholders from the public hearing. The Ministry has also failed to explain why clearance was finalized despite formal objections and requests for a second public hearing, and why the EAC site visit did not record local concerns. Accordingly, Paras 5 to 8 amount to procedural narration and do not cure the defects in the appraisal process or validate the Environmental Clearance dated 25.09.2025.

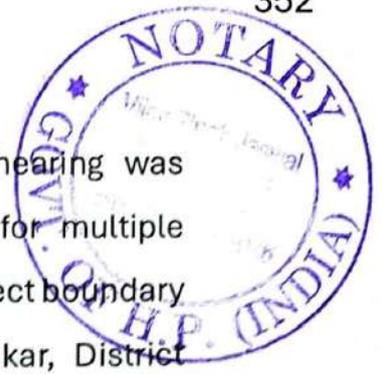
True Copy of Environmental Clearance, CGWB’s Ground Water Information Booklet Una 2013, Aquifer Mapping and Management of Ground Water Resources 2020 and GEC 2015 Methodology is Annexed as **Annexure: A/10, A/11, A/12 and A/13.**

9 – 11. Paras 9 to 11 are noted to the limited extent that the Bulk Drug Park falls under Item 7(c) of the Schedule to the EIA Notification, 2006 and is therefore classified as a Category ‘A’ project requiring prior appraisal by the Expert Appraisal Committee (EAC). The Applicant does not dispute the classification or the issuance of Terms of Reference (ToR). However, the Ministry’s reply is silent on whether the appraisal process complied with the substantive safeguards mandated under the Notification. The mere issuance of ToR and classification as Category ‘A’ does not cure the defects in the appraisal. The Ministry has failed to demonstrate that groundwater stress in Una and Hum valleys—documented as “Critical” in CGWB reports of 2011 and 2020—was considered either during the framing of ToR or during



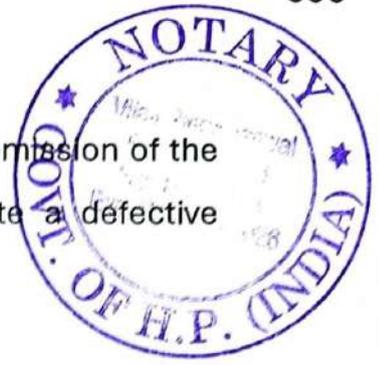
project appraisal. As per the GEC 2015 methodology, aquifer-wise assessment is mandatory, yet the appraisal relied on aggregate district-wise “safe” status, resulting in misrepresentation of data. The Ministry has not explained why this deviation was not flagged. Further, forest proximity and wildlife impacts were not properly assessed, despite the project boundary abutting the Polian Reserve Forest and the documented presence of Schedule I species. Hazardous waste appraisal was deferred, even though the TSDf is integral to the project layout and involves incinerators and secured landfills—components that require separate environmental clearance and public hearing under Schedule 7(d). Yet, the EC was granted piecemeal. Public consultation was also deficient, as cross-border stakeholders in Punjab were excluded and only four objections were recorded during the hearing. The reply fails to explain why clearance was finalized despite formal objections submitted by the Applicant (Annexures A/2 and A/3) and repeated requests for a second public hearing. The Ministry’s reliance on procedural steps such as ToR issuance cannot substitute for substantive appraisal of environmental risks. Accordingly, the Applicant submits that Paras 9 to 11 amount to procedural narration without engagement with the substantive defects in the clearance process and cannot validate the Environmental Clearance dated 25.09.2025.

- 12 – 13. Paras 12 and 13 are noted to the extent they narrate that a public hearing was conducted on 20.11.2024 and that the Project Proponent thereafter submitted its final EIA Report and application for Environmental Clearance on 14.01.2025. The Applicant, however, disputes the adequacy, legality, and fairness of the public hearing



process and the subsequent appraisal. The public hearing was procedurally defective and substantively inadequate for multiple reasons. First, there was cross-border exclusion: the project boundary lies within 100 meters of villages in Tehsil Garhshankar, District Hoshiarpur, Punjab, yet no hearing was conducted in Punjab and no objections from cross-border stakeholders were recorded. This violates the participatory mandate of the EIA Notification, 2006, which requires consultation with all affected persons. Second, the hearing suffered from low participation and inadequate dissemination. It was attended by only 114 persons, with barely 3–4 questions asked—grossly disproportionate to the affected population of over 400,000 residents in Haroli and Garhshankar. The EIA Report was not adequately disseminated in advance, depriving the public of a meaningful opportunity to study and respond. Third, substantive concerns raised during the hearing were not addressed. Questions regarding groundwater depletion and pollution control were met with vague analogies—such as comparisons to waste management under a cricket ground in Sydney—rather than proven scientific strategies. No detailed responses or enforceable conditions were recorded in the Environmental Clearance. Fourth, the Applicant had formally requested the Ministry to conduct a second public hearing with proper publicity and wider stakeholder inclusion. This request was ignored, despite the scale and long-term impact of the project. Accordingly, the Applicant submits that Paras 12 and 13 amount to a procedural narration of steps taken, but do not cure the defects in the public consultation process. The hearing was inadequate, exclusionary, and failed to meet the statutory requirements of meaningful participation

under the EIA Notification, 2006. The subsequent submission of the final EIA Report and EC application cannot validate a defective consultation process.

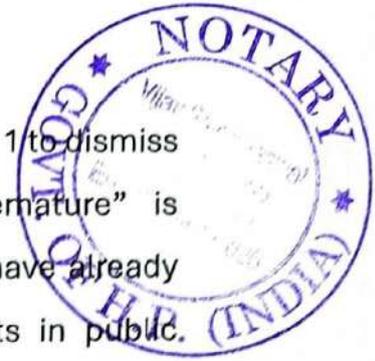


13 – 14. Paras 14 and 15 are noted to the extent they record that the Expert Appraisal Committee (EAC) deferred appraisal in its 398th meeting and directed a sub-committee to conduct a site visit, and that a visit was subsequently undertaken in May 2025. The Applicant, however, disputes the adequacy, fairness, and reliability of the site visit and the appraisal process. The site visit was procedurally defective and substantively inadequate. The sub-committee members stayed at the Polian Forest Rest House for barely five minutes, and no meaningful inspection of the project site or adjoining reserve forest was undertaken. Residents attempted to meet the committee and raise objections regarding forest encroachment, groundwater depletion, and wildlife impacts, but these objections were not recorded in the site visit report, thereby suppressing material facts. The report relied on project proponent presentations rather than independent field observations, and no GPS-based mapping, biodiversity survey, or aquifer verification was conducted. This approach contradicts the statutory mandate under the EIA Notification, 2006, which requires site visits to validate baseline data and record stakeholder concerns. A superficial visit without recording objections cannot constitute valid appraisal. Accordingly, the Applicant submits that Paras 14 and 15 amount to procedural narration of meetings and visits, but do not cure the defects in the appraisal process. The perfunctory nature of the site

visit and the suppression of local objections render the appraisal incomplete and procedurally invalid.

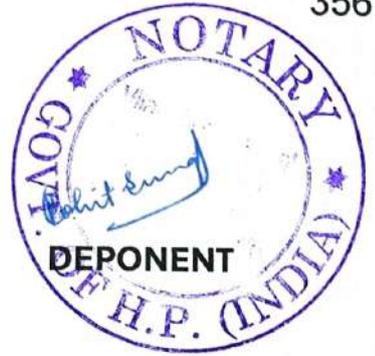
16. Para 16 is denied to the extent it asserts that no Environmental Clearance has been granted and that the proposal remains “delisted” on the PARIVESH portal. While it is possible that at the time of filing the reply the Ministry considered the proposal as pending, subsequent developments have overtaken this position. The Environmental Clearance dated 25.09.2025 has in fact been issued, and enabling works—including borewell drilling, recharge structures, tenders for CETP/ZLD and TSDF, and allocation of seed money for the Satluj lift scheme—were initiated well before the grant of clearance. The reliance on the “delisted” status is therefore no longer accurate. “Delisting” on PARIVESH merely reflects pendency of compliance submissions by the project proponent and does not negate the fact that clearance has now been finalized. The Applicant had also formally submitted objections and requested a second public hearing, which were ignored. Proceeding to finalize clearance despite these objections undermines the participatory mandate of the EIA Notification, 2006 and prejudices the Applicant’s right to meaningful adjudication. Accordingly, the Applicant submits that Para 16, though perhaps reflective of the Ministry’s understanding at the time of filing, has been overtaken by subsequent events. The subsequent grant of Environmental Clearance on 25.09.2025, despite pending objections and ongoing proceedings, was procedurally flawed and prejudiced the Applicant’s case. The Ministry’s reply therefore cannot cure the defects, and the clearance issued thereafter is unsustainable in law.





17 – 19. Paras 17 to 19 are denied. The attempt of Respondent No. 1 to dismiss the Applicant's concerns as "speculative" or "premature" is misplaced. The issues raised are not hypothetical but have already been substantiated in earlier replies, including defects in public consultation (Paras 12–13), inadequacy of the site visit (Paras 14–15), and contradictions in project status (Para 16). The Applicant has placed on record documentary evidence of tree enumeration, CGWB groundwater assessments, and enabling works already undertaken. By characterizing these concerns as speculative, the Ministry avoids substantive engagement with the evidence. Accordingly, the Applicant submits that Paras 17 to 19 amount to a blanket dismissal without addressing the material already on record. Reliance on procedural assurances of future appraisal cannot cure the defects highlighted in the preceding replies. The fact that clearance was nevertheless granted on 25.09.2025, despite these unresolved defects, demonstrates that Respondent No. 1 acted in disregard of statutory safeguards and judicial pendency.

20. That the contents of Para 20 are denied. The prayer of Respondent No. 1 for dismissal of the Application is misconceived and unsustainable. The Applicant has already placed on record substantive objections regarding groundwater stress, forest impacts, wildlife displacement, hazardous waste appraisal, and defects in public consultation and appraisal. These issues remain unaddressed in the reply and cannot be brushed aside by a general prayer for dismissal. Accordingly, the Applicant submits that Para 20 deserves to be rejected, and the Application merits consideration on its substantive grounds.

**VERIFICATION:**

I, Rohit Singh, Aged about 40 years, S/O Sh. K.P. Singh, 96 Basant Vihar, Near Rakkar Colony, Una, Himachal Pradesh, do hereby verify that the contents of this application as stated are true and correct to the best of my knowledge and belief and no part of it has is false and nothing material has been concealed there from.

27.11.2025
New Delhi

DEPONENT

BEFORE THE HON'BLE NATIONAL GREEN TRIBUNAL
PRINCIPAL BENCH AT NEW DELHI

ORIGINAL APPLICATION NO 148 OF 2025



IN THE MATTER OF:
Rohit Singh and Ors.

... Applicant

Versus

State of Himachal Pradesh and Ors.

...Respondent

AFFIDAVIT

I, Rohit Singh, aged 40 years, S/O Sh. K.P. Singh, 96 Basant Vihar, Near Rakkar Colony, Una, HP-174303 do hereby solemnly affirm and states as below:

1. That the deponent is applicant in the above-mentioned matter and as such he is well conversant with the facts and circumstances of the present case.
2. That the deponent has gone through the contents of the accompanying Rejoinder. The same has been drafted as per my instructions. The contents of the same are true and correct to the best of my knowledge and nothing material has been concealed there from.
3. That the annexure annexed to the accompanying Rejoinder are true copy of their respective original.

Rohit Singh
DEPONENT

I, the deponent named do hereby verify that the contents of this affidavit are true and correct to the best of my knowledge derived from the records and nothing relevant has been concealed there from.

Rohit Singh
DEPONENT

Dated: 26.11.2025

"Certified that this AA/abscv
is presented for attestation by Rohit Singh
S/o. Sh. K.P. Singh Resident
Village Rakkar Colony Distt Una
who is identified by 20/Anand Sharma
On who is present and is entered
at serial 18 on 26/11/25 at 11:25 AM
Time at UNA (Place)"

ATTESTED
[Signature]
NOTARY



सत्यमेव जयते

File No: 10/68/2023-IA.III
Government of India
Ministry of Environment, Forest and Climate Change
IA Division



ANNEXURE A/10

Date 25/09/2025



To,

Tilak Raj Sharma
HIMACHAL PRADESH BULK DRUG PARK INFRASTRUCTURE LIMITED
Himachal Pradesh Bulk Drug Park Infrastructure Limited Directorate of Industries Majitha House, Near
HP Secretariat Chhota Shimla, Shimla, SHIMLA, HIMACHAL PRADESH, 171002
trsharma4@gmail.com

Subject: Development of Proposed "Bulk Drug Park" at Villages Kuthar Beet, Pollian Beet, Tibbian, Jodian, Janani and Malluwal, Teh. Haroli, Distt. Una, Himachal Pradesh by M/s Himachal Pradesh Bulk Drug Park Infrastructure Ltd. under Department of Industries, Government of Himachal Pradesh-Environment Clearance reading.

Sir/Madam,

This is in reference to your application submitted to MoEF&CC vide proposal number IA/HP/INFRA1/517475/2025 dated 14/01/2025 for grant of prior Environmental Clearance (EC) to the proposed project under the provision of the EIA Notification 2006 and as amended thereof.

2. The particulars of the proposal are as below :

(i) EC Identification No.	EC25A3103HP5978020N
(ii) File No.	10/68/2023-IA.III
(iii) Clearance Type	Fresh EC
(iv) Category	A 7(c) Industrial estates/ parks/ complexes/ areas, export processing Zones (EPZs), Special Economic Zones, 7(d) Common hazardous waste treatment, storage and disposal facilities (TSDFs), 7(h) Common Effluent Treatment Plants (CETPs), 5(f) Synthetic organic chemicals industry
(v) Project/Activity Included Schedule No.	
(vi) Sector	INFRA-1 Proposed "Bulk Drug Park" at Villages Kuthar Beet, Pollian Beet, Tibbian, Jodian, Janani and Malluwal, Teh. Haroli, Distt. Una, Himachal Pradesh by M/s Himachal Pradesh Bulk Drug Park
(vii) Name of Project	

	Infrastructure Ltd. under Department of Industries, Government of Himachal Pradesh
(viii) Name of Company/Organization	HIMACHAL PRADESH BULK DRUG PARK INFRASTRUCTURE LIMITED
(ix) Location of Project (District, State)	UNA, HIMACHAL PRADESH
(x) Issuing Authority	MoEF&CC
(xi) Applicability of General Conditions as per EIA Notification, 2006	No

3. The proposal is for the 'Development of proposed 'Bulk Drug Park'' over an extent of 568.75 Ha (1405.41 Acres) at Villages Kuthar Beet, Pollian Beet, Tibbian, Jodian, Janani, and Malluwal, Tehsil Haroli, District Una, Himachal Pradesh by M/s Himachal Pradesh Bulk Drug Park Infrastructure Ltd. (HPBDPIL) under Department of Industries, Government of Himachal Pradesh'.

4. A New Industrial Estate in the name of Bulk Drug Park is proposed to be set up at Villages Kuthar Beet, Pollian Beet, Tibbian, Jodian, Janani, and Mulluwal, Tehsil Haroli, District Una, Himachal Pradesh. The proposed project comprises 110 Industrial Plots along with allied infrastructure and related services. The project site is falling in between the geographical coordinates ranging from 31°21'26.21" N and 76°10'22.98" E.

5. The proposed project activity is listed at schedule S.No.7(c) Industrial estates/parks/ complexes/Areas, export processing zones (EPZs), Special economic zones (SEZs), Biotech parks, Leather complexes under Category- 'A', of the schedule of the EIA Notification, 2006 and its amendments due to applicability of general condition i.e. Punjab-Himachal Pradesh border lies at a distance of approx.100m from the nearest project boundary and the proposed project. Total Project Cost is Rs. 1923 Cr.

6. Terms of References (TOR) Details: The ToR proposal was considered in the 367th EAC meeting held on 26th June 2024, the committee recommended the proposal for undertaking a detailed EIA/EMP report. Ministry granted the ToR vide letter No. 10/68/2023-IA.III dated 01.08.2024.

7. Public Hearing Details: The public hearing was conducted in the Una district of Himachal Pradesh state on 20.11.2024. The details of the public hearing are as follows:

Date	Venue	District and State	Chairman
20-11-2024	Open Ground, Near Forest Rest House, VPO Pollian Beet, Tehsil Haroli, District Una, Himachal Pradesh	Una District, Himachal Pradesh	Additional Deputy Commissioner, Una

8. Land use/Land cover of the project site: Out of 1,405.41 acres of land, 1,365.77 acres is the government land allotted to the Department of Industries and 39.64 acres is the private land purchased and transferred to the Department of Industries, Government of Himachal Pradesh for setup of the proposed industrial park.

Sl.No.	Description	Area (in Acres)	Area (in Ha)	Percentage (%)
1	Industrial Plot Area	558.28	225.93	39.72
2	Commercial Area	95.02	38.45	6.76
3	Electric Utilities	23.37	9.46	1.66
4	Utility Area	41.65	16.86	2.96
5	TSDf Area	29.46	11.92	2.10
6	Parking Area	18.46	7.47	1.31
7	Green Area:	465.18	188.25	33.09
	· Green area under Industrial Plots to be developed by individual industries	185.72	75.16	13.21
	· Green area developed by HPBDPIL	279.46	113.09	19.88

8	Treatment Units (STP/ETP/ MEE & WTP)	41.08	16.62	2.92
9	Logistic Hub and Warehouse	18.84	7.62	1.34
10	Area under Roads	86.45	34.98	6.15
11	Area under existing Water Bodies	27.33	11.06	1.94
12	Others (Semi-public Area)	0.30	0.12	0.02
	Total Area	1405.41	568.75	100

9. List of industries to be housed with the proposed project site are as following.

Category of Industries	As per EIA 2006 Notification	CPCB Classification
member industries (API units) Synthetic organic chemicals industry (dyes & dye intermediates; bulk drugs intermediates and excluding drug formulations; synthetic rubbers; basic organic chemicals, other synthetic organic chemicals and chemical intermediates)	5(f)	Red
Common Effluent Treatment Plants (CETP)	7(h)	-
Treatment, Storage and Disposal Facility (TSDF) (comprising a secured landfill with a solid-liquid feed incinerator)	7(d)	-

The upcoming industrial units in the Bulk Drug Park (BDP) will only be API manufacturing units based on chemical synthesis (approx. 70 to 80 industrial units in 110 industrial plots) and such units are covered under the Red Category (Serial No. 60) as per CPCB categorization of industries. BDP as a whole is covered under the Red Category (Serial No. 32) as per CPCB categorization. CETP, TSDF & Incinerator are covered under the Red Category (Serial No. 14) as per CPCB. Incinerator and a TSDF facility has been proposed within the boundary of Bulk Drug Park for the handling of Hazardous wastes. As per EIA Notification 2006 and its amendments thereof, Common hazardous waste treatment, storage and disposal facilities (TSDFs) falls under Schedule 7(d) and All integrated facilities having incineration & landfill site falls under category A. Hence, separate Environmental Clearance will be obtained.

10. Terrain and Topographical Features: The Project area comprises agricultural, barren, and bushy blocks with semi-hilly terrain. In general, most of the district lies between 600-900 m elevation and slope is less than 10°. Approx. elevation range of the entire project lies 390-590m above mean sea level (amsl). The drainage pattern of the project area is dendrite type and the flow of water is from NE to SW according to the natural slope of the surface i.e., towards river Beas. A total of five sharp slope areas with more than 45° angles were identified comprising an area of 2.96 acres. The details are as follows:

Sl. No.	Location of Slope	Area of Slope
1	Landfill site	0.89
2	Industrial Plot No. 110	0.68
3	Water Reservoir/ Pond	0.62
4	Common Steam Generation Area	0.57
5	Industrial Plot No. 93	0.20
Total Area (Acres)		2.96

11. Details of water bodies, impact on drainage:

Sl. No.	Water Bodies	Distance (~Kms.)
1	Soan/Swan River	8.0 (NE)
2	Panjoian Khad (Seasonal)	Within Project Site
3	Raamsar Pond	3.0 (NE)

12. Water requirements: The total water requirement for the proposed project will be 22.1 MLD; out of which 15 MLD will be extracted from groundwater through borewells (15 Nos.), for an initial period up to materialization of surface water supply scheme, and 7.1 MLD will be recycled water met from treated water. Breakup of the total water demand is given below:

Sl. No.	Description	Demand (MLD)	Source
---------	-------------	--------------	--------

1	Freshwater Demand (Portable + Process water demand)	15 (2.2+12.8)	Groundwater*
2	Flushing water demand	1.15	Treated water
3	AC Cooling demand	2.00	Treated water
4	Horticulture water demand	3.95	Treated water
5	Total Water Demand	22.1 MLD	Groundwater* & treated water

13. The groundwater abstraction scheme will only be there until the surface water scheme comes into place i.e. until the materialization of the surface water scheme. As a substitute for the groundwater supply, a comprehensive scheme for the surface water supply has been approved by the concerned authority Bhakra Beas Management Board (BBMB). Under this proposal, a dedicated pipeline of approx. 15 km length will be laid which will supply surface water from the River Satluj to the project. 50 MLD of fresh water from the River Satluj will be supplied and a dedicated storage tank of a capacity of 100 MLD is proposed within project premises. This scheme has been envisaged keeping in view the future expansions and upcoming allied industries as well as the proposed housing schemes in the vicinity. The M/s HPBDPIL has already paid the seed money to the BBMB for the initiation of this scheme. Surface water from the river Satluj will be used to meet the freshwater requirements onwards to the operationalization of the scheme. Principle approval for the same has already been obtained from Competent Authority of the state i.e. Jal Shakti Vibhag, IPH Wing and However formal NOC for the abstraction of ground water will be obtained at the time of initiation of the project at ground level.

14. Waste Management: Hazardous waste generation from the proposed Bulk Drug Park has been estimated as 10-12 TPD and CETP sludge & MEE residue) & incinerable/co-processing waste will be 650-800 TPD. An integrated TSD (comprising a secured landfill, and a solid-liquid feed incinerator is proposed inside the project for which 33.6 acres of land have been proposed. 4-5 kg/day of Biomedical waste is likely to be generated from the dispensary & Research Institute for Pharmaceutical advancement proposed within the project which includes minor first aid or medical use of disposable dressing material. This waste will be disposed of through the authorized Common Bio-medical Waste Collection and Disposal Agency as per Bio-medical Waste Management Rules, 2016 and its amendments. The solid waste generated will be 0.6 TPD during the construction and 8.8 TPD during the operation phase from various zones of the park. Biodegradable waste will be composted within project premises and recyclable components will be disposed of through authorized recycler vendors. The Solid Waste will be handled/disposed of as per the provision of Solid Waste Management Rules 2016 and its amendments. Nearly 80 kg/day of Plastic Waste and 4 TPM (i.e. 130 kg/day) of E-Waste is expected to be generated. Both these wastes i.e. E-Waste and Plastic Waste will be handled/disposed of to the authorized recyclers, strictly as per the provision of the prevailing/relevant Rules. Wastewater: Common Effluent Treatment Plant of capacity 5 MLD based upon physio-chemical cum biological treatment technology including UF, RO & MEE will be provided within the project to treat the industrial effluent to be generated from industrial processes. Total Industrial wastewater generation will be 5 MLD (approx. 62 KLD by individual unit) which will consist of 1.5 MLD of HTDS and 3.5 MLD of LTDS streams. Treatment of LTDS process effluents will be done in CETP with ZLD and effluents of HTDS stream will be fed to MEE. 2.9 MLD of domestic effluent will be generated which will be treated in the proposed STP of capacity 3 MLD based on MBBR/SBR Technology. Further the project has been conceived with ZLD (Zero Liquid Discharge) and optimum level of recirculation of treated wastewater has been proposed. Out of the total water requirement of 22.1 MLD, 35% i.e., 7.1 MLD will be met through the recycling of wastewater. Only 15 MLD of fresh water will be used. To support/sustain the groundwater in the long run, a parallel independent scheme has been chalked out by the State Govt. which will fetch 50 MLD of surface water from Sutlej River through dedicated pipeline.

15. Details of Tree Cutting and Green Belt Development: In Phase I, out of the total 45,600 trees, a maximum of 21,702 trees are allowed to be felled with prior approval from the Competent Authority, while 23,898 trees shall be retained. Similarly, in Phase II, out of 222 trees, 146 trees shall be felled after obtaining necessary permissions, and 76 trees need to be retained. The recommendation of the CBRI as well as of the ICAR-IISWC w.r.t. development of green belt and tree cutting issues have been duly considered which in-turn has necessitated the amendment in the layout plan and afforestation plan. With implementation of recommendations and due to amendment in the initial plans, compensatory plantation against each felled tree will be done in the ratio of 1:10 in principle and the density of the tree plantation will be 1100 numbers/ha. A total of 33.1% of the project area will be developed as a greenbelt. Of this, 113.1 ha (19.88% of the total area) will comprise plantations with approximately 34,400 native/local trees. The remaining greenbelt will be developed by member industries over 75.2 ha (13.21% of the total area) within their industrial premises along plot boundaries. Additionally, an area of 13.21 ha will be maintained under landscaping and plantation. Greenbelt of 50m width along major streams/nallah/khads and 15m width along minor streams and project boundary shall be developed. A

robust/sustainable green area will be developed/maintained to achieve the ecological balance.

16. Diversion of forestland: The instant proposal does not envisage any diversion of forestland as there is no forest land involved in the proposed project site except some reserve and protected forest patches i.e., Polian Shamlat Reserve Forest (Adjacent to project boundary in South), Saloh and Bhadsali Open Jungle (approx. 5 km in North) Kangar Protective Forest (6 km in North-West), Saunli and Birampur Protected Forests (approx. 8 km in South).

17. There are no notified ecologically sensitive areas such as National parks or Wildlife Sanctuaries, Biosphere Reserves, Wildlife Corridors, Ramsar sites, and Tiger/Elephant Reserves (existing as well as proposed) within 10 km radius of the project. The Schedule I species reported within the study area are Leopard, Sambhar, Wild Boar, Indian Porcupine, Hyena, Common Peafowl, Spanish Owl, Griffon Vulture, Spanish Imperial Eagle, King Cobra, Rock Python, Russel's Viper, etc. A wildlife conservation and mitigation plan has been prepared and submitted to the D.F.O the wildlife conservation plan has been forwarded to the Chief Wildlife Warden for approval vide letter No. RK/WL/8373 dated 16.01.2025.

18. Energy conservation measures with estimated saving: A total of 14.2 MW of solar power generation is proposed as alternate energy on the rooftops of commercial buildings/ areas, electrical utility areas, and treatment units. Solar streetlights are to be used and industries shall be asked to look at the feasibility of installing solar heaters to feed preheated water for process operations. The feasibility of installing solar panels with battery backup along internal roads & buffer areas shall be explored to conserve energy. Industries & commercial establishments shall formulate a proposal to harness solar power within their premises, particularly on rooftops.

19. Six multi fuel fired boilers have been proposed for common steam generation facility based on the availability of fuels in the region. Fuels like rice husk and specially biomass are easily available in the state with high calorific value on economic rates. The impacts of project and air quality modelling has been assessed based on the utilization of rice husk as fuel. However, use of cleaner fuel relates to the operational aspect of the project PNG will be utilised to operate common infrastructure as boilers for steam generation, GAIL is committed for the supply of PNG to BDP as the GAIL has already a presence in the Tahliwal Industrial area approx. 8 km from the Bulk Drug Park (BDP) site. MEE for wastewater treatment, and Incinerators for hazardous wastes management by HPBDPIL and other industrial processes/operations by member industries.

20. Details of Rainwater Harvesting: Construction of rooftop rainwater harvesting structures shall be made mandatory to conserve water resources as the freshwater demand of Bulk Drug Park (BDP) is 15 MLD. The project area falls in the Hum Valley and Swan catchment area with a groundwater extraction of about 70%. Hence to recharge groundwater, BDP will design a rainwater harvesting system in the Hum Valley and Swan catchment areas. Rainwater harvesting is proposed from rooftops of general buildings (other than industrial sheds) and other pucca areas through the dedicated drainage system. The provision for reservoir/storage tank for freshwater has been provided of capacity 50 ML (million liters). Additionally, the rainwater will be collected in a storage pond/ tank of 800 KL and surplus water will be collected in recharge wells/pits. After the treatment of rainwater, it will be reused in industrial processes, gardening, and flushing purposes.

21. Land acquisition and R&R issues involved: There is no R&R for the project. The area under the site falls under the "Banjar Kadim" category as per the revenue record with present ownership of the Department of Industries, Government of HP. The plot area of the project is 1,405.41 acres (568.75 Ha); out of which, 1,365.77 acres is the government land allotted to the Department of Industries and 39.64 acres is the private land purchased and transferred to the Department of Industries, Government of HP for setting up of the proposed industrial park. M/s Himachal Pradesh Bulk Drug Park Infrastructure Limited (HPBDPIL) under Department of Industries, Government of Himachal Pradesh is holding independent possession of the entire area of the project i.e., 568.75 Ha. Accordingly, Dept. of Revenue, Govt. of HP issued the Letter No. 105 dated 03.10.2020.

22. The EAC Sub-committee conducted the site visit during 29th–30th April 2025 and made certain recommendations. Based on recommendations, the Project Proponent (PP) entrusted CBRI to carry out the required studies. Initially, the National Institute of Technology (NIT), Hamirpur (H.P.), was engaged to conduct the study, covering aspects such as soil erosion, long-term project stability, extraction of drainage patterns, and modeling of flow directions and flow accumulation. Upon submission, the report was also sent to the Central Building Research Institute (CBRI), Roorkee. However, Central Building Research Institute (CBRI), Roorkee has submitted its independent assessment report on

Integrated Geo-Environmental Assessment and Planning for Safe Development of the Bulk Drug Park, providing specific recommendations and mitigation measures to ensure the safety and longevity of the project with respect to critical geological and geographical parameters, including environmental safeguards in the following major aspects (i) Landslide Susceptibility and Suggestive Remedial Measures, (ii) Layout Planning and (iii) Infrastructure Safety.

23. The seismic vulnerability, erosion issues, steep slopes and extent of area under building infrastructure has been deliberated upon in the CBRI report and accordingly the layout map has been amended. With amendment/revision in the layout map, the area under building infrastructure has been significantly reduced from 39.72% to 38.22%, thus significant area has been reduced under infrastructure. The amended/revised layout plan has been worked out in two different areas viz-a-viz area under Phase 1 and area under Phase 2. It is the blanket assurance/commitment to initiate the project starting with low lying areas with flatter terrain or terrains with gentle slopes under phase-1 and thereafter Phase-2 will be initiated in other slopes.

24. As per CBRI report

a. The areas at higher elevation with the initiation of drainage lines are prone to soil erosion and potential for landslides. Therefore, these areas with an spatial coverage of 169218.8 m² are declared as a Mandatory Green Zone. Special attention must be given in respect of adopting sustainable erosion control bio-engineering measures during the site development phase.

b. The slopes in the study area are relatively stable and not very steep. The Environmental Impact Assessment (EIA) report indicates an annual rainfall of about 1300 mm. This high rainfall intensity poses the risk of erosion and could cause instability in the slopes. Such instability may also affect any proposed superstructures in the vicinity. Therefore, the areas with higher elevations and $>30^\circ$ slope are declared as Restricted No-Build zones and may be considered for developing as green zone with suitable vegetation. The committee was of the view that considering increasing incidences of landslides and soil erosion it will be on safer side if the areas with higher elevation >25 degree slopes are declared as Restricted No-Build zones and may be considered for developing as green zone with suitable vegetation. Accordingly the layout plan, green belt plan and afforestation plan are revised.

25. The ICAR-ISWC has prepared report for soil conservation measures and made certain recommendations. The recommendations of the said report w.r.t. soil conservation and water conservation will be implemented at ground level in totality.

26. Employment Potential: During the construction phase, manpower of 2,500 to 3,000 persons will be employed. During the operational phase, the proposed employment is projected for the entire bulk drug park with a worker density of 120 employees per hectare. Thus, as such, an employment opportunity for approx. 40,000 no. of employees will be generated. Apart from this direct employment, there will be numerous numbers of persons with indirect employment will be connected with this project. The exact number of such persons cannot be assessed at this stage; as such kind of employment/job work activities come from the informal/unorganized sectors. However, for the calculation of wastewater generation and other related entities/activities, a floating population of 10% of direct employees has been considered i.e. 4,000 persons, thus arriving at a total population of 44,000 persons.

27. Benefits of the project: The Indian Govt. has initiated a noble concept of "Aatmanirbhar Bharat" and this project will negate the need to import from the neighbouring countries to certain effects, which will add to the self-sufficiency of the country. Hence, the project is the need of the hour and deserves all the encouragement and facilitation for implementation, to promote technologies and industry. The project is intended to facilitate development of a well-planned and resource-efficient industrial base, a World-class sustainable connectivity infrastructure. Bulk Drug Park (BDP) proposed to establish a mixed-use area on site for essential services staff initially and may develop discreet sites in the future away from the park which may facilitate local development due to increased demand for domestic services. The need for additional housing in the project vicinity will provide an opportunity for surrounding villagers to build and lease out their houses. The basic infrastructure for the community needs will be strengthened by extending health care, educational facilities, drainage, and drinking water quality to the village, building/strengthening existing roads in the area, etc. The occupational health facility proposed on-site with all amenities may be used by the surrounding population in case of emergency.

28. Details of Court cases: Original Application No. 148/2025 (PB) Rohit Singh Vs. Ministry of Environment, Forest and Climate & Ors. is pending in Honble NGT(PB)

29. The EAC based on the information submitted and clarifications provided by the project proponent and detailed discussions held on all the issues during 389th meeting of the Expert Appraisal Committee held on 29th-30th January, 2025 and 414th meeting during 02nd September, 2025 **recommended** the project for grant of environmental clearance with stipulated specific conditions along with other Standard EC Conditions.

30. The Ministry of Environment, Forest and Climate Change has considered the proposal based on the recommendations of the Expert Appraisal Committee (Infrastructure, CRZ and other Miscellaneous projects) and hereby decided to grant Environmental Clearance for environmental clearance for 'Bulk Drug Park' over an extent of 568.75 Ha (1405.41 Acres) at Villages Kuthar Beet, Pollian Beet, Tibbian, Jodian, Janani, and Malluwal, Tehsil Haroli, District Una, Himachal Pradesh by M/s Himachal Pradesh Bulk Drug Park Infrastructure Ltd. (HPBDPIL) under Department of Industries, Government of Himachal Pradesh' under the EIA Notification, 2006 as amended, subject to strict compliance of the following specific conditions, in addition to all standard conditions applicable for such projects.

31. This issues with the approval of the Competent Authority.

Copy To

1. The Chief Secretary, Department of Environment, Science Technology & Climate Change, Government of Himachal Pradesh, Press Villa, Paryavaran Bhawan, Near US Club, Shimla-171 001, Himachal Pradesh.
2. The Principal Chief Conservator of Forests (HoFF), Himachal Pradesh Forest Department, Talland, Shimla-171 001, Himachal Pradesh.
3. The Deputy Director General of Forests (Central), Ministry of Environment, Forest and Climate Change (MoEF&CC), Integrated Regional Office Shimla, 1st & 2nd Floor, C.G.O. Complex, Shivalik Block, Longwood, Shimla-171 001, Himachal Pradesh.
4. The Chairman, Central Pollution Control Board, Parivesh Bhawan, CBD-cum-Office Complex, East Arjun Nagar, Delhi-110 032.
5. The Member Secretary, Him Parivesh, Phase-III, New Shimla-171 009, Himachal Pradesh.
6. Compliance and Monitoring Division, Ministry of Environment, Forest and Climate Change (MoEF&CC), Indira Paryavaran Bhawan, Jor Bagh Road, New Delhi-110 003.
7. Parivesh Portal.
8. Guard File/ Monitoring File/ Record File.

Annexure 1

Specific EC Conditions for (Synthetic Organic Chemicals Industry)

1. Specific Conditions

S. No	EC Conditions
1.1	The EC is granted invoking the Specific Condition of the EIA Notification, 2006 for the proposed Bulk Drug Park. Since the bulk drug park is proposed with homogeneous type of industries, the individual industries including proposed industrial housing within such estates /complexes will not be required to take prior environmental clearance
1.2	Recommendations of the CBRI report pertaining to the Landslide Susceptibility and Suggestive Remedial Measures shall be implemented with letter and spirit subject to amendment that Restricted No-Building/construction Zone will be maintained for higher elevations and steeper >25° slopes to reduce the impact of building infrastructures on the fragile slopes of the project areas.

1431

S. No	EC Conditions
1.3	In view of the amendments in the recommendations of CBRI suggested in the proposed development layout plan, the greenbelt plan — including the mandatory green zone in higher elevations, green zones in no-building areas, and greenbelts along major and minor drainage systems — as well as the compensatory afforestation plan, shall be reworked in consultation with the State Forest Department and submitted to the IRO of MoEFCC prior to commencement of work, and in any case, not later than the date of submission of the first six-monthly compliance report.
1.4	A green Buffer Zone will be provided all along the boundary of the project as well as major and minor drains/nallahs (50 meter for major and 15 meter for minor). Green belt of at least 30 meter width shall be created all along the boundary of the project area.
1.5	All other recommendations of the CBRI report pertaining to lay out planning and Infrastructure Safety shall be implemented in true letter and spirit.
1.6	Overall developable area shall be between 65 to 70 % of total project area and ,in no case, shall exceed 70%.
1.7	As strongly recommended by the CBRI detailed surveys and geotechnical investigations for designing any stabilizing measures shall be carried out. Proper slope protection measures must include controlled cutting, strategic placement of suitable retaining structures with adequate drainage systems, and vegetation cover. Given the area's severe rainfall patterns, these measures are essential to withstand potential high-flow events and prevent damage to the infrastructure. Structural designing for infrastructure and industrial sheds shall be done in supervision of the CBRI, Roorkee and shall be based on the principle of minimum disturbance to topography and minimum earth cutting and filling. CBRI may consider the possibility of erecting the shed platform on stilts.
1.8	All mitigation measures and recommendations made by the CBRI and ICAR-IISWC report shall be implemented in letter and spirit during construction and operational phase, particularly with respect to site stability, landslide susceptibility, slope protection, soil erosion prevention, and preservation of natural drainage systems.
1.9	The recommendations in the report of the ICAR-ISWC for soil conservation and protection from the erosion shall be followed in direct supervision of the ISWC.
1.10	As proposed Development of the project shall be carried out in 2 phases. Actual felling of the trees in the field shall be initiated under the direction and supervision of the state forest department only after finalisation of the structural designs, another prerequisite for start of the work so that project area does not remain exposed to the erosion forces for a long period after felling . In Phase I, out of the total 45,600 trees, a maximum of 21,702 trees are allowed to be felled with prior approval from the Competent Authority, while 23,898 trees shall be retained. Similarly, in Phase II, out of 222 trees, 146 trees shall be felled after obtaining necessary permissions, and 76 trees need to be retained.
1.11	Green belt development plan/ afforestation plan as amended shall be executed under the supervision of the Forest Department.
1.12	Project Proponent shall strive to enhance the Green Belt beyond 33% and that the trees planted in this regard would be planted under the campaign " एक_पेड़_म_11_के_नाम " and the details of the trees planted would be uploaded on the portal https://merilife.nic.in .

1432

S. No	EC Conditions
1.13	The groundwater extraction shall be permitted for a maximum period of five (5) years from the grant of Environmental Clearance (EC). Beyond this period, the project proponent (PP) shall utilize water as per the proposed alternative arrangements made for surface water supply scheme approved by the Bhakra Beas Management Board (BBMB), which includes a 15 km dedicated pipeline from the Satluj River. Under this scheme, 50 MLD of fresh water will be supplied, supported by a 100 MLD storage tank earmarked exclusively for the project.
1.14	This arrangement is designed to cater not only to the present requirement but also to accommodate future expansions, allied industries, and nearby housing developments. Once operational, the surface water scheme will fully replace groundwater as the source of fresh water.
1.15	Construction spoils, including bituminous material and other hazardous materials, must not be allowed to contaminate watercourses and the dump sites for such material must be secured so that they should not leach into the groundwater.
1.16	Vehicles hired for bringing construction material to the site should be, in good condition and should have a pollution check certificate and should conform to applicable air and noise emission standards, and should be operated only during non-peak hours.
1.17	Any hazardous waste generated during the development/ construction phase, should be disposed off as per applicable rules and norms with necessary approvals of the Himachal Pradesh State Pollution Control Board.
1.18	The installation of the Sewage Treatment Plant (STP) shall be certified by an independent expert and a report in this regard shall be submitted along with the six-monthly EC compliance report to the concerned IRO of the Ministry before the project is commissioned for operation. Periodical monitoring of water quality of treated sewage shall be conducted. Necessary measures should be made to mitigate the odour problems from STP.
1.19	Sewage shall be treated in the STP with tertiary treatment i.e. Ultra Filtration. The treated effluent from STP shall be recycled/reused for flushing and landscaping.
1.20	Ambient air quality monitoring stations should be established in the downward direction as well as where maximum ground level concentration of PM10, PM2.5, SO2, and NOx are anticipated in consultation with SPCB within and outside the industrial estate area at least at four locations (one within and three outside the port area at an angle of 120° each), covering upwind and downwind directions. An appropriate Air Pollution Control (APC) system shall be provided for all the dust generating points including fugitive dust from all vulnerable sources, so as to comply with prescribed fugitive emission standards. Data on ambient air quality and emission shall be regularly submitted to the IRO, MoEF&CC along with the six-monthly EC & CRZ compliance report.
1.21	Installation of Ambient Air Quality data shall display units for public display.
1.22	The total renewable energy capacity up to solar power shall be explored and accordingly the plan shall be submitted to the IRO of the Ministry in its first six monthly compliance report and the progress of implementation of this plan be submitted in the subsequent 6 monthly compliance reports. Apart from this Industrial Estate shall ensure that individual industries utilize at least 10% of their total power requirement through renewable energy like solar etc.
1.23	Roofs should meet the prescriptive requirements as per the Energy Conservation Building Code by

S. No	EC Conditions
	using appropriate thermal insulation material to fulfill requirements.
1.24	Red category industrial units to be avoided near residential areas, habitations and water bodies.
1.25	All the recommendations of the EMP shall be complied with in letter and spirit. All the mitigation measures submitted in the EIA report shall be prepared in a matrix format and the compliance for each mitigation plan shall be submitted to RO, MoEF&CC along with a half yearly compliance report.

Standard EC Conditions for (Synthetic organic chemicals industry)

1.

S. No	EC Conditions
1.1	No further expansion or modifications in the plant, other than mentioned in the EIA Notification, 2006 and its amendments, shall be carried out without prior approval of the Ministry of Environment, Forest and Climate Change/SEIAA, as applicable. In case of deviations or alterations in the project proposal from those submitted to this Ministry for clearance, a fresh reference shall be made to the Ministry/SEIAA, as applicable, to assess the adequacy of conditions imposed and to add additional environmental protection measures required, if any.
1.2	The Project proponent shall strictly comply with the rules and guidelines issued under the Manufacture, Storage and Import of Hazardous Chemicals (MSIHC) Rules, 1989, as amended time to time, the Chemical Accidents (Emergency Planning, Preparedness and Response) Rules, 1996, and Hazardous and Other Wastes (Management and Trans-Boundary Movement) Rules, 2016 and other rules notified under various Acts.
1.3	The energy source for lighting purpose shall be preferably LED based, or advanced having preference in energy conservation and environment betterment.
1.4	The overall noise levels in and around the plant area shall be kept well within the standards by providing noise control measures including acoustic hoods, silencers, enclosures etc. on all sources of noise generation. The ambient noise levels shall conform to the standards prescribed under the Environment (Protection) Act, 1986 Rules, 1989 viz. 75 dBA (day time) and 70 dBA (night time).
1.5	The company shall undertake all relevant measures for improving the socio-economic conditions of the surrounding area. The activities shall be undertaken by involving local villages and administration. The company shall undertake eco-developmental measures including community welfare measures in the project area for the overall improvement of the environment.
1.6	The company shall earmark sufficient funds towards capital cost and recurring cost per annum to implement the conditions stipulated by the Ministry of Environment, Forest and Climate Change as well as the State Government along with the implementation schedule for all the conditions stipulated herein. The funds so earmarked for environment management/ pollution control measures shall not be diverted for any other purpose.
1.7	A copy of the clearance letter shall be sent by the project proponent to concerned Panchayat, Zilla Parishad/Municipal Corporation, Urban local Body and the local NGO, if any, from whom

1434

S. No	EC Conditions
	suggestions/ representations, if any, were received while processing the proposal.
1.8	The project proponent shall also upload/submit six monthly reports on Parivesh Portal on the status of compliance of the stipulated Environmental Clearance conditions including results of monitored data to the respective Integrated Regional Office of MoEF&CC, the respective Zonal Office of CPCB and SPCB. A copy of Environmental Clearance and six monthly compliance status report shall be posted on the website of the company.
1.9	The environmental statement for each financial year ending 31st March in Form-V as is mandated shall be submitted to the concerned State Pollution Control Board as prescribed under the Environment (Protection) Rules, 1986, as amended subsequently, shall also be put on the website of the company along with the status of compliance of environmental clearance conditions and shall also be sent to the respective Integrated Regional Office of MoEF&CC by e-mail.
1.10	The project proponent shall inform the public that the project has been accorded environmental clearance by the Ministry and copies of the clearance letter are available with the SPCB/Committee and may also be seen at Website of the Ministry and at https://parivesh.nic.in/ . This shall be advertised within seven days from the date of issue of the clearance letter, at least in two local newspapers that are widely circulated in the region of which one shall be in the vernacular language of the locality concerned and a copy of the same shall be forwarded to the concerned Regional Office of the Ministry.
1.11	The project authorities shall inform the Regional Office as well as the Ministry, the date of financial closure and final approval of the project by the concerned authorities and the date of start of the project.
1.12	This Environmental clearance is granted subject to final outcome of Hon'ble Supreme Court of India, Hon'ble High Court, Hon'ble NGT and any other Court of Law, if any, as may be applicable to this project.

2. Specific Conditions

S. No	EC Conditions
2.1	Process effluent/any wastewater shall not be allowed to mix with storm water. Storm water drain shall be passed through guard pond.



Series-E

For official use only

भारत सरकार
Government of India
जल संसाधन मंत्रालय
Ministry of Water Resources
केंद्रीय भूमि जल बोर्ड
CENTRAL GROUND WATER BOARD

**GROUND WATER INFORMATION BOOKLET
UNA DISTRICT, HIMACHAL PRADESH**



री हिमालय क्षेत्र
NORTHERN HIMALAYAN REGION

DHARAMSALA
सितम्बर, 2013
September, 2013



जल संरक्षण वर्ष 2013

स्वच्छ सुरक्षित जल - सुन्दर खुशहाल कल

CONSERVE WATER - SAVE LIFE

Gaurish



जल संरक्षण वर्ष 2013

स्वच्छ सुरक्षित जल – सुन्दर खुशहाल कल

CONSERVE WATER - SAVE LIFE

Ground Water Information Booklet Una District, Himachal Pradesh

CONTENTS

DISTRICT AT A GLANCE

1.0	INTRODUCTION	1
2.0	CLIMATE & RAINFALL	3
3.0	GEOMORPHOLOGY & SOILS	3
4.0	GROUND WATER SCENARIO	
4.1	Hydrogeology	5
4.2	Ground Water Resources	10
4.3	Ground Water Quality	11
4.4	Status of Ground Water Development	11
5.0	GROUND WATER MANAGEMENT STRATEGY	
5.1	Ground Water Development	13
5.2	Water Conservation & Artificial Recharge	13
6.0	GROUND WATER RELATED ISSUES & PROBLEMS	14
7.0	AWARENESS & TRAINING ACTIVITY	15
8.0	AREAS NOTIFIED BY CGWA / SGWA	16
9.0	RECOMMENDATIONS	16



जल संरक्षण वर्ष 2013

स्वच्छ सुरक्षित जल – सुन्दर खुशहाल कल

CONSERVE WATER - SAVE LIFE

UNA DISTRICT AT A GLANCE

Sl. No	ITEMS	Statistics
1.	GENERAL INFORMATION	
	i) Geographical area (sq km)	1,540
	ii) Administrative Divisions (2011)	
	• Number of Tehsil & sub-tehsils	4 & 1
	• Number of CD Blocks	5
	• Number of Panchayats	235
	• Number of Villages	814
	iii) Population (2001 Census)	
	• Total population	5,21,173
	• Population Density (pers/sq km)	338
	• Rural & Urban Population	91% & 9%
	• SC & ST Population (in percent)	22 % & 0.02%
	• Sex Ratio	976
	iv) Average Annual Rainfall (mm)	1,165
2.	GEOMORPHOLOGY	
	Major Physiographic units	<ul style="list-style-type: none"> • Structural hills & upland (elevation 650–1041 m asl) • Valley/ alluvial plain (elevation 360-550 m asl)
	Major Drainages	
	• Satjuj basin (95%)	Soan River, Lunchar khad
	• Beas basin	Sohan Nadi
3.	LAND USE (ha) (2009-10) Directorate of Land Records)	
	• Forest area	182
	• Cultivated area	232
	• Net area sown	380
4.	MAJOR SOIL TYPES	<ul style="list-style-type: none"> • Alluvial soil • Non-calcic soil
5.	AREA UNDER PRINCIPAL CROPS, (2011-12, Directorate of Agriculture)	In hectares
	• Rice	1,803
	• Wheat	32,452
	• Maize	31,168
	• Pulses	396
6.	IRRIGATION BY DIFFERENT SOURCES (MI census)	In Sq km
	• Net area irrigated by maj / med schemes	1.97
	• Net area irrigated through Ground water	66.40
	• Net area irrigated through surface water	16.66
	• Net area irrigated (Total)	85.03



जल संरक्षण वर्ष 2013

स्वच्छ सुरक्षित जल – सुन्दर खुशहाल कल

CONSERVE WATER - SAVE LIFE

7.	NUMBER OF GROUND WATER MONITORING WELLS OF CGWB (As on March 2013)	
	<ul style="list-style-type: none"> Number of Dug Wells 	20
	<ul style="list-style-type: none"> Number of Piezometers 	Nil
8.	PREDOMINANT GEOLOGICAL FORMATIONS	<ul style="list-style-type: none"> Alluvium/valley-fill (Quaternary) Siwalik Group (Tertiary)
9.	HYDROGEOLOGY	
	Major Water Bearing Formations	
	1. <i>Semi consolidated sediments (Siwalik Group)</i>	Covers major part (70%)
	<ul style="list-style-type: none"> Yield prospects 	Low to moderate (1-5 lps)
	<ul style="list-style-type: none"> GW structures 	Springs, open wells & tube wells
	2. <i>Unconsolidated porous sediments (Alluvium)</i>	In Una valley
	<ul style="list-style-type: none"> Yield prospects 	High (10-25 lps)
	<ul style="list-style-type: none"> GW structures feasible 	Open wells & tube wells
	Avg. Depth to water level (pre-monsoon)	2.00 – 45 m
	(post-monsoon)	1.50 – 42 m
	Long term water level trend (2003-2012)	0-2 m fall in major part of valley area
10	GROUND WATER EXPLORATION BY CGWB (as on 31.03.2013)	
	<ul style="list-style-type: none"> No of wells drilled 	56 (EW-54: OW-2)
	<ul style="list-style-type: none"> Depth Range (m) 	51.00 - 220
	<ul style="list-style-type: none"> Discharge (lps) 	2.00 - 55.00
	<ul style="list-style-type: none"> Static Water Level 	1.45 m agl - 43.00 m bgl
	<ul style="list-style-type: none"> Transmissivity (m²/day) 	85 - 2600
11.	GROUND WATER QUALITY	
	Presence of Chemical constituents more than permissible limits (eg. EC, F, As, Fe)	Nil
	Quality of Ground Water (EC Range in $\mu\text{S}/\text{cm}$)	Good (345 – 1380)
12.	DYNAMIC GROUND WATER RESOURCES (2011)	
	A. Una valley	
	<ul style="list-style-type: none"> Net Annual Ground Water Draft for all uses 	20,966 ham
	<ul style="list-style-type: none"> Net Ground Water availability for future Irrigation 	-1,493 ham
	<ul style="list-style-type: none"> Projected Demand for Domestic and industrial Uses up to 2025 	5,486 ham
	<ul style="list-style-type: none"> Stage of Ground Water Development 	108 % (Critical)



जल संरक्षण वर्ष 2013

स्वच्छ सुरक्षित जल – सुन्दर खुशहाल कल

CONSERVE WATER - SAVE LIFE

	B. Hum valley	
	• Net Annual Ground Water Draft for all uses	561 ham
	• Net Ground Water availability for future Irrigation	-16 ham
	• Projected Demand for Domestic and industrial Uses up to 2025	125 ham
	• Stage of Ground Water Development	99 % (Critical)
13.	AWARENESS AND TRAINING ACTIVITY	
	A. Mass Awareness Programmes i. KVK, Rampur, Una on 28-03-2006 ii. Badshera on 11.12.2007	2
	B. Training Programme on Aquifer Mapping i. Tier –III Training programme at Gagrate w.e.f. 30.01.2013 to 31.01.2013 ii. Tier –III Training programme at Una w.e.f. 01.02.2013 to 02.02.2013 iii. Tier-II Training programme at Una w.e.f. 04.02.2013 to 08.02.2013 iv. Tier-III Training programme at Amb w.e.f. 12.03.2013 to 13.03.2013	4
	C. Other Trainings i. Awareness Raising Training Programme under Hydrology Project-II at Una on 06.02.2009. ii. Orientation Training Course to State Govt. Officers on at Una w.e.f. 21.02.2013 to 25.02.2013	2
14.	EFFORTS OF ARTIFICIAL RECHARGE & RAINWATER HARVESTING	Under progress at Dhamandhari
15.	GROUND WATER CONTROL AND REGULATION	
	• Number of OE & Critical valley	2
	• No of blocks notified	Nil
16.	MAJOR GROUND WATER PROBLEMS AND ISSUES	
	• Depletion of water table	In valley area, mild declining trend in parts
	• Water scarcity & Deep water levels	In upland, Beet area, very deep water level; require exploration
	• Water logging	In patches along Soan river- requires remedial measures



जल संरक्षण वर्ष 2013

स्वच्छ सुरक्षित जल - सुन्दर खुशहाल कल

CONSERVE WATER - SAVE LIFE

DISTRICT GROUND WATER BOOKLET UNA DISTRICT, HIMACHAL PRADESH

1.0 INTRODUCTION

Una district came into existence on 1st September, 1972 and is situated in the southwestern part of the State of Himachal Pradesh. The district, with its headquarter at Una town, has a geographical area of 1540 sq km and covers 2.8 % area of the State. It lies between North latitude 31°18'00" & 31°55'00" and East longitude 75°55'00" & 76°28'00" and is covered by Survey of India degree sheet No.53A & 44M. Towards the north, it is bounded by Kangra district, towards north and east by Hamirpur and Bilaspur districts respectively and towards south-west by the State of Punjab.

Administratively, the district has been divided into two sub-divisions (Una & Amb) and comprises of 4 tehsils [Una, Amb, Bangana, Haroli] and 1 sub-tehsil (Bharwain). Further, there are 5 CD blocks [Una, Amb, Gagret, Dhundla (Bangana) & Haroli]. There are 5 towns (Una, Mehtpur Badshera, Gagret, Santhokhgarh and Daulatpur), 758 inhabited villages, 56 uninhabited and 235 Gram Panchayats in the district. Una district is well developed in the industrial sector due to close proximity to Punjab state with Mehatpur, Gagret, Tahliwal & Amb as main industrial centers. The district is well connected by rail and road network. The nearest airport is at Chandigarh.

As per 2011 census, district has a population of 5,21,173 with 338 persons /sq km. The male/female sex ratio is 976. Rural population is about 91% indicating thereby, that the district has a agricultural economy. Scheduled caste & scheduled tribe population constitutes about 22% & 2% of the total population respectively.

Agriculture is the major occupation of the people of the district, with more than 70% population engaged in the agriculture and allied sector. Major crops like maize, wheat, rice, sugarcane and pulses are grown, apart from vegetables in the district. Total cultivable area is 443 sq km and net area sown area is 388 sq km. Net area irrigated in the district is about 85 sq km. Ground water is the major source of water in the district for irrigation and domestic use. There are large number of water supply wells, tube wells, springs, *kulhs* (water channels) and lift irrigation schemes, implemented exclusively for irrigation purposes. The irrigated command area under the Bhabaur Sahib lift irrigation scheme, phase I and Phase II are 923 hectares and 2640 hectares respectively.

Central Ground Water Board (CGWB) has carried out extensive hydro-geological studies and ground water exploration in the district. Hydrogeological studies and exploration commenced in sixties, and under exploratory drilling programme 56 exploratory wells ranging in depth from 42 to > 200 m bgl have been drilled. CGWB under its national network, maintains 34 stations for ground water regime monitoring, where water level and ground water quality is monitored.



जल संरक्षण वर्ष 2013

स्वच्छ सुरक्षित जल - सुन्दर खुशहाल कल

CONSERVE WATER - SAVE LIFE

2.0 CLIMATE & RAINFALL

Climate of the district is tropical to temperate in nature, as the terrain varies from plains to high hills. Temperature varies from minimum of 4°C in winter to maximum of 46°C in summer. The area receives rainfall during monsoon period, extending from June to September and also non-monsoon period (winter). The annual average rainfall in the area is about 1040 mm, with about 55 average rainy days. The winter season starts from November and continues till the middle of March. Thereafter, the mercury continues rising till the onset of Monsoon which starts from the last week of June and continues till the middle of September.

3.0 GEOMORPHOLOGY & SOILS

Una district nestles between Siwalik ranges and forms part of the lesser Himalayas. It has a diverse landscape made of hills, valleys with piedmont zone, terraces. The elevations of the land surface in the district, vary from 340 m in south-eastern part to 1041 m above mean sea level (amsl) in eastern part of the district. There are three hill ranges i.e. *Chamukha Dhar* with maximum elevation of 1041m amsl, which borders with district Hamirpur, *Dhionsar Dhar* with maximum elevation of 950m amsl and *Ramgarh Dhar* with maximum elevation of 997m amsl. In the southwest along the border with Punjab, Siwalik hill ranges form hilly upland or plateau area with elevation up to 666 m amsl. The vast area between the northwesterly & southeasterly hill ranges, on both sides of river Soan is known as *Una valley*. The undulating to plain fertile Una valley has an area of about 455 sq km and it extends from Daulatpur in the north - west to Santokhgarh in the south - east.

Soan or Swan River, a tributary of river Satluj, drains the major part (80%) of the Una district. Soan is an intermittent river and maintains base flow in the lower reaches. Soan river has about 80% catchment area in Una district and divides the district into two parts. Soan river flows in a southeastern direction and has a wide channel and exhibits braided nature. It originates near Daulatpur in the northeastern part and leaves the district near Santokhgarh and subsequently joins river Satluj. Number of local streams (about 73 *khads*) joins the river within the district. During monsoon Soan river gets flooded due to shallow bank heights and large area on both sides get affected. Govt. of HP has initiated riverbank protection cum flood control measures and the work is in progress. In Bangana area, another stream (*Khad*), flowing parallel to Soan river, is Lunkhar khad, which debouches in Govind Sagar lake. Also, in the extreme north-western part of the district small area forms the catchments of a tributary of Beas river basin.

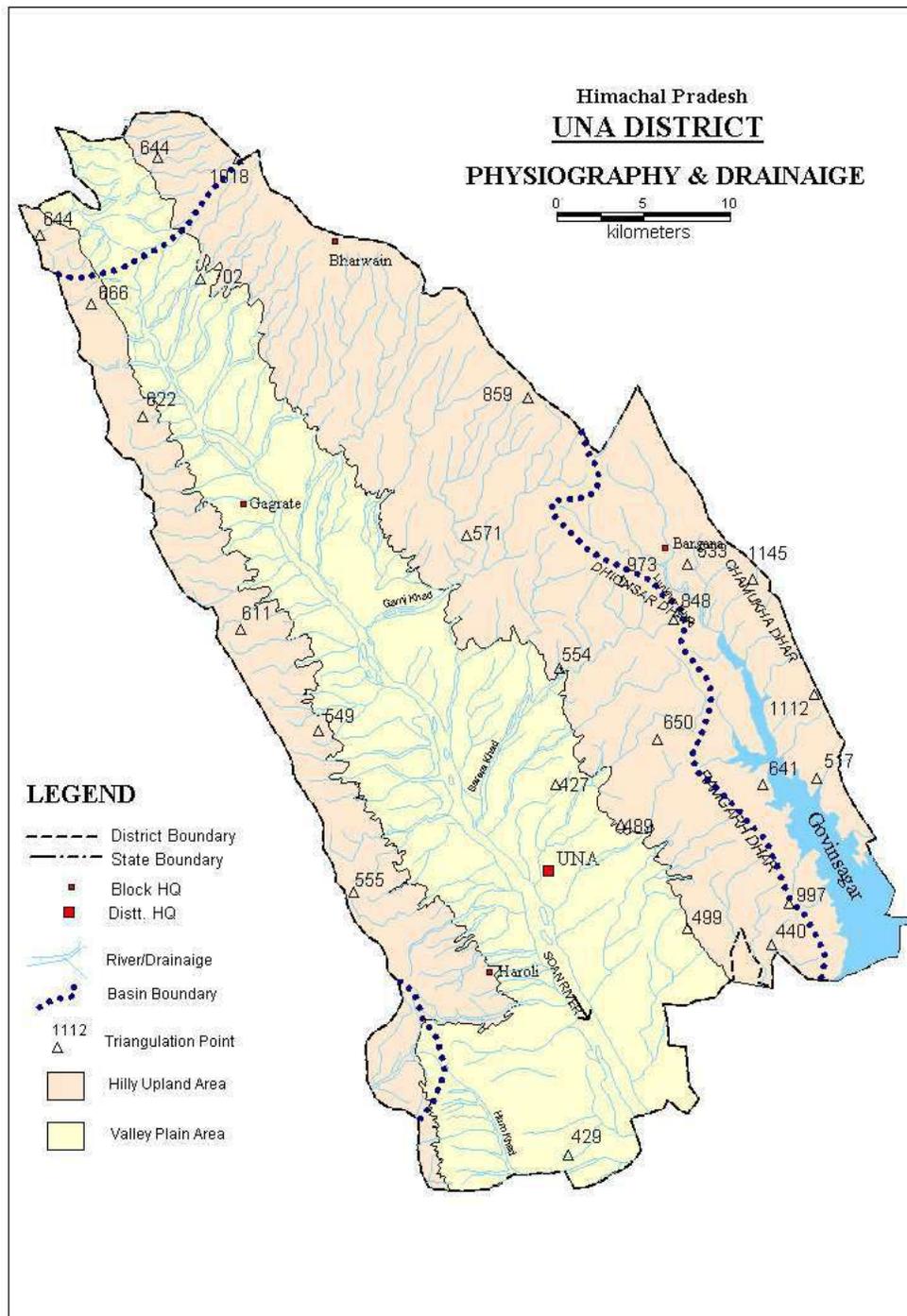
Two types of soils are observed in the district viz., alluvial soil and non-calcic brown soil. Most of the area in the district is covered with alluvial soil and only about 25% of the area i.e. hilly area in the district is covered with non-calcic brown soil. Soils are rich in nutrients and thus are fertile.



जल संरक्षण वर्ष 2013

स्वच्छ सुरक्षित जल - सुन्दर खुराहाल कल

CONSERVE WATER - SAVE LIFE





जल संरक्षण वर्ष 2013
स्वच्छ सुरक्षित जल – सुन्दर खुशहाल कल
CONSERVE WATER - SAVE LIFE

4.0 GROUND WATER SCENARIO

4.1 Hydrogeology

The rock formations occupying the district, range in age from pre-Cambrian to Quaternary period. The generalized geological succession in the district is given below:

<u>ERA</u>	<u>PERIOD</u>	<u>FORMATION</u>	<u>DESCRIPTION</u>
Quaternary	Recent to sub-Recent	Alluvium; fluvial, terrace, piedmont	Sand, silt, clay, gravel, pebble and cobble etc.
		Undifferentiated	Sand, clay, gravel, pebble, cobble and boulders
Tertiary	Pliocene to Mid. Miocene	Upper Siwalik	Soft sandstone, brownish clay, shale, poorly sorted, crudely bedded conglomerate & boulder beds.
		Middle Siwalik	Gray sandstone, and brownish clay/shale
		Lower Siwalik	Red and purple sandstone and shale

Hydro-geologically, the unconsolidated valley fill or alluvial formations, occurring in the valley area and semi-consolidated sediments belonging to Siwalik Group form aquifer system in the district. Porous alluvial formation, forms the most prolific aquifer system in the valley area, where as the sedimentary semi-consolidated formation form aquifer of low yield prospect.

The ground water in the Siwalik group of rocks occur under the unconfined to semi confined conditions, mainly in the arenaceous rocks viz., sandstone, siltstone, gravel boulder beds etc. The occurrence and movement of ground water is controlled by inter granular pore spaces and also the fracture porosity. Siwalik sediments underlie Hilly/undulating areas, where springs (mostly gravity/contact type) and *bowries* are the main ground water structures apart from hand pumps. The discharges of the springs, varies from seepages to 0.50 lps. *Bowries* are dug well type constructions on the hill slopes/ nalas for tapping the seepages. In the low lying areas underlain by Siwalik rocks, dug wells and hand pumps are the main ground water structures, that range in depth from 3.00 to 25.00 m bgl, where in depth to water level ranges from 2.50 to 15.00 m bgl. In upland/plateau areas, the water level is generally deep. In *Beet* area water level is more than 60 m below land surface has been observed.

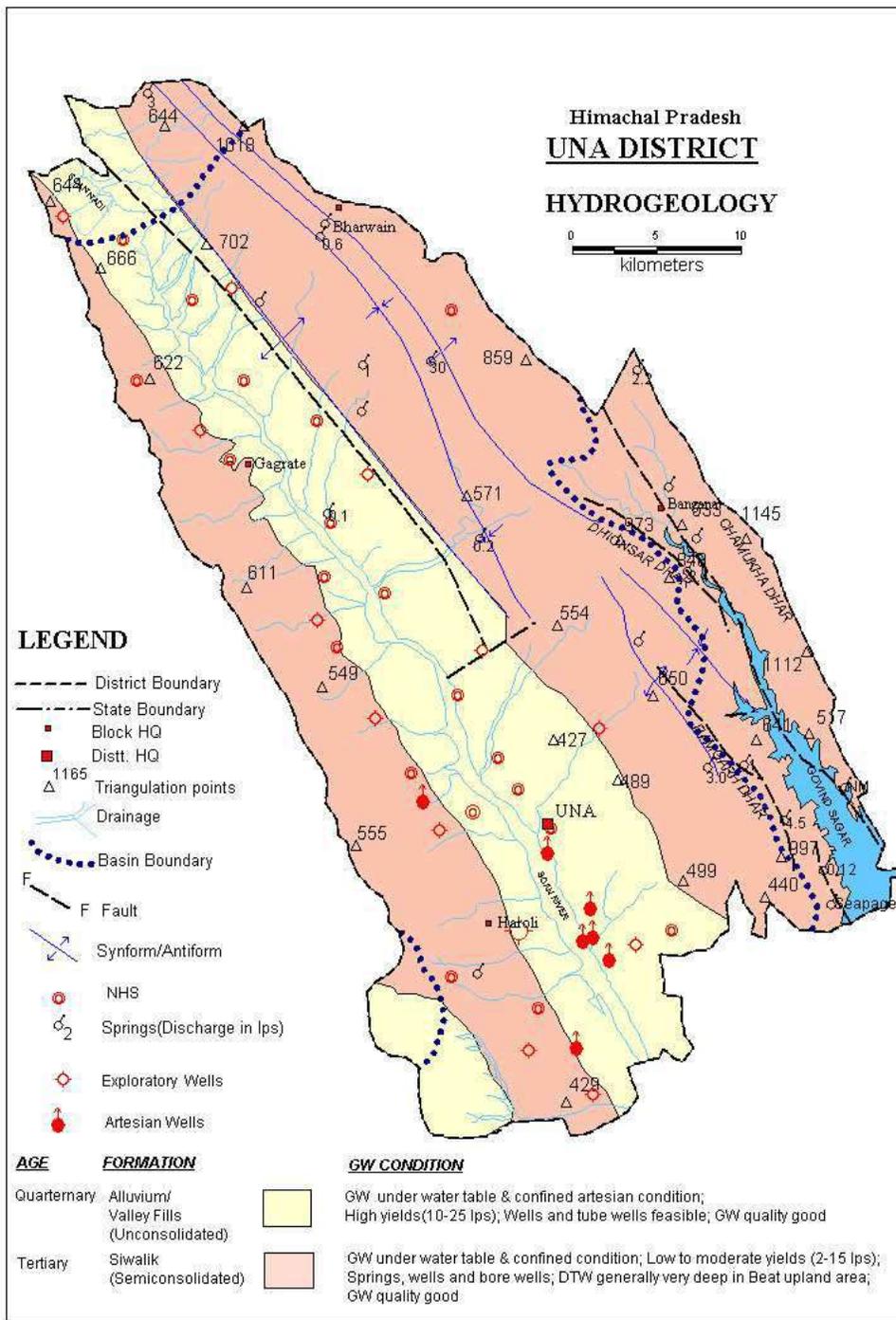
In Una valley area, the ground water occurs in porous unconsolidated / alluvial formation (valley fills) comprising sand, silt, gravel, cobbles / pebbles etc., and forms prolific aquifer. Ground water occurs both under



जल संरक्षण वर्ष 2013

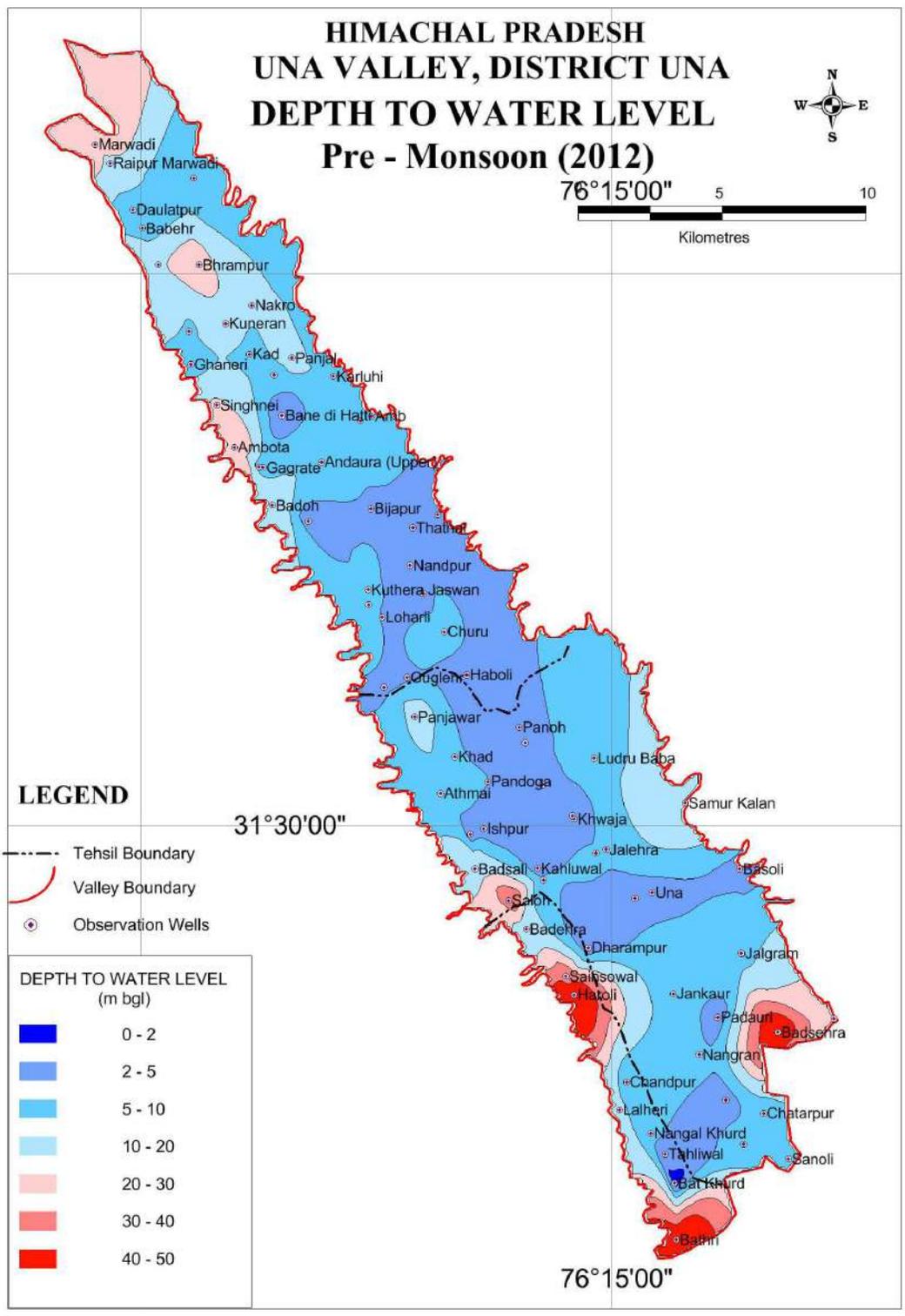
स्वच्छ सुरक्षित जल - सुन्दर खुशहाल कल

CONSERVE WATER - SAVE LIFE





जल संरक्षण वर्ष 2013
 स्वच्छ सुरक्षित जल - सुन्दर खुशहाल कल
CONSERVE WATER - SAVE LIFE

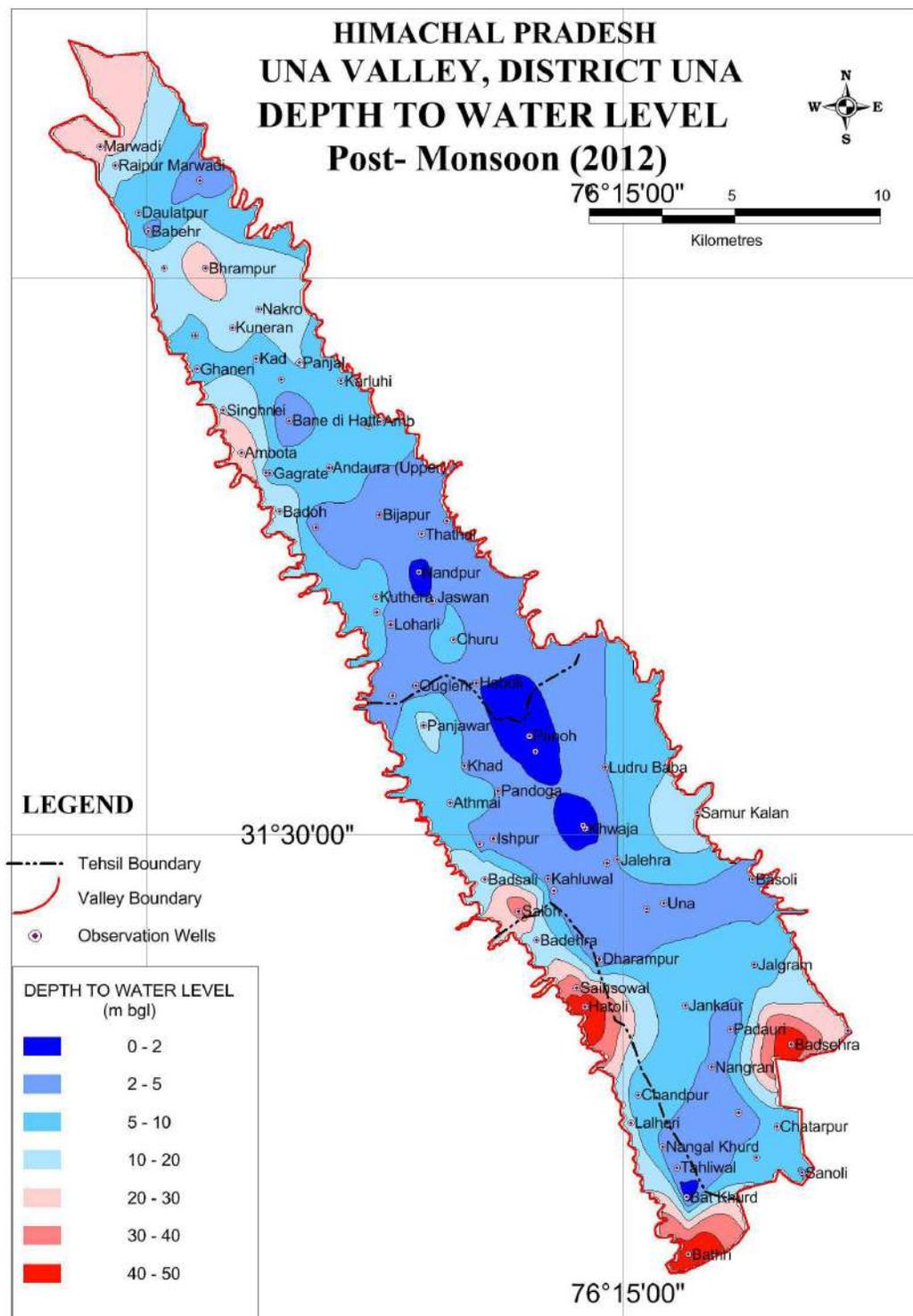




जल संरक्षण वर्ष 2013

स्वच्छ सुरक्षित जल - सुन्दर खुराहाल कल

CONSERVE WATER - SAVE LIFE

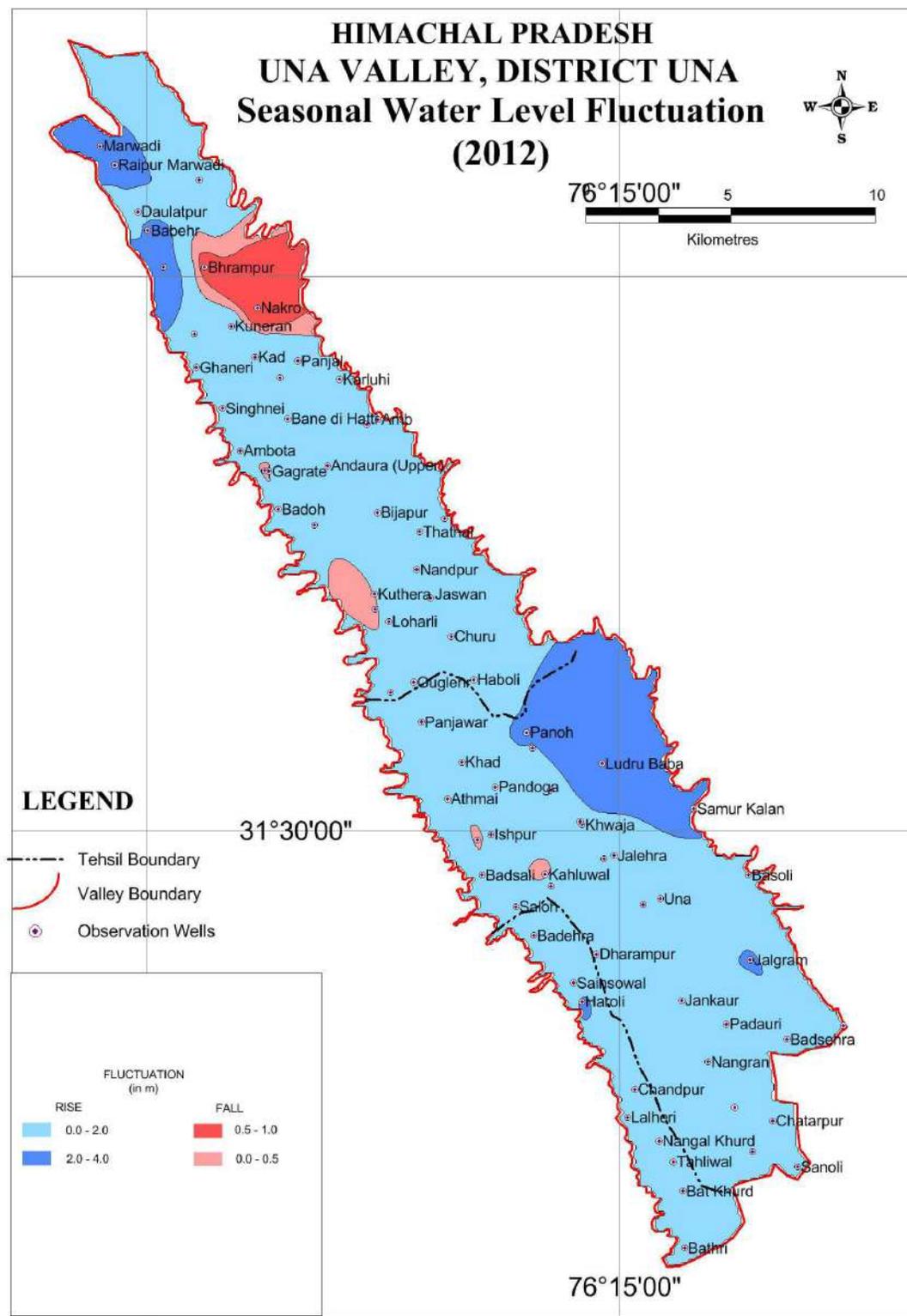




जल संरक्षण वर्ष 2013

स्वच्छ सुरक्षित जल - सुन्दर खुशहाल कल

CONSERVE WATER - SAVE LIFE





जल संरक्षण वर्ष 2013

स्वच्छ सुरक्षित जल – सुन्दर खुशहाल कल

CONSERVE WATER - SAVE LIFE

phreatic and confined/artesian conditions. Free flowing wells are also observed in the lower part of Soan river. Ground water is being extensively developed in the area by medium to deep tube wells, dugwells, dug cum borewells and also by hand pumps. Depth of dugwells and dug cum bored wells in area, ranges from 4.00 to 70.00 m bgl, whereas depth to water level ranges from near surface to 26.46 m bgl in pre monsoon. Yield of shallow aquifer is moderate with well discharges up to 10 lps.

CGWB has drilled/constructed 56 exploratory wells in the district, in the depth range of 51.00 to 220.00 mbgl. Static water level of the tubewells ranges from 1.45 m agl to 43.20 m bgl and discharge ranges from 553 to 3500 lpm with the drawdown less than 8-10 m Free flowing bore wells are observed along the terrace deposits on the both banks of Soan river.

In Una valley depth to water level shows wide variation. During pre-monsoon period (May 2012) it ranged from less than 1.00 to 65.00 m bgl. Deeper water levels are confined mainly in south west (*Beet* area) and localized patches in north eastern and central part of Una valley. In major parts of Una valley, depth to water level ranged between 2.00 to 10.00 m bgl. Some areas in discharge zone along the river Soan, show water logging conditions, where water level is less than 1.5 m bgl. Seasonal fluctuation (rise) up to 3.56 m was observed between pre and post monsoon (2012) period. Long-term water level fluctuation was analysed for the period of May 2012, with respect to decadal average of 2002 - 2011. In general, fall in water level up to 2 m is observed in most part of the valley. However, in isolated pockets in north western and south eastern part of Una valley rise of water level up to 4 m is also observed.

4.2 Ground Water Resources

Rainfall is the major source of recharge to the groundwater body, apart from the influent seepage from the rivers, irrigated fields and inflow from upland areas, whereas discharge from ground water mainly takes place from wells and tube wells; effluent seepages of ground water in the form of springs and base flow in streams etc.

Ground water resources and irrigation potential for Una valley and Hum valley of the district, have been computed as per the GEC-97 methodology, the resources for the year 2011 are presented below.

DYNAMIC GROUND WATER RESOURCES (2011)

A. Una valley

• Net Annual Ground Water Draft for all uses	20966 ham
• Net Ground Water availability for future Irrigation	-1493 ham
• Projected Demand for Domestic and industrial Uses up to 2025	5486 ham
• Stage of Ground Water Development	108%
• Category	Critical



जल संरक्षण वर्ष 2013

स्वच्छ सुरक्षित जल - सुन्दर खुशहाल कल

CONSERVE WATER - SAVE LIFE

B. Hum valley

- Net Annual Ground Water Draft for all uses 561 ham
- Net Ground Water availability for future Irrigation -16 ham
- Projected Demand for Domestic and industrial Uses up to 2025 125 ham
- Stage of Ground Water Development 99%
- Category Critical

The stage of ground water development in Una valley and Hum valley of Una district, is 108% & 99% and both valleys fall under “Critical” category. There is thus no scope for further ground water development.

4.3 Ground Water Quality

Chemical quality data of ground water from shallow as well as deep aquifers in the district, indicates that ground water is generally alkaline in nature and suitable both for domestic and irrigation use. All the parameters analysed are well within the permissible limit of safe drinking water, set by Bureau of Indian Standard (BIS). The range of chemical parameters of Ground Water Monitoring Stations of CGWB (May 2011) in the district, are summarized below:

<i>S. No</i>	<i>Parameter</i>	<i>Range</i>		
		<i>Min</i>	<i>Max</i>	
1.	pH	7.3	8.01	
2.	EC	μS/cm	310	1080
3.	HCO ₃	(mg/l)	79	362
4.	Cl	(mg/l)	15	142
5.	NO ₃	(mg/l)	Tr	46
6.	F	(mg/l)	Tr	0.38
7.	Ca	(mg/l)	10	68
8.	Mg	(mg/l)	10	50
9.	Na	(mg/l)	8.2	110
10.	K	(mg/l)	0.2	34
11.	TH as CaCO ₃	(mg/l)	85	265

Quality of ground water in shallow aquifer, is good for domestic and irrigation purpose in the district.

4.4 Status of Ground Water Development

Ground water development, particularly in valley areas underlain by alluvium/valley fills of the district, is moderate to high. In these areas, all the major irrigation and drinking water supplies depend on ground water viz., open wells and tube wells. The



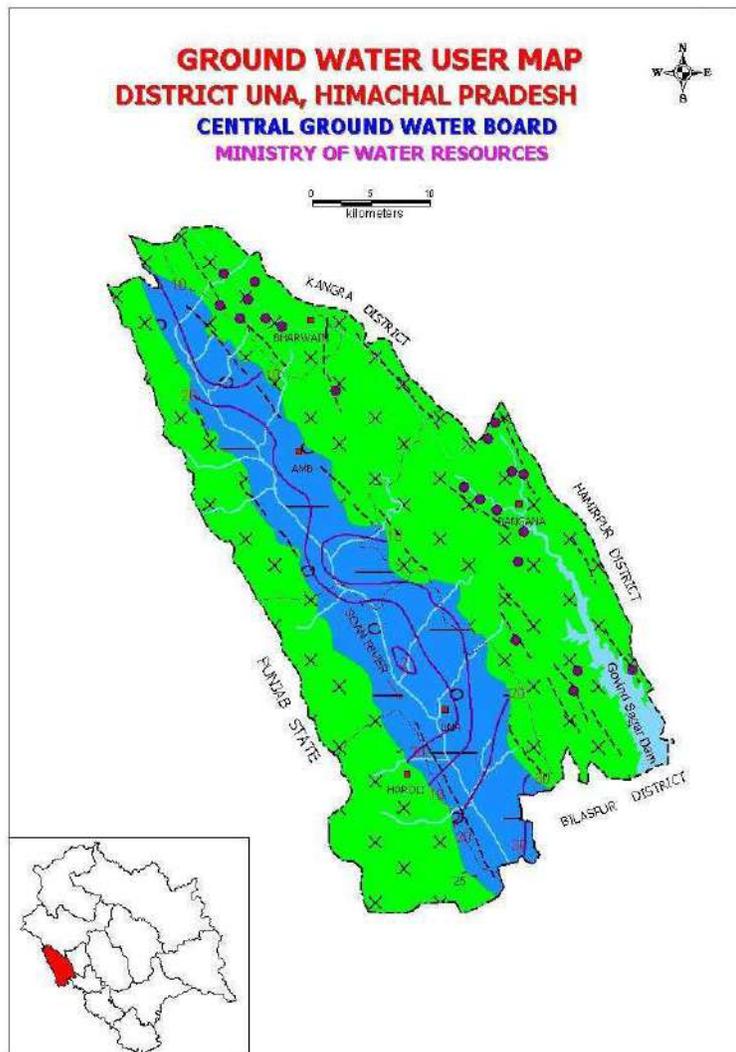
जल संरक्षण वर्ष 2013

स्वच्छ सुरक्षित जल - सुन्दर खुशहाल कल

CONSERVE WATER - SAVE LIFE

deeper aquifers in the area are being extensively developed by tube wells and about 600 tube wells have been constructed in Una valley, most of them in govt. sector. The tube wells range in depth from 51.0 to 220.0 m bgl where water level rest above ground level (Free flow) to 45.00 m bgl in valley area. The well yields are high, with discharge ranging from 553 to 3500 lpm, for 7-10 m draw down. An average tube well of about 100m depth yields about 20 - 25 lps. In the sedimentary areas (Sivalik Group) deep exploration has not been carried out. The piezometric head in tube wells are reported to be more than 100m bgl in upland areas.

State departments have also drilled shallow bore wells or handpumps in the district, with the depth ranging from 25 to 60 m, depending upon the lithology of the area, with a discharge varying from 0.5 lps to 3 lps. Few of them are energized with submersible pumps fitted. As per MI census, there are about 227 dug wells and 1448 shallow tube wells in the district.



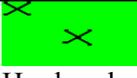


जल संरक्षण वर्ष 2013

स्वच्छ सुरक्षित जल - सुन्दर खुशहाल कल

CONSERVE WATER - SAVE LIFE

LEGEND

	Wells feasible	Rigs suitable	Depth of Well (m)	Discharge (lpm)	Suitable artificial Recharge structures
 Soft rock aquifers	Tube well	Percussion & Percussion cum Rotary Manual	100-120	1200-2500	Check dam, Check dam cum ground water dam, Recharge shaft
	Dug well		10-20	300-500	
 Hard rock aquifers	Dug well	Manual	10-20	300-500	
	Spring development			30-2000	
• Spring				5 Water level contour (m bgl) (Pre monsoon decadal mean, 1993-2002)	
 Major drainage  Reservoir				 Fault/lineament  Tehsil boundary  District boundary  State boundary	

5.0 GROUND WATER MANAGEMENT STRATEGY**5.1 Ground Water Development**

As on March 2011, the stage of groundwater development in Una and Hum valleys of the district is 108% & 99% and falls under *Critical category* of development. There is thus no scope for further ground water development by constructing additional wells and tube wells in the valley area. However tubewells can be constructed by tapping deeper aquifers of depth range of 300m. There is thus an urgent need to simultaneously monitor the behavior of deeper aquifers, in order to take preventive measures in future. Water logged areas along the Soan river should be developed for water supply schemes and for irrigated agriculture in the district.

In hilly upland and plateau areas underlain by Siwalik sedimentary formation, there is need to explore deep aquifers say down to the depth of 300 m to evaluate aquifer potentialities, as these areas are in general water scarce due to typical hydro-geomorphic set up.

5.2 Water Conservation & Artificial Recharge

Ground water is the major source for irrigation & domestic water supply, both in rural and urban areas. Water level observation data has revealed declining trends in water



जल संरक्षण वर्ष 2013

स्वच्छ सुरक्षित जल - सुन्दर खुशहाल कल

CONSERVE WATER - SAVE LIFE

level, in some parts of the district. The stage of ground water development in valley is under *critical category*, and declining water levels in patches suggest need for cautious and well-planned ground water development. Further, there is an urgent need to monitor development pattern by the implementing agencies.

In some parts, the availability of water during summer is limited, particularly in drought years and requires immediate attention to conserve and augment this resource. Based upon the climatic conditions, topography, hydro-geology of the area, suitable structure for rain water harvesting and artificial recharge to ground water body, need to be planned and implemented. There is need to switch over from development phase to management phase in GW sector. Roof top rainwater harvesting in urban/rural areas and water harvesting in rural area need to be adopted and proper scientific intervention for spring development and revival of traditional water storage is required in water scarce hilly upland areas.

In hilly areas structures like nalla bunds, gabbion structures, check dams, check dam cum ground water dams, subsurface dykes, revival of ponds are recommended while in low hill ranges, check dam and roof top rain water harvesting structures can be adopted.

6.0 GROUND WATER RELATED ISSUES & PROBLEMS

Most of the ground water issues and problems in the district are localized and need to be treated independently, by taking the micro level studies in a particular area. The most common issues are deep water level and development of deep aquifer in some areas, viz, the *Beet* area, where water level are more than 100 m bgl. In valley area, extensive development has resulted in depleting water levels in parts and there is need to conserve and augment resources by adopting appropriate recharge measures.

Further, in Una valley due to extensive ground water development for irrigation and the recently set up industrial units, the water levels are likely to show depleting trend. There is urgent need for the State government to initiate water level monitoring network, both in shallow and deep aquifers to monitor its behavior on short as well as long term basis.

On both sides of Soan River, localized areas remain waterlogged through out the year. There is need to develop ground water resources in such areas, so that the water levels are 3-4 m below ground level and area can be reclaimed for use.



जल संरक्षण वर्ष 2013

स्वच्छ सुरक्षित जल - सुन्दर खुशहाल कल

CONSERVE WATER - SAVE LIFE

7.0 AWARENESS & TRAINING ACTIVITY

Mass Awareness Programme (MAP) & Water Management Training Programme (WMTP) by CGWB

CGWB, under the aegis of CGWA, conducted one Mass Awareness Programme on Rainwater Harvesting and Water Management on 28th March, 2006 at Krishi Vigyan Kendra at Rampur and at Bsdehra on 11th December, 2007.

Farmers including the officers and officials of Agriculture and I&PH department attended the programme. Lectures were delivered by CGWB and agriculture department officers on the need for harvesting water for various uses and artificial recharge to ground water for future use. The Regional Director, CGWB stressed the need for change in cropping pattern, optimum utilization of water to various crops and to adopt water conservation measures.

An exhibition displaying roof top rainwater harvesting models, charts, maps and other displays were arranged by CGWB to aware the gathering on the theme.

Participation in Exhibition, Mela, Fair etc

CGWB exhibited its models, posters, displays during the mass awareness programmes at KVK Una in the district.

Aquifer Mapping Training Programme

Tier –II Training programme on “Aquifer information system and aquifer management plan” was organized at Una w.e.f. 04.02.2013 to 08.02.2013. Engineers and Hydrogeologists from I & PH Deptt., NGOs participated in this training.

Tier-III Training programme on “Village Level Aquifer Management Plan” was organised at Gagate w.e.f. 30.01.2013 to 31.01.2013 and at Una w.e.f. 01.02.2013 to 02.02.2013 and at Amb w.e.f. 12.03.2013 to 13.03.2013. The officers from I&PH Deptt., & Forest Deptt., NGOs and farmers of respective area participated in the training.

Presentation & Lectures delivered in public forum / Radio/TV/Institution of repute/Grassroots association /NGO/Academic institutions etc

So far presentation and lectures are delivered amongst the gathering during the MAP and WMTP only.



जल संरक्षण वर्ष 2013

स्वच्छ सुरक्षित जल – सुन्दर खुशहाल कल

CONSERVE WATER - SAVE LIFE

8.0 AREAS NOTIFIED BY CGWA / SGWA

The stage of ground water development in Una and Hum valleys of the district, as on March, 2011, is 108% & 99% respectively and falls under critical category. No area or block has been notified from groundwater development point of view.

9.0 RECOMMENDATIONS

- The stage of ground water development in Una and Hum valley of Una district (2011), is 108% & 99% respectively, and area falls in *critical category*. There is no scope for developing the ground water resource in the district.
- Groundwater development by constructing open wells and shallow tube wells can be constructed on both sides of Soan river, where water level is shallow or has water-logged.
- There is need to take up deep exploration in upland plateau and hilly areas underlain by sedimentary formations, to effectively tackle water scarcity problems.
- Construction of roof top rain water harvesting structures should be made mandatory, in all new constructions and rain water harvesting in rural areas should be promoted. Traditional water storage systems need to be revived.
- There should be mandatory provision of water level monitoring in all tube wells by implementing departments. Extensive ground water monitoring is required in and around industrial areas in the district.
- Traditional resources like springs & *bowries* needs to be revived and developed/protected for use. Public participation in water resource development projects should be encouraged.

SAVE WATER – SECURE THE FUTURE



जल संरक्षण वर्ष 2013

स्वच्छ सुरक्षित जल – सुन्दर खुशहाल कल

CONSERVE WATER - SAVE LIFE

Contributors

Vidya Nand Negi
Scientist-C

Prepared under the guidance of

J.S. Sharma
Regional Director Incharge
and
Dalel Singh
Suptdg Hydrologist

Our Vision

Water security through sound groundwater
management

1457



जल संरक्षण वर्ष 2013

स्वच्छ सुरक्षित जल - सुन्दर खुशहाल कल

CONSERVE WATER - SAVE LIFE

For Technical Assistance Relating to
Rainwater Harvesting
&
Artificial Recharge to Ground Water

Contact:

CENTRAL GROUND WATER BOARD
NORTHERN HIMALAYAN REGION
Dove Cottage, Near Ramnagar, Dharmsala
District Kangra, (H.P.)

Phone: 01892- 224775, 227160

Telefax: 01892-223535

e-mail: rdnhr-cgwb@nic.in

website: www.cgwb.gov.in

SAVE WATER SERVE HUMANITY

Gaurav



केंद्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण
विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

Department of Water Resources, River
Development and Ganga Rejuvenation,
Ministry of Jal Shakti
Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES UNA, DISTRICT, HIMACHAL PRADESH

उत्तरी हिमालयी क्षेत्र, धर्मशाला

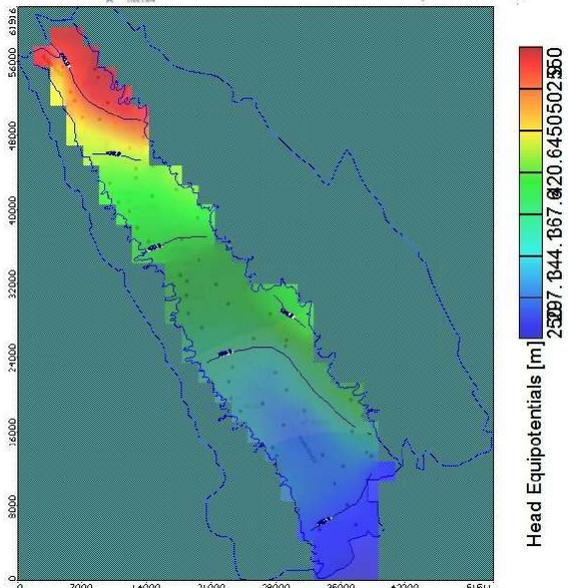
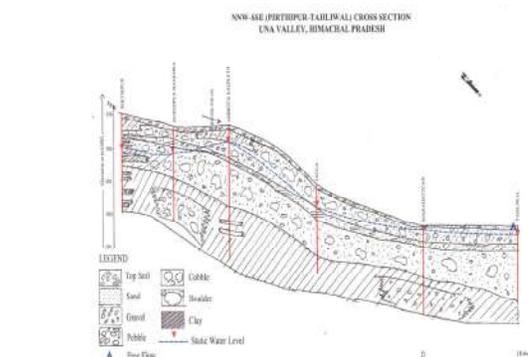
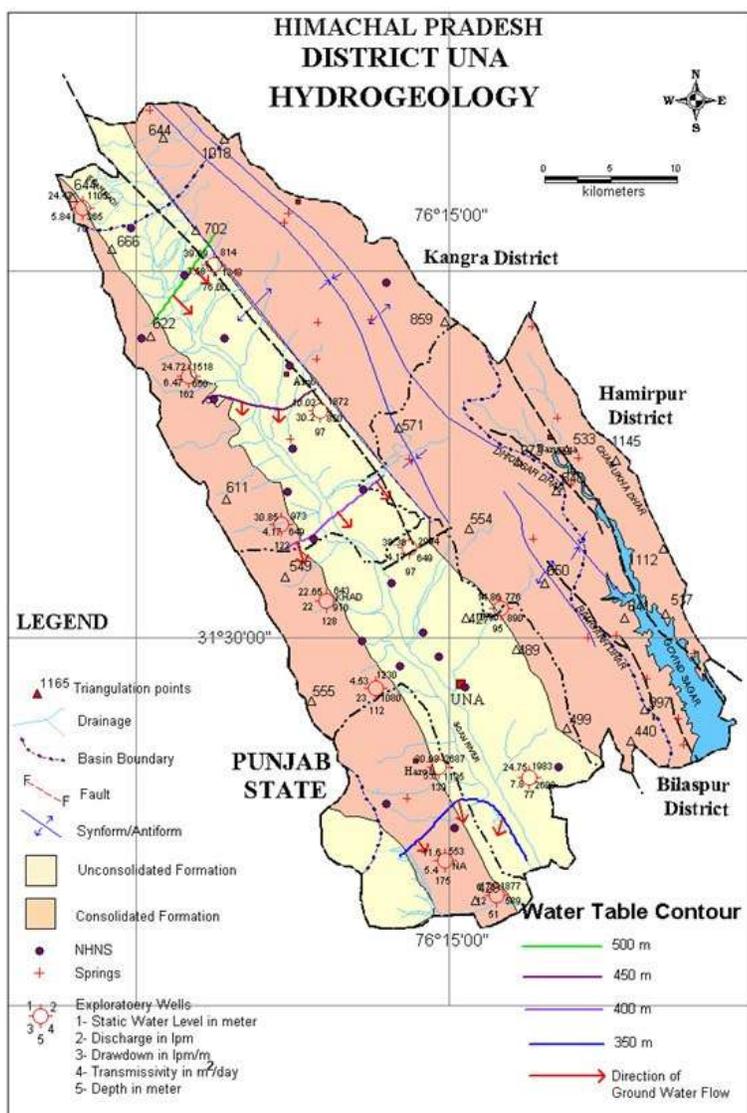
Northern Himalayan Region, Dharamshala

Gaurish



GOVERNMENT OF INDIA
CENTRAL GROUND WATER BOARD
DEPARTMENT OF WATER RESOURCES, RD& GR
MINISTRY OF JAL SHAKTI

AQUIFER MAPPING IN UNA DISTRICT
HIMACHAL PRADESH



1460 AQUIFER MAPPING IN UNA DISTRICT HIMACHAL PRADESH

CONTENTS

1.	INTRODUCTION	1-18
	<ul style="list-style-type: none"> • Objective 2 • Scope of the Study 2 • Approach & Methodology 2 • Location, Extent and Accessibility 4 • Land use, irrigation and cropping pattern 5 • Cropping Pattern 5 • Industrial Activities 6 • Climate 8 • Temperature 8 • Humidity 8 • Physiography 9 • Drainage 9 • Soil characteristics 11 • Land use 12 • Genral Geology 13 • Hydrogeology 16 • Aquifer Parameters 16 • Occurrence of Ground Water 18 	
2.	DATA GAP ANALYSIS	19-31
	<ul style="list-style-type: none"> • Una Valley 19 <ul style="list-style-type: none"> ○ Ground Water Exploration 20 ○ Ground Water Quality 22 ○ Subsurface Geophysical Survey (VES) 23 ○ Soil Infiltration 24 • Parts of Una District 26 <ul style="list-style-type: none"> ○ Ground Water Exploration 27 ○ Water Level Monitoring 28 ○ Subsurface Geophysical Survey (VES) 29 ○ Soil Infiltration 30 	
3.	DATA COLLECTION AND GENERATION	32-37
	<ul style="list-style-type: none"> • Water Level Monitoring 32 • Aquifer Characteristics 37 • Lithological Disposition and Aquifer Disposition 37 	
4.	GROUND WATER RESOURCES	38-39
5.	GROUND WATER MODELLING	40-43
6.	ISSUES AND AQUIFER MANAGEMENT STRATAGIES	44-47

**AQUIFER MAPPING IN UNA DISTRICT
HIMACHAL PRADESH
(1312 Sq.km Una valley & Parts of Una District)**

1. INTRODUCTION

The delineation of aquifers along with their extent and potential through ground water surveys, exploration and monitoring is an on-going activity of Central Ground Water Board. The entire country including the valley areas of Himachal Pradesh has already been covered under Systematic Hydrogeological Surveys to generate basic hydrogeological data. Reappraisal Hydrogeological Surveys/ Ground Water Management Studies have been conducted to study the changes in the groundwater regime over a period of time. The hydrogeological map of the entire country was compiled on 1: 2,000,000 scale and was first published in 1984. Subsequently, it was revised and again published in 2002 based on the data collected by CGWB through ground water survey, investigation and exploration program supported by exploratory drilling, geophysical investigations and hydro chemical studies. Aquifer Atlas of Himachal Pradesh was prepared on 1:250,000 scale.

In today's scenario, increasing population, rapid urbanization and industrial development and human interventions in the ecosystem pose a challenge for water resource managers. Any strategy for management of ground water resources on sustainable basis depends on proper understanding of the characteristics of the aquifer system. In view of the emergent challenges in the ground water sector in the country, an urgent need was felt for comprehensive and realistic information pertaining to various aspects of ground water resources available in different hydro-geological settings through a process of systematic data collection, compilation, data generation, analysis and synthesis.

In view of this the micro level aquifer mapping programme has been taken up by Central Ground Water Board (CGWB) during the XII Five Year Plan. Aquifer mapping is a multidisciplinary scientific process wherein a combination of geological, hydrogeological, geophysical, hydrological and water quality data are integrated to characterize the quantity, quality and movement of ground water in the aquifers. Under the National Aquifer Management Programme (NAQUIM) North Western Himalayan Region had undertaken aquifer mapping of Una District of Himachal Pradesh.

Objectives

The objective of aquifer mapping is delineation of geometry of the underlying aquifer systems in horizontal as well as vertical domain and their characterization, estimating their yield potential and formulation of aquifer management plans to ensure water availability on sustainable basis.

Scope of the study

The scope of the present study is broadly within the framework of NAQUIM being implemented by CGWB. There are four major components of this activity viz.: (i) Data collection /compilation (ii) Data gap analysis (iii) Data generation, and (iv) Preparation of aquifer maps and management plan.

Data compilation included collection, and wherever required procurement, of all the maps from concerned Agencies, such as the Survey of India, Geological Survey of India, State Governments, etc., computerization and analyses of all acquired data, and preparation of a knowledge base.

Identification of Data Gap was included to ascertain the requirement for further data generation in respect of hydrogeological, geophysical, chemical, hydrological studies, etc.

Data generation included those pertaining to exploratory drilling and aquifer characteristics, sub-surface geophysics, chemical quality of ground water and geophysical survey. Generation of chemical quality data of ground water was accomplished by collection of water samples and their laboratory analyses for all major parameters and heavy metals. Sub-surface geophysical studies incorporated Vertical Electrical Sounding and borehole logging.

Based on integration of data generated from various studies of hydrogeology & geophysics, aquifers have been delineated and characterized in terms of quality and potential. Various maps have been prepared bringing out Characterization of Aquifers, which can be termed as Aquifer maps providing spatial variation (lateral & vertical), quality, water level and potential (quality & quantity). Finally, a suitable strategy for sustainable development and management of the aquifer in the area has been evolved based on the acquired data.

Approach and Methodology

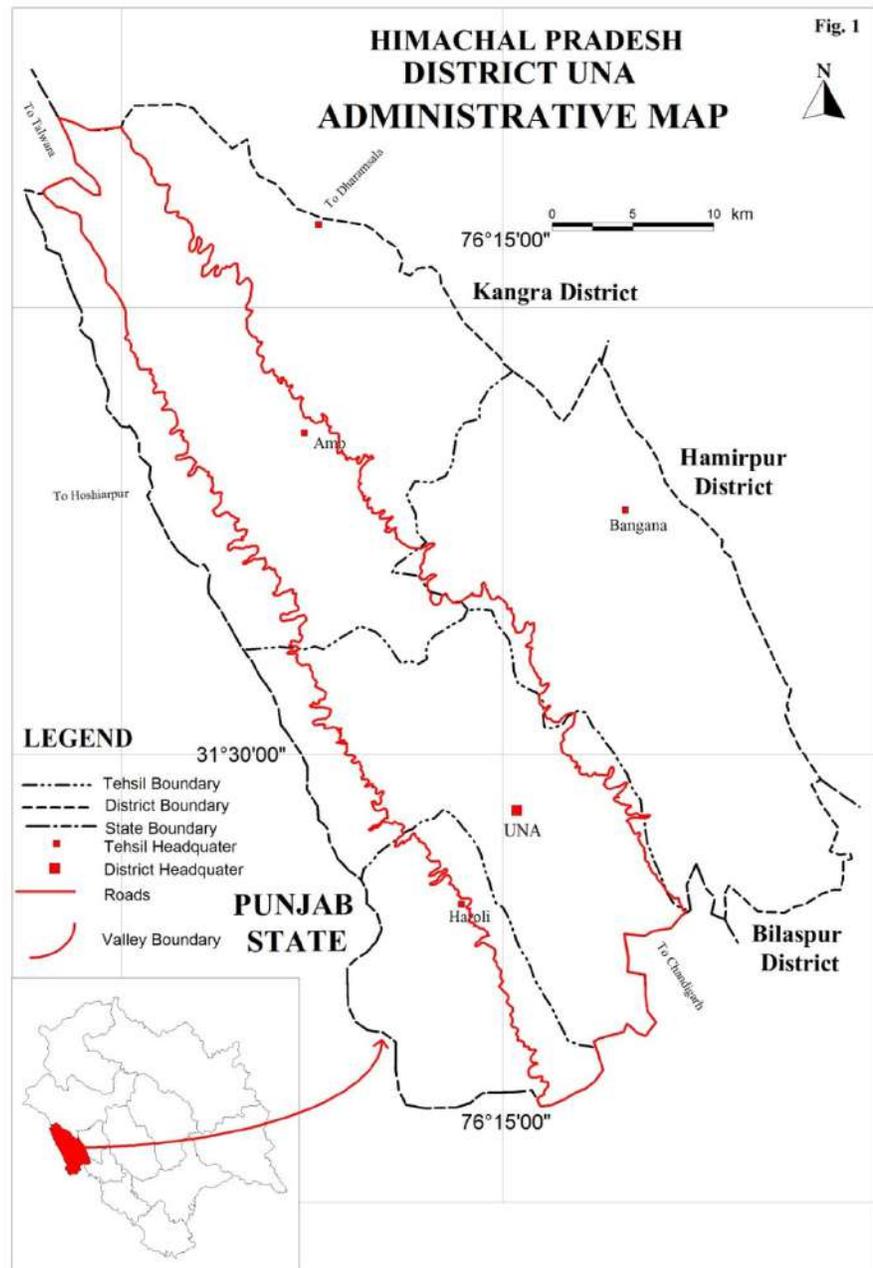
The study involves collection of existing data from various sources including CGWB records, State Government agencies, available literature and other sources relevant for the purpose of aquifer mapping and management. Central Ground Water Board has been continuous groundwater exploration in the area till date. District Reports and report of Reappraisal Hydrogeological surveys in Una valley and District Ground water Brochures was compiled, analysed, examined, synthesized and interpreted from available sources. Since these

sources had predominantly non-computerized data, all the data available and collected was converted into computer based GIS data sets, which were used to prepare various thematic layers. These layers were integrated to generate aquifer maps. Finally an attempt was made to formulate aquifer management plans.

With these aims, Aquifer Mapping Study was carried out in Una valley, district Una under Annual Action Programme 2012-13 and parts of Una district in 2015-16. These surveys are made to integrate the information on the scenario of groundwater occurrence, availability and utilization in terms of

quality and quantity along with exploratory drilling, monitoring of water levels with quality, pumping tests, infiltration tests, geophysical surveys etc.

Development of aquifer mapping at the appropriate scale and formulation of sustainable management plan will help in achieving drinking water security, improving irrigation facility and sustainability of water resources development. It will also result in better management of vulnerable areas.



During this study, 66 key observation wells (Dug wells) were established. Subsequently, all the available data of ground water from the earlier studies are compiled and integrated with these studies. This report brings out the ground water scenario, lateral & vertical characteristics of the aquifer and suggests better management plan of ground water in scientific manner.

Location, Extent and Accessibility

The Aquifer mapping area, i.e. Una District (Una valley and Parts of Una district) is one of the southwestern district of Himachal Pradesh lying between North latitude 31°08'00" & 31°55'00" and East longitude 75°55'00" & 76°28'00" (Fig. 1). It falls in survey of India degree sheet Nos. 44M & 53A and covers area of 1312 sq. km. The area is bounded by Kangra district in north, Hamirpur and Bilaspur districts in northeast and southeast and Punjab State in southwest and south.

The district is well connected by rail and road network. All the tehsil headquarters are connected with metalled roads and State Highway No 23 passes through the area. The nearest airport is at Chandigarh, about 125 km from Una. Goddess temple at Chintpurni, Dera Baba Bhadbhag Singh and Rudru Baba are the important pilgrim centers in the district.

The district has been divided into two sub-divisions namely Una and Amb and comprises of four tehsils viz., Una, Amb, Bangana and Haroli (Fig. 1). For development purposes, the district has been divided in five community development blocks namely Una, Amb, Gagret, Dhundla and Haroli. There are five major towns i.e. Una, Mehtpur Badshera, Gagret, Santhokhgarh and Daulatpur, 758 inhabited villages, 56 uninhabited and 235 Gram Panchayats in the district (Table1).

Table-1 : Administrative Divisions and Population of Una District (Census 2011)

S. No	C.D. Block	Area (sq km)	Population					Density
			Total	Rural	Urban	SC	ST	
1.	Amb	336.24	95,406	95,406	0	23,040	2,649	284
2.	Gagrate	251.98	91,234	83,624	7610	22,104	1,688	362
3.	Bangana	418.51	73,035	73,035	0	20,626	864	145
4.	Una	215.72	1,55,901	1,18,598	37303	22,946	247	723
5.	Haroli	306.28	1,05,597	1,05,597	0	19,330	3,004	345
Total		1540.00	5,21,173	476,260	44,913	1,15,491	8,601	338

Source : Primary Census Abstract, Census, 20011

As per 20011 census, district has a population of 5,21,173 with 338 persons /sq km density of population. The male/female sex ratio is 976. Rural population is about 91% indicating

thereby that the district has a agricultural economy. Scheduled caste population constitutes about 22% of the total population.

Land use, irrigation and cropping pattern

In the district, agriculture is the primary occupation of the people. The land utilization of the district for the year 2011-2012 is given in Table-2.

Table-2 : Land Utilization, Una district.

S. No.	Land Use	Area in Hectares
1	Total geographic area of the district:	154200
2	Total forest area:	18165
3	Barren and uncultivated area:	22064
4	Land put to non agricultural use:	18871
5	Net area sown:	41591
6	Area sown more than once:	34463
7	Cultivable waste land:	2360
8	Current fallows:	2668
9	Other fallows:	2340
10	Total cropped area:	76054
11	Total irrigated area:	7800

Ground water is the major source of water in the district for irrigation and domestic use. There are large numbers of water supply wells and tube wells, springs, *kulhs* (water channels) and lift irrigation schemes implemented exclusively for irrigation purposes. About 80 Sq. km area is being irrigated by these sources.

The major irrigation scheme in the area is Bhabaur Sahib Lift Irrigation Scheme and have been implemented under two phases i.e. Phase-I and Phase-II and Nangal dam is the source of water for this scheme. The Phase-I was commenced from year 1993 and it has a CCA of 923 hect. comprising of village Bangarh, Bhatoli, Morebar, Jakhera, Mehtpur, Raipur, Dehlan, Bharolian and Behdala. The Phase-II was commenced from the year 2001 and it has a CCA of 2640 hect. comprising of villages Bangarh, Dehlan, Chattara, Jakhera, Behdala, Raipur, Basdehra, Charatgarh, Jatpur, Ajauli, Udaipur, Lamlehra, Sasan, Nangran, Badehar, Judowal, Pekghubella, Fatehpur and Chhatterpur Dhada

Cropping Pattern

The Kharif and the Rabi are the two principal crops. The kharif crops largely depend on the rainfall. The major crops like maize, wheat, rice, sugarcane and pulses are grown apart from the

vegetables in the district. Very limited area is irrigated by the assured irrigation water supply. The area covered under food grain crops is given in Table-3.

Table-3 : Cropping Pattern, Una district

S.No.	Crops	Area (Hectares) (in Hectares)	Production (Tones)
1.	Rice	1538	1124
2.	Wheat	6816	43171
3.	Maize	3270	12254
4.	Pulses	37	28
5.	Sugar cane	154	2572
6.	Potato	698	3239

Source: District at a Glance, 2012

Industrial Activities

There is not much industrial development in the area. However, there are few small and large-scale industries are existing. The major industries are given below:

1. Industries at Industrial area Mehtpur:

- i) Rangar Brewries Ltd.
- ii) Panjab Lamminations
- iii) RM Minerals-Calcium carbide
- iv) Him Valves-regulators
- v) Pyara raxines
- vi) Capson polycots
- vii) Hard chem. Agro-induction furnace

2. Industries at Industrial area Tahliwal:

- i) Mehk Chemicals- bleaching powder
- ii) B.B. Chemicals-detergents and acids
- iii) Tara Mandal-blanket
- iv) Viran Agro- soap
- v) Kosol roller flour mill
- vi) Mahindra glass crafting

3. Industries at Industrial area Gagate:

- i) BDM-fruit processing industries
- ii) Omid engineering

4. Industries at Industrial area Amb:

- i) Him cylinders
- ii) International motor cars
- iii) Sar silicon
- iv) Him alloy

5. Industries at Industrial area Jalehra:

- i) Una chemicals
- ii) Hari Om Industries
- iii) May Fair Biotech- medicine
- iv) Par roller mills
- v) Nipro polycots
- vi) Trinity autofast engineering

Climate

Climate of the district is tropical to temperate in nature as the terrain varies from plains to high hills. Temperature varies from minimum of 4°C in winter to the maximum of 46°C in summer. The winter starts from the November and continues till the middle of March. Thereafter the mercury continues rising till the set of monsoon which starts from the last week of June and continues till the middle of September.

The area receives rainfall during monsoon period extending from June to September and also non-monsoon period (winter). The annual average rainfall in the district is about 1040 mm. There are three rain gauge stations at Una, Amb and Bangana in Una district, monitored by IMD.

Table 4. : The district average rainfalls in mm shown below are the arithmetic average of rainfall of stations under the district.

Year	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
2009	14.6	45.0	31.8	31.2	25.3	44.2	430.9	454.3	84.1	20.6	30.2	0.0
2010	10.8	38.4	2.4	1.3	52.4	79.5	270.4	409.6	217.9	35.1	5.8	58.7
2011	32.4	124.2	42.7	26.9	29.3	166.5	176.1	443.8	203.5	17.8	0.0	9.2
2012	110.4	16.1	7.6	55.1	0.5	29.4	175.0	347.4	255.0	2.8	6.7	43.0
2013	29.6	81.9	35.4	7.5	13.2	293.2	430.4	370.6	95.5	61.1	7.8	31.9

(Source: <http://www.imd.gov.in/section/hydro/distrainfall/webrain/hp/una.txt>)

Temperature

The temperature in the different parts of the district varies according to the elevations. After the end of February temperature increases gradually till June, which is the hottest month of the year. Over most of the district the summer is hot. With the onset of the monsoon by about the end of June there is decrease in temperature. During the summer maximum temperature ranges between 40°C and 44°C and during winter, the maximum and minimum temperatures are 16°C and 4°C respectively.

After the withdrawal of the monsoon by about the middle of the September temperatures decrease gradually at first and fairly rapidly after November. January is generally the coldest month in association with cold waves in the wake of western disturbances that affect the district.

Humidity

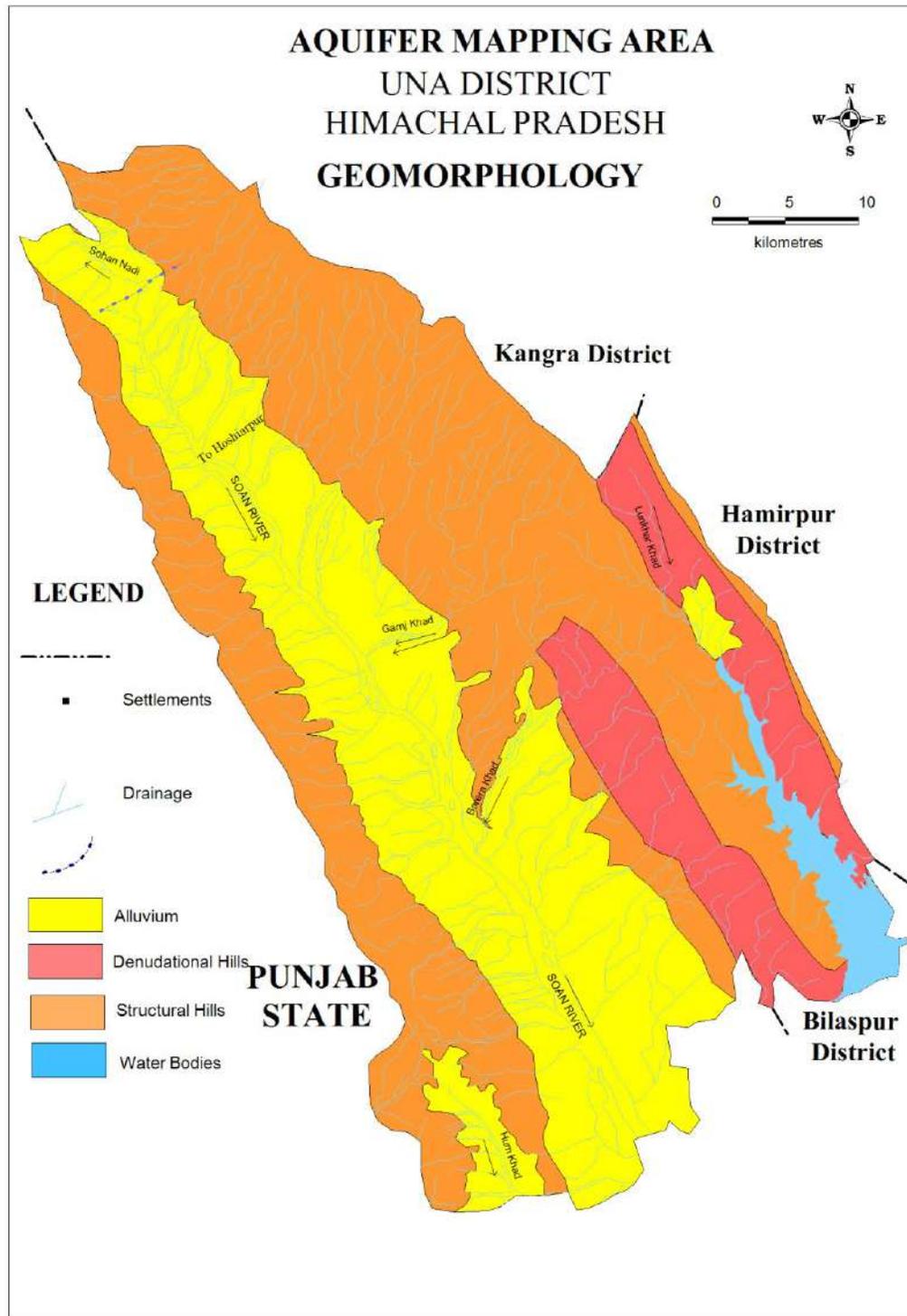
In the southwest monsoon season, the humidity is high. In the post-monsoon, winter and the early part of the summer the humidity is generally low particularly in the higher regions. By June the humidity begins to increase.

Physiography

Una district nestles between Siwalik ranges and forms part of the lesser Himalaya (Fig. 2). It has a diverse landscape made of the hills, valleys with piedmont zone, terraces. The elevations of the land surface in the district vary from 340 m in southeastern part to 1041 m above sea level (amsl) in eastern part of the district. There are three hill ranges i.e. Chamukha Dhar with maximum elevation of 1041m amsl which borders with district Hamirpur, Dhionsar Dhar with maximum elevation of 950m amsl and Ramgarh Dhar with maximum elevation of 997m amsl. In the southwest border with Punjab, Siwalik hill ranges forms hilly area with elevation up to 666 m above mean sea level. The vast area between the northwesterly & southeasterly hill ranges, on both sides of river Swan is the *Una valley*. The undulating to plain fertile Una valley has an area of about 655 sq km and it extends from Daulatpur in the northwest to Santokhgarh in the southeast.

Drainage

The major part of the Una district (80%) is drained by Soan river, Sohan nadi and Lunkhar khad and their tributaries. Soan river a tributary of river Satluj (Fig. 2.) Soan is a seasonal river with its 80% catchments in Una district and divides the district into two parts. Soan River flows in a southeastern direction and has a wide channel and exhibits braided nature. It originates near Daulatpur in the northeastern part and leaves the district near Santokhgarh and subsequently joins Satluj River. About 73 local streams or khads joins the river within the district. During monsoon Soan River gets flooded due to shallow bank heights & large area on both sides are affected. Government has initiated riverbank protection cum flood controls measures and the work is in progress. The main tributaries of Swan river are Sunkaliwali *Khad* (stream), Ambwali khad, Panjoa ki khad, Una di khad, Gubji khad, Barera khad, Khurd ki khad, Barewali khad etc. Siwalik hills run in the north to north-easterly direction to meet Soan river with the tributaries of harer khad, Barwali khad, Parwsati khad, Kalwali khad, Surian ki khad etc.

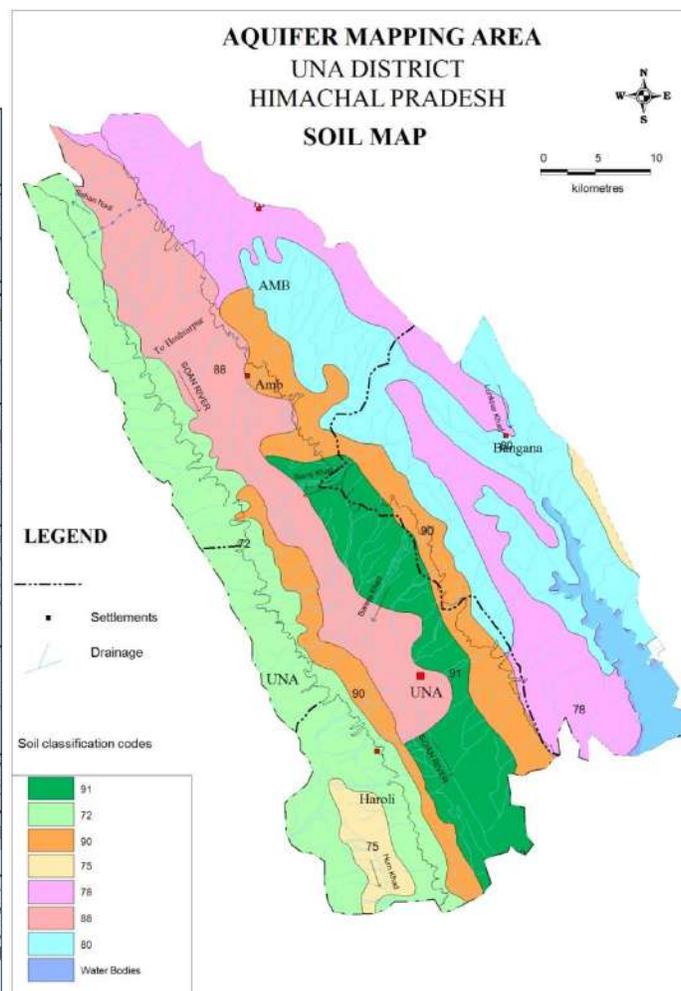


In the Bangana area, another Khad flowing parallel to Soan River is Lunchar khad, which debouches in the Govind Sagar reservoir. In the extreme northwestern part of the district small area form the catchments of Sohan Nadi, a tributary of Beas river. Hum khad forms the main drainage in the southwestern part of the district.

Soil characteristics

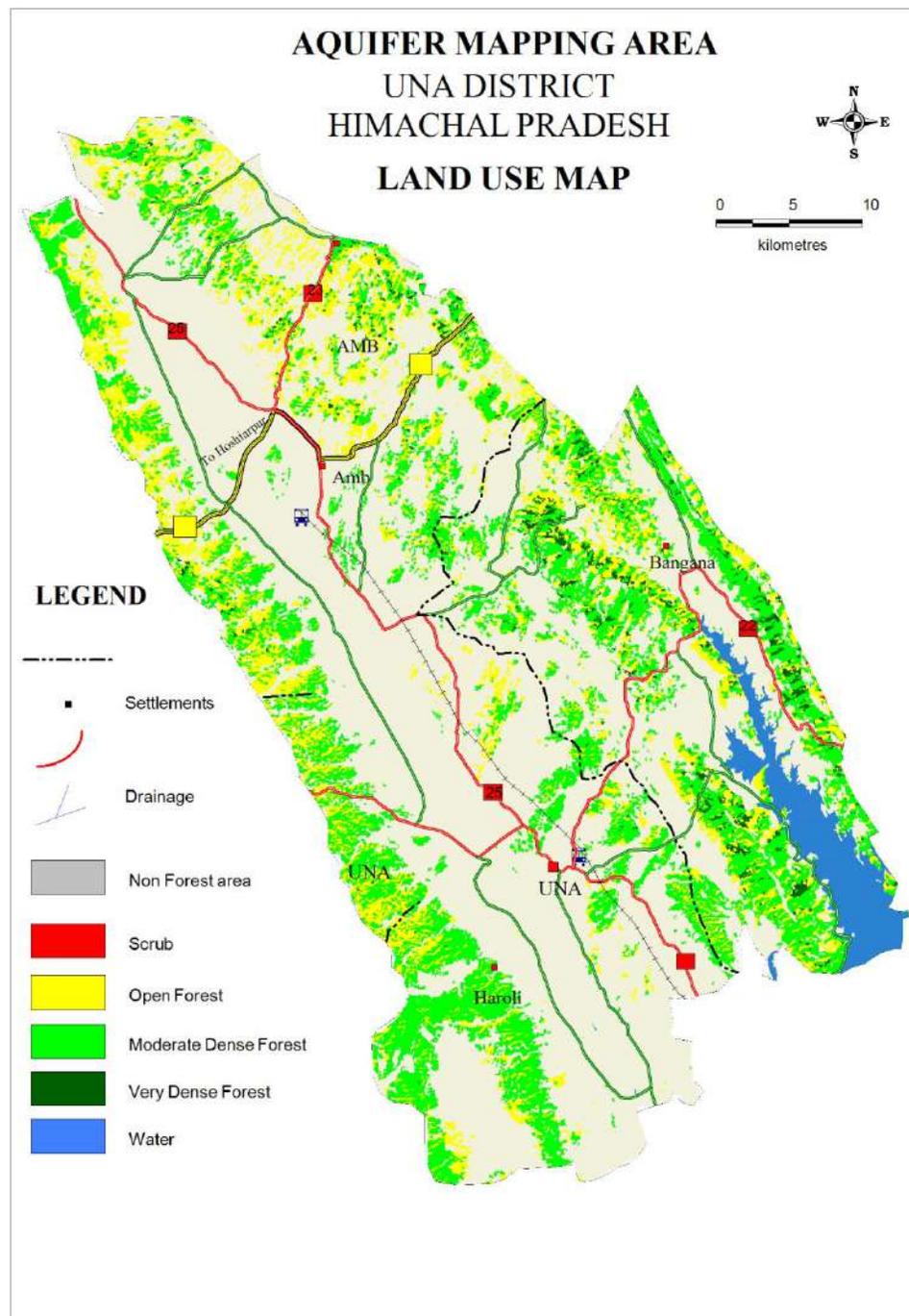
Two types of soils are observed in the district viz., alluvial soil and non-calcic brown soil. Most of the area in district is covered with alluvial soil and only about 25% of the area i.e. hilly area in the district is covered with non-calcic brown soil. These soils are restricted to major drainage courses. They consist of very deep dark brown to dark grayish brown. Silty clayey loams are seasonally submerged. These are well drained and suitable for perennial irrigation. pH is 8.0. They are low in N and P and medium in K.

Soil Classification Code	Soil Description
88	Shallow, well drained, hyperthermic, sandy soils on very gentle slopes with sandy surface and moderate erosion; associated with: Shallow, well drained, coarse-loamy soils with loamy surface and moderate erosion.
72	Medium deep to deep, well drained, thermic, loamy-skeletal soils on steep slopes with loamy surface and severe erosion; associated with: Medium deep, well drained, calcareous, fine-loamy soils with loamy surface and moderate erosion.
80	Medium deep, well drained, thermic, loamy skeletal soils on moderately steep slopes with loamy surface and severe erosion; associated with: Medium deep, well drained, fine-loamy soils with loamy surface and severe erosion.
90	Deep, well drained, hyperthermic, coarse loamy soils on very gentle slopes with loamy surface and severe erosion; associated with: Medium deep, well drained, coarse-loamy soils with loamy surface and moderate erosion.
78	Medium deep, well drained, thermic, coarse-loamy soils on gentle slopes with loamy surface and severe erosion; associated with: Medium deep, moderately well drained, fine-loamy soils with loamy surface and severe erosion.
91	Medium deep, well drained, hyperthermic, coarse-loamy soils on gentle slopes with loamy surface and slight erosion; associated with: Deep, well drained, coarse-loamy, calcareous soils with loamy surface and moderate erosion.
75	Medium deep, well drained, thermic, loamy skeletal soils on very gentle slopes with loamy surface, moderate erosion and moderate stoniness; associated with: Deep, well drained, fine-loamy soils with loamy surface and slight erosion.



Landuse

The district-wise land-use and land-cover map prepared by the National Natural Resource Centre and National Remote Sensing Centre of ISRO, Hyderabad was downloaded from bhuvan-noeda.nrsr.gov.in/theme. It has been observed that major parts of the area are covered by agricultural land. The wasteland, gullied/ravenous land is observed adjoining to the river and drainage channels. Almost whole of the aquifer mapping area has spread of settlements.



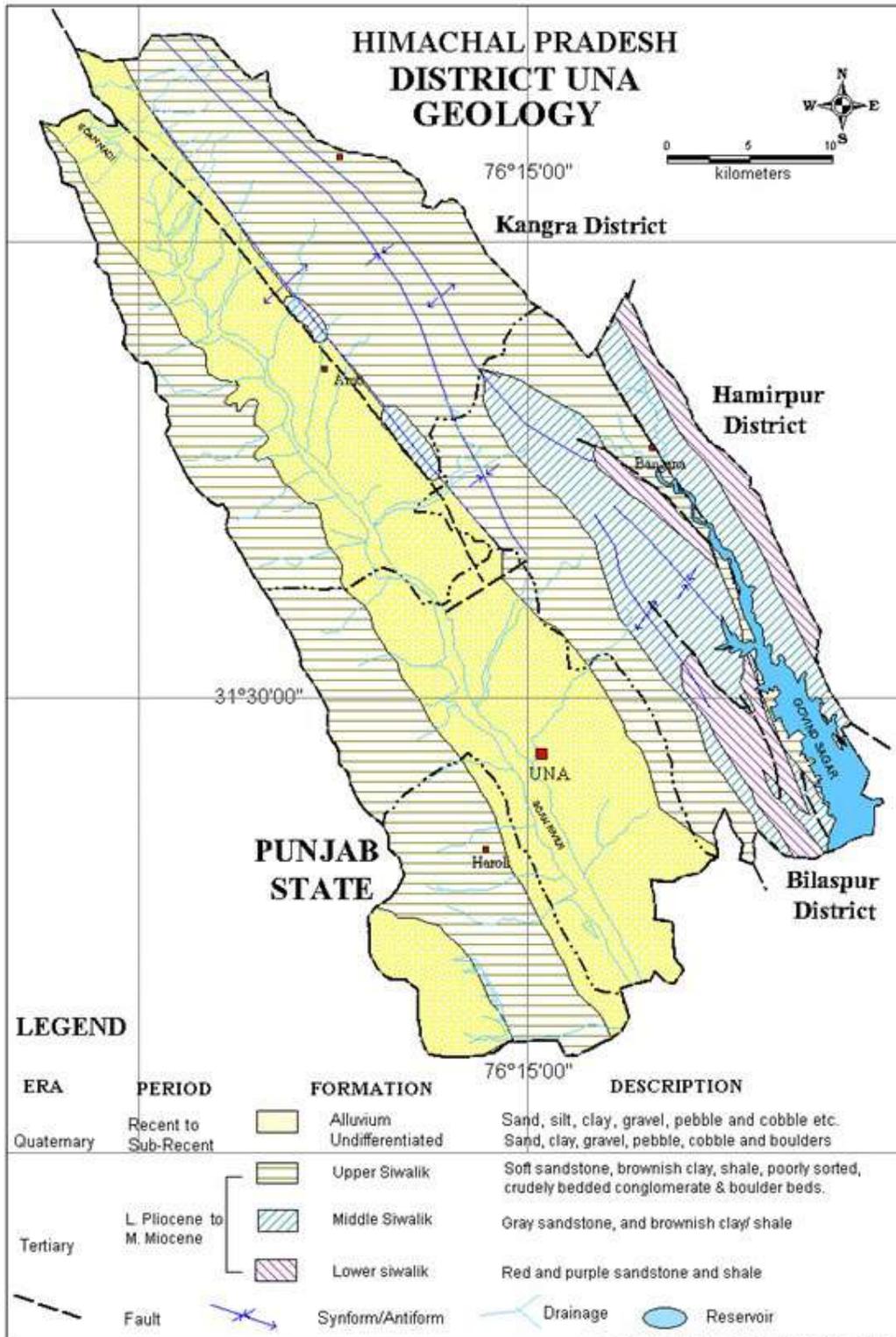
General Geology

The Geology of the area can be described under two broad heads (i) Hilly areas, comprising of upper, middle and lower Siwalik formations.(ii) Quaternary sediments constituting the valley area.

The area is mainly occupied by the Siwalik formation of Tertiary age with narrow longitudinal tectonic valley i.e. Una valley (Fig. 3). The Una valley extends from Daulatpur to Santokhgarh and beyond the northern border of Dun-Syncline in the area is a thrust plane called Soan Thrust. Apart from Una valley, the rest of the area of the district is hilly. Geological sequence is given bellow.

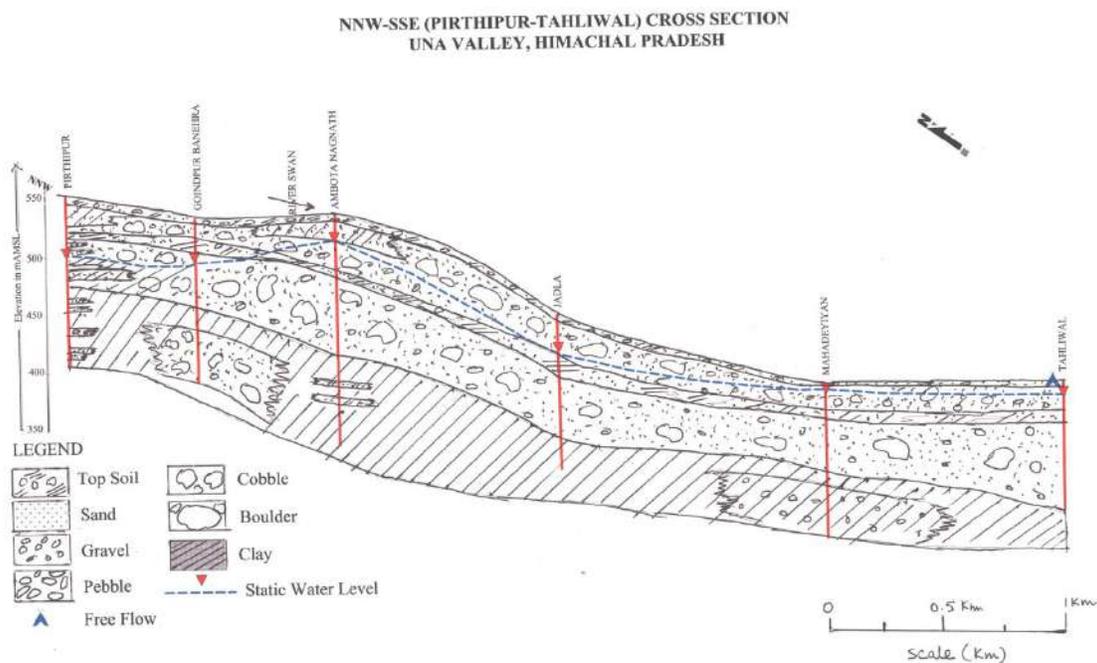
The younger valley fill deposits are Pleistocene to Recent in age and constitute unconsolidated elastic sediments comprising chiefly granular deposits interest ratified in the clays and clay-boulder beds. In the sub-mountain tracts along the Siwalik Hills, the piedmont deposits comprising sand, gravel, pebbles, cobbles and boulders occur. Coarse-grained deposits usually fringe the hills and grade into fine-grained aggregates towards the central parts of the Una valley. The granular beds are interbedded with clays, of varying thickness. In the low lying area of Una valley i.e. Central parts of the valley and the streams traversing the northern part of the valley finer elastic sediments comprising sand, silt and clay chiefly occur.

Era	Period	Formation	Lithology
Quaternary	Recent	Alluvium	Sand, gravel, pebble and cobble
	Lower Pleistocene to Recent	Undifferentiated	Sand, gravel, pebble, cobble and soft sandstone
Tertiary	Lower Pliocene to Lower Pleistocene	Upper Siwalik	Brownish clay, Conglomerate and shale
	Middle Miocene to Lower Pliocene	Middle Siwalik	Gray sandstone, shale and brownish clay
	Lower Miocene to Middle Miocene	Lower Siwalik	Red and purple sandstone and shale



The older valley fill deposits (Terraces) occur along the left bank of the Soan river and on the northern slopes of the valley chiefly comprise gravel, pebbles, boulders interstratified with thin clay lenses. The terrace formations in the Una valley are older than the river alluvium. The piedmont deposits occur along the sub. Mountain tract of Siwalik hills and comprise sand, pebbles, cobbles & boulders.

The upper Siwalik rocks are found in north and south east of the Una valley comprising of indurated sands, sandstones, silts and brown clays. The conglomerate beds also occur at places. Coarser sediments mainly comprise pebbles beds are prominent in the northwestern part of the area. In the southern parts, the boulder bed forms the upper most part, consist of pebbles, cobbles and boulders with intervening thin beds of clays. North of the valley, upper Siwalik formations are chiefly represented by massive sandstone and



conglomerate with beds of clay and indurate sands. Sandstones are usually soft friable and pebbly.

The middle Siwalik includes hard, gray or brown colour sandstones with small proportion of drab shales, orange clays and occasional beds of gravel. Between Kathaulas-ki-Khad and Panjoa-ki-khad there are two isolated outcrops of middle Siwalik rocks comprising of moderately hard, massive medium to coarse grained micaceous sands tones with the thin intercalations of clays.

The lower Siwalik comprises hard sandstones with clay nodules and purple shale. The sandstone generally forms conspicuous strike ridges. The valley fill comprises

unconsolidated fluvial deposits consisting gravels, pebbles, cobbles and boulders intermixed with clays. The various khads emerging on the left bank and joining Soan and formed piedmont deposits and fan deposits those are likely to emerges as potential ground water horizons.

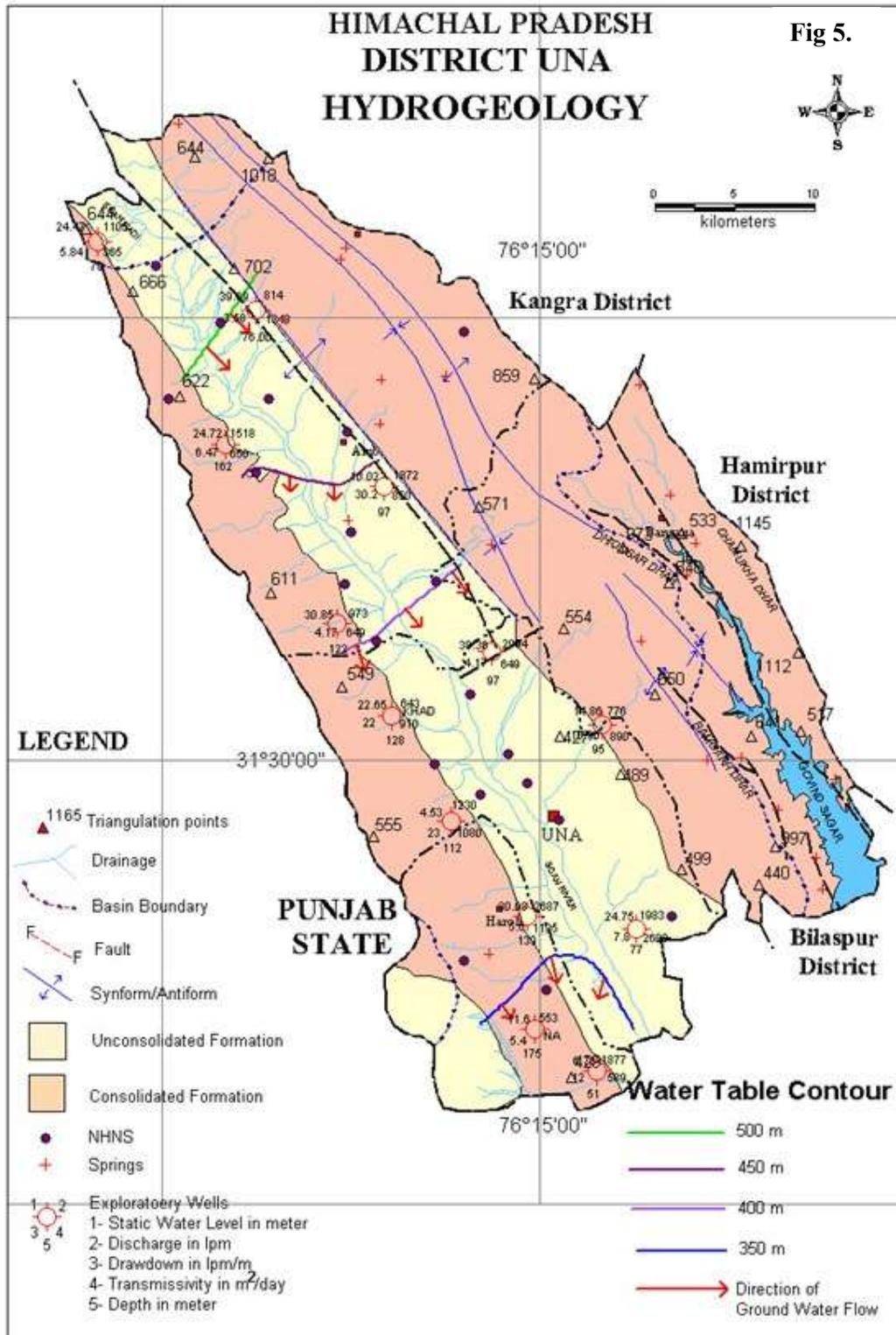
Hydrogeology

Hydrogeologically, the entire area of the Una district is divided into two aquifer system i.e. Consolidated and Unconsolidated aquifer system. The hilly areas comprise the rocks belonging to upper, middle and lower Siwalik. The major rocks are sandstones, shale, clay, conglomerate and boulder beds exposed in the upland areas like Bhangana and Bharwain. (Fig.5). Ground Water in these formations are poorly developed by constructing shallow dug wells along the drainage lines in low topography. Dug wells in the area with overburden have depth to water level varying from 2 to about 8 m. and most of these structures dried up during peak summers. Springs exist in the low topographic areas along the lineaments, contact of various formations and along the streams.

The unconsolidated formations are confined to valley areas only. These covers low lying areas of the valleys and upland terrace deposits. These formations consist of pebble, cobble and boulder mixed with varying proportion of sand interstratified with clay and clay boulder bed. Proportion of coarse-grained sediments increases towards the hills and deposits become finer towards the Soan river i.e. central part of the Una valley. In terrace deposits the granular zones are more promising and forms potential water bearing horizons.

Aquifer Parameters

Central Ground Water Board has constructed 45 exploratory tube wells in the Una valley varying in depth from 90 m to 163 m. The static water level varies from artesian 1.45 m agl (Rampur) to 43.20 m bgl at Chalet. The yield of tube wells ranges from 338 lpm (Badehra) to 3430 lpm (Athman). The discharge of the exploratory wells tapping the aquifers between 27m to 168m bgl varies from 68 lpm to 3430 lpm for a drawdown of 2 to 40 m. The artesian wells tapping confined aquifers at Bhadsali, Kaloh and Rampur yielded 1230 lpm, 3290 lpm and 886 lpm for drawdown of 24m, 39m and 11 m respectively. Transmissivity in the Valley area



ranges from 150 m²/day to 2600 m²/day. The lithological log of the borehole data of exploratory tube wells drilled by CGWB is given in Annexure-1.

Irrigation and Public Health (I&PH) department, Himachal Pradesh has also constructed about 300-tube wells range in depth from 51.0 to 220.0. The water level varies in these tube wells from artesian condition to 45.00 m. The well yields are high with discharge ranging from 553 to 3500 lpm for 7-10 m draw down. Out of 300-tube wells, 270-tube wells are being utilized for water supply and remaining 30 tube wells for irrigation purpose. In all the hilly areas of Una district, I&PH department has drilled some shallow bore-wells (fitted with hand pumps) to provide the clean drinking water to the hamlets. in depth from 45 to 80 m and their yield or discharges are less than 0.5 lps. Dug wells in the overburden with shallow depth (2-8 mbgl) exist in the Bhangana and Bharwain area. The lithological log of the borehole data of .exploratory tube wells drilled by I&PH department is given in Annexure-II.

Occurrence of Ground Water

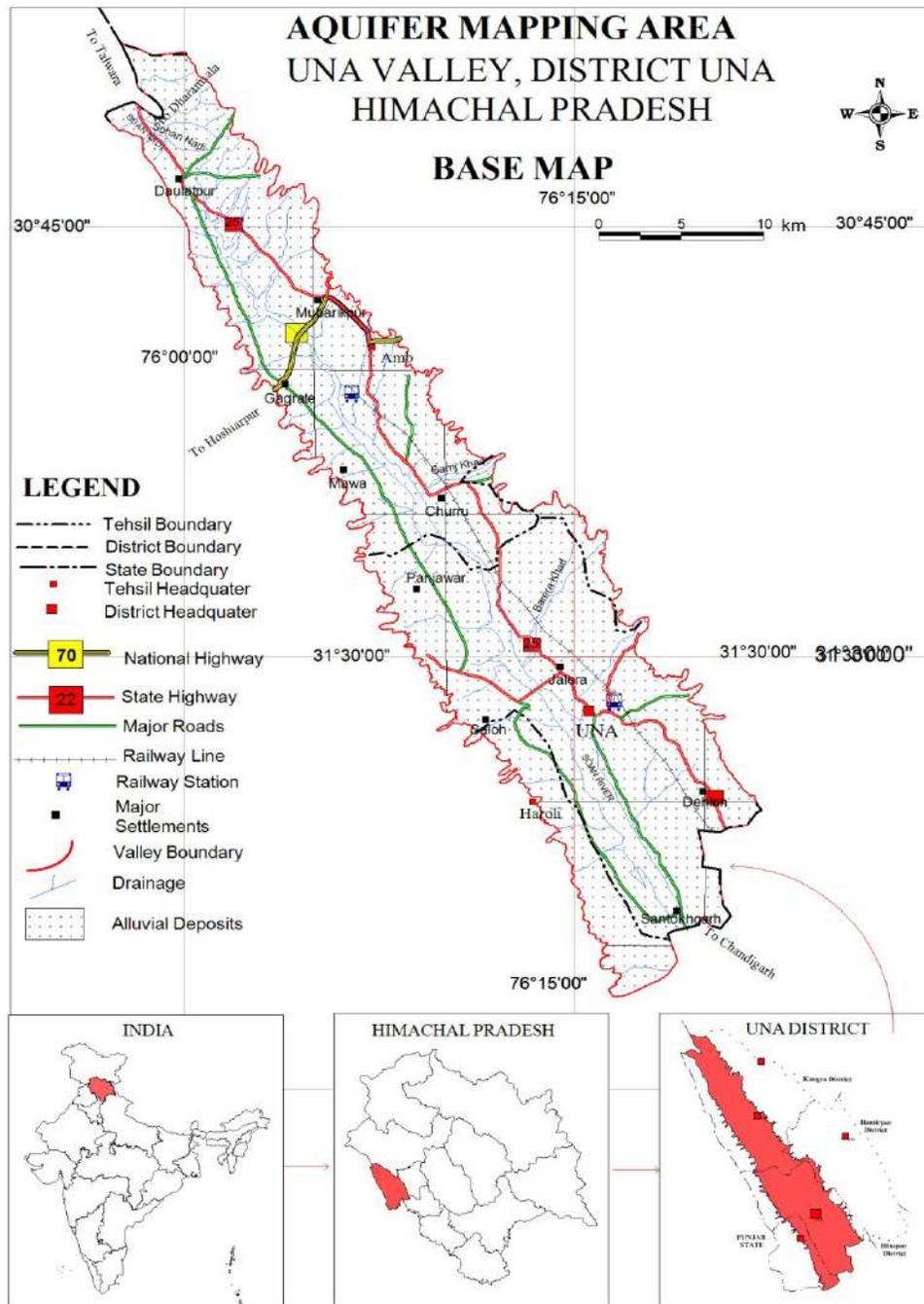
The ground water in the Siwalik group of rocks occur under the unconfined to semi-confined conditions mainly in the arenaceous rocks viz., sandstone, siltstone, gravel boulder beds etc. The occurrence and movement of ground water is controlled by inter granular pore spaces and also the fracture porosity. Siwalik sediments underlie hilly/undulating areas where springs (mostly gravity/contact type) and *bowries* are the main ground water structures apart from the hand pumps. The discharges of the springs, varies from seepages to 0.50 lps. *Bowries* are dug well type constructed on the hill slopes/nalas for tapping the seepages from the sediments. In the low lying areas underlain by Siwalik rock, dug wells and hand pumps are the main ground water structures that range in depth from 3.00 to 25.00 m bgl.

In larger part of the Una valley, the ground water occurs in porous unconsolidated/alluvial formation (valley fills) comprising, sand, silt, gravel, cobble/pebble etc. Ground water occurs both under phreatic & confined conditions. Artesion conditions are also observed in the lower part of Soan river. Ground water is being extensively developed in the area by medium to deep tube wells, dug wells, dug-cum-borewells and also by hand pumps. Depth of dug wells and dug- cum-borewell in area ranges from 4.00 to 70.00m bgl.

2. DATA GAP ANALYSIS

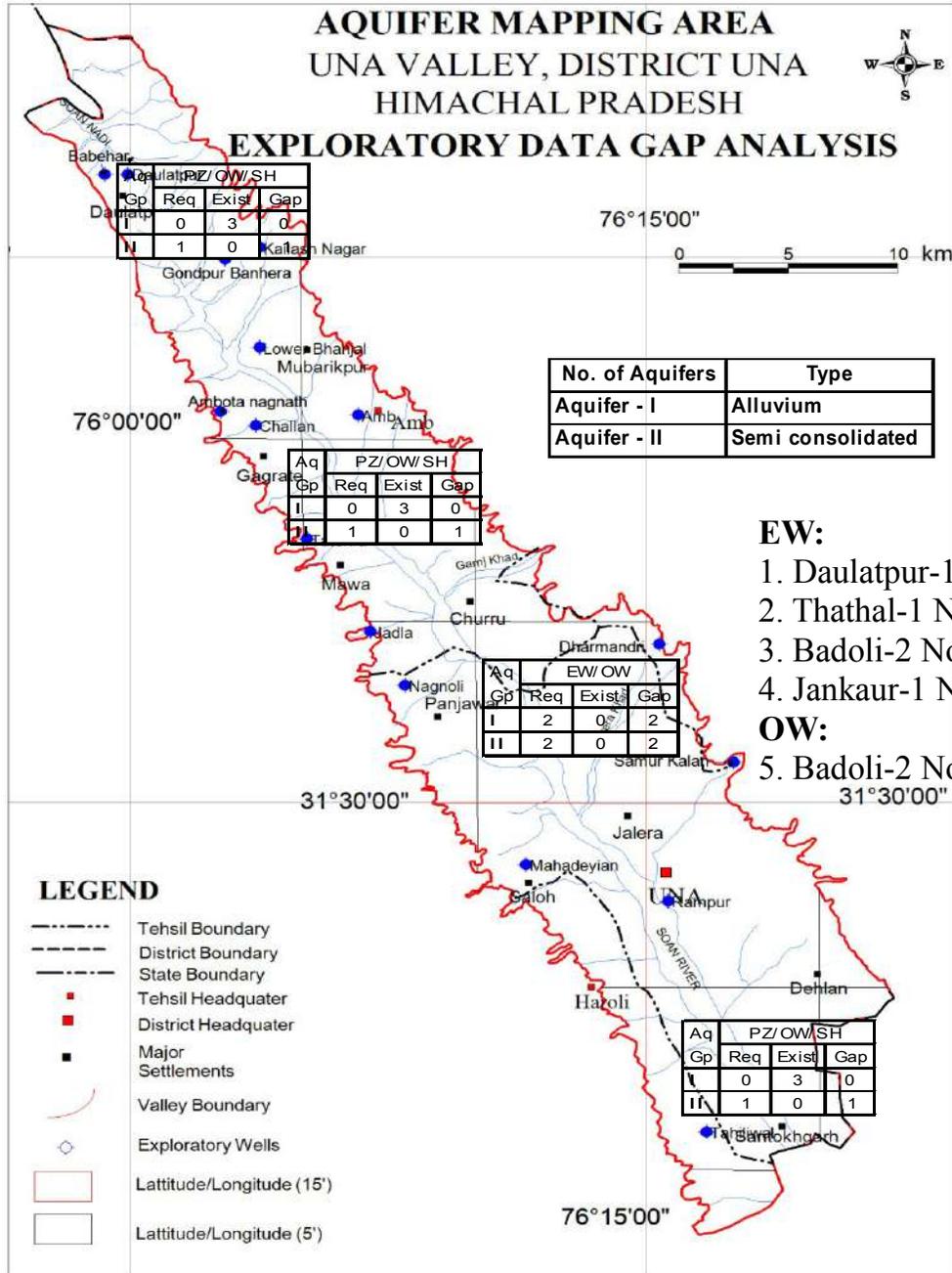
Una Valley

The data gap analysis for Aquifer mapping in Una valley, district Una has been carried out on the basis of EFC guidelines for soft rock area. Una valley is supposed to be a two aquifer system consisting of valley fill alluvium as a first aquifer. The base map for data gap analysis is shown in The analyses done are detailed below:



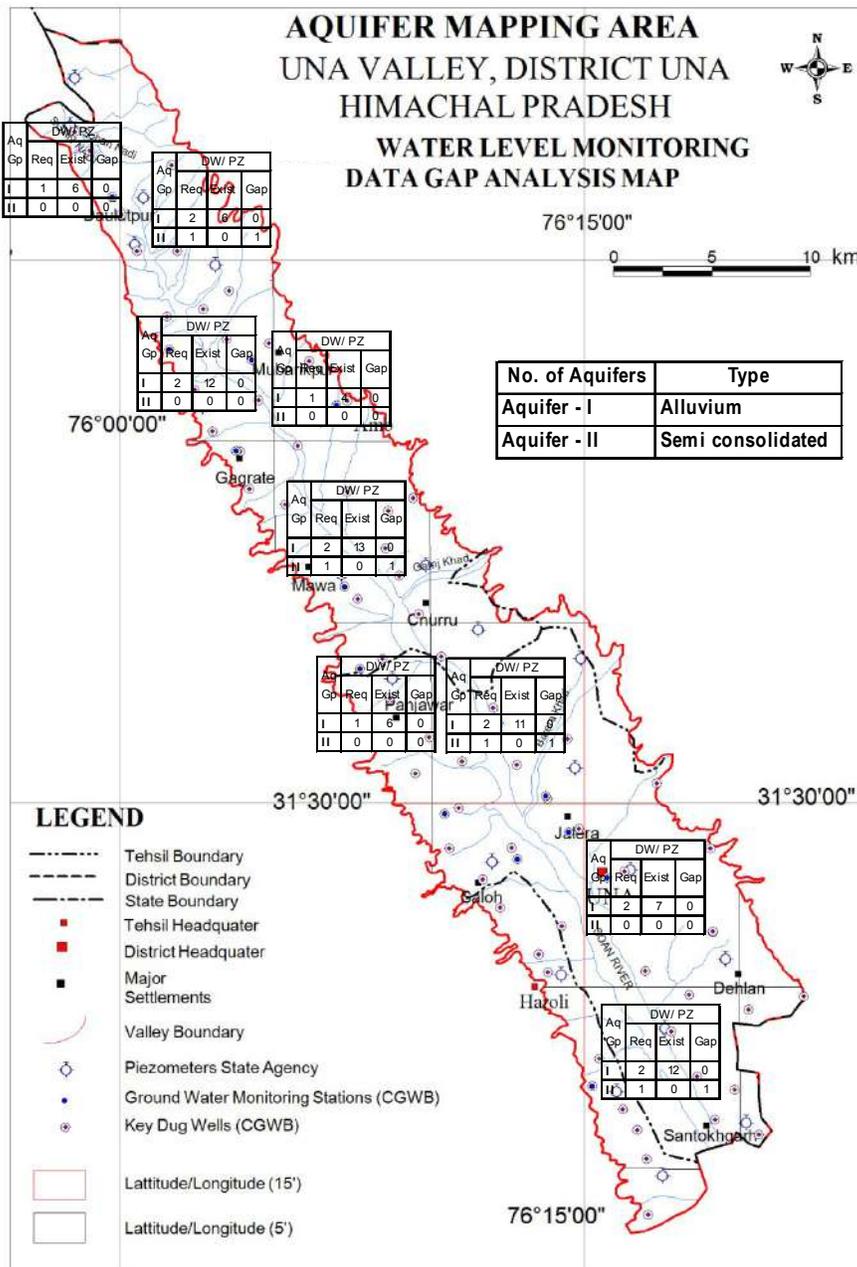
Ground Water Exploration:

As per the EFC guidelines there should be one well field and three special purpose wells i.e. 5 EW and 2 OW. 4 EW for first aquifer and 1 EW & 1 OW for the second aquifer should be constructed. The proposed sites for EW & OW are also given.



Water Level Monitoring:

As per the EFC guidelines there should be 21 No. of monitoring stations. There is no gap for water level monitoring due to the available dug wells for monitoring of first aquifer. The list of observation wells and data gap analysis is shown in fig.

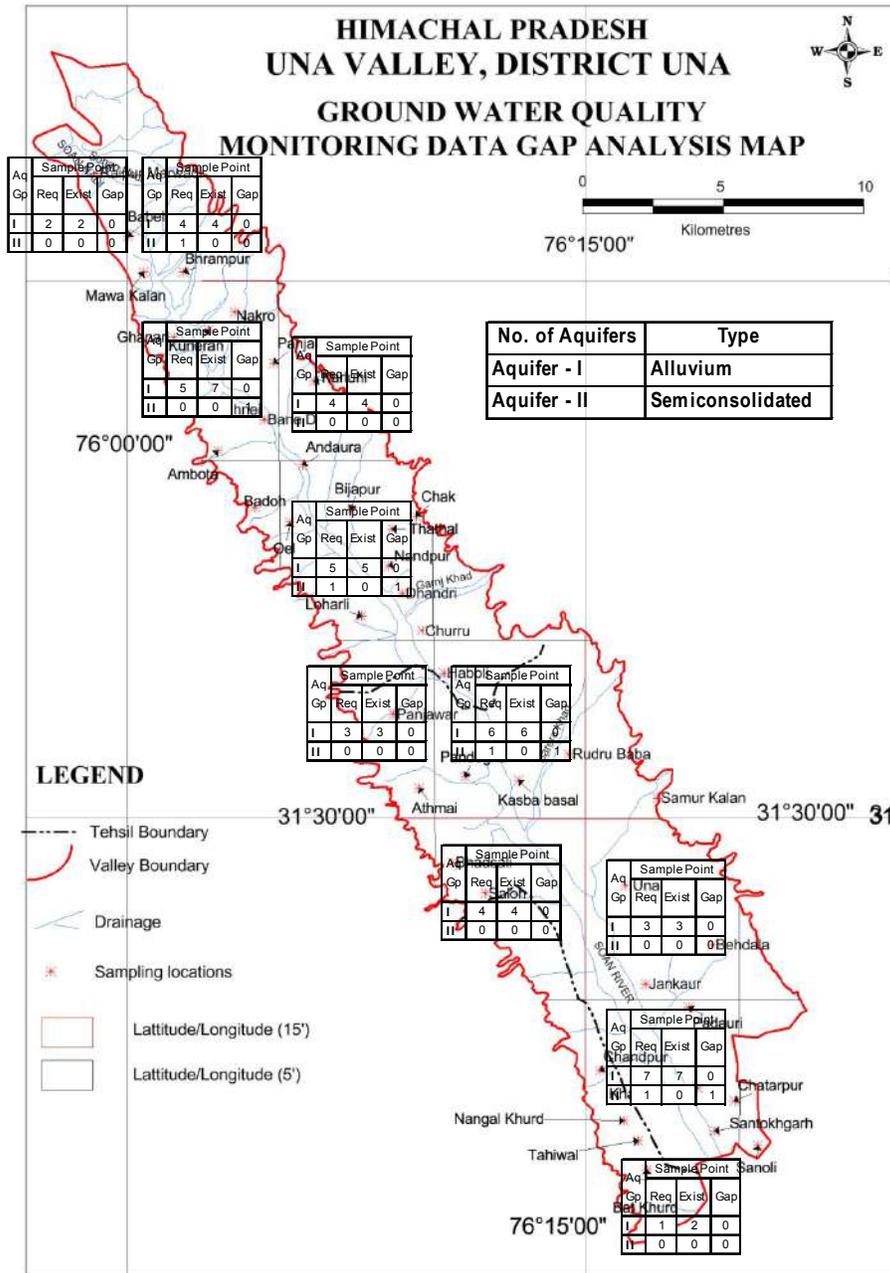


Total 21 No. EW:

1. Daulatpur
 2. Thathal
 3. Badoli
 4. Jankaur
- OW: PZ/GWMS:**
5. Dangoh
 6. Marwari
 7. Mawa
 8. Ganehri
 9. Singhnei
 10. Badoh
 11. Panjaware
 12. Ishpur
 13. Padauri
 14. Nangal Khurd.
 15. Nangran
 16. Una
 17. Dehlan
 18. Khwaja
 19. Bhaira
 20. Thathal
 21. Andaura

Ground Water Quality:

As per the EFC guidelines there should be 44 No. sampling locations. There is no gap for sampling locations due to the available dug wells. The list of tentative sampling points and data gap analysis is shown.

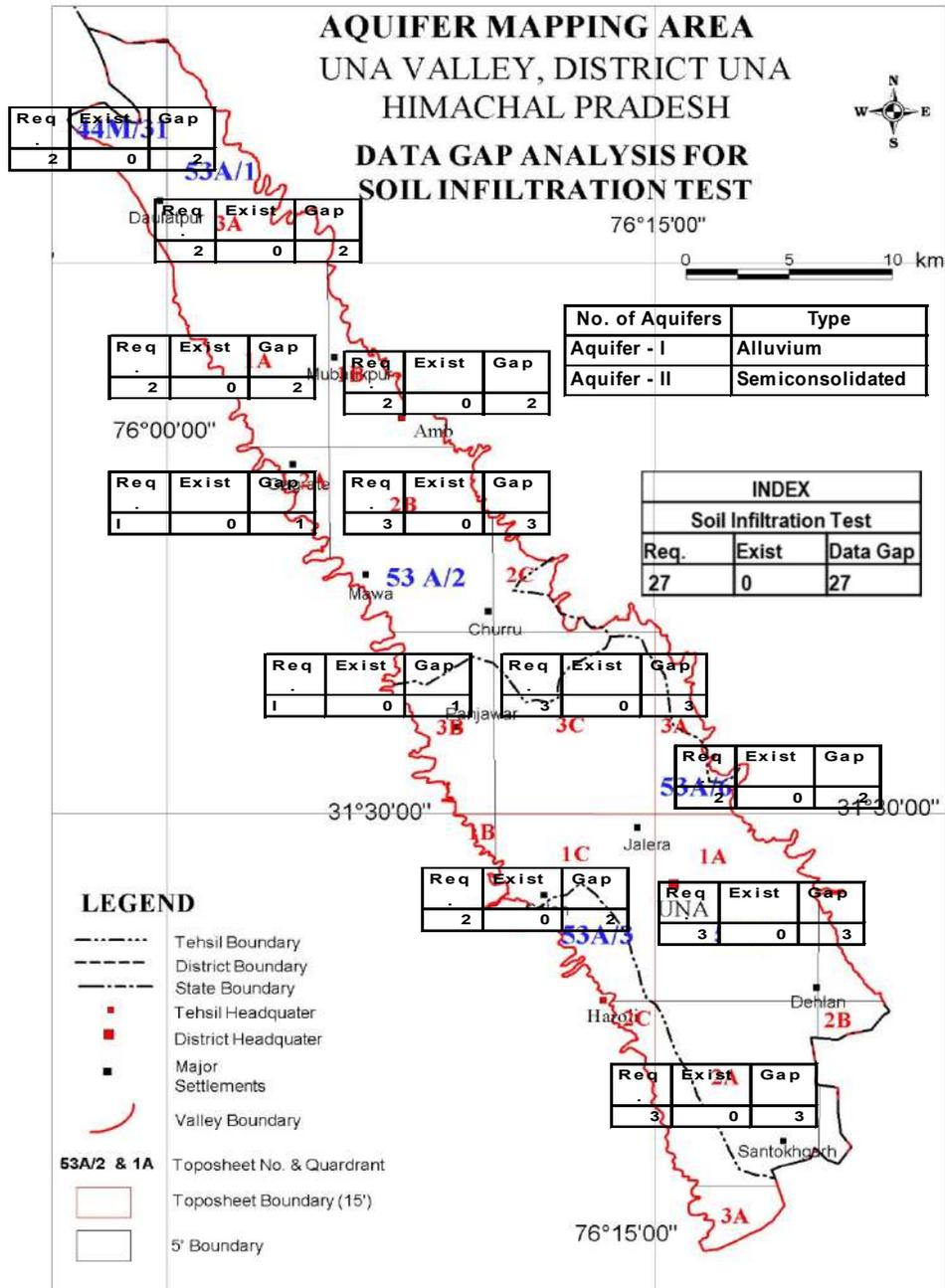


Total 44 No.

1. Daulatpur
2. Thathal
3. Badoli
4. Jankaur
5. Dangoh
6. Marwari
7. Mawa
8. Ganehri
9. Singhnei
10. Badoh
11. Panjwar
12. Ishpur
13. Padauri
14. Nangal Khurd.
15. Nangran
16. Una
17. Dehlan
18. Khwaja
19. Bhaira
20. Thathal
21. Andaura
22. Santokhgarh
23. Bathri
24. Tahliwal
25. Khanpur
26. Jankaur
27. Kahluwal
28. Dharampur
29. Badsali
30. Panoh
31. Khad
32. Athma
33. Guglehr
34. Gagrate
35. Loharli
36. Ambota
37. Karluhi
38. Panjal
39. Mubarikpur
40. Nakro
41. Babehr
42. Marwari
43. Oel
44. Nandpur

Soil Infiltration:

As per the EFC guidelines there should be 27 No. sites for soil infiltration studies. The data gap analysis is shown in the Fig.



1485

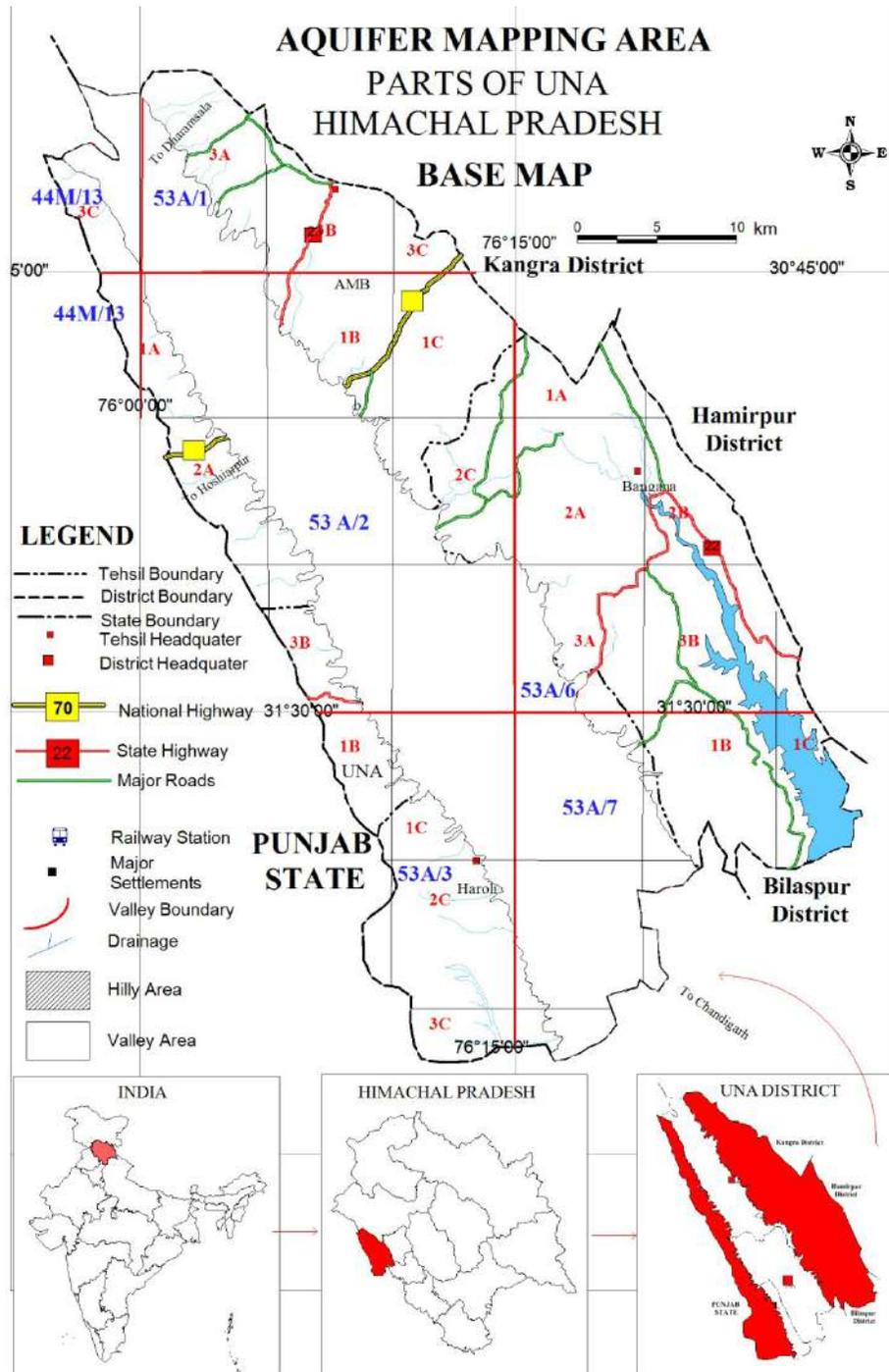
The final Data Gap analysis for Aquifer mapping in Una valley is given in the table 5.

Table 5. Data Gap Analysis for Aquifer Mapping in Una Valley, Una District
Toposheet No: 44M/13, 53A/1, 53A/2, 53 A/3, 53A/6 & 53A/7

Quadrant No.	No. of additional EWs Required		No. of additional OWs Required		No. of additional Special Purpose Wells Required (EW / PZ)		No. of additional VES/TEM Required		No. of additional water level monitoring stations Required		No. of additional Water Quality Stations Required		No. of Soil Infiltration Test Required
	Aq-I	Aq-II	Aq-I	Aq-II	Aq-I	Aq-II	Aq-I	Aq-II	Aq-I	Aq-II	Aq-I	Aq-II	
44M/13-3C	0	0	0	0	0	0	0	1	0	0	0	0	2
53A/1-3A	0	0	0	0	0	1	0	2	0	0	0	0	2
53A/2-1A	0	0	0	0	0	0	0	2	0	0	0	0	2
53A/2-1B	0	0	0	0	0	0	0	0	0	0	0	0	2
53A/2-2A	0	0	0	0	0	0	0	0	0	0	0	0	1
53A/2-2B	0	0	0	0	0	1	0	3	0	0	0	0	3
53A/2-2C	0	0	0	0	0	0	0	0	0	0	0	0	0
53A/2-3B	0	0	0	0	0	0	0	1	0	0	0	0	1
53A/2-3C	1	1	1	1	0	0	0	3	0	0	0	0	3
53A/6-3A	0	0	0	0	0	0	0	0	0	0	0	0	2
53A/3-1C	0	0	0	0	0	0	0	2	0	0	0	0	2
53A/7-1A	0	0	0	0	0	0	0	3	0	0	0	0	3
53A/7-1B	0	0	0	0	0	0	0	0	0	0	0	0	0
53A/2-2C	0	0	0	0	0	0	0	0	0	0	0	0	0
53A/7-2A	0	0	0	0	0	1	0	3	0	0	0	0	3
53A/7-2B	0	0	0	0	0	0	0	0	0	0	0	0	0
53A/7-3A	0	0	0	0	0	0	0	1	0	0	0	0	1
TOTAL	1	1	1	1	0	3	0	21	0	0	0	0	27

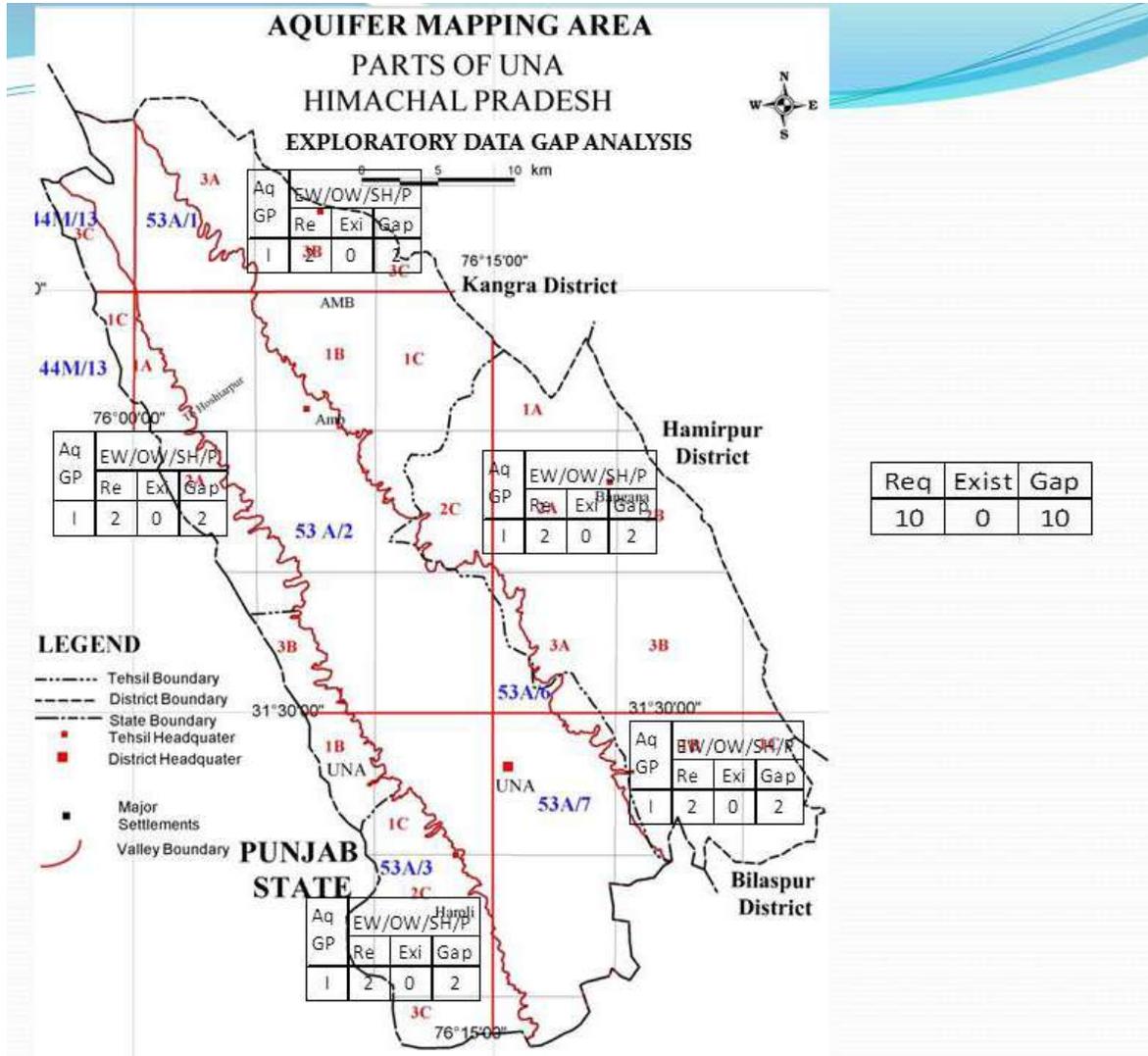
Parts of Una District

The data gap analysis for Aquifer mapping in Una valley, district Una has been carried out on the basis of EFC guidelines for soft rock area. Una valley is supposed to be a two aquifer system consisting of valley fill alluvium as a first aquifer. The base map for data gap analysis is shown in The analyses done are detailed below:



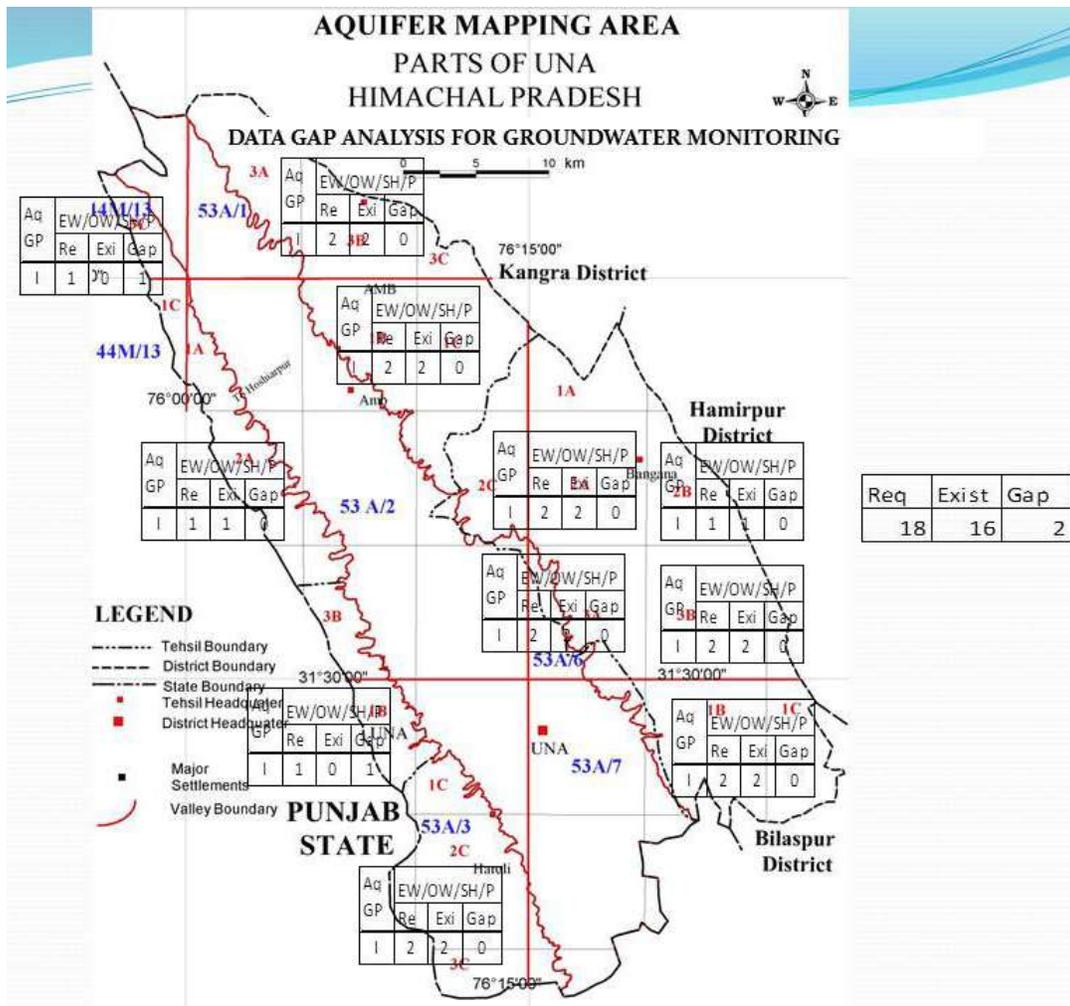
Ground Water Exploration

As per the EFC guidelines there should be one well field and three special purpose wells i.e. 5 EW and 5 OW. The proposed sites for EW & OW are also given



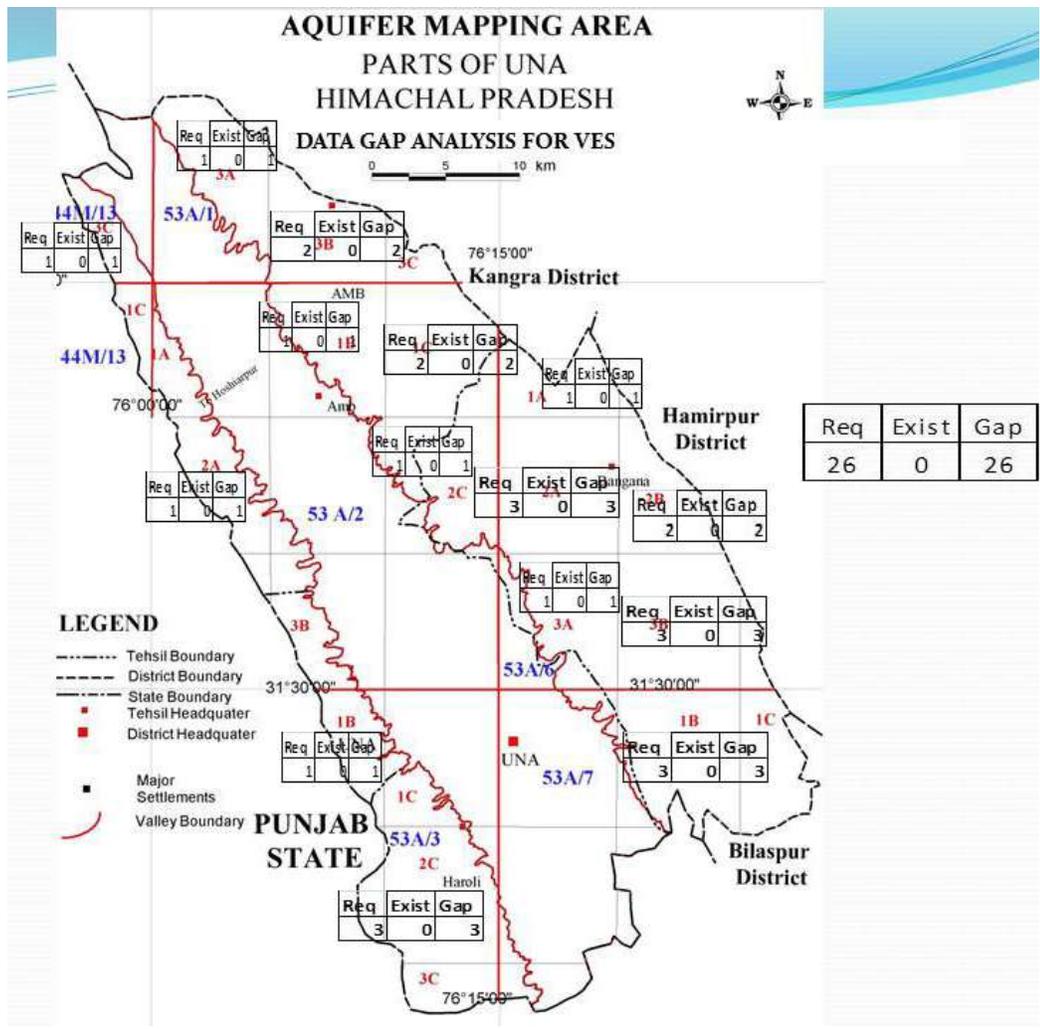
Water Level Monitoring:

As per the EFC guidelines there should be 18 No. of monitoring stations. There is no gap for water level monitoring due to the available dug wells for monitoring of first aquifer. The list of observation wells and data gap analysis is shown in fig



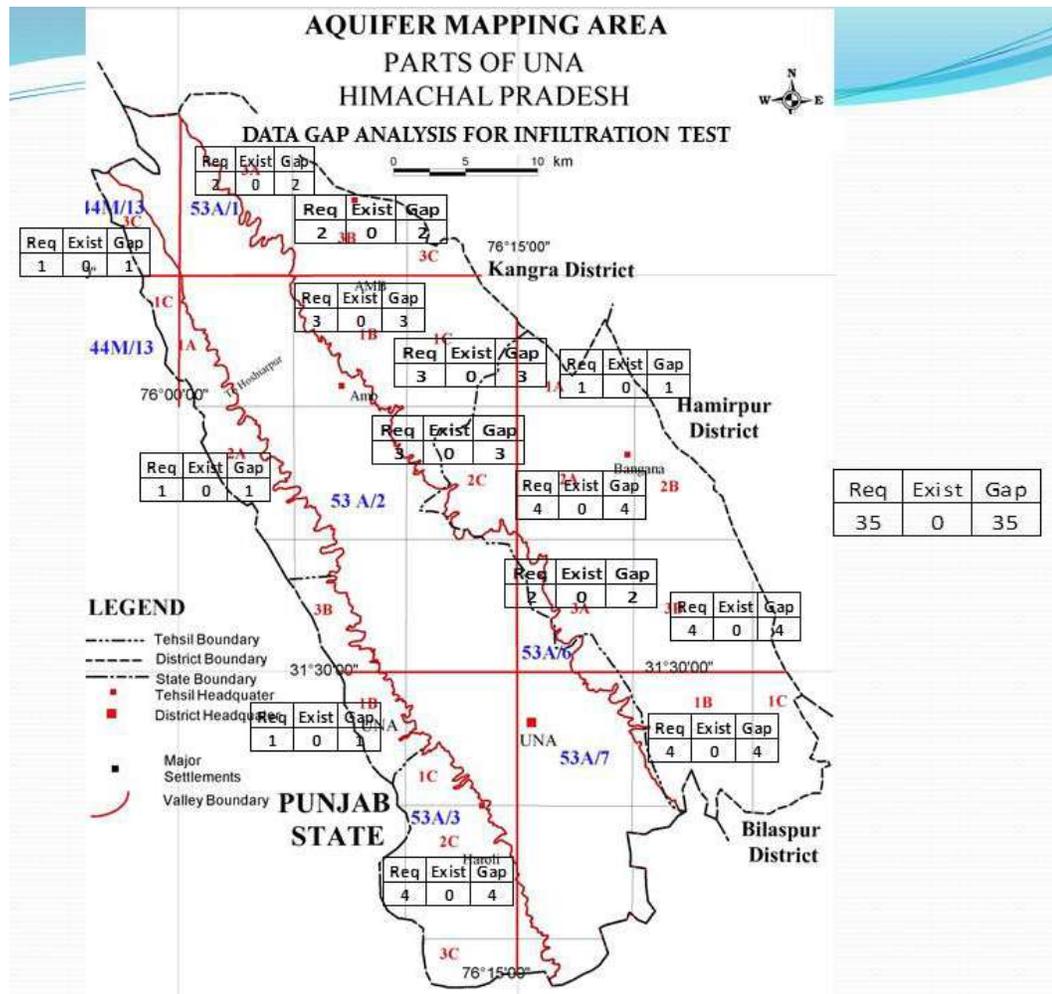
Subsurface Geophysical Survey (VES):

As per the EFC guidelines there should be 26 No. sites for VES for subsurface geophysical survey. The data gap analysis is shown in the Fig..



Soil Infiltration:

As per the EFC guidelines there should be 27 No. sites for soil infiltration studies. The data gap analysis is shown in the Fig.



The final Data Gap analysis for Aquifer mapping in Una valley is given in the table

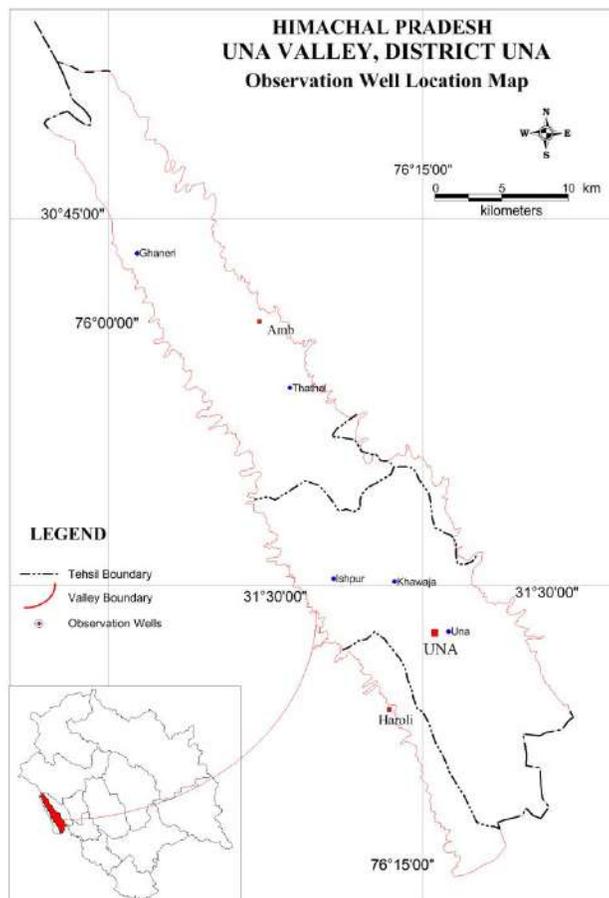
DATA GAP ANALYSIS					
Aquifer Mapping Area, Parts of Una, Una District					
Toposheet No: 44M/13, 53A/1, 53A/2, 53 A/3, 53A/6 & 53A/7					
Quadrant No.	No. of additional EWs Required	No. of additional OWs Required	No. of additional water level monitoring stations Required	No. of additional VES Required	No. of Infiltrations
	Aq-I	Aq-I	Aq-I	Aq-I	Aq-I
53A/1-3A	0	0	0	1	2
53A/1-3B	1	1	0	2	2
53A/1-3C	0	0	0	0	0
53A/2-1B	0	0	0	1	3
53A/2-1C	0	0	0	2	3
53A/2-2C	0	0	0	1	1
53A/6-1A	0	0	0	1	3
53A/6-2A	1	1	0	3	4
53A/6-3A	0	0	0	1	2
53A/6-3B	0	0	0	2	0
53A/6-3B	0	0	0	3	4
53A/7-1B	1	1	0	3	4
53A/7-1C	0	0	0	0	0
44M/13-3C	0	0	1	1	1
44M/14-1C	0	0	0	0	0
53A/2-1A	0	0	0	0	0
53A/2-2A	1	1	0	1	1
53A/2-3B	0	0	0	0	0
53A/3-1B	0	0	1	1	1
53A/3-2C	1	1	0	3	4
53A/3-3C	0	0	0	0	0
Total	5	5	2	26	35

3. DATA COLLECTION AND GENERATION

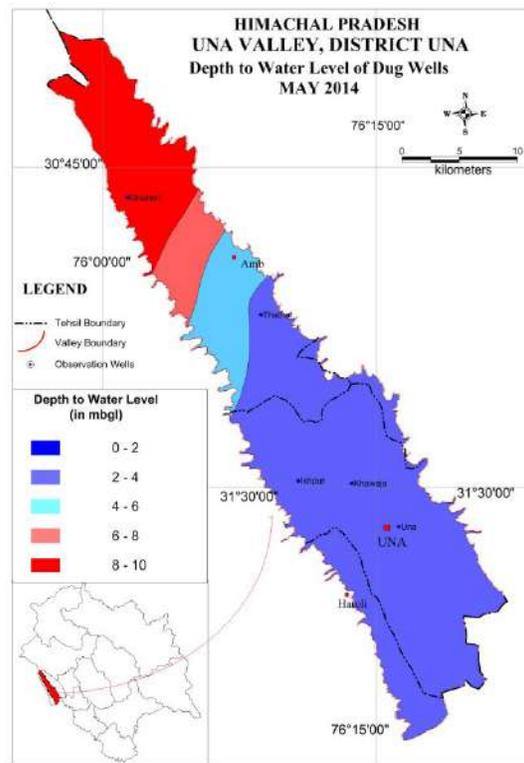
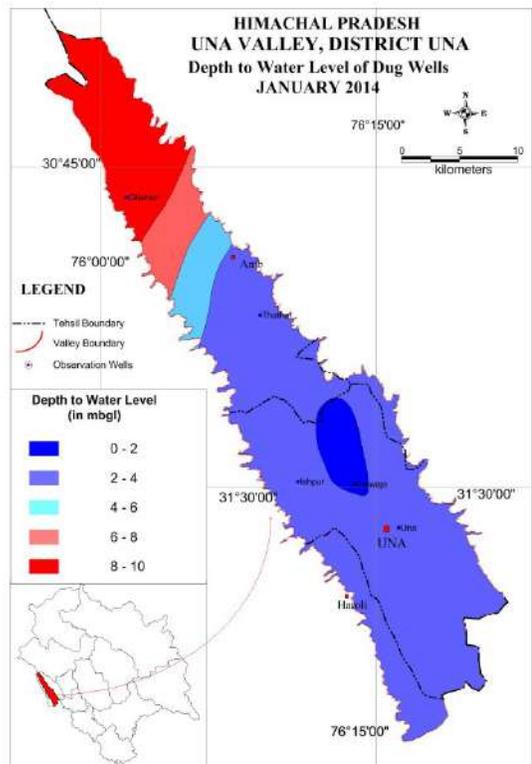
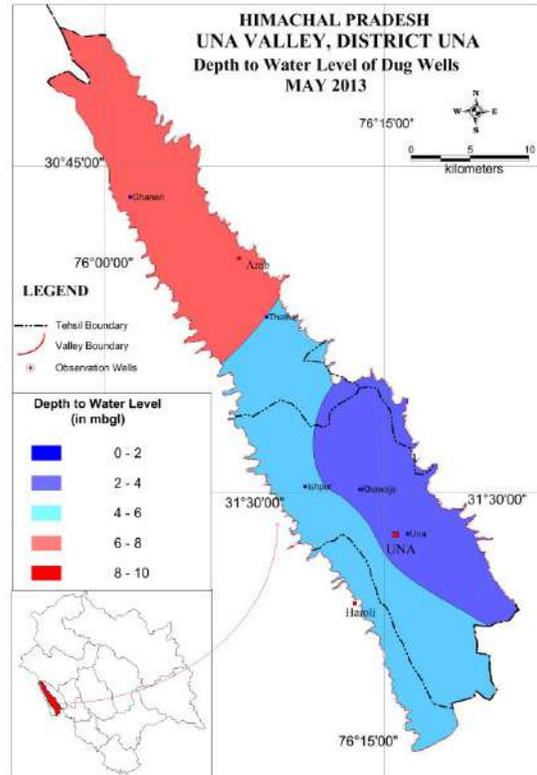
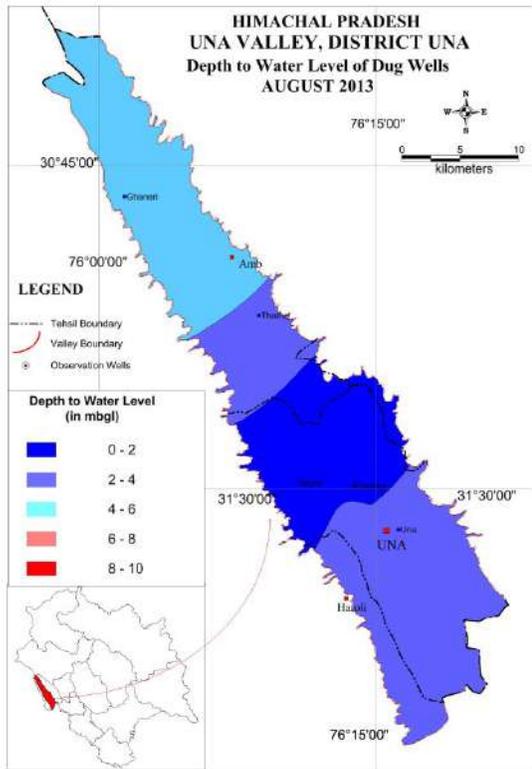
Data on various attributes of Aquifer Mapping has been generated based on the data availability and data gap analysis discussed in previous section. The data generated and data collected from various state government departments.

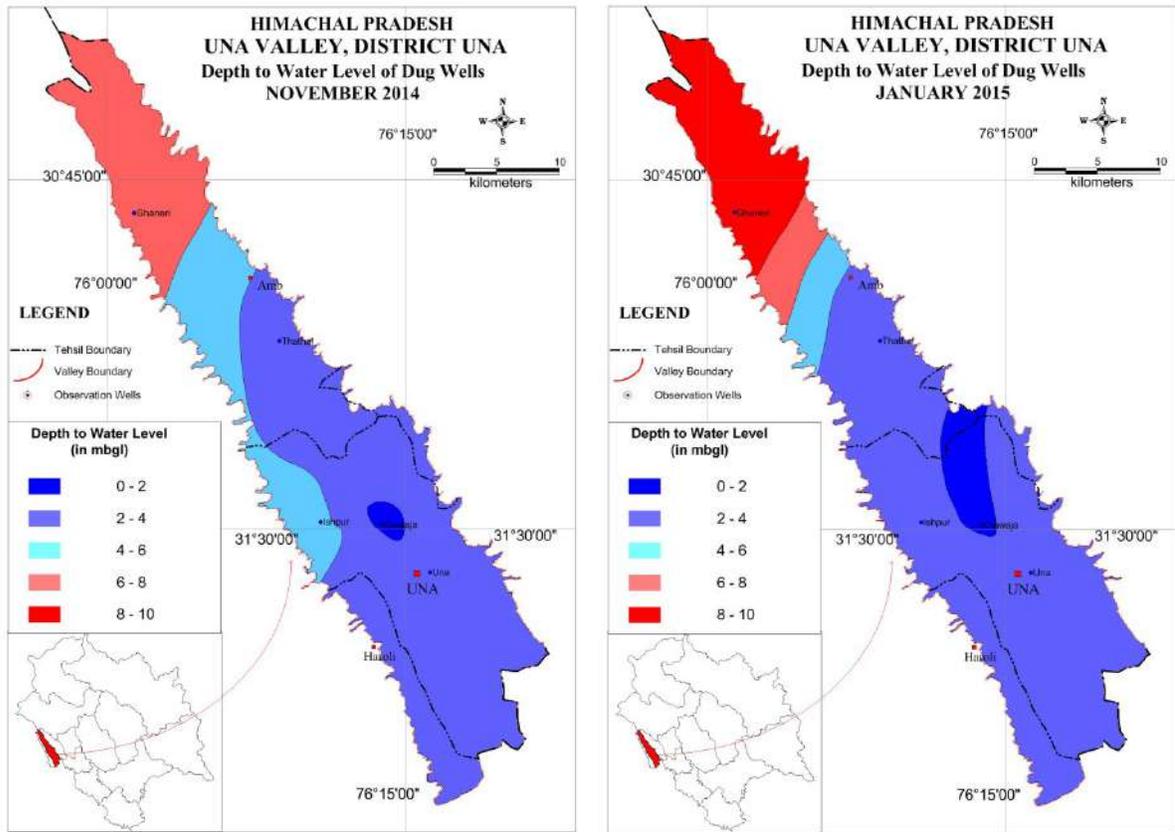
Water Level Monitoring:

To know the water level and its behavior with respect to time and space, the dug wells have been inventoried. Aquifer mapping in Una district (Fig.-). The wells were therefore monitored to study the impact of various development related activities on the ground water regime. The depth to water level contour map was generated for Una Valley only as it is not possible to prepare the contours for the hilly area. Therefore only point values are being given for the well observed in parts of Una district (Fig)

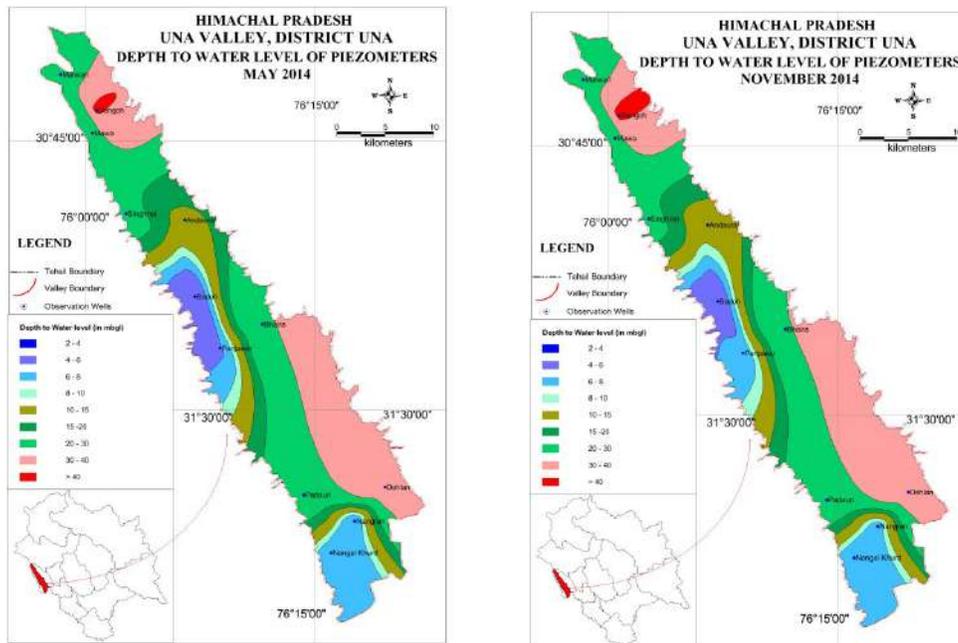


The depth to water level contour map generated during the August, 2013, November, 2013, January, 2014, May, 2014, August, 2014, November, 2014 and January, 2015 are as given in Fig.

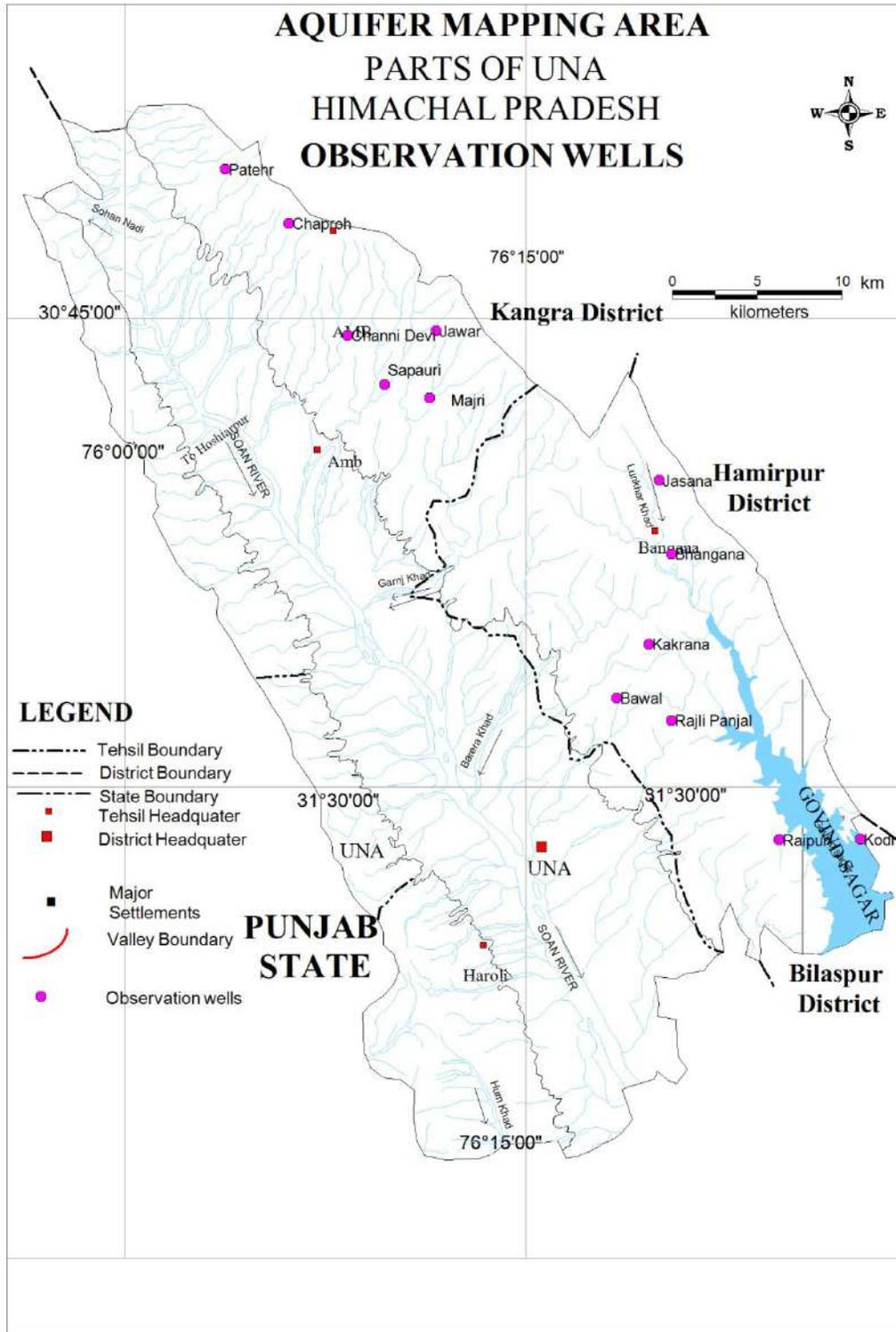


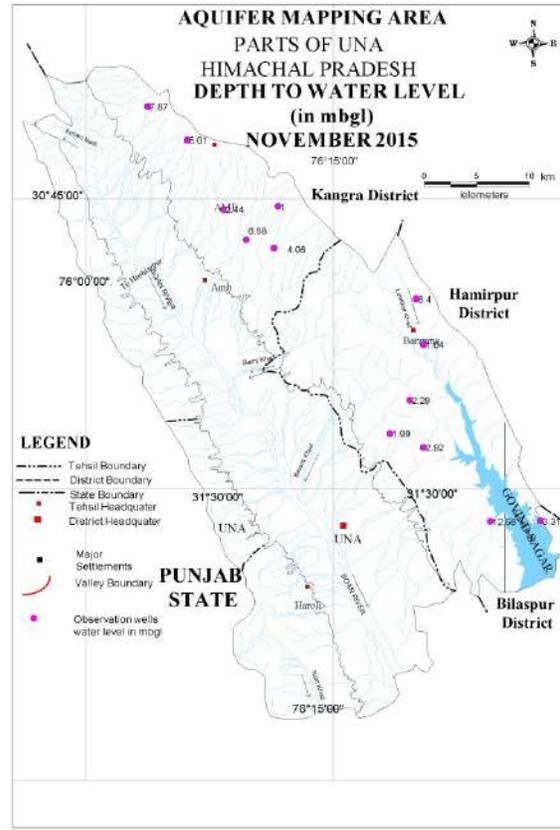
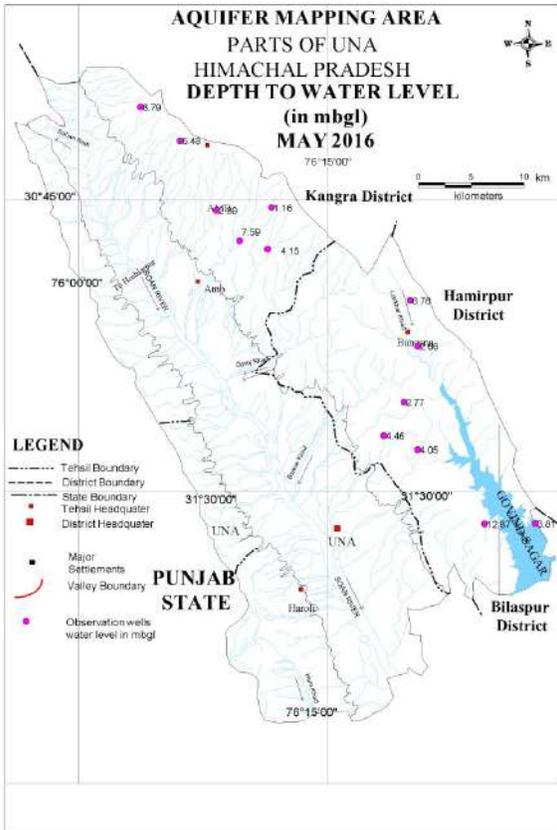
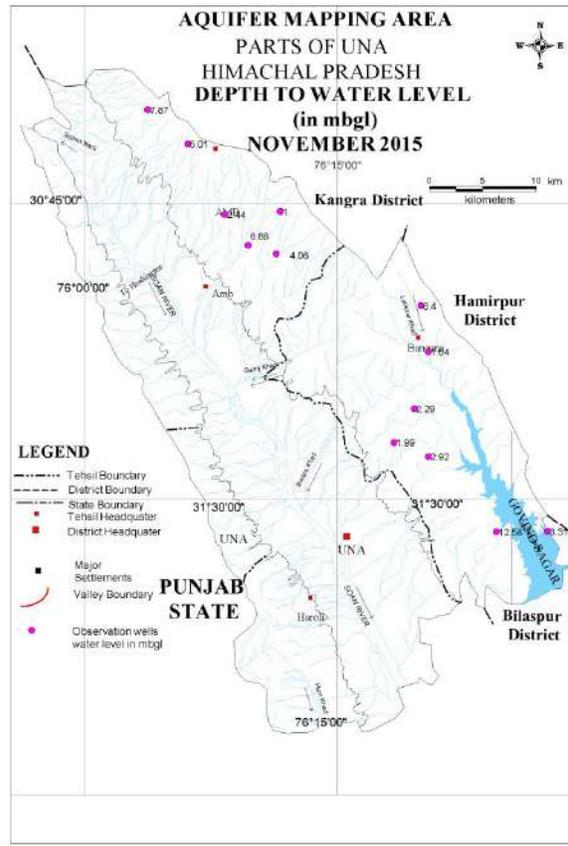
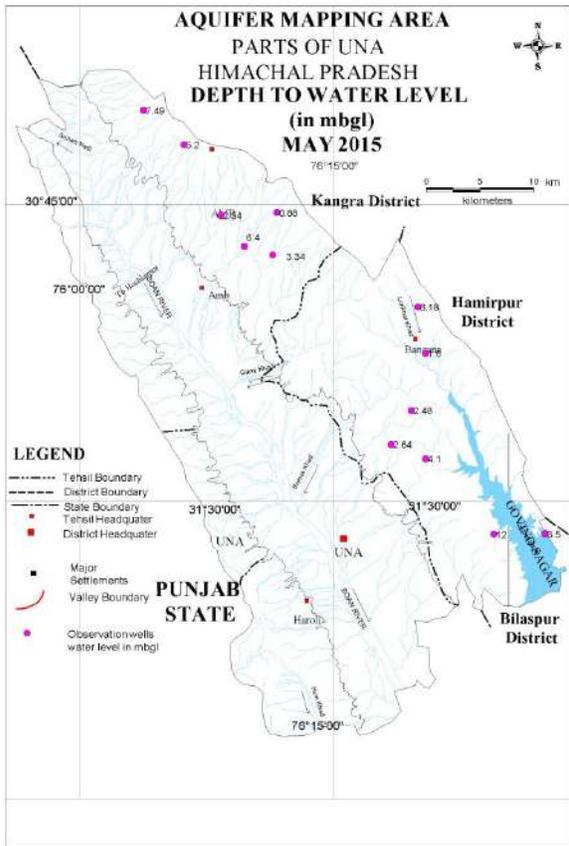


Depth to Water Level map has also been generated on the basis of the Piezometers constructed by state agencies. The location maps of Piezometers is given in Fig.



The point values map of the observation well located in Parts of Una District:





Aquifer Characteristics

The data of ground water exploration of Central Ground Water Board in the shape of lithologs was extracted from old files and was computerized in MS Excel. The strata charts from Irrigation & Public Health Department were collected and their co-ordinates and elevations were worked out in the field and on toposheets. This data was also brought into digital form. The unified lithologs were prepared according to the standard legend decided.

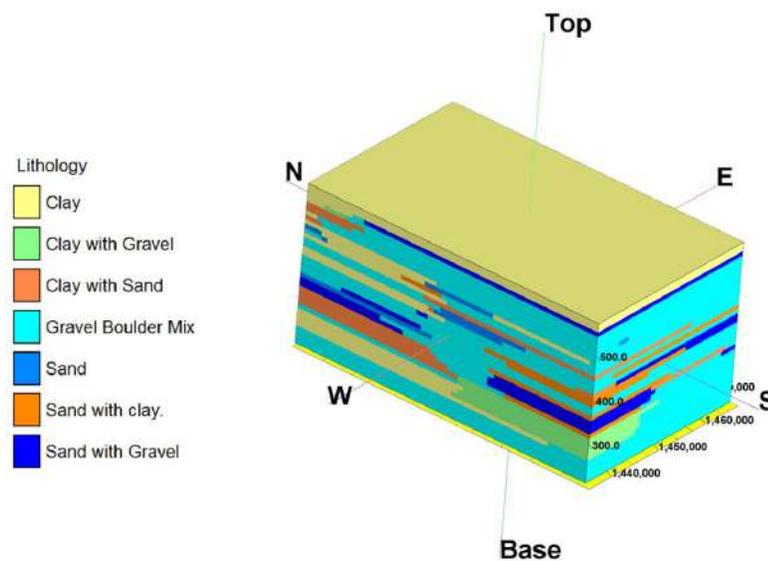
The lithological layers are generated using borehole data. The layers are broadly classified into eight types– sand; clay; shale; sandstone; conglomerate, boulder, cobble, pebble, gravel, sand; boulder, cobble, pebble, gravel, sand; clay with boulder, cobble, pebble, gravel, sand; and sand, boulder, cobble, pebble, gravel.

Lithological Disposition and Aquifer Disposition

The lithological disposition and the aquifer disposition interpreted through the models, fence and cross sections prepared using the rockworks software. The sections drawn for sub-surface formations and aquifers, have vertical and horizontal scales in meters.

The lithological and aquifer model of the complete aquifer mapping area depicts that the northern part is at higher elevations and the depth of exploration is limited to 100 m in this part. There is an abundance of granular horizon but the water levels are deep. The valley part is at shallow elevations and water levels are very shallower in this part. In the hilly area the water bearing zone is very less.

The 3D model of Una valley has been created on the basis of the lithology as given in fig.



4. GROUND WATER RESOURCES

Rainfall is the major source of recharge to the groundwater body, apart from the influent seepage from the rivers, irrigated fields and inflow from upland areas, whereas discharge from ground water mainly takes place from wells and tube wells; effluent seepages of ground water in the form of springs and base flow in streams etc.

The quantitative estimation of various inputs to ground water resources and their temporal variation in space and time is imperative for a planned management and development of ground water resources. The resources in the surveyed area are computed on the basis of methodology recommended by the Ground Water Estimation Committee of Ministry of Water Resources, Govt. of India, 1997.

Methodology adopted

The primary source of recharge of groundwater in the Una valley is rainfall. Therefore rainfall infiltration method has been used for estimating the resources. Rainfall recharge factor or Infiltration factor is a recharge parameter that indicates a quantum of water recharged to the groundwater system in relation to the rainfall. It is a function of rate of infiltration and ability of the system to accept the infiltrated water. The infiltration factor can be expressed as follows

$$IF = (Q_i/Q_a) \times SY,$$

Where,

IF = Infiltration Factor

Q_i = Quantum of water infiltrated over the test period in m

Q_a = Quantum of water applied in m

SY = Specific Yield

Recharge of ground water involves several components and the rainfall being the major one. The other components are return irrigation flow from surface water and ground water.

Ground water resources and irrigation potential for Una valley and Hum valley of the district have been computed as per the GEC-97 methodology, the resources for the year 2013 are presented below.

1499

DYNAMIC GROUND WATER RESOURCES (2013)**A. Una valley**

• Net Annual Ground Water Draft for all uses	9559.66 ham
• Net Ground Water availability for future Irrigation	4503.63 ham
• Projected Demand for Domestic and industrial Uses up to 2025	1290.67 ham
• Stage of Ground Water Development	74.43%
• Category	Safe

B. Hum valley

• Net Annual Ground Water Draft for all uses	539.46 ham
• Net Ground Water availability for future Irrigation	-33.01ham
• Projected Demand for Domestic and industrial Uses up to 2025	164.32 ham
• Stage of Ground Water Development	90.29 %
• Category	Critical

The stage of ground water development in Una valley and Hum valley of Una district, is 74.43% & 90.29% and both valleys fall under “Critical” category. There is thus no scope for further ground water development.

5. GROUND WATER MODELLING

Three-dimensional mathematical models of regional groundwater flow are beneficial to the management of groundwater resources as they allow the approximation of the components of hydrological processes and provide a mechanistic description of the flow of water in an aquifer.

Numerical three-dimensional groundwater flow model was developed for the Una valley, District Una, Himachal Pradesh with the following objectives:

- To simulate regional groundwater flow to identify the distribution of heads,
- Impact on the aquifer system due to various hydrological stresses.
- To develop few scenarios for proper understanding of the aquifer system.
- For Efficient and sustainable management of the aquifer system.

The conceptual model of the system was arrived from the detailed study of geology, borehole lithology, geophysical resistivity survey & logs, cross section and water level fluctuations in wells. Groundwater of the study area is found to occur in the alluvial formation in the valley area and surrounded by Siwalik formation. Groundwater is found to occur in unconfined conditions in the alluvial formation.

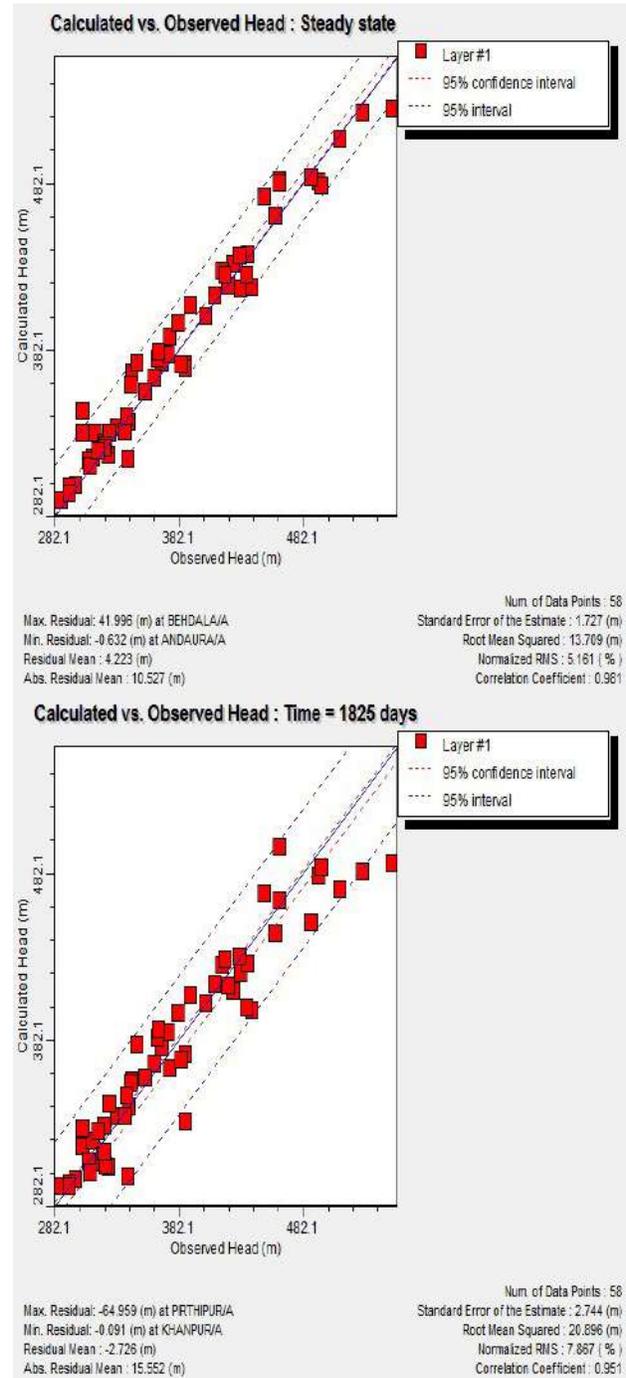
The calibration strategy was to initially vary the best known parameters as little as possible, and vary the poorly known or unknown values the most to achieve the best overall agreement between simulated and observed.

i. Steady state model:

Steady state model calibration was carried out to minimize the difference between the computed and field water level condition. Steady state calibration was carried out with the water level data of May 2013 in 60 wells distributed over the study area. Out of all the input parameters, the Specific yield value is the only poorly known as only 15 pumping tests were available in this area. The lithological variations in the area and borehole lithology of existing wells were studied. Based on this it was decided to vary hydraulic conductivity values upto 10% of the pumping test results for layer in order to get a good match of the computed and observed heads. The figure indicates that there is a very good match between the calculated and observed water heads in most of the wells of the study area. Root mean square error and the mean error were minimized through numerous trial runs.

ii. Transient State Model:

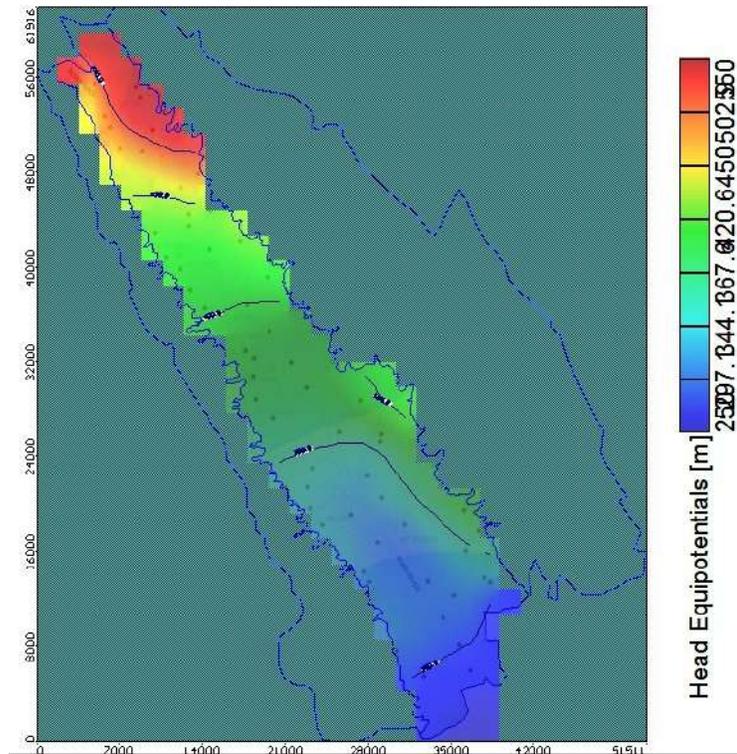
Transient state simulation was carried out for a period of 5 years from Jan 2013 to Dec 2017 with season wise stress periods during monsoon and non-monsoon for 245 days and 120 days respectively. The trial and error process by which calibration of transient model was achieved by several trials until a good match between computed and observed heads over space and time. The hydraulic conductivity and recharge values incorporated in the transient model were modified slightly from those calibrated by the steady state model. Based on the close agreement between measured and computed heads from Jan 2013 to Dec 2017 at 60 observation wells distributed through out the aquifer, the transient models were considered to be calibrated satisfactorily. The sensitivity of the model to input parameters were tested by varying only the parameter of interest over a range of values and monitoring the response of the model by determining the root mean square error of the simulated heads compared to the measured heads.



The model was simulated in transient condition for a period of 5 years from January 2013 to December 2017. There was fairly good agreement between the computed and observed heads (Figure.7). A study of the simulated potentiometric surface of the aquifer indicates that the highest heads are found on the North-western

side of the study area, which is a general reflection of the topography. The regional groundwater flow direction is from north-east to south-west. The groundwater flow vectors for the month of

December 2012 is given in figure.. The comparison of observed and computed heads . The computed and observed heads for Daulatpur and Amb village clearly shows the match in the pattern and trends (Fig.). The transient simulation clearly shows the matching of pattern of the groundwater head with change in time.



The aquifer response for different input and output fluxes was studied in order to sustainably manage the aquifer system. The model was run for a further period of 05 years from 2017 to 2022. Before commencement of this simulation, the data of normal rainfall, abstraction, and recharge was provided to the model upto 2022.

One prediction runs were planned to evolve optimal management schemes.

i. Normal rainfall condition

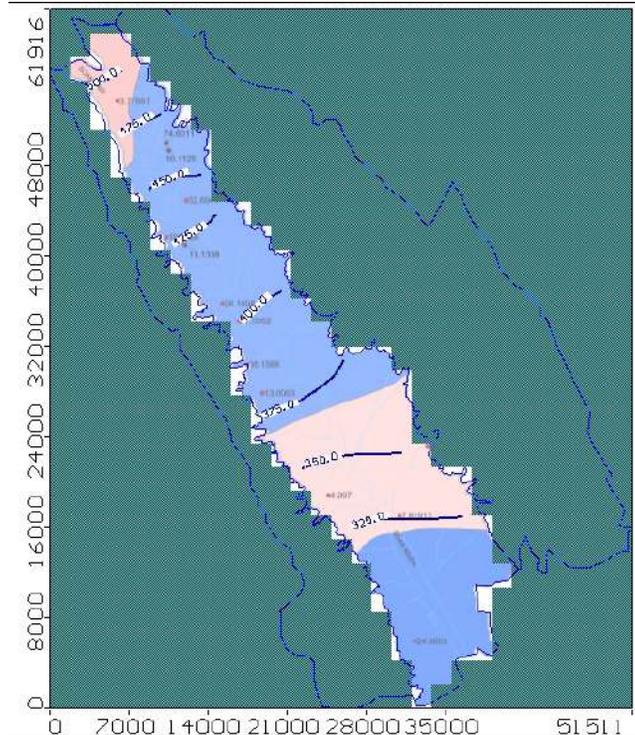
The model was run to predict the regional groundwater head in this area until the year 2022. For these runs the monthly average rainfall calculated from 05 years rainfall data was used. The present level of groundwater abstraction was considered for this simulation. The simulated regional groundwater head for September 2022 is shown in Figure. There is not much increase or decrease in water level. Such observation is made in most of the locations. This clearly indicates that the model is stable under the present pumping conditions.

ii. Increase in Pumping

The model was run to predict the regional groundwater head in area until the year 2022 with 30

% increase in pumping for which the normal monsoon and non monsoon rainfall data was used. The predicted model indicates that there is uniform decline of ground water head in the aquifer of study area (Figure. 10).

Three-layered finite-difference flow model was used to simulate the groundwater head in the Una aquifer system for a period of 5 years (Jan 2013-Dec



2017) for better understanding of the aquifer system. All the data was inputted into the model and Visual Modflow Classic 4.6.0.166 was used to simulate the model. The model was calibrated for steady and transient state conditions. There was a reasonable match between the computed and observed heads. Based on the modelling results, it is found that this aquifer system is stable at this pumping rate. The transient model was run until the year 2022 to forecast the dynamic groundwater flow under various scenarios of over pumping and less recharge. The model predicts the behavior of this aquifer system under various hydrological stress conditions. The simulated results indicate that this aquifer system is stable under the present conditions. The spatial groundwater head follows the topography. The groundwater water flows from the north to south -south eastern. The computed groundwater head mimics the observed groundwater head in several locations. The model helps in understanding the groundwater head trend and illustrates the impact of changes in hydrological conditions, thus enables the water managers for an effective management tool.

6. ISSUES AND AQUIFER MANAGEMENT STRATAGIES

Major ground water related issues in Una district

- Deeper Water Levels in hilly area or Beet area
- Decline in Water Levels
- Comparatively Steeper slopes
- Large no. of springs
- Open Dug Wells losing their Utility
- Deforestation led to reduced recharge
- Artesian Conditions: Ground water is lost through natural drainages
- Surface flows: Huge volume of unaccounted water flowing waste
- Water Logged Area – Reduced – declining ground water levels
- High NO₃ at a few isolated places

Issues in Una District

1. Deeper Water Levels

There is acute shortage of water in the hilly area of Siwalik formation where the water tables are deep seated. The lithology in the area is less pervious and not capable of receiving large volumes of recharge.

2. Decline in Water Levels in both Hilly and valley area.

3. Comparatively Steeper slopes in hilly area

4. Large number of Ponds

There are a large number of ponds/tanks in Beat area. In earlier days water from these ponds was being used for washing, bathing and even drinking at places. These ponds also acted as recharge structures. With the coming up of piped water supply these ponds have been put to dis-use and have even been encroached upon, and their inlets have been disturbed. Some ponds are being filled up by tubewells installed near them which are putting stress on aquifers.

5. There exist a large number of dug wells (open wells and most of them belong to the village community) in the area, which have lost their utility with the coming up of piped water supply. These dug wells are either being filled up with garbage or they are being covered up with RCC slabs to avoid falling of children and animals in them.

6. High NO₃ and Fe at a few isolated places

Contamination of water from septic tanks occurs under various conditions viz, Poor placement of septic leach fields, high density placement of tanks, leakage from sewer lines. Nitrate is also mostly found in the return flow from the agriculture area.

9. Artesian Conditions:

Huge amount of ground water is lost through the free flow artesian wells. Number of tubewell is being constructed in some part of the valley area of free flow wells for irrigation purposes. The ground water emerging through these free flow tubewells can be channelised and utilized for irrigating the fields. Absence of water and electricity budgeting provisions are a cause of wastage of fresh utilisable ground water.

10. Surface flows: Springs

The entire hilly area of the district consists of springs, which are due to gravitational forces only, and generally springs are contact, fracture or depression in origin. To define the magnitude of springs, Meinzer, 1923 proposed a classification by discharge. The discharge of the spring depends on the area contributing recharge to the aquifer and the rate of recharge.

Magnitude	Mean Discharge
I	>10 m ³ /sec
II	1-10 m ³ /sec
III	0.1-1 m ³ /sec
IV	10-100 lps
V	1-10 lps
VI	0.1-1 lps
VII	10-100 ml/sec
VIII	<10 ml/sec

Most of the springs in the area come under the category VI of Meinzer's classification for springs. The only spring that comes under category V is at spring no. 53A/2-1C1 at Daulidhar has a discharge of 1 lps in pre-monsoon period. The pre- monsoon post-monsoon fluctuation of spring discharge ranges from zero to 0.5 lps at Biru

Aquifer Management Plan:

An outline of the Aquifer Management Plan includes details regarding population, rainfall, average annual rainfall, agriculture and irrigation, water bodies, ground water resource availability, ground water extraction and water level behavior. Aquifer disposition and various cross sections have also been given.

Plan for Sustainable Management of the Resource

- The major aquifer system of the Una valley is alluvial deposits.
- Valley fill deposits and terraces are to be fully explored by constructing test wells for studying the precise distribution of ground water horizons and scope for development.
- In hard rock area all the weak zones, like thrust, faults, fractures, lineaments, and contact of different formation are to be studied in detail for demarcating the aerial extent and vertical distribution of ground water potential zones by micro level hydrogeological/geophysical studies followed by exploratory drilling based on which suitable ground water structures can be constructed for the development of ground water resources.
- As per GEC 1997 methodology, ground water resources for Una Valley and Hum Valley was estimated and observed that there is a scope for ground water development as the stage of ground water development in Una valley and Hum valley of Una district, is 74.43% & 90.29% and both valleys fall under “Critical” category. There is thus no scope for further ground water development.
- There is need to protect traditional water harvesting structures like ponds, tanks, talavs to utilized these for rain water harvesting and recharging shallow aquifers.
- In hilly and mountainous terrain, traditional ground water sources viz., springs, bowries etc needs to be developed and protected for better health and hygiene with proper scientific intervention.
- Proper development of springs in hilly area is essential as it is observed that most of the spring in the district does not have collection chamber or tanks from where water can be distributed under gravity. The objective of spring development should be to collect the flowing water underground, to protect it from surface contamination and store it in sanitary spring box for supply. Similarly, seepage springs along hill sides also need to develop for harnessing ground water in such areas.
- Roof top rainwater harvesting practices can be adopted in hilly areas and urban areas, since the district receives fair amount of rainfall. Construction of roof top rain water

1507

harvesting structures should be made mandatory in all new construction and rain water harvesting in rural areas should be promoted. Traditional water storage systems need to be revived.

- In the district, for most of the households, IPH department supplies water, so the people put their dugwells abandoned without using it. These unused and abandoned dugwells can be used as rainwater harvesting and artificial recharge structure to recharge ground water.
- People's participation is a must for any type of developmental activities. So proper awareness for utilization and conservation of water resources is required.
- Constrictions of bore well near to spring source in hilly area should be avoided as this could lead to drying of the natural water sources.
- Recharge structures feasible in hilly areas are check dams, Gabion structures and staggered contour trends at suitable locations.

Gaurish

**REPORT OF THE
GROUND WATER RESOURCE ESTIMATION COMMITTEE
(GEC-2015)**

METHODOLOGY

**Ministry of Water Resources, River Development & Ganga Rejuvenation
Government of India**

**NEW DELHI
October, 2017**

Gaurav

FOREWORD

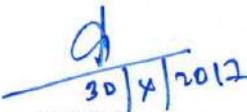
Ground water is an important source to meet the water requirements of various sectors like irrigation, domestic and industries. Groundwater usage if left unregulated may lead to serious inter-sectoral conflicts. Hence growth in both agriculture and industry is impinging on how India is able to manage her groundwater resources, particularly the aquifers in different parts of the country. The sustainable development of ground water resource requires precise quantitative assessment based on reasonably valid scientific principles. The fundamental basis for good ground water management is a clear understanding of aquifers, and the status of ground water accumulation and movement in these aquifers. The Ground Water Estimation Committee- 1997 has been the basis of ground water assessment in the country for last two decades. The ground water development programme implemented in the country was also guided by ground water resource availability worked out using this methodology. The experience gained in last more than one decade of employing this methodology supplemented by a number of research and pilot project studies has brought to focus the need to update this methodology of ground water resource assessment. The National Water Policy also enunciates periodic assessment of ground water potential on scientific basis. The Ministry of Water Resources, Govt. of India, therefore, constituted a committee consisting of experts in the field of ground water to recommend a revised methodology. This report is the final outcome of the recommendations of the Committee. The revised methodology as recommended has incorporated number of changes compared to the recommendations of Ground Water Estimation Committee - 1997.

The revised methodology GEC 2015 recommends aquifer wise ground water resource assessment to which demarcation of lateral as well as vertical extent and disposition of different aquifers is pre-requisite. However, it is recommended that ground water resources may be assessed to a depth of 100m in hard rock areas and 300m in soft rock areas till the aquifer geometry is completely established throughout the country through aquifer mapping.

It also recommends estimation of Replenishable and in-storage ground water resources for both unconfined and confined aquifers. Keeping in view of the rapid change in ground water extraction, GEC-2015 recommends resources estimation once in every three years. This methodology recommends that after the assessment is done, a quality flag may be added to the assessment unit for parameters salinity, fluoride and arsenic.

In inhabited hilly areas, where surface and sub-surface runoff is high and generally water level data is missing, it is difficult to compute the various components of water balance equation. Hence, it is recommended that wherever spring discharge data is available, the same may be assessed as a proxy for 'ground water resources' in hilly areas.

This report is the ultimate culmination of the efforts of the members of the committee and other experts in the field of ground water who have made significant contribution in revising this methodology. The group to draft the report of this committee has done a laudable job in not only preparing the draft report for discussions of the committee members but has also finalised the same after modifications as desired by them. I would like to express my appreciation to Shri G.C. Pati, Member Secretary and Member, Central Ground Water Board who with his untiring efforts and significant contributions has ably assisted the committee in preparing this report. It is hoped that the recommendations of the committee would be followed by different states for reassessing the ground water resources on realistic basis.



30/4/2012
Akhil Kumar

Joint Secretary (A & GW), MoWR, RD & GR &
Chairman, Central Ground Water Board

CONTENTS

1.0 INTRODUCTION.....	1
1.1 PREAMBLE.....	1
1.2 COMPOSITION OF THE COMMITTEE.....	3
1.3 TERMS OF REFERENCE	4
1.4 PROCEEDINGS OF THE COMMITTEE	5
2.0 NATIONAL SCENARIO OF GROUND WATER	7
2.1 HYDROGEOLOGICAL SETUP	7
2.2 AQUIFER SYSTEMS OF INDIA	7
2.3 GROUND WATER QUALITY.....	14
2.4 GROUND WATER RESOURCE POTENTIAL	14
2.5 GROUND WATER DEVELOPMENT SCENARIO.....	15
2.6 NATIONAL WATER POLICY	16
3.0 RECOMMENDATIONS OF THE EXISTING METHODOLOGY (GEC 1997)	18
3.1 REVIEW OF GROUND WATER RESOURCE ASSESSMENT METHODOLOGIES.....	18
3.2 RECOMMENDATIONS OF GEC 1997.....	19
3.3 NORMS RECOMMENDED BY GEC 1997	29
4.0 REVIEW OF GROUND WATER ESTIMATION METHODOLOGY (1997) AND RECENT CASE STUDIES.....	34
4.1 INTRODUCTION.....	34
4.2 MERITS OF EXISTING METHODOLOGY	35
4.3 LIMITATIONS OF EXISTING METHODOLOGY	37
4.4 IMPROVEMENTS IN THE EXISTING METHODOLOGY	39
4.5 REVISION OF NORMS FOR GROUND WATER ASSESSMENT.....	40
5.0 PROPOSED METHODOLOGY	42
5.1 APPROACH OF GEC-2015	42
5.2 PERIODICITY OF ASSESSMENT	42
5.3 GROUND WATER ASSESSMENT UNIT	42

5.4 GROUND WATER ASSESSMENT SUB-UNITS.....	43
5.5 GROUND WATER RESOURCES OF AN ASSESSMENT UNIT.....	44
5.6 GROUND WATER ASSESSMENT OF UNCONFINED AQUIFER.....	44
5.7 GROUND WATER ASSESSMENT OF CONFINED AQUIFER SYSTEM.....	65
5.8 GROUND WATER ASSESSMENT OF SEMI-CONFINED AQUIFER SYSTEM.....	67
5.9 TOTAL GROUND WATER AVAILABILITY OF AN AREA.....	68
5.10 GROUND WATER ASSESSMENT IN URBAN AREAS.....	68
5.11 GROUND WATER ASSESSMENT IN COASTAL AREAS.....	69
5.12 GROUND WATER ASSESSMENT IN WATER LEVEL DEPLETION ZONES	70
5.13 MICRO LEVEL STUDY FOR NOTIFIED AREAS.....	70
5.14 NORMS TO BE USED IN THE ASSESSMENT.....	71
5.15 SUMMARY REPORT OF GROUND WATER ASSESSMENT.....	81
6.0 PROPOSED DATABASE FOR THE ESTIMATION.....	87
6.1 DATA ELEMENTS USED IN THE ASSESSMENT.....	87
6.2 STANDARDIZATION OF DATA ELEMENTS USED IN THE GROUND WATER RESOURCES ESTIMATION.....	90
6.3 NORMS USED IN THE RESOURCE ESTIMATION.....	107
7.0 FUTURE STRATEGIES.....	109
7.1 REFINEMENTS TO THE RECOMMENDED METHODOLOGY.....	109
7.2 ALTERNATIVE METHODOLOGY.....	111
7.3 R & D Studies.....	113
BIBLIOGRAPHY.....	114
PRINCIPAL CONTRIBUTORS.....	116
ANNEXURES.....	118

1

INTRODUCTION

1.1 PREAMBLE

Ground Water is the backbone of India's agriculture and drinking water security in urban and rural areas. Nearly 90% of rural domestic water use is based on groundwater while 70% of water used in agriculture is pumped from aquifers. Increasing evidence points to the fact that 50% of urban water usage is groundwater. Groundwater is also important for the industrial sector in a large measure and if left unregulated may lead to serious inter-sectoral conflicts. Hence growth in both agriculture and industry is impinging on how India is able to manage her groundwater resources, particularly the aquifers in different parts of the country. A serious groundwater crisis prevails currently in India due to excessive over-extraction and groundwater contamination covering nearly 60 percent of all districts in India and posing a risk to drinking water security of the population. In addition to over-extraction and biological and chemical contamination, excess groundwater and water logging is also a serious problem in many regions, impacting livelihood security of large sections of society. The acute problems relating to groundwater warrant a change in both the perspective on our aquifers as well as the approach in the use and management of groundwater resources. It is necessary to acknowledge the hydrogeological characteristics of groundwater and its integral link to land, vegetation and surface water resources and perceive it as a 'resource' rather than a 'source'.

Acknowledging the ubiquity of groundwater usage and its importance to all sections of society, it is necessary to recognize it as a common pool resource and adopt an aquifer-based approach to its management. The existing legal framework derived from common law principles and judicial interpretation that recognises private property rights over water is inappropriate for the emerging status, conflicts and dynamics of groundwater. It is imperative to recognise groundwater as a natural resource vital to life, livelihood and environment, and to change the existing legal status of groundwater. Respect for established fundamental rights and application of accepted norms and principles of environmental law is another key change needed to respond to the contemporary challenges. Most importantly, regulation and improvement of groundwater is inevitable to ensure safe and adequate drinking water for everyone and thereby for the realisation of the right to water. Given the highly decentralised

way in which groundwater is being used, the regulatory and institutional framework need to apply the principle of decentralisation and participation effectively by replacing the existing centralised licensing mechanism. However, first and foremost, it is important to back the above-mentioned reforms in India's approach to managing aquifers with a more robust groundwater assessment methodology that is backed not only by data at finer granularity, but also by improved analysis and synthesis that will enable decisions that are in tune with the tenets of equitable, efficient and sustainable management of our aquifers.

The primary basis for classification of assessment units (largely administrative units – blocks/talukas/mandals/ firkas, and in some cases hydrological units - watersheds) into safe, semi-critical, critical and overexploited categories is the relationship between pumping and annual replenishment. However, the status of ground water resources in India, presents only a part of a more complete picture. This is because the problems surrounding ground water overuse are not just a matter of the share of pumping to the annual replenishment. The relationship between these two important parameters is complex and depends upon the “aquifers” from which ground water is tapped by wells, tube wells and bore wells; and, in many cases, which supply water to springs. The fundamental basis for good ground water management is a clear understanding of aquifers, and the status of ground water accumulation and movement in these aquifers.

Understanding aquifers is primarily based on a proper understanding of the geology of an area– rock types and rock structure (the hydrogeological setting). The geological diversity in India makes understanding aquifers challenging, but all the more important because local conditions are important in determining approaches to managing ground water resources. Moreover, these local conditions also define the implications of ground water overuse, droughts, floods etc. on how drinking water security is endangered, both in the short and the long terms. Much of the purpose of the ground water assessment in the country has revolved around the estimation of potential of ground water resources. Given the seriousness of ground water related problems, the estimation of ground water potential is no longer restricted to finding ground water but it also involves understanding aquifers. Many of the states have moved forward in formulating and legislating Ground water Acts. Proactive implementation of such legislation, in combination with community-based, participatory forms of management would require more accurate assessment of ground water resources. The revision of methodology will enable integration of ground water legislation and participatory ground water management.

Shift from a ground water assessment to an ‘aquifer’ based ground water assessment has many advantages. First and foremost, it is linked to the National Aquifer Mapping Programme (NAQUIM) taken up by Central Ground Water Board during XII Five Year Plan. Though, achieving an aquifer-wise assessment for the entire country in the next few assessments is difficult, but keeping that as a goal will enable significant improvement in the current assessment. Improvement is envisaged on the following counts:

- Data and data-base used for the assessment
- Estimation methods, including the use of simple algorithms and models
- Comprehensiveness and granularity of data used in the assessment

1.2 COMPOSITION OF THE COMMITTEE

With the above background in view, the Ministry of Water Resources, River Development & Ganga Rejuvenation, Government of India, constituted a committee headed by Chairman, CGWB to review and revise the Ground Water Resource Estimation Methodology 1997 (GEC-97) and to look into related issues (Annexure I). The committee consisted of the following members and special invitees:

1	The Chairman, Central Ground Water Board	Chairman
2	The Joint Secretary (WSM), Ministry of Rural Development, Government of India, New Delhi.	Member
3	The General Manager, National Bank for Agriculture, & Rural Development(NABARD), Sterling Centre, Shivsagar Estate, Dr. Annie Besant Road, PostBoxNo.6552,Mumbai-400018	Member
4	The Dy. Director General, Geological Survey of India, CGPB Secretariat, Geological Survey of India, Pushpa Bhawan, A-Block, 2nd Floor, Madangir Road, New Delhi – 110062.	Member
5	The Director, State Water Investigation Directorate, Government of West Bengal, Sech. Bhawan (3 rd Floor),Salt Lake, Kolkata – 700 091.	Member
6	The Chief Engineer (PWD), State Ground and Surface Water Resources Data Centre, Water, Government of Tamil Nadu,IWS Campus, Tharamani, Chennai – 600 113.	Member
7	Superintending Geohydrologist, Government of Madhya Pradesh, Ground Water Survey Circle, Bhopal(MP).	Member
8	The Managing Director, Gujarat Water Resources Development Corporation Ltd., Government of Gujarat, Sector-10 A, Near BijBhawan, Gandhinagar – 382043.	Member
9	The Director, State Ground Water Department, Government of Andhra Pradesh, B.R.K.R. complex, 7 th and 8 th Floor, B-Block, Tank Bund Road, Hyderabad – 500063.	Member
10	The Director, Groundwater Survey and Development Agency, Government of Maharashtra, Bhujal Bhawan, Shivaji Nagar, Pune – 411 005.	Member

1516

11	The Director, Water Resources & Environment Directorate, Government of Punjab, SCO- 32-34, Sector-17C Chandigarh.- 160017	Member
12	The Director, UP Ground Water Department, Government of Uttar Pradesh, 9 th Floor, Indira Bhavan, Ashok Marg, Lucknow – 226 001.	Member
13	Member(TT&WQ), CGWB, NH-IV, Faridabad	Member Secretary

Special Invitees:

1	The Commissioner (SP), Government of India, Ministry of Water Resources, Krishi Bhawan, NewDelhi-110001.	Member
2	The Head, Ground Water Hydrology Division, National Institute of Hydrology, Jalvigyan Bhawan, Roorkee - 247667	Member
3	Professor Dr. N. J. Raju, School of Environmental Sciences, Jawaharlal University, New Delhi	Member
4	Prof.Dr. A.K. Gosain, Department of Civil Engineering, IIT Delhi	Member
5	Dr. S. K. Srivastav, IIRS, Dept. of Space, Govt. of India 4, Kalidas Road, Dehradun - 248 001 (India)	Member
6	Dr. Himanshu Kulkarni, Advanced Centre for Water resources Development And Management, Pune, Maharashtra	Member
7	The Member(SAM), Central Ground Water Board, NH-IV, Faridabad	Member
4	The Member (SM&L) and Member Secretary, CGWA, R.K. Puram, New Delhi	Member

Shri Rana Chatterjee, Scientist D will assist the committee

1.3 TERMS OF REFERENCE

The terms of reference of this Committee are as follows:

1. Firming up/updating various parameters and their values currently used in the assessment of ground water resources based on the scientific work carried out by various organizations.
2. To look into the details of the methodology recommended by Ground Water Estimation Committee (1997) and to suggest aspects which call for a revision. The Committee may, if consider necessary, update the existing or recommend a new methodology for the assessment of ground water resources in different hydrogeological situations and climatic zones.
3. To recommend the smallest assessment unit for assessment of ground water resources based on hydrogeological/hydrological and/or administrative division.
4. To recommend a methodology for assessment of ground water resource in urban areas/specific areas.
5. Suggest alternative approaches for real time assessment of ground water resources.
6. Committee should suggest modality and methodology for incorporating quality consideration in assessment of ground water resources.

7. Review and recommend methodology for assessment of Total Ground Water Availability.
8. Any other aspects relevant to the terms referred to above.

1.4 PROCEEDINGS OF THE COMMITTEE

After the constitution of the Committee, views on ground water estimation methodology were sought from the State Ground water Departments, Scientific and research organizations dealing with ground water, Universities, NABARD, and Ground water experts. Based on these views an Approach Paper on “Revision of Ground Water Estimation Methodology” was prepared for consideration of the Committee. The first meeting of the Committee was held on 10.02.2015 under the Chairmanship of Shri K.C.Naik, Member (TT & WQ), CGWB. Minutes of the meeting are enclosed in **Annexure II**. After reviewing the Approach Paper, the Committee decided to constitute three sub groups each headed by a Convenor and assisted by a Resource Person to facilitate working of the committee and timely completion of the terms of references of the committee. The deliverables of the subgroups are as follows:

- (i) Sub-Group I - Refinement in the Ground Water Assessment Methodology
- (ii) Sub-Group II - Database used for Ground Water Resources Estimation
- (iii) Sub-Group-III - Alternative approach for Assessment Involving Advanced Technology

The sub committees consisted of the following members:

Sub-Group I - Refinement in the Ground Water Assessment Methodology

Dr. Himanshu Kulkarni, Director, Advanced Center for Water Resources Development and Management (ACWADAM), Pune	Convener
Sh. E. Sampath Kumar, Member (SM&L), CGWB, New Delhi	Member
DR. N.J. Raju, Professor, School of Environmental Science, JNU, New Delhi	Member
Dr. K. Venugopal, Director, AP Ground Water Department	Member
Sh. P.S. Bhogal, Director, Water Resources, Punjab	Member
Sh. S.K. Sahni, Joint Director, Ground Water Department, UP	Member
Sh. Rana Chatterjee, Scientist D, CGWB, New Delhi	Resource Person

Sub-Group II - Database used for Ground Water Resources Estimation

Dr. A.R. Khan, Deputy General Manager, NABARD	Convener
Dr. Dipankar Saha, Member(RGI), CGWB	Member
Dr. S.K. Srivastava, Group Head, Remote Sensing & Geoinformatics Group, IIRS, Dehradun	Member
DDG & National Mission Head II, Geological Survey of India, Maharashtra	Member
Shri Vimal Chaurasia, SE, Ground Water Survey Circle, Madhya Pradesh, Bhopal	Member
Dr S. Suresh, Scientist D, CGWB, Faridabad	Member

Shri A.V.S.S. Anand, Scientist C, RGNGWTRI, CGWB, Raipur.

Resource Person

Sub-Group-III - Alternative approach for Assessment Involving Advanced Technology

Dr. A.K. Gosain, Professor, IIT, Delhi	Convener
Shri. K.C. Naik, Member (SAM), CGWB, Faridabad	Member
Dr. N.C. Ghosh, Scientist 'G' and Head, Groundwater hydrology division, NIH, Roorkee	Member
Shri. Vivek Kapadia, MD, GWRDC, Govt. of Gujarat	Member
Shri. V. Shanmugan, Chief Engineer, SG&SWRDC, Tamil Nadu	Member
Shri. S. K. Sinha, Scientist 'D', CGWB, Faridabad	Member
Shri. R.K. Ray, Scientist 'C', CGWB, Faridabad	Resource Person

The second meeting exclusively for the sub group members was convened on 03.07.2015 under the Chairmanship of Shri K.B.Biswas Chairman, CGWB, Minutes of the meeting are enclosed in **Annexure III**. During the meeting, the reports submitted by the three Sub Groups were discussed and a few modifications were suggested. Another meeting of the committee to review and revise GEC 97 Methodology was convened on 18.09.2015. During the meeting final reports of the Sub Groups were approved. A drafting committee headed by Shri G.C. Pati, Member (TT & WQ), CGWB was constituted for compilation of the final report. The Drafting Committee consisted of the following members:

Shri. G.C. Pati, Member (TT & WQ), Central Ground Water Board, CHQ, Faridabad

Dr.B.C. Joshi, Scientist-D, Central Ground Water Board, CHQ, Faridabad

Shri A.V.S.S. Anand, Scientist-D, Central Ground Water Board, NGWTRI, Raipur.

Ms. Rumi Mukherjee, Scientist-C, Central Ground Water Board, CHQ, Faridabad.

Ms. Parveen Kaur, Scientist-B, Central Ground Water Board, CHQ, Faridabad

The group finalised its report and the draft report was circulated to all the members of the Committee for their views. During the fourth meeting of the committee, held on 03-12-2015 under the Chairmanship of Shri K.B. Biswas, Chairman, CGWB, the draft report of "Ground Water Resource Estimation Committee - 2015 (GEC 2015) was discussed in detail. The views expressed by the members for revised methodology were considered and necessary modifications were made and report of the Committee was finalised. The minutes of the meeting are enclosed as Annexure IV.

As decided in the meeting held on 09.02.2016 at New Delhi on Revision of Ground water estimation Methodology-97, a workshop on "Ground Water Resource Estimation Methodology - 2015" was held on 24th January 2017 at CWPRS, Khadakwasla, Pune involving stakeholders and experts. The major changes proposed in the workshop were (i) to change the criteria for categorization of assessment units and (ii) to remove the potentiality tag. The recommendations have been suitably incorporated in the present report.

* * *

2

NATIONAL SCENARIO OF GROUND WATER

2.1 HYDROGEOLOGICAL SETUP

India is a vast country with varied hydrogeological situations resulting from diversified geological, climatological and topographic setups. The rock formations, ranging in age from Archaean to Recent, control occurrence and movement of ground water, widely vary in composition and structure. Physiography varies from rugged mountainous terrains of Himalayas, Eastern and Western Ghats and Deccan plateau to the flat alluvial plains of the river valleys and coastal tracts, and the aeolian deserts in western part.

Based on ground water bearing properties the geological formations of the country are broadly classified into following two categories.

1. Porous rock formations

(a) Unconsolidated formations.

(b) Semi - consolidated formations.

2. Hard rock/consolidated formations

2.2 AQUIFER SYSTEMS OF INDIA

The various rock formations with distinctive hydrogeological characteristics act as different aquifer systems of various dimensions. The various major rock formations of India can be broadly categorized in to 14 Principal aquifer Systems based on their broad hydrogeological properties. A brief account of the Principal Aquifer Systems is discussed in the following paragraphs. The principal Aquifer systems as identified by Central Ground Water Board are shown in **Fig 1**. The Principal Aquifers are further divided into 42 Major Aquifers (**Fig 2**) depending on their distinctive hydrological characteristics and their spatial distribution. The details are given as **Table 1**.

2.2.1 Alluvial Aquifers

The unconsolidated Quaternary sediments comprising Recent Alluvium, Older Alluvium, Aeolian and Coastal Alluvium along the eastern coast of India, by and large forms

the major Alluvial Aquifers. These sediments are essentially composed of clays, silts, sands, pebbles, Kankar etc.

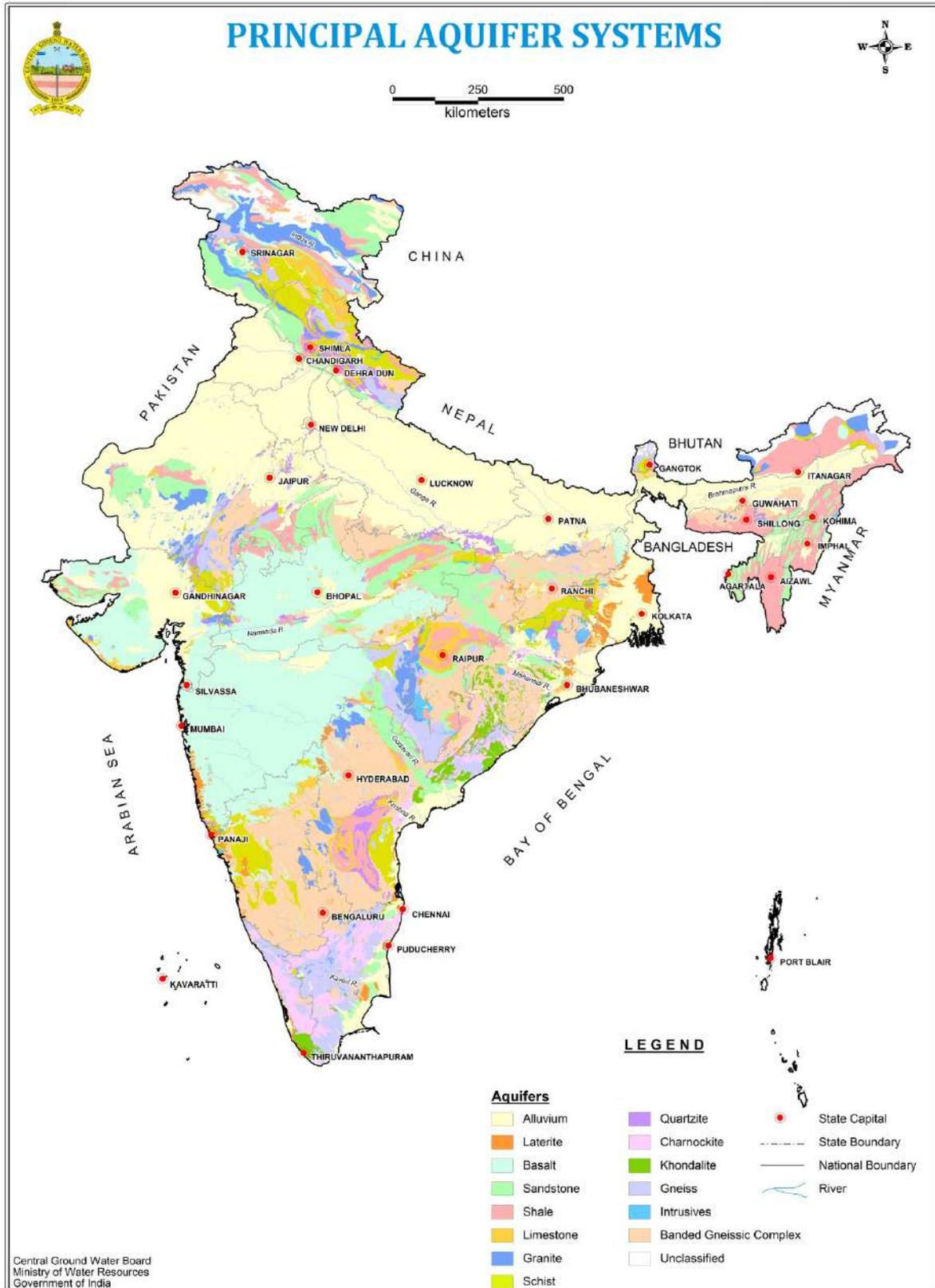


Fig 1. Principal Aquifer Systems of India

Alluvial Aquifers are the most significant ground water reservoirs which support large scale and extensive development of the country. The Indo-Ganga-Brahmaputra basin having distinctive hydrogeological environment and ground water regime conditions have enormous fresh ground water potential. Bestowed with high incidence of rainfall and underlain by a thick sequence of porous sediments, the alluvial aquifers in Indo-Ganga-Brahmaputra basin get replenished every year and are being used extensively. In addition to the Annual Replenishable Ground Water Resources in the zone of Water Level Fluctuation (Dynamic Ground Water Resource), a huge ground water reserve occurs below the zone of fluctuation in unconfined aquifers and as well as in the deeper confined aquifers. The coastal aquifers though have replenishable ground water resources show wide variation in the water quality, both laterally and vertically, thus imposing quality constraints for ground water development.

2.2.2 Laterite Aquifer

Laterites are formed due to leaching (chemical weathering) of parent sedimentary rocks (sandstones, clays, limestones); metamorphic rocks (schists, gneisses, migmatites) and igneous rocks (granites, basalts, gabbros, peridotites) under hot and humid climatic conditions. Laterites rich in iron and aluminium contents are the most wide spread and extensively developed aquifer especially in the peninsular states of India. Laterite forms potential aquifers along valleys and topographic lows where thick saturated zone sustain large diameter open wells for domestic and irrigation use.

2.2.3 Sand Stone, Shale Aquifer

The sand stone and shale generally belong to the group of rocks ranging in age from Carboniferous to Mio-Pliocene forms this aquifer. The terrestrial freshwater deposits belonging to Gondwana System and the Tertiary deposits along the west and east coast of the peninsular region are included under this category. The Gondwana sandstones form highly potential aquifers, locally. Elsewhere, they have moderate potential and in places they yield meagre supplies. The Gondwanas, Lathis, Tipams, Cuddalore sandstones and their equivalents are the most extensive productive aquifers.

2.2.4 Limestone Aquifer

The consolidated sedimentary rocks include carbonate rocks such as limestone, dolomite and marble. Limestone is the dominating rock type among the carbonate rocks, which is widely distributed in the country. In the carbonate rocks the secondary porosity like fractures and solution cavities form the aquifer. Consolidated sedimentary rocks of Cuddapah and Vindhyan subgroups and their equivalents consist of limestone/dolomites apart from

other major litho-units such as conglomerates, sandstones, shale, slates and quartzite form this principal aquifer.

2.2.5 Basalt aquifers

Basalt is the basic volcanic rock which forms alternate layers of compact and vesicular beds of lava flows as seen in the Deccan trap area. The ground water occurrence in the basalts are controlled by nature and extent of weathering, presence of vesicles and lava tubes, thickness, number of flows and the nature of inter-trappean layers. The basalts have usually medium to low permeability. Ground water occurrence in the Deccan Traps is controlled by the contrasting water bearing properties of different flow units, thus, resulted in multiple aquifer system, at places. The water bearing zones are the weathered and fractured zones.

2.2.6 Crystalline Aquifers

The crystalline hard rock aquifers such as granite, gneisses and high grade metamorphic rocks viz. charnockite and khondalite constitute moderate to good repository of ground water. Hard rocks generally neither receive nor transmit water, due to negligible or limited primary porosity. However, these may form good aquifers if weathered and/or have good secondary porosity in the form of faults, fractures, joints and bedding planes. The crystalline rocks also form the aquifers with weathered zone or the fracture system. The weathered mantle cover and associated secondary porosity do not occur uniformly, but are rather localised phenomena. The weathered zone is underlain by semi-weathered saprolite zone followed by fractured and massive rock.

In these aquifers, ground water occurs under phreatic condition in the weathered mantle cover and under semi-confined to confined state in underlying fissured, fractured, and jointed hard rock. The volume of ground water stored under semi-confined condition within the body of the hard rock is much lower than the storage in the overlying phreatic aquifer which is often much greater. Hydraulically connected fissures and fractures underlying weathered mantle cover generally serves as a permeable conduit feeding the deeper wells. Ground water flow rarely occurs across the topographical water divides so far as the unconfined aquifer is concerned and each basin or sub-basin can be treated as a separate hydro geological unit for planning the development of ground water resources.

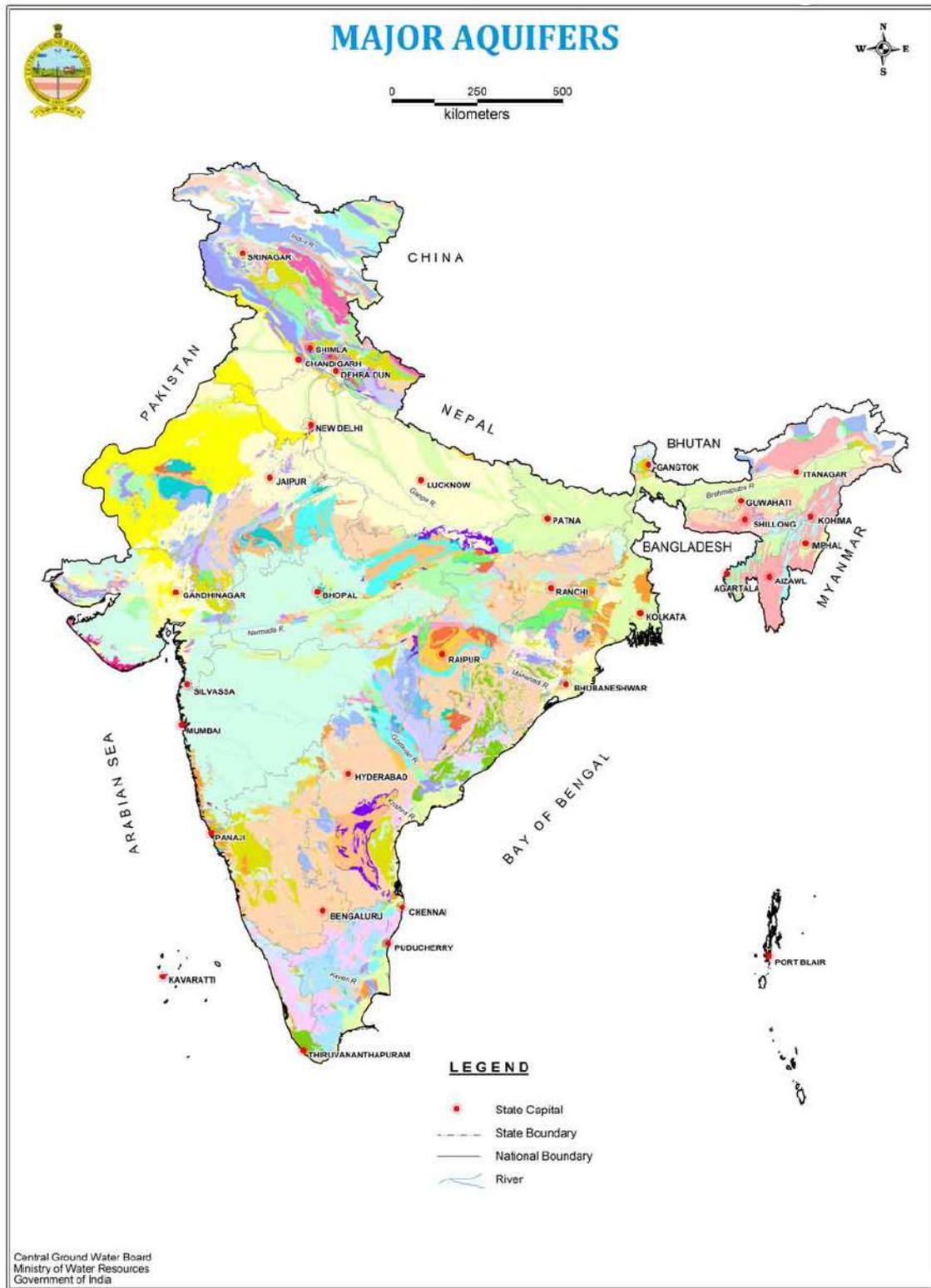


Fig 2. Major Aquifer Systems of India

Table 1. Description of Major Aquifer Systems of India

S. No	Principal Aquifer Systems		Yield (m ³ / day)	Major Aquifers		Area Covered (Sq km)	Age
	Code	Name		Code	Name		
1	AL	Alluvium (945753 sq km) (29.82 %)	10-6500	AL01	Younger Alluvium (Clay/Silt/Sand/ Calcareous concretions)	339298	Quaternary
2				AL02	Pebble / Gravel/ Bazada/ Kandi	5203	Quaternary
3				AL03	Older Alluvium (Silt/Sand/Gravel/Lith omargic clay)	407490	Quaternary
4				AL04	Aeolian Alluvium (Silt/ Sand)	149208	Quaternary
5				AL05	Coastal Alluvium (Sand/Silt/Clay)	40661	Quaternary
6				AL06	Valley Fills	3864	Quaternary
7				AL07	Glacial Deposits	31	Quaternary
8	LT	Laterite (40925 sq km) (1.29 %)	5 - 6000	LT01	Laterite / Ferruginous concretions	40926	Quaternary
9	BS	Basalt (512302 sq km) (16.15 %)	1-480	BS01	Basic Rocks (Basalt)	512290	Mesozoic to Cenozoic
10				BS02	Ultra-Basic	12	Mesozoic to Cenozoic
11	ST	Sandstone (260415 sqkm) (8.21 %)	5 - 3700	ST01	Sandstone/Conglomer ate	50026	Upper Palaeozoic to Cenozoic
12				ST02	Sandstone with Shale	75355	Upper Palaeozoic to Cenozoic
13				ST03	Sandstone with Shale/ Coal beds	37720	Upper Palaeozoic to Cenozoic
14				ST04	Sandstone with Clay	21540	Upper Palaeozoic to Cenozoic
15				ST05	Sandstone/Conglomer ate	56354	Proterozoic to Cenozoic
16				ST06	Sandstone with Shale	19420	Proterozoic to Cenozoic
17	SH	Shale (225397 sqkm) (7.11 %)	8 -2900	SH01	Shale with Limestone	3784	Upper Palaeozoic to Cenozoic
18				SH02	Shale with Sandstone	87771	Upper Palaeozoic to Cenozoic
19				SH03	Shale, Limestone and Sandstone	45539	Upper Palaeozoic to Cenozoic
20				SH04	Shale	5938	Upper Palaeozoic to Cenozoic
21				SH05	Shale/Shale with Sandstone	64265	Proterozoic to Cenozoic

1525

S. No	Principal Aquifer Systems		Yield (m ³ / day)	Major Aquifers		Area Covered (Sq km)	Age
	Code	Name		Code	Name		
22				SH06	Shale with Limestone	18100	Proterozoic to Cenozoic
23	LS	Limestone (62898 sqkm) (1.98 %)	4 - 2100	LS01	Miliolitic Limestone	2946	Quaternary
24				LS02	Limestone / Dolomite	19747	Upper Palaeozoic to Cenozoic
25				LS03	Limestone/Dolomite	34708	Proterozoic
26				LS04	Limestone with Shale	5499	Proterozoic
27				LS05	Marble	995	Azoic to Proterozoic
28				GR	Granite (100991 sqkm) (3.18 %)	10-1440	GR01
29	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.)	100858				Proterozoic to Cenozoic
30	SC	Schist (140934.90 sqkm) (4.44%)	3-550	SC01	Schist	93026	Azoic to Proterozoic
31				SC02	Phyllite	31589	Azoic to Proterozoic
32				SC03	Slate	16321	Azoic to Proterozoic
33	QZ	Quartzite (46904 sqkm) (1.48%)	2 - 400	QZ01	Quartzite	20830	Proterozoic to Cenozoic
34				QZ02	Quartzite	26074	Azoic to Proterozoic
35	CK	Charnockite (76359 sq km) (2.41%)	1 - 3000	CK01	Charnockite	76360	Azoic
36	KH	Khondalite (32913 sq km) (1.04 %)	20-1500	KH01	Khondalite, Granulite	32914	Azoic
37	BG	Banded Gneissic Complex (478382 sq km) (15.09 %)	2 - 3600	BG01	Banded Gneissic Complex	478383	Azoic
38	GN	Gneiss (158753 sq km) (5.01 %)	10 - 2500	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic	59260	Azoic to Proterozoic
39				GN02	Gneiss	43266	Azoic to Proterozoic
40				GN03	Migmatitic Gneiss	56228	Azoic
41	IN	Intrusive (19895 sqkm) (0.63 %)	Low Yield	IN01	Basic Rocks (Dolerite, Anorthosite etc.)	11167	Proterozoic to Cenozoic
42				IN02	Ultra-Basics (Epidiorite, Granophyre etc.)	8729	Proterozoic to Cenozoic

2.3 GROUND WATER QUALITY

Ground water quality data generated in various scientific studies and the data of National Quality Monitoring Stations of Central Ground Water Board indicate that the ground water in major part of the country is potable. However, some parts of various states are contaminated by inland & coastal Salinity, Arsenic, Fluoride, Iron and Nitrate. Higher concentration of arsenic in ground water is generally geogenic and partly occur due to anthropogenic activities like application of fertilizers, burning of coal, leaching from coal-ash tailings and from mining activity. Arsenic in ground water beyond the permissible limit of 10 ppb has been reported from 10 states namely West Bengal, Bihar, Uttar Pradesh, Assam, Manipur, Jharkhand, Punjab, Haryana, Chhattisgarh and Karnataka. Mostly the Indo-Gangetic alluvium and the Brahmaputra alluvium have higher concentration of arsenic in localized pockets. Fluoride contamination (more than 1.5 mg/l) in ground water is widely prevalent in different parts of India mostly in the states of Telangana, Andhra Pradesh, Rajasthan, Maharashtra, Madhya Pradesh, West Bengal, Bihar, Odisha, Punjab, Haryana, Tamil Nadu, Uttar Pradesh, Karnataka and Gujarat. Some parts of Chhattisgarh, Delhi and Kerala are also affected by Fluoride contamination. Salinity in ground water is found mainly in western, north western and southern parts of India. Salinity has been observed in all major aquifer systems. Inland salinity caused by high sulphate in ground water has also been reported from some parts of the country. Besides salinity originated from saline water intrusion in coastal areas due to over pumping of ground water in various scales has been reported in the states of Tamil Nadu, West Bengal, Odisha, Gujarat and Andhra Pradesh.

High levels of iron in ground water (more than 1 mg/l) have been reported from many states. Pollution due to human and animal wastes and fertilizer application has resulted in higher levels of nitrate and potassium in ground water in some parts of the country. Ground water pollution due to indiscriminate disposal of industrial effluents has been observed as localised contamination in major industrial zones.

2.4 GROUND WATER RESOURCE POTENTIAL

The dynamic ground water resources are also known as the Annual Replenishable Ground Water Resources since it gets replenished/ recharged every year. The Annual Replenishable Ground Water Resource for the entire country has been assessed as 433 billion cubic meter (bcm). The major source of ground water recharge is the monsoon rainfall. About 58% of the annual replenishable resources i.e. 253 bcm are contributed by monsoon rainfall recharge. The overall contribution of rainfall to country's Annual Replenishable Ground

Water Resource is 68% and the share of other sources viz. canal seepage, return flow from irrigation, recharge from tanks, ponds, and water conservations structures taken together is 32%. The contribution from other sources such as canal seepage, return flow from irrigation, seepage from water bodies etc. in Annual Replenishable Ground Water Resource is more than of 33% in the states of Andhra Pradesh, Delhi, Haryana, Gujarat, Goa, Jammu & Kashmir, Karnataka and Punjab,

In spite of the national scenario that the availability of ground water being favourable, there are pockets in certain areas in the country that face scarcity of water. This may happen due to non-uniform ground water development, being quite intensive in some areas resulting in over-exploitation leading to fall in water levels and even salinity ingress in coastal areas. The declining water levels have resulted in failure of wells or deepening of extraction structures leading to additional burden on the farmers.

Out of 6607 number of assessed administrative units (Blocks/ Taluks/ Mandals/ Districts), 1071 units are Over-exploited, 217 units are Critical, 697 units are Semi-critical, and 4530 units are Safe (Ground Water Assessment, 2011). Apart from these, there are 92 assessment units which are completely saline. Number of Over-exploited and Critical administrative units are significantly higher (more than 15% of the total assessed units) in Delhi, Haryana, Himachal Pradesh, Karnataka, Punjab, Rajasthan, Tamil Nadu and Uttar Pradesh and also the Union Territories of Daman & Diu and Puducherry.

2.5 GROUND WATER DEVELOPMENT SCENARIO

During the past four-five decades, there has been a phenomenal increase in the growth of ground water abstraction structures due to implementation of technically viable schemes for development of the resource, backed by liberal funding from institutional finance agencies, improvement in availability of electric power and diesel, good quality seeds, fertilisers, government subsidies, etc. The net irrigated area tripled from 21 million hectares in 1950–51 to 63 million hectares in 2008–09; the share of ground water irrigation through wells rose substantially from 28 per cent to 61 per cent. The main contribution in this came from rapid growth in tube well irrigation, the share of which rose from zero in 1950–51 to over 41 per cent by 2008–09. This shows that ground water irrigation with the advent of tube well irrigation technology has made a huge contribution to irrigation growth in India. This could also be assessed from the facts that during the period 1951-92, the number of dug wells increased from 3.86 million to 10.12 million that of shallow tube wells from 3000 to 5.38 million and public bore/tube wells from negligible to 68000. The number of electric pump

sets has increased from negligible to 9.34 million and the diesel pump sets from 66,000 to about 4.59 million. Such a magnitude of ground water development requires realistic assessment of ground water resources to avoid any deleterious effects on ground water regime and to provide sustainability to the ground water development process.

2.6 NATIONAL WATER POLICY

The 'National Water Policy (2012) adopted by the Government of India regards water as a scarce natural resource, fundamental to life, livelihood, food security and sustainable development. It emphasizes that the efforts to develop, conserve, utilise and manage this resource have to be guided by national perspective. The concerns related to water are generally the skewed accessibility to safe water for drinking and other domestic needs, general perception that ground water is an individual's property rather than community resource, encroachment of river channels, blockage of recharge zones and inter regional disputes in sharing water etc. Safe water for drinking and sanitation should be considered as pre-emptive needs, followed by high priority allocation for other basic domestic needs including needs of animals, achieving food security, supporting sustenance agriculture and minimum eco-system needs. The National Water Policy enunciates the following guidelines for ground water in particular.

- The availability of water resources and its use by various sectors in various basins and states in the country need to be assessed scientifically and reviewed at periodic intervals, say every five years.
- Water is essential for sustenance of eco-system and therefore, minimum ecological needs should be given due consideration.
- The anticipated increase in variability in availability of water because of climate change should be dealt with by increasing water storage in its various forms, namely soil moisture, ponds, ground water, small and large reservoirs and their combination.
- There is a need to map the aquifers so as to know the quantum and quality of ground water resources replenishable as well as non replenishable in the country.
- Quality conservation and improvement is very important for ground water since cleaning of it is very difficult.
- Declining ground water levels in over exploited areas need to be arrested by introducing improved technologies of water use, incentivizing efficient water use and encouraging community based management of aquifers.

1529

- Watershed development activities with ground water perspectives need to be taken up in a comprehensive manner to increase soil moisture, reduce sediment yield and increase overall land& water productivity.

The present action of revising the ground water estimation methodology is a sequel to the tenets of the National Water Policy for periodic reassessment of ground water potential on scientific basis.

* * *

3

RECOMMENDATIONS OF THE EXISTING METHODOLOGY (GEC 1997)

3.1 REVIEW OF GROUND WATER RESOURCE ASSESSMENT METHODOLOGIES

Attempts have been made from time to time by various Working Groups/Committees/Task Force, constituted by Government of India to estimate the ground water resources of the country based on status of available data and in response to developmental needs. But, due to paucity of scientific data and incomplete understanding of the parameters involved in recharge and discharge processes, all these early estimations were tentative and at best approximation. In 1972, guidelines for an approximate evaluation of ground water potential was circulated by the Ministry of Agriculture, Government of India to all the State Governments and financial institutions. The guidelines recommended norms for ground water recharge from rainfall and from other sources.

The first attempt to estimate the ground water resources on a scientific basis was made in 1979. A High Level Committee, known as Ground Water Over Exploitation Committee was constituted by the then Agriculture Refinance and Development Corporation (ARDC). The committee was headed by the Chairman, CGWB and representatives from the state ground water organizations and financial institutions were included as its members. This Committee recommended definite norms for ground water resources computations.

In the year 1982, Government of India constituted "Ground Water Estimation Committee" (GEC) with the members drawn from various organizations engaged in hydrogeological studies and ground water development. In 1984 this Committee, after reviewing the data collected by central and state agencies, research organisations, universities, etc. recommended the methods for ground water recharge estimation. This is popularly known as GEC 1984. This was the first methodology which dealt with the subject exhaustively and assessed the resources on a fool proof methodology. This methodology was in practice for next 12 years.

In the year 1996, Government of India again constituted “Ground Water Estimation Committee” (GEC) with the members taken from various organizations engaged in hydrogeological studies and ground water development. In 1997 this Committee, after reviewing the data collected by central and state agencies, research organisations, universities, etc. recommended the methods for ground water recharge estimation. This is popularly known as GEC 1997. The recommendations of this Committee are summarised in this chapter.

3.2 RECOMMENDATIONS OF GEC 1997

Two basic approaches recommended by the GEC - 1984, namely ground water level fluctuation method and rainfall infiltration factor method, still form the basis for ground water assessment. In GEC 1997 methodology, distinctions such as hard rock areas and alluvial areas, canal command areas and non-command areas and recharge in monsoon season and non-monsoon season, are kept in view. The resources are estimated based on the Ground water balance equation.

3.2.1 Unit for Ground Water Recharge Assessment

Watershed with well-defined hydrological boundaries is an appropriate hydrological unit for ground water resource estimation. In hard rock areas, the hydrogeological and hydrological units normally coincide, which may not be the case in alluvial areas where the aquifers traverse the basin boundaries. In hard rock areas which occupy about 2/3rd area of the country, assessment of ground water resources on watershed as a unit is more desirable. In many states where the development unit is either a block, taluka or a mandal, the ground water resources worked out on watershed as a unit, may be apportioned and presented finally on block/taluka/mandal-wise basis, for planning of development programmes. In case of alluvial areas where it is difficult to identify watershed considering the trans-boundary aquifer system, assessment of ground water potential on block/taluka/mandal-wise basis may prevail.

3.2.2 Delineation of Subareas in the Assessment Unit

GEC - 1997 recommends identifying hilly areas where slope is more than 20% as these areas are likely to contribute more to run off than to ground water recharge. Such hilly areas should be subtracted from the total geographical area of the unit. The areas where the quality of ground water is beyond the usable limits, should also be identified and handled separately. The remaining area need to be re-delineated as (a) Non-command areas which do

not come under major/medium surface water irrigation schemes and (b) Command areas which come under major/medium surface water irrigation schemes.

3.2.3 Season-Wise Assessment of Ground Water Resources

Ground water recharge assessment is to be made separately for the non-command, command areas and poor ground water quality areas in the assessment unit. For each of these subareas, recharge in the monsoon season and non-monsoon season is to be estimated separately. For most parts of the country receiving the main rainfall from South west monsoon, the monsoon season would pertain to *kharif* period of cultivation. In areas, such as Tamil Nadu, where the primary monsoon season is the North east monsoon, the period of monsoon season should be suitably modified. For the purposes of recharge assessment using water level fluctuation method, the monsoon season may be taken as May/June to October/November for all areas, except those where the predominant rainfall is due to the North east monsoon. In areas where the predominant rainfall is due to North east monsoon, the period for recharge assessment may be based on pre-monsoon (October) to post monsoon (February) water level fluctuations.

3.2.4 Estimation of Ground Water Draft

Ground water draft is estimated for all the ground water uses viz. Domestic, Irrigation and Industrial. Domestic draft can be estimated based on well census method or requirement method. Irrigation draft can be estimated using well census method, cropping pattern method or power consumption method. Industrial draft can be estimated using well census method, power consumption method or requirement method. Sum of all these drafts is the Gross ground water draft.

3.2.5 Estimation of Ground Water Recharges

Ground water recharge due to rainfall is to be estimated using ground water level fluctuation method and rainfall infiltration factor method.

3.2.5.1 Ground water level fluctuation method

The water level fluctuation method is applied for the monsoon season to estimate the recharge using ground water balance equation. The ground water balance equation for the monsoon season is expressed as,

$$R_G - D_G - B + I_S + I = \Delta S$$

Where

R_G = gross recharge due to rainfall and other sources including recycled water

D_G = gross ground water draft

B = base flow into streams from the area

I_S = recharge from streams into ground water body

I = net ground water inflow into the area across the boundary (inflow - outflow)

ΔS = increase in ground water storage

In the above equation, if the area under consideration is a watershed, the net ground water inflow (I) may be taken as zero. If there is inflow and outflow across the boundary, theoretically, the net inflow may be calculated using Darcy law, by delineating the inflow and outflow sections of the boundary. Besides such delineation, the calculation also requires estimate of transmissivity and hydraulic gradient across the inflow and outflow sections. For the present ground water assessment as prescribed in these recommendations, the net inflow may be dropped. There are similar difficulties in estimating the base flow and recharge from streams in the above equation. Hence, it is recommended that the base flow and recharge from stream in the above equation may also be dropped. After deleting net inflow and base flow the equation is now rewritten as,

$$R = \Delta S + D_G = h \times S_y \times A + D_G$$

Where

R = Possible recharge, which is gross recharge minus the natural discharges in the area in the monsoon season ($R_G - B + I + I_S$)

h = rise in water level in the monsoon season

A = area for computation of recharge

S_y = specific yield

ΔS = increase in ground water storage

D_G = gross ground water draft

The recharge calculated from the above equation gives the available recharge from rainfall and other sources for the particular monsoon season. For non-command areas, the recharge from other sources may be recharge from recycled water from ground water irrigation, recharge from tanks and ponds and recharge from water conservation structures, The recharge from rainfall is given by,

$$R_{rf} = R - R_{gw} - R_{wc} - R_t = h \times S_y \times A + D_G - R_{gw} - R_t - R_{wc}$$

Where

R_{rf} = recharge from rainfall

R_{gw} = recharge from ground water irrigation in the area

R_{wc} = recharge from water conservation structures

R_t = Recharge from tanks and ponds

In command areas there are two more components in recharge due to other sources viz. recharge due to canals and return flow from surface water irrigation. Hence the rainfall recharge can be estimated using the following formula.

$$R_{rf} = h \times S_y \times A + D_G - R_c - R_{sw} - R_{gw} - R_t - R_{wc}$$

Where,

R_{rf} = rainfall recharge

h = rise in water level in the monsoon season

S_y = specific yield

A = area for computation of recharge

D_G = gross ground water draft in the monsoon season

R_c = recharge due to seepage from canals

R_{sw} = recharge from surface water irrigation

R_{gw} = recharge from ground water irrigation

R_t = recharge from tanks and ponds

R_{wc} = recharge from water conservation structures

3.2.5.2. Estimation of normal rainfall recharge during monsoon season

The rainfall recharge obtained by using above equations provide the recharge in any particular monsoon season for the associated monsoon season rainfall. This estimate is to be normalised for the normal monsoon season rainfall which in turn is obtained as the average of the monsoon season rainfall for the recent 30 to 50 years. The normalisation procedure requires that, a set of pairs of data on recharge and associated rainfall are first obtained. To eliminate the effects of drought or surplus years, it is recommended that the rainfall recharge during monsoon season is estimated not only for the current year for which assessment is being made, but also for at least four more preceding years.

Two possible methods are recommended for the normalisation procedure. The first method is based on a linear relationship between recharge and rainfall of the form,

$$R = a r$$

Where,

R = rainfall recharge during monsoon season

r = monsoon season rainfall

a = a constant

The computational procedure to be followed in the first method is as given below:

$$R_{rf}(\text{normal}) = \frac{\sum_{i=1}^N \left[R_i \times \frac{r(\text{normal})}{r_i} \right]}{N}$$

The second method is also based on a linear relation between recharge and rainfall. However, this linear relationship is of the form,

$$R = ar + b$$

Where,

R = rainfall recharge

r = rainfall

a and b = constants.

The two constants 'a' and 'b' in the above equation are obtained through a linear regression analysis.

The computational procedure to be followed in the second method is as given below:

$$a = \frac{NS_4 - S_1S_2}{NS_3 - S_1^2}$$

$$b = \frac{S_2 - aS_1}{N}$$

Where

N = No. of datasets and

$$S_1 = \sum_{i=1}^N r_i \quad S_2 = \sum_{i=1}^N R_i \quad S_3 = \sum_{i=1}^N r_i^2 \quad S_4 = \sum_{i=1}^N r_i R_i$$

The rainfall recharge during monsoon season for normal monsoon rainfall condition is computed as below:

$$R_{rf}(\text{normal}) = a \times r(\text{normal}) + b$$

3.2.5.3 Rainfall Infiltration Factor Method

Recharge from rainfall in monsoon season can also be estimated based on the Rainfall Infiltration Factor method and is estimated using the following equation

$$R_{rf} = f \times A \times \text{Normal rainfall in monsoon season}$$

Where

f = rainfall infiltration factor

A = area for computation of recharge

3.2.5.4 Percent Deviation

After the estimation of rainfall recharge for normal monsoon season rainfall using the water table fluctuation method and rainfall infiltration factor method, Percent Deviation(PD) which is the difference between the two methods expressed as a percentage of the latter is computed as,

$$PD = \frac{R_{rf}(\text{normal, wtfm}) - R_{rf}(\text{normal, rifm})}{R_{rf}(\text{normal, rifm})} \times 100$$

Where,

$R_{rf}(\text{normal, wtfm})$ = Rainfall recharge for normal monsoon season rainfall estimated by the water table fluctuation method

$R_{rf}(\text{normal, rifm})$ = Rainfall recharge for normal monsoon season rainfall estimated by the rainfall infiltration factor method

The rainfall recharge for normal monsoon season rainfall is finally adopted as per criteria given below:

If PD is greater than or equal to -20%, and less than or equal to +20%, $R_{rf}(\text{normal})$ is taken as the value estimated by the water table fluctuation method.

If PD is less than -20%, $R_{rf}(\text{normal})$ is taken as equal to 0.8 times the value estimated by the rainfall infiltration factor method.

If PD is greater than +20%, $R_{rf}(\text{normal})$ is taken as equal to 1.2 times the value estimated by the rainfall infiltration factor method.

3.2.5.5 Recharge due to Other Sources

Recharge due to other sources constitute recharges from Canals, Applied Surface Water irrigation, Applied Ground Water Irrigation, Tanks & Ponds and Water Conservation Structures in Command areas. Whereas in Non-command areas only the recharge due to Applied Ground Water Irrigation, Tanks & Ponds and Water Conservation Structures are possible.

3.2.5.5.1 Recharge due to Canal: Recharge due to canals is estimated based on the following formula:

$$R_C = WA * SF * \text{Days}$$

Where:

R_C = Recharge Due to Canals

WA = Wetted Area

SF = Seepage Factor

Days = Number of Canal Running Days.

3.2.5.5.2 Recharge due to Applied Surface Water Irrigation: Recharge due to applied surface water irrigation is estimated based on the following formula:

$$R_{SWI} = AD * Days * RFF$$

Where:

R_{SWI} = Recharge due to applied surface water irrigation

AD= Average Discharge

Days=Number of days water is discharged to the Fields

RFF= Return Flow Factor

3.2.5.5.3 Recharge due to Applied Ground Water Irrigation: Recharge due to applied ground water irrigation is estimated based on the following formula:

$$R_{GWI} = GD_I * RFF$$

Where:

R_{GWI} = Recharge due to applied ground water irrigation

GD_I = Gross Ground Water Draft For Irrigation

RFF= Return Flow Factor

3.2.5.5.4 Recharge due to Tanks & Ponds: Recharge due to Tanks & Ponds is estimated based on the following formula:

$$R_{TP} = AWSA * R * RF$$

Where:

R_{TP} = Recharge due to Tanks & Ponds

AWSA= Average Water Spread Area

N=Number of days Water is available in the Tank/Pond

RF= Recharge Factor

3.2.5.5.5 Recharge due to Water Conservation Structures: Recharge due to Water Conservation Structures is estimated based on the following formula:

$$R_{WCS} = GS * RF$$

Where:

R_{WCS} = Recharge due to Water Conservation Structures

GS= Gross Storage= Storage Capacity X No. of Fillings.

RF= Recharge Factor

3.2.5.6 Recharge during Monsoon Season

The sum of Normalized Monsoon Rainfall Recharge and the recharge due to other sources during monsoon season is the total recharge during Monsoon season.

3.2.5.7 Recharge during Non-Monsoon Season

The rainfall recharge during non monsoon season is estimated using Rainfall Infiltration factor Method only when the non monsoon season rainfall is more than 10% of normal annual rainfall. The sum of Non-Monsoon Rainfall Recharge and the recharge due to other sources during non monsoon season is the total recharge during Non-Monsoon season.

3.2.5.8 Total Annual Ground Water Recharge

The sum of the recharge during monsoon season and Non monsoon season is the Total Annual Ground Water Recharge.

3.2.6 Unaccounted Natural Discharges

The Unaccounted Natural Discharges are estimated based on the method with which rainfall recharge is estimated during monsoon season. If the rainfall recharge is computed using water table fluctuation method, 5% of the Total Annual Ground Water Recharge is taken as unaccounted Natural discharges else it is 10% of the Total Annual Ground Water Recharge.

3.2.7 Net Annual Ground Water Availability

The difference between total annual ground water recharge and the unaccounted natural discharges is the net annual ground water availability.

3.2.8 Stage of Ground Water Development

Stage of Ground Water Development is to be computed using the following formula.

$$\text{Stage of Ground Water Development} = \frac{\text{Existing gross ground water draft for all uses}}{\text{Net annual ground water availability}} \times 100$$

3.2.9 Ground Water Level Trends

GEC 1997 Methodology links the categorization to Dual criteria: one is the Stage of Ground Water Development and the other is Ground water level trends. For each assessment sub unit the long term ground water level trends are to be determined for categorizing the assessment sub unit.

3.2.10 Categorization

Based on the dual criteria shown in the Table below the assessment sub unit is categorized. The original categorization provided by GEC 1997 is not complete hence GEC 2004 has modified the categorization and provided the following Table 2.

Table 2. CATEGORIZATION OF ASSESSMENT SUB UNITS AS PER GEC-2004.

Stage	Declining Pre-Monsoon Trend	Declining Post-Monsoon Trend	Category
<=70%	No	No	Safe
<=70%	No	Yes	To Be Reassessed
<=70%	Yes	No	To Be Reassessed
<=70%	Yes	Yes	To Be Reassessed
>70% and <=90%	No	No	Safe
>70% and <=90%	No	Yes	Semi-Critical
>70% and <=90%	Yes	No	Semi-Critical
>70% and <=90%	Yes	Yes	To Be Reassessed
>90% and <=100%	No	No	To Be Reassessed
>90% and <=100%	No	Yes	Semi-Critical
>90% and <=100%	Yes	No	Semi-Critical
>90% and <=100%	Yes	Yes	Critical
>100%	No	No	To Be Reassessed
>100%	No	Yes	Over-Exploited
>100%	Yes	No	Over-Exploited
>100%	Yes	Yes	Over-Exploited

3.2.11 Allocation for Future Domestic and Industrial Needs

Allocation is estimated based on the following formula for the future domestic and Industrial needs.

$$A = 22 * N * L_g$$

Where

A = Allocation for domestic and Industrial water Requirement in mm/year.

N = Projected Population density of the sub unit in thousands per square kilometer.

L_g = Fractional Load on ground water for domestic and industrial water supply (≤ 1.0)

3.2.12 Net Annual Ground Water Availability for Future Irrigation Use

The net Annual Ground Water availability for future irrigation use is computed by subtracting current Gross Ground Water draft for Irrigation and Future Allocation for Domestic and Industrial Needs from the Net Ground Water Availability.

3.2.13 Potential Resource Due to Shallow Water Table Areas

Potential Resource Due to Shallow Water Table areas is a onetime resource which is available in the aquifers above 5.0m bgl. This can be computed using the following formula.

$$PRWL = (5-DTW) * A * S_Y$$

Where

PRWL = Potential Resource in Water Logged and Shallow Water Table Areas

DTW = Average Depth to Water Level

A = Area of the Water logged Zone

S_Y = Specific Yield in the zone upto 5.0m bgl.

3.2.14 Potential Resource in the Flood Prone Area

Potential Resource in the Flood Prone Area is a onetime resource which is available in the Flood Prone Areas only. This can be computed using the following formula.

$$PRFL = 1.4 * N * A/1000$$

Where

PRFL = Potential Recharge in Flood Prone Areas

N = No of Days Water is Retained in the Area

A = Flood Prone Area

3.2.15 Static Ground Water Resources

Static Ground Water Resources of an area are the resources which remain available below the dynamic zone of water table fluctuation. This is not replenished every year and extracting this water is ground water mining. This can be computed using the following formula.

$$SGWR = A * (Z_2 - Z_1) * S_Y$$

Where

SGWR = Static Ground Water Resources

A = Area of the Assessment Unit

Z₂ = Bottom of Unconfined Aquifer

Z₁ = Maximum extension of Zone of Water Table Fluctuation

S_Y = Specific Yield in the Zone of static ground water resources

3.2.16 Apportioning

Wherever the resources are computed hydrological unit wise. This should be apportioned to development units i.e. block, so that management plans can easily be developed. Hence GEC 1997 recommends to apportion all these resources to development units.

3.2.17 Confined Aquifer

There are two types of situations of occurrence of confined aquifers. In hard rock areas, the upper water table aquifer in the weathered zone is connected to the deeper fracture zone, which is semi-confined. In such situations, the assessment procedure already given for unconfined aquifer accounts for the full recharge, and hence no separate assessment is to be made for the confined aquifer.

In specific alluvial areas, resource from a deep confined aquifer may be important. If the confined aquifer is hydraulically connected to the overlying shallow water table aquifer, it is a semi-confined aquifer, and not strictly a confined aquifer. If there is no hydraulic connection to the overlying water table aquifer, the resource may have to be estimated by specific detailed investigations, taking care to avoid duplication of resource assessment from the upper unconfined aquifers.

3.3 NORMS RECOMMENDED BY GEC 1997

3.3.1 Norms for specific yield

The norms for Specific yield as recommended by GEC 1997 are given in Table 3.

Table 3. NORMS FOR SPECIFIC YIELDS RECOMMENDED BY GEC 1997

S.No	Formation	Recommended Value (%)	Minimum Value (%)	Maximum Value (%)
(a)	Alluvial areas			
	Sandy alluvium	16.0	12.0	20.0
	Silty alluvium	10.0	8.0	12.0
	Clayey alluvium	6.0	4.0	8.0
(b)	Hard rock areas			
	Weathered granite, gneiss and schist with low clay content	3.0	2.0	4.0
	Weathered granite, gneiss and schist with significant clay content	1.5	1.0	2.0
	Weathered or vesicular, jointed basalt	2.0	1.0	3.0
	Laterite	2.5	2.0	3.0
	Sandstone	3.0	1.0	5.0
	Quartzite	1.5	1.0	2.0
	Limestone	2.0	1.0	3.0
	Karstified limestone	8.0	5.0	15.0
	Phyllites, Shales	1.5	1.0	2.0
	Massive poorly fractured rock	0.3	0.2	0.5

Note : Usually the recommended values should be used for assessment, unless sufficient data based on field study is available to justify the minimum, maximum or other intermediate values.

3.3.2 Norms for Rainfall Infiltration Factor

The norms for Rainfall Infiltration factor as recommended by GEC 1997 are given below in Table 4.

Table 4. NORMS FOR RAINFALL INFILTRATION FACTOR AS RECOMMENDED BY GEC 1997

S.No	Formation	Recommended Value (%)	Minimum Value (%)	Maximum Value (%)
(a)	Alluvial areas			
	Indo-Gangetic and inland areas	22	20	25
	East coast	16	14	18
	West coast	10	8	12
(b)	Hard rock areas			
	Weathered granite, gneiss and schist with low clay content	11	10	12
	Weathered granite, gneiss and schist with significant clay content	8	5	9
	Granulite facies like charnockite etc.	5	4	6
	Vesicular and jointed basalt	13	12	14
	Weathered basalt	7	6	8
	Laterite	7	6	8
	Semi-consolidated sandstone	12	10	14
	Consolidated sandstone, quartzite, limestone (except cavernous limestone)	6	5	7
	Phyllites, shales	4	3	5
	Massive poorly fractured rock	1	1	3

Note:1. Usually, the recommended values should be used for assessment, unless sufficient information is available to justify the use of minimum, maximum or other intermediate values.

- An additional 2% of rainfall recharge factor may be used in such areas or part of the areas where watershed development with associated soil conservation measures are implemented. This additional factor is subjective and is separate from the contribution due to the water conservation structures such as check dams, nalla bunds, percolation tanks etc. The norms for the estimation of recharge due to these structures are provided separately. This additional factor of 2% is, at this stage, only provisional, and will need revision based on pilot studies.

3.3.3 Norms for Recharge due to seepage from canals

The norms for Recharge due to seepage from canals as recommended by GEC 1997 are given below in Table 5.

Table 5. NORMS FOR RECHARGE DUE TO SEEPAGE FROM CANALS AS RECOMMENDED BY GEC 1997

(a) Unlined canals in normal soils with some clay content along with sand	1.8 to 2.5 cumecs per million sq m of wetted area (or) 15 to 20 ham/day/million sq m of wetted area
(b) Unlined canals in sandy soil with some silt content	3.0 to 3.5 cumecs per million sq m of wetted area (or) 25 to 30 ham/day/million sq m of wetted area
(c) Lined canals and canals in hard rock area	20% of above values for unlined canals

Notes:

1. The above values are valid if the water table is relatively deep. In shallow water table and waterlogged areas, the recharge from canal seepage may be suitably reduced.
2. Where specific results are available from case studies in some states, the adhoc norms are to be replaced by norms evolved from these results.

3.3.4 Norms for Return flow from irrigation

The recharge due to return flow from irrigation may be estimated, based on the source of irrigation (ground water or surface water), the type of crop (paddy, non-paddy) and the depth of water table below ground level. The norms for Return flow from irrigation as recommended by GEC 1997 are given below in Table 6.

Table 6. NORMS FOR RETURN FLOW FROM IRRIGATION AS RECOMMENDED BY GEC 1997

Source of irrigation	Type of crop	Water table below ground level		
		<10m	10-25 m	>25m
Ground water	Non-paddy	25	15	5
Surface water	Non-paddy	30	20	10
Ground water	Paddy	45	35	20
Surface water	Paddy	50	40	25

Notes:

1. For surface water, the recharge is to be estimated based on water released at the outlet. For ground water, the recharge is to be estimated based on gross draft.
2. Where continuous supply is used instead of rotational supply, an additional recharge of 5% of application may be used.
3. Where specific results are available from case studies in some states, the adhoc norms are to be replaced by norms evolved from these results.

3.3.5 Recharge from Storage Tanks and Ponds

1.4 mm/day for the period in which the tank has water, based on the average area of water spread. If data on the average area of water spread is not available, 60% of the maximum water spread area may be used instead of average area of the water spread.

3.3.6 Recharge from Percolation Tanks

50% of gross storage, considering the number of fillings, with half of this recharge occurring in the monsoon season, and the balance in the non-monsoon season.

3.3.7 Recharge due to Check Dams and Nala Bunds

50% of gross storage (assuming annual de-silting maintenance exists) with half of this recharge occurring in the monsoon season, and the balance in the non-monsoon season.

* * *

4

REVIEW OF GROUND WATER ESTIMATION METHODOLOGY (1997) AND RECENT CASE STUDIES

4.1 INTRODUCTION

Ground water estimation methodology, 1997 is based on water balance theory. Various input and output components of ground water balance are computed to estimate the Ground Water Recharge. The Ground Water Draft is estimated and assessment unit is also categorised based on the percentage of ground water draft with respect to ground water recharge. The methodology is robust and is reflective of field conditions. However, with time, the ground water scenario of the country has changed significantly. The extraction of ground water resources has increased manifold. As a consequence, the storage of ground water resources have depleted in over-exploited areas. National Water Policy, 2012 suggests that assessment of ground water resource should take into consideration the base flow as well as other elements of water cycle. Assessment of the ground water resources should also include information on quality of ground water along with its quantity which should be based on the knowledge of aquifer disposition and characteristics in different hydrogeological settings of the country.

Improvement in the existing methodology requires a relook on the concepts and details of the methodology applied as well as evaluation and incorporation of the findings of the case studies of ground water assessment carried out in recent years in different parts of the country. While going through such a review process, one may also keep in view the status of current data available for ground water resource evaluation. The methodology as recommended by the GEC - 1997 is reviewed here both on its merits and limitations. The chapter also provides a review of recent case studies on ground water assessment in various parts of the country and the type of data that is available, both from routine observations and from special studies.

4.2 MERITS OF EXISTING METHODOLOGY

The existing methodology outlined in Chapter 3 has many basic merits. This methodology is conceptually best suited to the situation of the day taking into account the limitations of the data available with the State and Central Government Organizations. Even though conceptual thoroughness was categorically mentioned in the methodology, some components were ignored depending on the complexities of the estimation procedure. This has many improvements over earlier methodology like deciding on the hydrogeological assessment unit for hard rock areas, dividing the unit into sub units and assessing the resources for monsoon and non monsoon seasons etc.

4.2.1 Unit for Ground Water Resource Assessment

Even though an administrative unit is convenient for assessing the resources from development angle, GEC 1997 recommends watershed as an assessment unit in hard rock areas. In contrast to hard rock areas where surface and subsurface water divides coincide, in alluvial areas, there may be ground water flow across watershed boundaries also. Hence, it is recommended to continue with the administrative unit (block/Taluka/ Mandal) as an assessment unit in alluvial areas..

4.2.2 Delineation of Areas within an Assessment Unit

The estimation of ground water recharge as per GEC-1997 has basically two components: (a) recharge from rainfall (b) recharge from other sources. Among these, the recharge from rainfall is the only component which is available in a distributed way over the entire block or taluka. Recharge from other sources viz. recharge from canals and recharge due to applied surface water irrigation are mainly relevant only to canal command areas. Hence GEC1997 methodology recommends separate assessment for command areas and non command areas. To some extent assessment based on quality of ground water is also considered in this methodology by way of separating quality affected area as Poor Ground Water Quality area.

4.2.3 Season-wise Assessment of Ground Water Resources

The water availability in any area is not uniform. It depends on time.GEC 1997 recommends the assessment of ground water resources in two annual seasons viz. monsoon season and non monsoon season.

4.2.4 Ground Water Resource Estimation in Confined Aquifer

GEC -1997 has made a brief mention regarding ground water resource estimation in confined aquifers based on Darcy's law where it is proven that the resources are not

duplicated in semi-confined aquifers where part of the recharge is contributed from the unconfined aquifer as leakage.

4.2.5 Estimation of Specific Yield

The ground water level fluctuation method requires the use of specific yield value as a key input for assessment of ground water recharge. The specific yield determined by the pumping test is for the aquifer material which occurs within the cone of depression created during the pumping test. It may introduce an error in computation unless and until there are sufficient number of pumping tests conducted in the assessment sub unit. Secondly, pumping tests are more useful for estimating transmissivity value than specific yield value. Small duration pumping tests on dug wells are not suitable for the estimation of specific yield. Thirdly, an estimation of parameters (including specific yield) from long duration pumping tests in hard rock areas, requires the use of fairly sophisticated modelling techniques. Simplified estimates based on Theis curve (or some other simple models) may result in wrong assessment of specific yield. Hence, GEC 1997 recommends using dry season ground water balance method for estimating specific yield which represents entire area of the assessment sub unit.

4.2.6 Ground Water Draft Estimation

Ground water draft refers to the quantity of ground water that is being withdrawn from the aquifer. Ground water draft is a key input in ground water resource estimation. Hence, accurate estimation of ground water draft is highly essential to calculate the actual ground water balance available. The following three methods are normally used in the country for ground water draft estimation.

- (a) Based on well census data: In this method, the ground water draft is estimated by multiplying the number of wells of different types available in the area with the unit draft fixed for each type of abstraction structure in that area. This method is being widely practiced in the country.
- (b) Based on electrical power consumption: In this method, the ground water draft estimation is done by multiplying the number of units of power consumed for agricultural pump sets with that of the quantity of water pumped for unit power.
- (c) Based on the ground water irrigated area statistics: In this method, the ground water draft is estimated by multiplying the acreage of different irrigated crops (cultivated using ground water) with that of the crop water requirement for each crop.

4.2.7 Return flow from ground water Irrigation

Unlike the earlier methodology, GEC-1997 recommends to separately estimate return flow from ground water irrigation. In the earlier methodology, it was suggested to use a resulting term of gross draft and return flow from ground water irrigation as net ground water draft.

4.2.8 Separating Potential Resources from Normal Assessment

In the earlier methodologies, the computation of potential resource because of shallow water table and flood prone areas were linked to the normal ground water resources and even categorization of the area. This methodology explained that the availability of potential resources is not regular. The potential resource in shallow water table areas is only one time resource and even the potential resource in the flood prone areas is also not regular and is not available every year. Hence, GEC 1997 recommended separating the estimation of the potential resource from the regular assessment and emphasized that it should not be used in the categorization.

4.2.9 Detailed Guidelines for the Estimation

The GEC 1997 methodology provides detailed guidelines; even though it is not part of the final recommendations. The methodology provides the procedures to be followed. The computational complexities were explained in detail and the recommended formats were also provided in the report. This makes the implementation of the methodology easy without any difficulty in the country.

4.2.10 Constitution of R&D Advisory Committee

Based on the recommendations of the GEC 1997 and supported by GEC 2004, an R&D Advisory committee was constituted with the ultimate powers in modifying the methodology without waiting for the constitution of another estimation committee. This is a permanent body, which will solve the day to day problems in the assessment by studying the merits of the proposal without affecting the overall purpose of the estimation.

4.3 LIMITATIONS OF EXISTING METHODOLOGY

Even though this methodology was built on a robust concept, strong theoretical base and with the support of detailed guidelines, there are certain issues which need to be modified with the advent of fast computing systems and availability of data. The limitations of the existing methodology are summarised as follows.

4.3.1 Quality Based Assessment

GEC 1997 methodology recommends assessing the resources for poor ground water quality sub units separately. But it doesn't provide any clarity as to what is meant by poor ground water quality. It is left for the states to decide on this. Presently this assessment is carried out only for areas where electrical conductivity is more than $3000\mu\text{S}/\text{cm}$ at 25°C . Though, the poor ground water quality area can be an area where Fluoride and Arsenic are also not within the permissible limits. Present methodology recommends not to categorize these areas as there is no extraction for these waters. But as on now, there are users even for brines and hence the categorization of these sub units is also important.

4.3.2 No Importance to the Aquifer wise Assessment

GEC 1997 methodology mentions about the resources of confined aquifers. However, it has not stressed upon the aquifer wise resource estimation. Central Ground Water Board has taken up country wide programme for aquifer mapping which will provide hydrogeological information on major aquifer systems of the country. Assessing ground water resources aquifer wise may become a reality in near future.

4.3.3 Spring Discharges are Ignored

GEC 1997 Methodology recommends to remove hilly area from the assessed areas where the runoff will be more than the infiltration. In most of the hilly areas there occurs isolated aquifers which occasionally manifest in the form of springs. These springs can sustain the water needs of the inhabitants for the time being or forever. There is no provision in the existing methodology to account for this resource.

4.3.4 Base Flows are not Estimated

GEC 1997 Methodology recommends to ignore the base flow component as it is difficult to assess. Even though one can use the data if available, however, the same has not been used in the present studies undertaken for resource assessment. Though GEC 1997 methodology recommends having at least one stream gauge station at the mouth of the watershed, it has never been practiced.

4.3.5 Directly Linking Trends to Categorization

GEC 1997 Methodology recommends to categorize the assessment sub unit on dual criteria viz. Stage of ground water development and Ground water level trends. There are serious objections on this.

- If there is no observation well in the sub unit, at least for another 10 years, one cannot assess the resources and categorize.

- If the percent deviation of rainfall recharge computed using water level fluctuation method and rainfall infiltration factor method is more than 20% or less than -20%, finally one has to depend on the estimate made using rainfall infiltration factor method. However the trend of the same wells is used for categorization.
- In case of command areas where rejected recharge is more and hence the percent deviation is within the required range, the trends of these wells are also not truly reflecting the situation.

4.3.6 No Direct Reflection of Ground Water Mining

The ground water resources of the country have been assessed three times using this methodology during the years 2003-2004, 2008-2009 and 2010-2011 and 2012-2013. The ground water resources of the country are always estimated around 430bcm. Common man cannot understand why the resources are constant even though there is over exploitation in certain parts of the country. The reason being normalised rainfall data is used for resource estimation which does not change annually. The normal rainfall data gets affected in a span of 20-30 years, even though the annual rainfall figures are different. The effect of annual rainfall is not reflected in resources computed on normalised rainfall data. Even though the water levels are declining day by day in over exploited areas, it is difficult to explain the effects of ground water mining in these areas because of the lacuna in this methodology. Unless and until the availability of total ground water resources i.e. dynamic and in storage/ static resources of confined and unconfined aquifers in an area is estimated, this cannot be answered.

4.3.7 No Database Structure

Even though the guidelines have provided very good procedural details, it has not mentioned about the type of data and its precision and how it is to be stored in computer compatible format.

4.3.8 Detailed Methodology for Estimating the Resources in Confined Aquifer

Even though GEC 1997 methodology indicates that the resources of the confined aquifer are to be assessed using flow concept, it has not provided any compulsions or detailed procedures to compute the resources in the confined aquifer.

4.4 IMPROVEMENTS IN THE EXISTING METHODOLOGY

After due consideration of the limitations discussed above, several improvements are proposed in the existing methodology. These are as follows.

- The frequency of assessment is proposed to be increased from once in every five years as proposed in GEC 1997 to once in every three years.
- Estimation of base flow in the ground water balance equation wherever possible.
- Estimation of lateral flow or through flow wherever possible.
- Estimation of Aquifer-wise Exploitable GW Resources and In-storage Resources wherever Aquifer Geometry have been established. Till such time general guidelines are provided for assessing the resources up to a certain predetermined depth.
- Recommends to compute Potential Resource due to springs in hilly areas wherever possible.
- Ground Water Level Trends are proposed to be used as Validation of the exercise instead of one of the criterion for categorization.
- Categorisation of Assessment units is based on ground water quantity and there will be ground water quality tag wherever the ground water is of poor quality i.e. effected by salinity, arsenic or fluoride.
- Proposed to assess Total Ground Water Availability which can reflect Ground Water Mining
- Database Structure is proposed which is to be followed.
- Detailed Methodology for Estimating the Resources in Confined Aquifers is also provided.
- Refinement of Norms of parameters used in computation of ground water resources. It is proposed to have some field studies before conducting periodical assessment. The data of the field studies should be maintained with proper documentation for future reference.

4.5 REVISION OF NORMS FOR GROUND WATER ASSESSMENT

As stated earlier, there is a need to apply the recommended norms for recharge assessment in situations where adequate field data is not available. However, these norms need to be revised periodically on basis of the results and observations of ground water assessment studies carried out in various parts of the country by a number of central and state government agencies, research institutions, universities, non-government organisations etc. These studies are varied in nature; consultation and analysis of these require considerable time. In the limited time available for the committee, only some of these studies could be consulted.

While it is reasonable to adopt a specific standardised methodology of ground water assessment, it is necessary to update the norms on regular basis, considering the results of case studies. For this, it is recommended that the R& D Advisory committee may be revived and strengthened with additional members and supporting staff. This committee may be

authorised to revise the norms periodically and circulate it to the different states. The present committee has made a limited review of case studies of ground water assessment in the last 10 to 15 years, in order to revise the norms for ground water assessment.

4.5.1 Case Studies of Ground Water Assessment

The studies carried out on ground water assessment in recent years can be broadly categorised as follows:

- (a) Ground water assessment by State Ground Water Agencies and Central Ground Water Board, based on the recommendations of the GEC - 1997.
- (b) Pilot Aquifer Mapping by Central Ground Water Board
- (c) Ground water assessment through modelling as part of the pilot studies referred above or otherwise.
- (d) Special Studies carried out by Central Ground Water Board and State Ground Water Departments.

The committee recommends that all the agencies involved in Ground Water Resource Estimation should be encouraged to conduct field studies and use the norms thus computed in the assessment. Even though every user agency follows the methodology suggested, there is a possibility of error cropping in at various levels in the field study and hence the committee is of the opinion that maximum and minimum values for all the norms be suggested which can be used in the estimation. If the agency has not computed the norms through their own field studies, the norms suggested and values given in chapter 5 may be used for the assessment of resources.

* * *

5

PROPOSED METHODOLOGY

5.1 APPROACH OF GEC-2015

The revised methodology GEC 2015 recommends aquifer wise ground water resource assessment. Ground water resources have two components – Replenishable ground water resources or Dynamic ground water resources and In-storage resources or Static resources. GEC 2015 recommends estimation of Replenishable and in-storage ground water resources for both unconfined and confined aquifers. Wherever the aquifer geometry has not been firmly established for the unconfined aquifer, the in-storage ground water resources have to be assessed in the alluvial areas up to the depth of bed rock or 300m whichever is less. In case of hard rock aquifers, the depth of assessment would be limited to 100m. In case of confined aquifers, if it is known that ground water extraction is being taken place from this aquifer, the dynamic as well as in-storage resources are to be estimated. If it is firmly established that there is no ground water extraction from this confined aquifer, then only in-storage resources of that aquifer has to be estimated

5.2 PERIODICITY OF ASSESSMENT

Keeping in view of the rapid change in ground water extraction, the committee recommends more frequent estimation of ground water resources. The committee observes that the comprehensive assessment of ground water resources is a time intensive exercise. Hence as a trade-off, it recommends that the resources should be assessed once in every three years. As per the present practice, there is a considerable time lag between assessment and publication of the results. Hence the committee recommends to make all out efforts to reduce the time lag and the results may be reported within the successive water year.

5.3 GROUND WATER ASSESSMENT UNIT

This methodology recommends aquifer wise ground water resource assessment. An essential requirement for this is to demarcate lateral as well as vertical extent and disposition of different aquifers. A watershed with well-defined hydrological boundaries is an appropriate unit for ground water resource estimation if the principal aquifer is other than

alluvium. Ground water resources worked out on watershed as a unit, may be apportioned and presented on administrative units (block/taluka/mandal/ firka). This would facilitate local administration in planning of ground water management programmes. Areas occupied by unconsolidated sediments (alluvial deposits, aeolian deposits, coastal deposits etc.) usually have flat topography and demarcation of watershed boundaries may be difficult in such areas. Even if the demarcation is done, this may lead to trans boundary movement of ground water because of excessive pumping in one of the watersheds. Until Aquifer Geometry is established on appropriate scale, the existing practice of using watershed in hard rock areas and blocks/mandals/ firkas in soft rock areas may be continued.

5.4 GROUND WATER ASSESSMENT SUB-UNITS

It is recommended that ground water recharge may be estimated for the entire assessment unit. Out of the total geographical area of the unit, hilly areas wherever slope is greater than 20%, are to be identified and subtracted as these areas have more runoff than infiltration. The hilly areas wherever slope is more than 20% may be demarcated using DEM data and geomorphological maps. This would allow the valleys, terraces, plateaus occurring within >20% slope zone to be considered for recharge computations. It is quite likely that with hilly areas, densely forested area may also be excluded; this may affect to some extent ground water losses caused due to transpiration by deep rooted trees in the area of assessment. Apart from this it is also important that the areas where the quality of ground water is beyond the usable limits (for drinking water in particular) in terms of salinity is to be identified and handled separately. This methodology recommends that after the assessment is done, a quality flag may be added to the assessment unit for parameters salinity, fluoride and arsenic.

In inhabited hilly areas, where surface and sub-surface runoff is high and generally water level data is missing, it is difficult to compute the various components of water balance equation. Hence, it is recommended that wherever spring discharge data is available, the same may be assessed as a proxy for 'ground water resources' in hilly areas. The assessment of spring discharge would constitute the 'replenishable potential ground water resource' but it will not be accounted for in the categorisation of ground water assessment, at least not in the near future.

The ground water resource beyond the permissible quality limits in terms of the salinity has to be computed separately. The remaining area after excluding the area with poor ground water quality is to be delineated as follows:

- (a) Non-command areas which do not come under major/medium surface water irrigation schemes. (command area <100 Ha in the assessment unit should be ignored)
- (b) Command areas which come under major/medium surface water irrigation schemes which are actually supplying water (>100 Ha of command area in the assessment unit.)

It is proposed to have all these areas of an assessment unit in integer hectares to make it national database with uniform precision.

5.5 GROUND WATER RESOURCES OF AN ASSESSMENT UNIT

The ground water resources of any assessment unit is the sum of the total ground water availability in the principal aquifer (mostly unconfined aquifer) and the total ground water availability of semi-confined and confined aquifers existing in that assessment unit. The total ground water availability of any aquifer is the sum of dynamic ground water resources and the in-storage or static resources of the aquifer.

5.6 GROUND WATER ASSESSMENT OF UNCONFINED AQUIFER

As mentioned earlier, assessment of ground water includes assessment of dynamic and in-storage ground water resources. The development planning should mainly depend on dynamic resource only as it gets replenished every year. Changes in static or in-storage resources reflect impacts of ground water mining. Such resources may not be replenishable annually and may be allowed to be extracted only during exigencies with proper recharge planning in the succeeding excess rainfall years.

5.6.1 Assessment of Annually Replenishable or Dynamic Ground Water Resources

The methodology for ground water resources estimation is based on the principle of water balance as given below –

$$\text{Inflow} - \text{Outflow} = \text{Change in Storage (of an aquifer)} \quad 1$$

Equation 1 can be further elaborated as -

$$\Delta S = R_{RF} + R_{STR} + R_C + R_{SWI} + R_{GWI} + R_{TP} + R_{WCS} \pm VF \pm LF - GE - T - E - B \quad 2$$

Where,

ΔS – Change in storage

R_{RF} – Rainfall recharge

R_{STR} – Recharge from stream channels

R_C – Recharge from canals

R_{SWI} – Recharge from surface water irrigation

R_{GWI} - Recharge from ground water irrigation

R_{TP} - Recharge from Tanks& Ponds

R_{WCS} – Recharge from water conservation structures

VF – Vertical inter aquifer flow

LF- Lateral flow along the aquifer system (throughflow)

GE-Ground Water Extraction

T- Transpiration

E- Evaporation

B-Base flow

It is preferred that all the components of water balance equation should be estimated in an assessment unit. The present status of database available with government and non-government agencies is not adequate to carry out detailed ground water budgeting in most of the assessment units. Therefore, it is proposed that at present the water budget may be restricted to the major components only taking into consideration certain reasonable assumptions. The estimation is to be carried out using lumped parameter estimation approach keeping in mind that data from many more sources if available may be used for refining the assessment.

5.6.1.1 Rainfall Recharge

It is recommended that ground water recharge should be estimated on ground water level fluctuation and specific yield approach since this method takes into account the response of ground water levels to ground water input and output components. This, however, requires adequately spaced representative water level measurement for a sufficiently long period. It is proposed that there should be at least three spatially well distributed observation wells in the assessment unit, or one observation well per 100 sq. Km. Water level data should also be available for a minimum period of 5 years (preferably 10years), along with corresponding rainfall data. Regarding frequency of water level data, two water level readings, during pre and post monsoon seasons, are the minimum requirement. It would be ideal to have monthly water level measurements to record the peak rise and maximum fall in the ground water levels. In units or subareas where adequate data on ground water level fluctuations are not available as specified above, ground water recharge may be estimated using rainfall infiltration factor method only. The rainfall recharge during non-monsoon season may be estimated using rainfall infiltration factor method only.

5.6.1.1.1 Ground water level fluctuation method

The ground water level fluctuation method is to be used for assessment of rainfall recharge in the monsoon season. The ground water balance equation in non-command areas is given by

$$\Delta S = R_{RF} + R_{STR} + R_{SWI} + R_{GWI} + R_{TP} + R_{WCS} \pm VF \pm LF - GE - T - E - B \quad 3$$

Where,

ΔS – Change in storage

R_{RF} – Rainfall recharge

R_{STR} – Recharge from stream channels

R_{SWI} – Recharge from surface water irrigation (Lift Irrigation)

R_{GWI} – Recharge from ground water irrigation

R_{TP} – Recharge from tanks & ponds

R_{WCS} – Recharge from water conservation structures

VF – Vertical inter aquifer flow

LF – Lateral flow along the aquifer system (throughflow)

GE – Ground water Extraction

T – Transpiration

E – Evaporation

B – Base flow

Whereas the water balance equation in command area will have another term i.e., Recharge due to canals (R_C) and the equation will be as follows:

$$\Delta S = R_{RF} + R_{STR} + R_C + R_{SWI} + R_{GWI} + R_{TP} + R_{WCS} \pm VF \pm LF - GE - T - E - B \quad 4$$

A couple of important observations in the context of water level measurement must be followed. It is important to bear in mind that while estimating the quantum of ground water extraction, the depth from which ground water is being extracted should be considered. One should consider only the draft from the same aquifer for which the resource is being estimated.

The change in storage can be estimated using the following equation:

$$\Delta S = \Delta h * A * S_y \quad 5$$

Where

ΔS – Change in storage

Δh – rise in water level in the monsoon season

A – area for computation of recharge

S_y – Specific Yield

Substituting the expression in equation 5 for increase in storage i.e. ΔS in terms of water level fluctuation and specific yield, the equations 3 & 4 becomes,

$$R_{RF} = h \times S_y \times A - R_{STR} - R_{SWI} - R_{GWI} - R_{TP} - R_{WCS} \pm VF \pm LF + GE + T + E + B \quad 6$$

$$R_{RF} = h \times S_y \times A - R_{STR} - R_C - R_{SWI} - R_{GWI} - R_{TP} - R_{WCS} \pm VF \pm LF + GE + T + E + B \quad 7$$

The recharge calculated from equation 6 in case of non-command sub units and equation 7 in case of command sub units and poor ground water quality sub units gives the rainfall recharge for the particular monsoon season. However, it may be noted that in case base flow/ recharge from stream and through flow have not been estimated, the same may be assumed to be zero.

The rainfall recharge obtained by using equation 6 & equation 7 provides the recharge in any particular monsoon season for the associated monsoon season rainfall. This estimate is to be normalised for the normal monsoon season rainfall as per the procedure indicated below.

Normalization of Rainfall Recharge

Let R_i be the rainfall recharge and r_i be the associated rainfall. The subscript i takes values 1 to N where N is the number of years for which data is available. This should be at least 5. The rainfall recharge, R_i is obtained as per equation 6 & equation 7 depending on the sub unit for which the normalization is being done.

$$R_i = h_i \times S_y \times A - R_{STR} - R_{SWI} - R_{GWI} - R_{TP} - R_{WCS} \pm VF \pm LF + GE + T + E + B \quad 8$$

$$R_i = h_i \times S_y \times A - R_{STR} - R_C - R_{SWI} - R_{GWI} - R_{TP} - R_{WCS} \pm VF \pm LF + GE + T + E + B \quad 9$$

where,

R_i = Rainfall recharge estimated in the monsoon season for the i^{th} particular year

h_i = Rise in ground water level in the monsoon season for the i^{th} particular year

S_y = Specific yield

A = Area for computation of recharge

R_{STR} = Recharge from stream channels in the monsoon season for i^{th} particular year

R_C = Recharge from canals in the monsoon season for i^{th} particular year

R_{SWI} = Recharge from surface water irrigation including lift irrigation in the monsoon season for the i^{th} particular year

R_{GWI} = Recharge from ground water irrigation in the monsoon season for the i^{th} particular year

R_{TP} = Recharge from tanks and ponds in the monsoon season for the i^{th} particular year

R_{WCS} = Recharge from water conservation structures in the monsoon season for the i^{th} particular year

LF = Recharge through Lateral flow/ Through flow across assessment unit boundary in the monsoon season for the i^{th} particular year

VF – Vertical inter aquifer flow in the monsoon season for the i^{th} particular year

T- Transpiration in the monsoon season for the i^{th} particular year

E- Evaporation in the monsoon season for the i^{th} particular year

GE = Ground water extraction in monsoon season for the i^{th} particular year

B = Base flow the monsoon season for the i^{th} particular year

After the pairs of data on R_i and r_i have been obtained as described above, a normalisation procedure is to be carried out for obtaining the rainfall recharge corresponding to the normal monsoon season rainfall. Let $r(\text{normal})$ be the normal monsoon season rainfall obtained as the average of recent 30 to 50 years of monsoon season rainfall. Two methods are possible for the normalisation procedure.

The first method is based on a linear relationship between recharge and rainfall of the form

$$\mathbf{R} = \mathbf{a} \mathbf{r} \quad \mathbf{10}$$

where,

R = Rainfall recharge during monsoon season

r = Monsoon season rainfall

a = a constant

The computational procedure to be followed in the first method is as given below:

$$R_{rf}(\text{normal}) = \frac{\sum_{i=1}^N R_i \times \frac{r(\text{normal})}{r_i}}{N} \quad \mathbf{11}$$

Where,

$R_{rf}(\text{normal})$ - Normalized Rainfall Recharge in the monsoon season.

R_i - Rainfall Recharge in the monsoon season for the i^{th} year.

$r(\text{normal})$ - Normal monsoon Season rainfall.

r_i - Rainfall in the monsoon season for the i^{th} year.

N - No. of years for which data is available.

The second method is also based on a linear relation between recharge and rainfall.

However, this linear relationship is of the form,

$$\mathbf{R} = \mathbf{ar+b} \quad 12$$

where,

R = Rainfall recharge during monsoon season

r = Monsoon season rainfall

a and b = constants.

The two constants 'a' and 'b' in the above equation are obtained through a linear regression analysis.

The computational procedure to be followed in the second method is as given below:

$$a = \frac{NS_4 - S_1S_2}{NS_3 - S_1^2} \quad 13$$

$$b = \frac{S_2 - aS_1}{N} \quad 14$$

Where

$$S_1 = \sum_{i=1}^N r_i \quad S_2 = \sum_{i=1}^N R_i \quad S_3 = \sum_{i=1}^N r_i^2 \quad S_4 = \sum_{i=1}^N r_i R_i$$

The rainfall recharge during monsoon season for normal monsoon rainfall condition is computed as below:

$$\mathbf{R_{rf} (normal) = a \times r(normal) + b} \quad 15$$

5.6.1.1.2 Rainfall Infiltration Factor method

The rainfall recharge estimation based on Water level fluctuation method reflects actual field conditions since it takes into account the response of ground water level. However the ground water extraction estimation included in the computation of rainfall recharge using water level fluctuation approach is often subject to uncertainties. Therefore, it is recommended to compare the rainfall recharge obtained from water level fluctuation approach with that estimated using rainfall infiltration factor method.

Recharge from rainfall is estimated by using the following relationship -

$$\mathbf{R_{rf} = RFIF * A * (R - a)/1000} \quad 16$$

Where,

R_{rf} = Rainfall recharge in ham

A = Area in Hectares

RFIF = Rainfall Infiltration Factor

R = Rainfall in mm

a = Minimum threshold value above which rainfall induces ground water recharge in mm

The relationship between rainfall and ground water recharge is a complex phenomenon depending on several factors like runoff coefficient, moisture balance, hydraulic conductivity and Storativity/Specific yield of the aquifer etc. In this report, certain assumptions have been adopted for computation of Rainfall recharge factor. These assumptions may be replaced with actual data in case such area specific studies are available. At the same time, it is important to bring in elements of rainfall distribution and variability into sharpening the estimates of precipitation. Average rainfall data from nearby rain gauge stations may be considered for the ground water assessment unit and the average rainfall may be estimated by the Thiessen polygon or isohyet method. Alternatively, other advanced methods may also be used.

The threshold limit of minimum and maximum rainfall event which can induce recharge to the aquifer is to be considered while estimating ground water recharge using rainfall infiltration factor method. The minimum threshold limit is in accordance with the relation shown in equation 16 and the maximum threshold limit is based on the premise that after a certain limit, the rate of storm rains is too high to contribute to infiltration and they will only contribute to surface runoff. It is suggested that 10% of Normal annual rainfall may be taken as minimum rainfall threshold and 3000 mm as maximum rainfall limit. While computing the rainfall recharge, 10% of the normal annual rainfall is to be deducted from the monsoon rainfall and balance rainfall would be considered for computation of rainfall recharge. The same recharge factor may be used for both monsoon and non-monsoon rainfall, with the condition that the recharge due to non-monsoon rainfall may be taken as zero, if the normal rainfall during the non-monsoon season is less than 10% of normal annual rainfall. In using the method based on the specified norms, recharge due to both monsoon and non-monsoon rainfall may be estimated for normal rainfall, based on recent 30 to 50 years of data.

5.6.1.1.3 Percent Deviation

After computing the rainfall recharge for normal monsoon season rainfall using the ground water level fluctuation method and rainfall infiltration factor method these two estimates have to be compared with each other. A term, Percent Deviation (PD) which is the difference between the two expressed as a percentage of the later is computed as

$$PD = \frac{R_{rf}(\text{normal, wtfm}) - R_{rf}(\text{normal, rfm})}{R_{rf}(\text{normal, rfm})} \times 100 \quad 17$$

where,

Rrf (normal, wlfm) = Rainfall recharge for normal monsoon season rainfall estimated by the ground water level fluctuation method

Rrf (normal, rifm) = Rainfall recharge for normal monsoon season rainfall estimated by the rainfall infiltration factor method

The rainfall recharge for normal monsoon season rainfall is finally adopted as per the criteria given below:

- If PD is greater than or equal to -20%, and less than or equal to +20%, Rrf (normal) is taken as the value estimated by the ground water level fluctuation method.
- If PD is less than -20%, Rrf (normal) is taken as equal to 0.8 times the value estimated by the rainfall infiltration factor method.
- If PD is greater than +20%, Rrf (normal) is taken as equal to 1.2 times the value estimated by the rainfall infiltration factor method.

5.6.1.2 Recharge from other Sources

Recharge from other sources constitutes recharges from canals, surface water irrigation, ground water irrigation, tanks & ponds and water conservation structures in command areas where as in non-command areas it constitutes the recharge due to surface water irrigation, ground water irrigation, tanks & ponds and water conservation structures are possible.

5.6.1.2.1 Recharge from Canals: Recharge due to canals is to be estimated based on the following formula:

$$R_C = WA * SF * Days \quad 18$$

Where:

R_C = Recharge from Canals

WA = Wetted Area = Wetted Perimeter X Length of Canal Reach.

SF = Seepage Factor

$Days$ = Number of Canal Running Days.

5.6.1.2.2 Recharge from Surface Water Irrigation: Recharge due to applied surface water irrigation, either by means of canal outlets or by lift irrigation schemes is to be estimated based on the following formula:

$$R_{SWI} = AD * Days * RFF \quad 19$$

Where:

R_{SWI} = Recharge due to applied surface water irrigation

AD = Average Discharge

$Days$ = Number of days water is discharged to the Fields

RFF= Return Flow Factor

5.6.1.2.3 Recharge from Ground Water Irrigation: Recharge due to applied ground water irrigation isto be estimated based on the following formula:

$$\mathbf{R_{GWI} = GE_{IRR} * RFF} \quad \mathbf{20}$$

Where:

R_{GWI} = Recharge due to applied ground water irrigation

GE_{IRR} = Ground Water Extraction for Irrigation

RFF= Return Flow Factor

5.6.1.2.4 Recharge due to Tanks & Ponds: Recharge due to Tanks &Ponds isto be estimated based on the following formula:

$$\mathbf{R_{TP} = AWSA * N * RF} \quad \mathbf{21}$$

Where:

R_{TP} = Recharge due to Tanks & Ponds

AWSA= Average Water Spread Area

N=Number of days Water is available in the Tank/Pond

RF= Recharge Factor

5.6.1.2.5 Recharge due to Water Conservation Structures: Recharge due to Water Conservation Structures isto be estimated based on the following formula:

$$\mathbf{R_{WCS} = GS * RF} \quad \mathbf{22}$$

Where:

R_{WCS} = Recharge due to Water Conservation Structures

GS= Gross Storage = Storage Capacity multiplied by number of fillings.

RF= Recharge Factor

5.6.1.3. Lateral flow along the aquifer system (Throughflow)

In equations 6 & 7, if the area under consideration is a watershed, the lateral flow across boundaries can be considered as zero in case such estimates are not available. If there is inflow and outflow across the boundary, theoretically, the net inflow may be calculated using Darcy law, by delineating the inflow and outflow sections of the boundary. Besides such delineation, the calculation also requires estimate of transmissivity and hydraulic gradient across the inflow and outflow sections. These calculations are most conveniently done in a computer model. It is recommended to initiate regional scale modelling with well-defined flow boundaries. Once the modelling is complete, the lateral throughflows (LF) across boundaries for any assessment unit can be obtained from the model. In case Lateral

Flow is calculated using computer model, the same should be included in the water balance equation.

5.6.1.4 Baseflow and Stream Recharge

If stream gauge stations are located in the assessment unit, the base flow and recharge from streams can be computed using Stream Hydrograph Separation method, Numerical Modelling and Analytical solutions. If the assessment unit is a watershed, a single stream monitoring station at the mouth of the watershed can provide the required data for the calculation of base flow. Any other information on local-level base flows such as those collected by research centres, educational institutes or NGOs may also be used to improve the estimates on base flows.

Base flow separation methods can be divided into two main types: non-tracer-based and tracer-based separation methods. Non-tracer methods include Stream hydrograph analysis, water balance method and numerical ground water modelling techniques. Digital filters are available for separating base flow component of the stream hydrograph.

Hydro-chemical tracers and environmental isotope methods also use hydrograph separation techniques based on mass balance approach. Stream recharge can be computed either using modelling techniques or simply by applying the Darcy Law.

Base flow assessment and Stream recharge should be carried out in consultation with Central Water Commission in order to avoid any duplicity in the estimation of total water availability in a river basin.

5.6.1.5 Vertical Inter Aquifer Flow

This can be estimated provided aquifer geometry and aquifer parameters are known. This can be calculated using the Darcy's law if the hydraulic heads in both aquifers and the hydraulic conductivity and thickness of the aquitard separating both the aquifers are known. Ground water flow modelling is an important tool to estimate such flows. As envisaged in this report regional scale modelling studies will help in refining vertical inter aquifer flow estimates.

5.6.1.6 Evaporation and Transpiration

Evaporation can be estimated for the aquifer in the assessment unit if water levels in the aquifer are within the capillary zone. It is recommended to compute the evaporation through field studies. If field studies are not possible, for areas with water levels within 1.0mbgl, evaporation can be estimated using the evaporation rates available for other adjoining areas. If depth to water level is more than 1.0mbgl, the evaporation losses from the aquifer should be taken as zero.

Transpiration through vegetation can be estimated if water levels in the aquifer are within the maximum root zone of the local vegetation. It is recommended to compute the transpiration through field studies. Even though it varies from place to place depending on type of soil & vegetation, in the absence of field studies the following estimation can be followed. If water levels are within 3.5m bgl, transpiration can be estimated using the transpiration rates available for other areas. If it is greater than 3.5m bgl, the transpiration should be taken as zero.

For estimating evapotranspiration, field tools like Lysimeters can be used to estimate actual evapotranspiration. Usually agricultural universities and IMD carry out lysimeter experiments and archive the evapotranspiration data. Remote sensing based techniques like SEBAL (Surface Energy Balance Algorithm for Land) can be used for estimation of actual evapotranspiration. Assessing offices may apply available lysimeter data or other techniques for estimation of evapotranspiration. In case where such data is not available, evapotranspiration losses can be empirically estimated from PET data provided by IMD.

5.6.1.7 Recharge/ Accumulations during Monsoon Season

The sum of normalized monsoon rainfall recharge and the recharge from other sources and lateral and vertical flows into & out of the sub unit and stream inflows & outflows during monsoon season is the total recharge/ accumulation during monsoon season for the sub unit. Similarly, this is to be computed for all the sub units available in the assessment unit.

5.6.1.8 Recharge/ Accumulations during Non-Monsoon Season

The rainfall recharge during non-monsoon season is estimated using rainfall infiltration factor Method only when the non-monsoon season rainfall is more than 10% of normal annual rainfall. The sum of non-monsoon rainfall recharge and the recharge from other sources and lateral and vertical flows into & out of the sub unit and stream inflows & outflows during non-monsoon season is the total recharge/ accumulation during non-monsoon season for the sub unit. Similarly, this is to be computed for all the sub units available in the assessment unit.

5.6.1.9 Total Annual Ground Water Recharge

The sum of the recharge/ accumulations during monsoon and non-monsoon seasons is the total annual ground water recharge/ accumulations for the sub unit. Similarly, this is to be computed for all the sub units available in the assessment unit.

5.6.1.10 Annual Extractable Ground Water Resource (EGR)

The Total Annual Ground Water Recharge cannot be utilised for human consumption, since ecological commitments need to be fulfilled, before the extractable resources is defined.

The National Water Policy, 2012 stresses that the ecological flow of rivers should be maintained. Therefore, ground water base flow contribution limited to the ecological flow of the river should be determined which will be deducted from Annual Ground Water Recharge to determine Annual Extractable Ground Water Resources (EGR). The ecological flows of the rivers are to be determined in consultation with Central Water Commission and other concerned river basin agencies.

In case base flow contribution to the ecological flow of rivers is not determined then following assumption is to be followed. In the water level fluctuation method, a significant portion of base flow is already accounted for by taking the post monsoon water level one month after the end of rainfall. The base flow in the remaining non-monsoon period is likely to be small, especially in hard rock areas. In the assessment units, where river stage data are not available and neither the detailed data for quantitative assessment of the natural discharge are available, present practice (GEC 1997) of allocation of unaccountable natural discharges to 5% or 10% of annual recharge may be retained. If the rainfall recharge is assessed using water level fluctuation method this will be 5% of the annual recharge and if it is assessed using rainfall infiltration factor method, it will be 10% of the annual recharge. The balance will account for Annual Extractable Ground Water Resources (EGR).

5.6.1.11 Estimation of Ground Water Extraction

Ground water draft or extraction is to be assessed as follows.

$$GE_{ALL} = GE_{IRR} + GE_{DOM} + GE_{IND}$$

23

Where,

GE_{ALL} = Ground water extraction for all uses

GE_{IRR} = Ground water extraction for irrigation

GE_{DOM} = Ground water extraction for domestic uses

GE_{IND} = Ground water extraction for industrial uses

5.6.1.11.1 Ground Water Extraction for Irrigation(GE_{IRR}): The single largest component of the ground water balance equation in large regions of India is the ground water extraction and the precise estimation of ground water extraction is riddled with uncertainties. Therefore it is recommended that at least two of the three methods for estimation of ground water extraction maybe employed in each assessment sub unit. The methods for estimation of ground water extraction are as follows.

Unit Draft Method: – In this method, season-wise unit draft of each type of well in an assessment unit is estimated. The unit draft of different types (eg. Dug well, Dug cum bore well, shallow tube well, deep tube well, bore well etc.) is multiplied with the number of wells of that particular type to obtain season-wise ground water extraction by that particular structure. This method is being widely practiced in the country. There are several sources which maintain records on well census. These include Minor Irrigation Census conducted by MoWR, RD, GR, Government of India, and data maintained at the Tehsil level. It is recommended that a single source of well census should be maintained for resources computation at all India level. Minor Irrigation Census of MoWR, RD, GR would be the preferred option.

Crop Water Requirement Method: – For each crop, the season-wise net irrigation water requirement is determined. This is then multiplied with the area irrigated by ground water abstraction structures. The database on crop area is obtained from Revenue records in Tehsil office, Agriculture Census and also by using Remote Sensing techniques.

Power Consumption Method: –Ground water extraction for unit power consumption (electric) is determined. Extraction per unit power consumption is then multiplied with number of units of power consumed for agricultural pump sets to obtain total ground water extraction for irrigation.

Direct metering of ground water draft in select irrigation and domestic wells and in all wells established for industrial purpose may be initiated. Enforcing fitting of water meters and recording draft in all govt. funded wells could also be a feasible option. The unit drafts obtained from these sample surveys can be used to assess ground water extraction. In addition to metering, dedicated field sample surveys (instantaneous discharge measurements) can also be taken up.

5.6.1.11.2 Ground Water Extraction for Domestic Use(GE_{DOM}): There are several methods for estimation of extraction for domestic use(GE_{DOM}). Some of the commonly adopted methods are described here.

Unit Draft Method: – In this method, unit draft of each type of well is multiplied by the number of wells used for domestic purpose to obtain the domestic ground water extraction.

Consumptive Use Method: – In this method, population is multiplied with per capita consumption usually expressed in litre per capita per day (lpcd). It can be expressed using following equation.

$$GE_{DOM} = \text{Population} \times \text{Consumptive Requirement} \times L_g \quad 24$$

Where,

L_g = Fractional Load on Ground Water for Domestic Water Supply

The Load on Ground water can be obtained from the Information based on Civic water supply agencies in urban areas.

5.6.1.11.3 Ground water Extraction for Industrial use (GE_{IND}): The commonly adopted methods for estimating the extraction for industrial use are as below:

Unit Draft Method: - In this method, unit draft of each type of well is multiplied by the number of wells used for industrial purpose to obtain the industrial ground water extraction.

Consumptive Use Pattern Method: – In this method, water consumption of different industrial units is determined. Number of Industrial units which are dependent on ground water are multiplied with unit water consumption to obtain ground water extraction for industrial use.

$$GE_{IND} = \text{Number of industrial units} \times \text{Unit Water Consumption} \times L_g \quad 25$$

Where,

L_g = Fractional load on ground water for industrial water supply

The load on ground water for industrial water supply can be obtained from water supply agencies in the Industrial belt. Other important sources of data on ground water extraction for industrial uses are- Central Ground Water Authority, State Ground Water Authority, National Green Tribunal and other Environmental Regulatory Authorities.

Ground water extraction obtained from different methods need to be compared and based on field checks, the seemingly best value may be adopted. At times, ground water extraction obtained by different methods may vary widely. In such cases, the value matching the field situation should be considered. The storage depletion during a season, where other recharges are negligible can be taken as ground water extraction during that particular period.

5.6.1.12 Stage of Ground Water Extraction

The stage of ground water extraction is defined by,

$$\text{Stage of Ground Water Extraction}(\%) = \frac{\text{Existing gross ground water extraction for all uses}}{\text{Annual Extractable Ground water Resources}} \times 100 \quad 26$$

The existing gross ground water extraction for all uses refers to the total of existing gross ground water extraction for irrigation and all other purposes. The stage of ground water extraction should be obtained separately for command areas, non-command areas and poor ground water quality areas.

5.6.1.13 Validation of Stage of Ground Water Extraction

The assessment based on the stage of ground water extraction has inherent uncertainties. The estimation of ground water extraction is likely to be associated with considerable uncertainties as it is based on indirect assessment using factors such as electricity consumption, well census and area irrigated from ground water. The denominator in equation 26, namely Annual Extractable Ground Water Resources also has uncertainties due to limitations in the assessment methodology, as well as uncertainties in the data. In view of this, it is desirable to validate the 'Stage of Ground Water Extraction' with long term trend of ground water levels.

Long term water level trends are to be prepared for a minimum period of 10 years for both pre-monsoon and post-monsoon period. The water level trend would be average water level trend as obtained from the different observation wells in the area.

In interpreting the long-term trend of ground water levels, the following points may be kept in view. If the pre and post monsoon water levels show a fairly stable trend, it does not necessarily mean that there is no scope for further ground water development. Such a trend indicates that there is a balance between recharge, extraction and natural discharge in the unit. However, further ground water development may be possible, which may result in a new stable trend at a lower ground water level with associated reduced natural discharge.

If the ground water resource assessment and the trend of long term water levels contradict each other, this anomalous situation requires a review of the ground water resource computation, as well as the reliability of water level data. The mismatch conditions are enumerated below.

SOGWE	Ground Water Level Trend	Remarks
≤70%	Significant decline in trend in both pre-monsoon and post-monsoon	Not acceptable and needs reassessment
>100%	No significant decline in both pre-monsoon and post-monsoon long term trend	Not acceptable and needs reassessment

In case, the category does not match with the water level trend given above, a 'reassessment' should be attempted. If the mismatch persists even after reassessment, the sub unit may be categorized based on Stage of Ground Water Extraction of the reassessment. However, the sub unit should be flagged for strengthening of observation well network and parameter estimation.

5.6.1.14 Categorisation of Assessment Units

As emphasised in the National Water Policy, 2012, a convergence of Quantity and Quality of ground water resources is required while assessing the ground water status in an assessment unit. Therefore, it is recommended to separate estimation of resources where water quality is beyond permissible limits for the parameter salinity.

5.6.1.14.1 Categorisation of Assessment Units Based on Quantity: The categorisation based on status of ground water quantity is defined by Stage of Ground Water Extraction as given below:

Stage of Ground Water Extraction	Category
$\leq 70\%$	Safe
$>70\%$ and $\leq 90\%$	Semi-Critical
$>90\%$ and $\leq 100\%$	Critical
$> 100\%$	Over Exploited

5.6.1.14.2 Categorisation of Assessment Units Based on Quality

GEC 1997 proposed categorisation of assessment units based on ground water extraction only. To adequately inform management decisions, quality of ground water is also an essential criterion. The committee deliberated upon the possible ways of categorizing the assessment units based on ground water quality in the assessment units. It was realised that based on the available water quality monitoring mechanism and available database on ground water quality it may not be possible to categorise the assessment units in terms of the extent of quality hazard. As a trade-off, the committee recommends that each assessment unit, in addition to the quantity based categorisation (safe, semi-critical, critical and over-exploited) should bear a quality hazard identifier. Such quality hazards are to be based on available ground water monitoring data of State Ground Water Departments and/or Central Ground Water Board. If any of the three quality hazards in terms of Arsenic, Fluoride and Salinity are encountered in the assessment sub unit in mappable units, the assessment sub unit may be tagged with the particular quality hazard.

5.6.1.15 Allocation of Ground Water Resource for Utilisation

The Annual Extractable Ground Water Resources are to be apportioned between domestic, industrial and irrigation uses. Among these, as per the National Water Policy, requirement for domestic water supply is to be accorded priority. This requirement has to be based on population as projected to the year 2025, per capita requirement of water for domestic use, and relative load on ground water for urban and rural water supply. The estimate of allocation for domestic water requirement may vary for one sub unit to the other in different states. In situations where adequate data is not available to make this estimate, the following empirical relation is recommended.

$$\text{Alloc} = 22 \times N \times L_g \text{ mm per year}$$

Where

Alloc=Allocation for domestic water requirement

N = population density in the unit in thousands per sq. km.

L_g = fractional load on ground water for domestic water supply (≤ 1.0)

In deriving equation 27, it is assumed that the requirement of water for domestic use is 60 lpd per head. The equation can be suitably modified in case per capita requirement is different. If by chance, the estimation of projected allocation for future domestic needs is less than the current domestic extraction due to any reason, the allocation must be equal to the present day extraction. It can never be less than the present day extraction as it is unrealistic.

5.6.1.16 Net Annual Ground Water Availability for Future Use

The water available for future use is obtained by deducting the allocation for domestic use and current extraction for Irrigation and Industrial uses from the Annual Extractable Ground Water Recharge. The resulting ground water potential is termed as the net annual ground water availability for future use. The Net annual ground water availability for future use should be calculated separately for non-command areas and command areas. As per the recommendations of the R&D Advisory committee, the ground water available for future use can never be negative. If it becomes negative, the future allocation of Domestic needs can be reduced to current extraction for domestic use. Even then if it is still negative, then the ground water available for future uses will be zero.

5.6.1.17 Additional Potential Resources under Specific Conditions

5.6.1.17.1 Potential Resource Due to Spring Discharge: Spring discharge constitutes an additional source of ground water in hilly areas which emerges at the places where ground water level cuts the surface topography. The spring discharge is equal to the ground water recharge minus the outflow through evaporation and evapotranspiration and vertical and lateral sub-surface flow. Thus, Spring Discharge is a form of 'Annual Extractable Ground Water Recharge'. It is a renewable resource, though not to be used for Categorisation. Spring discharge measurement is to be carried out by volumetric measurement of discharge of the springs. Spring discharges multiplied with time in days of each season will give the quantum of spring resources available during that season. The committee recommends that in hilly areas with substantial potential of spring discharges, the discharge measurement should be made at least 4 times a year in parity with the existing water level monitoring schedule.

Potential ground water resource due to springs = Q x No of days **28**

Where

Q= Spring Discharge

No of days= No of days spring yields.

5.6.1.17.2 Potential Resource in Waterlogged and Shallow Water Table Areas: The quantum of water available for development is usually restricted to long term average recharge or in other words “Dynamic Resources”. But the resource calculated by water level fluctuation approach is likely to lead to under-estimation of recharge in areas with shallow water table, particularly in discharge areas of sub-basin/watershed/block/taluka/ Firka and waterlogged areas. In such cases rejected recharge may be substantial and water level fluctuations are subdued resulting in under-estimation of recharge component. It is therefore, desirable that the ground water reservoir should be drawn to optimum limit before the onset of monsoon, to provide adequate scope for its recharge during the following monsoon period.

In the area where the ground water level is less than 5m below ground level or in waterlogged areas, the resources up to 5m below ground level are potential and would be available for development in addition to the annual recharge in the area. It is therefore recommended that in such areas, ground water resources may be estimated up to 5m bgl only assuming that where water level is less than 5m bgl, the same could be depressed by pumping to create space to receive recharge from natural resources. It is further evident that this potential recharge would be available mostly in the shallow water table areas which would have to be demarcated in each sub-basin/watershed/block/taluka/ mandal/ Firka. The computation of potential resource of the ground water reservoir can be done by adopting the following equation:

Potential ground water resource in shallow water table areas = (5-D) x A x S_Y **29**

Where

D = Depth to water table below ground surface in pre-monsoon period in shallow aquifers.

A = Area of shallow water table zone.

S_Y = Specific Yield

The planning of future minor irrigation works in the waterlogged and shallow water table areas as indicated above should be done in such a way that there should be no long term adverse effects of lowering of water table up to 5m and the water level does not decline much

below 5m in such areas. The behaviour of water table in the adjoining area which is not water logged should be taken as a bench mark for development purposes.

This potential resource of ground water is available only after depression of water level up to 5m bgl. This is not an annual resource and should be recommended for development on a very cautious approach so that it does not adversely affect the ground water potentials in the overall area.

5.6.1.17.3 Potential Resource in Flood Prone Areas: Ground water recharge from a flood plain is mainly the function of the following parameters-

- Areal extent of flood plain
- Retention period of flood
- Type of sub-soil strata and silt charge in the river water which gets deposited and controls seepage

Since collection of data on all these factors is time taking and difficult, in the meantime, the potential resource from flood plain may be estimated on the same norms as for ponds, tanks and lakes. This has to be calculated over the water spread area and only for the retention period using the following formula.

$$\text{Potential ground water resource in Flood Prone Areas} = 1.4 \times N \times A/1000 \quad 30$$

Where

N = No of Days Water is Retained in the Area

A = Flood Prone Area

5.6.1.18 Apportioning of Ground Water Assessment from Watershed to Development Unit:

Where the assessment unit is a watershed, there is a need to convert the ground water assessment in terms of an administrative unit such as block/taluka/mandal/ firka. This may be done as follows.

A block may comprise of one or more watersheds, in part or full. First, the ground water assessment in the subareas, command, non-command and poor ground water quality areas of the watershed may be converted into depth unit (mm), by dividing the annual recharge by the respective area. The contribution of this subarea of the watershed to the block, is now calculated by multiplying this depth with the area in the block occupied by this sub-area. This procedure must be followed to calculate the contribution from the sub-areas of all watersheds occurring in the block, to work out the total ground water resource of the block.

The total ground water resource of the block should be presented separately for each type of sub-area, namely for command areas, non-command areas and poor ground water quality areas, as in the case of the individual watersheds.

5.6.2 Assessment of In-Storage Ground Water Resources or Static Ground Water Resources

The quantum of ground water available for development is usually restricted to long term average recharge or dynamic resources. Presently there is no fine demarcation to distinguish the dynamic resources from the static resources. While water table hydrograph could be an indicator to distinguish dynamic resources, at times it is difficult when water tables are deep. For sustainable ground water development, it is necessary to restrict it to the dynamic resources. Static or in-storage ground water resources could be considered for development during exigencies that also for drinking water purposes. It is also recommended that no irrigation development schemes based on static or in-storage ground water resources be taken up at this stage.

Assessment of In-storage ground water resources has assumed greater significance in the present context, when an estimation of Storage Depletion needs to be carried out in Over-exploited areas. Recently Remote Sensing techniques have been used in GRACE studies, to estimate the depletion of Ground Water Resources in North West India. Such estimation presents larger scale scenario. More precise estimation of ground water depletion in the over-exploited area based on actual field data can be obtained by estimating the Change in In-storage during successive assessments. Thus In-storage computation is necessary not only for estimation of emergency storage available for utilisation in case of natural extremities (like drought) but also for an assessment of storage depletion in over-exploited areas for sensitising stakeholders about the damage done to the environment.

The computation of the static or in-storage ground water resources may be done after delineating the aquifer thickness and specific yield of the aquifer material. The computations can be done as follows: -

$$\text{SGWR} = A * (Z_2 - Z_1) * S_Y \quad 31$$

Where,

SGWR = Static or in-storage Ground Water Resources

A = Area of the Assessment Unit

Z_2 = Bottom of Unconfined Aquifer

Z_1 = Pre-monsoon water level

S_Y = Specific Yield in the In storage Zone

5.6.3 Assessment of Total Ground Water Availability in Unconfined Aquifer

The sum of Annual Exploitable Ground Water Resource and the In storage ground water resources of an unconfined aquifer is the Total Ground Water Availability of that aquifer.

5.7 GROUND WATER ASSESSMENT OF CONFINED AQUIFER SYSTEM

Assessment of ground water resources of confined aquifers assumes crucial importance, since over-exploitation of these aquifers may lead to far more detrimental consequences than to those of shallow unconfined aquifers. If the piezometric surface of the confined aquifer is lowered below the upper confining layer so that desaturation of the aquifer occurs, the coefficient of storage is no longer related to the elasticity of the aquifer but to its specific yield. In view of the small amounts of water released from storage in the confined aquifers, large scale pumpage from confined aquifers may cause decline in piezometric levels amounting to over a hundred metre and subsidence of land surface posing serious geotectonical problems.

It is recommended to use ground water storage approach to assess the ground water resources of the confined aquifers. The co-efficient of storage or storativity of an aquifer is defined as the volume of water it releases or takes into storage per unit surface area of the aquifer per unit change in head. Hence the quantity of water added to or released from the aquifer (ΔV) can be calculated as follows

$$\Delta V = S \Delta h \quad 32$$

If the areal extent of the confined aquifer is A then the total quantity of water added to or released from the entire aquifer is

$$Q = A \Delta V = SA\Delta h \quad 33$$

Where

Q = Quantity of water confined aquifer can release (m^3)

S = Storativity

A = Areal extent of the confined aquifer (m^2)

Δh = Change in Piezometric head (m)

Most of the storage in confined aquifer is associated with compressibility of the aquifer matrix and compressibility of water. Once the piezometric head reaches below the top confining bed, it behaves like an unconfined aquifer and directly dewateres the aquifer and there is a possibility of damage to the aquifer as well as topography. Hence ground water

potential of a confined aquifer is nothing but the water available for use without damaging the aquifer. Hence the resources available under pressure are only considered as the ground water potential. The quantity of water released in confined aquifer due to change in pressure can be computed between piezometric head (h_t) at any given time 't' and the bottom of the top confining layer (h_o) by using the following equation.

$$Q_p = SA\Delta h = SA (h_t - h_o) \quad 34$$

Where

Q_p = Ground Water Potential of Confined Aquifer

S = Storativity

A = Areal extent of the confined aquifer

Δh = Change in Piezometric head

h_t = Piezometric head at any particular time

h_o = Bottom of the top Confining Layer

If any development activity is started in the confined aquifer, then there is a need to assess the dynamic as well as in storage resources of the confined aquifer. To assess the ground water resources of the confined aquifer, there is a need to have sufficient number of observation wells tapping exclusively that particular aquifer and proper monitoring of the piezometric heads is also needed.

5.7.1 Dynamic Ground Water Resources of Confined Aquifer

To assess the dynamic ground water resources of the confined aquifer the following equation can be used with the pre and post monsoon piezometric heads of the particular aquifer.

$$Q_D = SA\Delta h = SA (h_{POST} - h_{PRE}) \quad 35$$

Where

Q_D = Dynamic Ground Water Resource of Confined Aquifer (m^3)

S = Storativity

A = Areal extent of the confined aquifer (m^2)

Δh = Change in Piezometric head (m)

h_{post} = Piezometric head during post-monsoon period(m amsl)

h_{PRE} = Piezometric head during pre-monsoon period(m amsl)

5.7.2 In storage Ground Water Resources of Confined Aquifer

For assessing the in- storage ground water potential of a confined aquifer, one has to compute the resources between the pre monsoon piezometric head and bottom of the top confining layer. That can be assessed using the following formula:

$$Q_I = SA\Delta h = SA (h_{PRE} - h_0) \quad 36$$

Where

Q_I = In storage Ground Water Resource of Confined Aquifer (m^3)

S = Storativity

A = Areal extent of the confined aquifer (m^2)

Δh = Change in Piezometric head (m)

h_0 = Bottom level of the top confining layer (m amsl)

h_{PRE} = Piezometric head during pre-monsoon period (m amsl)

If the confined aquifer is not being exploited for any purpose, the dynamic and static resources of the confined aquifer need not be estimated separately. Instead the in storage of the aquifer can be computed using the following formula.

$$Q_p = SA\Delta h = SA (h_{POST} - h_0) \quad 37$$

Where

Q_p = In -storage Ground Water Resource of the confined aquifer or the Quantity of water under pressure (m^3)

S = Storativity

A = Areal extent of the confined aquifer (m^2)

Δh = Change in Piezometric head (m)

H_{POST} = Piezometric head during post-monsoon period (m amsl)

h_0 = Bottom of the Top Confining Layer (m amsl)

The calculated resource includes small amount of dynamic resource of the confined aquifer also, which replenishes every year. But to make it simpler this was also computed as part of the static or in-storage resource of the confined aquifer.

5.7.3 Assessment of Total Ground Water Availability of Confined Aquifer

If the confined aquifer is being exploited, the Total Ground Water Availability of the confined aquifer is the sum of Dynamic Ground Water Resources and the In storage ground water resources of that confined aquifer whereas if it is not being exploited, the Total Ground Water Availability of the confined aquifer comprises of only one component i.e. the In-storage of that confined aquifer.

5.8 GROUND WATER ASSESSMENT OF SEMI-CONFINED AQUIFER SYSTEM

The Assessment of Ground Water Resources of a semi-confined aquifer has some more complications. Unless and until, it is well studied that the recharge to this is not computed either in the over lying unconfined aquifer or underlying/overlying semi confined aquifers, it

should not be assessed separately. If it is assessed separately, there is a possibility of duplication of estimating the same resource by direct computation in one aquifer and as leakage in the other aquifer. As it is advisable to under estimate rather than to overestimate the resources, it is recommended not to assess these resources separately as long as there is no study indicating its non-estimation. If it is found through field studies that the resources are not assessed in any of the aquifers in the area, these resources are to be assessed following the methodology similar to that used in assessing the resources of Confined aquifers.

5.9 TOTAL GROUND WATER AVAILABILITY OF AN AREA

The Total Ground Water Availability in any area is the Sum of Dynamic Ground Water Resources, the static/in-storage ground water resources in the unconfined aquifer and the dynamic and In-storage resources of the Confined aquifers and semi confined aquifers in the area.

5.10 GROUND WATER ASSESSMENT IN URBAN AREAS

The Assessment of Ground Water Resources in urban areas is similar to that of rural areas. Because of the availability of draft data and slightly different infiltration process and recharge due to other sources, the following few points are to be considered.

- Even though the data on existing ground water abstraction structures are available, accuracy is somewhat doubtful and individuals cannot even enumerate the well census in urban areas. Hence it is recommended to use the difference of the actual demand and the supply by surface water sources as the withdrawal from the ground water resources.
- The urban areas are sometimes concrete jungles and rainfall infiltration is not equal to that of rural areas unless and until special measures are taken in the construction of roads and pavements. Hence, it is proposed to use 30% of the rainfall infiltration factor proposed for urban areas as an adhoc arrangement till field studies in these areas are done and documented field studies are available.
- Because of the water supply schemes, there are many pipelines available in the urban areas and the seepages from these channels or pipes are huge in some areas. Hence this component is also to be included in the other resources and the recharge may be estimated. The percent losses may be collected from the individual water supply agencies, 50% of which can be taken as recharge to the ground water system.

- In the urban areas in India, normally, there is no separate channels either open or sub surface for the drainage and flash floods. These channels also recharge to some extent the ground water reservoir. As on today, there is no documented field study to assess the recharge. The seepages from the sewerages, which normally contaminate the ground water resources with nitrate also contribute to the quantity of resources and hence same percent as in the case of water supply pipes may be taken as norm for the recharge on the quantity of sewerage when there is sub surface drainage system. If estimated flash flood data is available the same percent can be used on the quantum of flash floods to estimate the recharge from the flash floods. Even when the drainage system is open channels, till further documented field studies are done same procedure may be followed.
- It is proposed to have a separate ground water assessment for urban areas with population more than 10 lakhs.

5.11 GROUND WATER ASSESSMENT IN COASTAL AREAS

The Assessment of Ground Water Resources in coastal areas is similar to that of other areas. Because of the nature of hydraulic equilibrium of ground water with sea water care should be taken in assessing the ground water resources of this area. While assessing the resources in these areas, following few points are to be considered.

- The ground water resources assessment in coastal areas include the areas where the influence of sea water has an effect on the existence of fresh water in the area. It can be demarcated from the Coastal Regulatory zone or the Geomorphological maps or from the maps where sea water influences are demarcated..
- Wherever, the pre monsoon and post monsoon water levels are above mean sea level the dynamic component of the estimation will be same as other areas.
- If both these water levels are below sea level, the dynamic component should be taken as zero.
- Wherever, the post monsoon water table is above sea level and pre monsoon water table is below sea level the pre monsoon water table should be taken as at sea level and fluctuation is to be computed.
- The static or in storage resources are to be restricted to the minimum of 40 times the pre monsoon water table or the bottom of the aquifer.

5.12 GROUND WATER ASSESSMENT IN WATER LEVEL DEPLETION ZONES

There may be areas where ground water level shows a decline even in the monsoon season. The reasons for this may be any one of the following : (a) There is a genuine depletion in the ground water regime, with ground water extraction and natural ground water discharge in the monsoon season(outflow from the region and base flow) exceeding the recharge. (b) There may be an error in water level data due to inadequacy of observation wells.

If it is concluded that the water level data is erroneous, recharge assessment may be made based on rainfall infiltration factor method. If, on the other hand, water level data is assessed as reliable, the ground water level fluctuation method may be applied for recharge estimation. As ΔS in equation 3& 4 is negative, the estimated recharge will be less than the gross ground water extraction in the monsoon season. It must be noted that this recharge is the gross recharge minus the natural discharges in the monsoon season. The immediate conclusion from such an assessment in water depletion zones will be that the area falls under the over-exploited category which requires micro level study.

5.13 MICRO LEVEL STUDY FOR NOTIFIED AREAS

In all areas which are 'Notified' for ground water regulation by the Central and/ or State Ground Water Authorities, it is necessary to increase the density of observation wells for carrying out micro-level studies to reassess the ground water recharge and draft. Following approach may be adopted:

1. The area may be sub-divided into different hydrogeological sub-areas and into recharge area, discharge area and transition zone and also on quality terms.
2. The number of observation wells should be increased to represent each such sub-areas with at least one observation well with continuous monitoring of water levels.
3. Hydrological and hydrogeological parameters particularly the specific yield should be collected for different formations in each sub-area.
4. Details regarding other parameters like seepage factor from canals and other surface water projects should be collected after field studies, instead of adopting recommended norms. Base flow should be estimated based on stream gauge measurement.

5. The data of number of existing structures and unit draft should be reassessed after fresh surveys and should match with the actual irrigation pattern in the sub-area.
6. All data available with Central Ground Water Board, State Ground Water Departments and other agencies including research institutions and universities etc. should be collected for the watershed/sub-areas and utilised for reassessment.
7. Ground water assessment for each sub-area may be computed adopting the recommended methodology and freshly collected values of different parameters. The assessment may be made separately for monsoon and non-monsoon period as well as for command, non-command and poor ground water quality areas.
8. The ground water potential so worked out may be cross-checked with behaviour of ground water levels in the observation wells and both should match. If it does not, the factor that causes such an anomaly should be identified and the revised assessment should be re-examined.
9. Based on the micro-level studies, the sub-areas within the unit and the unit as a whole may be classified adopting norms for categorisation as recommended elsewhere in the methodology.

5.14 NORMS TO BE USED IN THE ASSESSMENT

The committee recommends that the state agencies should be encouraged to conduct field studies and use these computed norms in the assessment. For conducting field studies, it is recommended to follow the field-tested procedures for computing the norms. There is the possibility of error creeping in at various levels in the field study and hence the committee is of the opinion to give a maximum and minimum values for all the norms used in the estimation. The committee can foresee the handicap of the state agencies which are not able to compute the norms by their own field study. In such cases, it suggests an average of the range of norms to be used as the recommended value for the norm. This has been further clarified in the following paragraphs.

5.14.1 Specific Yield

Recently under Aquifer Mapping Project, Central Ground Water Board has classified all the aquifers into 16 Principal Aquifers which in turn were divided into 42 Major Aquifers. Hence, it is required to assign Specific Yield values to all these aquifer units. The values recommended in the Table 7 may be followed in the future assessments. The Major aquifer map can be obtained from Regional offices of Central Ground Water Board.

The recommended Specific Yield values are to be used for assessment, unless sufficient data based on field studies are available to justify the minimum, maximum or other intermediate values. The Norms suggested below are nothing but the redistribution of norms suggested by GEC-1997 methodology and hence people are encouraged to conduct field studies and strengthen the Norms database.

TABLE 7: NORMS RECOMMENDED FOR THE SPECIFIC YIELD

Sl.No	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
1	Alluvium	AL01	Younger Alluvium (Clay/Silt/Sand/ Calcareous concretions)	Quaternary	10	8	12
2	Alluvium	AL02	Pebble / Gravel/ Bazada/ Kandi	Quaternary	16	12	20
3	Alluvium	AL03	Older Alluvium (Silt/Sand/Gravel/Lithomargic clay)	Quaternary	6	4	8
4	Alluvium	AL04	Aeolian Alluvium (Silt/ Sand)	Quaternary	16	12	20
5	Alluvium	AL05	Coastal Alluvium (Sand/Silt/Clay)	Quaternary	10	8	12
6	Alluvium	AL06	Valley Fills	Quaternary	16	12	20
7	Alluvium	AL07	Glacial Deposits	Quaternary	16	12	20
8	Laterite	LT01	Laterite / Ferruginous concretions	Quaternary	2.5	2	3
9	Basalt	BS01	Basic Rocks (Basalt) - Weathered, Vesicular or Jointed	Mesozoic to Cenozoic	2	1	3
10	Basalt	BS01	Basic Rocks (Basalt) - Massive Poorly Jointed	Mesozoic to Cenozoic	0.35	0.2	0.5
11	Basalt	BS02	Ultra Basic - Weathered, Vesicular or Jointed	Mesozoic to Cenozoic	2	1	3
12	Basalt	BS02	Ultra Basic - Massive Poorly Jointed	Mesozoic to Cenozoic	0.35	0.2	0.5
13	Sandstone	ST01	Sandstone/Conglomerate	Upper Palaeozoic to Cenozoic	3	1	5
14	Sandstone	ST02	Sandstone with Shale	Upper Palaeozoic to Cenozoic	3	1	5
15	Sandstone	ST03	Sandstone with shale/ coal beds	Upper Palaeozoic to Cenozoic	3	1	5
16	Sandstone	ST04	Sandstone with Clay	Upper Palaeozoic to Cenozoic	3	1	5
17	Sandstone	ST05	Sandstone/Conglomerate	Proterozoic to Cenozoic	3	1	5
18	Sandstone	ST06	Sandstone with Shale	Proterozoic to Cenozoic	3	1	5
19	Shale	SH01	Shale with limestone	Upper Palaeozoic to Cenozoic	1.5	1	2
20	Shale	SH02	Shale with Sandstone	Upper Palaeozoic to Cenozoic	1.5	1	2
21	Shale	SH03	Shale, limestone and sandstone	Upper Palaeozoic to Cenozoic	1.5	1	2

1585

Sl.No	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
22	Shale	SH04	Shale	Upper Palaeozoic to Cenozoic	1.5	1	2
23	Shale	SH05	Shale/Shale with Sandstone	Proterozoic to Cenozoic	1.5	1	2
24	Shale	SH06	Shale with Limestone	Proterozoic to Cenozoic	1.5	1	2
25	Limestone	LS01	Miliolitic Limestone	Quarternary	2	1	3
26	Limestone	LS01	KarstifiedMiliolitic Limestone	Quarternary	10	5	15
27	Limestone	LS02	Limestone / Dolomite	Upper Palaeozoic to Cenozoic	2	1	3
28	Limestone	LS02	KarstifiedLimestone / Dolomite	Upper Palaeozoic to Cenozoic	10	5	15
29	Limestone	LS03	Limestone/Dolomite	Proterozoic	2	1	3
30	Limestone	LS03	KarstifiedLimestone/Dolomite	Proterozoic	10	5	15
31	Limestone	LS04	Limestone with Shale	Proterozoic	2	1	3
32	Limestone	LS04	KarstifiedLimestone with Shale	Proterozoic	10	5	15
33	Limestone	LS05	Marble	Azoic to Proterozoic	2	1	3
34	Limestone	LS05	KarstifiedMarble	Azoic to Proterozoic	10	5	15
35	Granite	GR01	Acidic Rocks (Granite,Syenite, Rhyolite etc.) - Weathered , Jointed	Mesozoic to Cenozoic	1.5	1	2
36	Granite	GR01	Acidic Rocks (Granite,Syenite, Rhyolite etc.)-Massive or Poorly Fractured	Mesozoic to Cenozoic	0.35	0.2	0.5
37	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Weathered, Jointed	Proterozoic to Cenozoic	3	2	4
38	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.35	0.2	0.5
39	Schist	SC01	Schist - Weathered, Jointed	Azoic to Proterozoic	1.5	1	2
40	Schist	SC01	Schist - Massive, Poorly Fractured	Azoic to Proterozoic	0.35	0.2	0.5
41	Schist	SC02	Phyllite	Azoic to Proterozoic	1.5	1	2
42	Schist	SC03	Slate	Azoic to Proterozoic	1.5	1	2
43	Quartzite	QZ01	Quartzite - Weathered, Jointed	Proterozoic to Cenozoic	1.5	1	2
44	Quartzite	QZ01	Quartzite - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.3	0.2	0.4
45	Quartzite	QZ02	Quartzite - Weathered, Jointed	Azoic to Proterozoic	1.5	1	2
46	Quartzite	QZ02	Quartzite- Massive, Poorly Fractured	Azoic to Proterozoic	0.3	0.2	0.4
47	Charnockite	CK01	Charnockite - Weathered, Jointed	Azoic	3	2	4
48	Charnockite	CK01	Charnockite - Massive, Poorly Fractured	Azoic	0.3	0.2	0.4
49	Khondalite	KH01	Khondalites, Granulites - Weathered, Jointed	Azoic	1.5	1	2
50	Khondalite	KH01	Khondalites, Granulites - Mssive, Poorly Fractured	Azoic	0.3	0.2	0.4

Sl.No	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
51	Banded Gneissic Complex	BG01	Banded Gneissic Complex - Weathered, Jointed	Azoic	1.5	1	2
52	Banded Gneissic Complex	BG01	Banded Gneissic Complex - Massive, Poorly Fractured	Azoic	0.3	0.2	0.4
53	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Weathered, Jointed	Azoic to Proterozoic	1.5	1	2
54	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Massive, Poorly Fractured	Azoic to Proterozoic	0.3	0.2	0.4
55	Gneiss	GN02	Gneiss -Weathered, Jointed	Azoic to Proterozoic	3	2	4
56	Gneiss	GN02	Gneiss-Massive, Poorly Fractured	Azoic to Proterozoic	0.3	0.2	0.4
57	Gneiss	GN03	Migmatitic Gneiss - Weathered, Jointed	Azoic	1.5	1	2
58	Gneiss	GN03	Migmatitic Gneiss - Massive, Poorly Fractured	Azoic	0.3	0.2	0.4
59	Intrusive	IN01	Basic Rocks (Dolerite, Anorthosite etc.) - Weathered, Jointed	Proterozoic to Cenozoic	2	1	3
60	Intrusive	IN01	Basic Rocks (Dolerite, Anorthosite etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.35	0.2	0.5
61	Intrusive	IN02	Ultrabasics (Epidiorite, Granophyre etc.) - Weathered, Jointed	Proterozoic to Cenozoic	2	1	3
62	Intrusive	IN02	Ultrabasics (Epidiorite, Granophyre etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.35	0.2	0.5

5.14.2 Rainfall Infiltration Factor

It is recommended that to assign Rainfall Infiltration Factor values to all the aquifer units recently classified by the Central Ground Water Board. The values recommended in Table 8 may be followed in the future assessments. The recommended Rainfall Infiltration Factor values are to be used for assessment, unless sufficient data based on field studies are available to justify the minimum, maximum or other intermediate values.

An additional 2% of rainfall recharge factor may be used in such areas or parts of the areas where watershed development with associated soil conservation measures are implemented. This additional factor is subjective and is separate from the contribution due to the water conservation structures such as check dams, nalla bunds, percolation tanks etc. The norms for the estimation of recharge due to these structures are provided separately. This additional factor of 2% is at this stage, only provisional, and will need revision based on pilot studies.

The Norms suggested below are nothing but the redistribution of norms suggested by GEC-1997 methodology and hence people are encouraged to conduct field studies and strengthen the Norms database.

TABLE 8: NORMS RECOMMENDED FOR THE RAINFALL INFILTRATION FACTOR

Sl.No	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
1	Alluvium	AL01	Younger Alluvium (Clay/Silt/Sand/ Calcareous concretions)	Quaternary	22	20	24
2	Alluvium	AL02	Pebble / Gravel/ Bazada/ Kandi	Quaternary	22	20	24
3	Alluvium	AL03	Older Alluvium (Silt/Sand/Gravel/Lithomargic clay)	Quaternary	22	20	24
4	Alluvium	AL04	Aeolian Alluvium (Silt/ Sand)	Quaternary	22	20	24
5	Alluvium	AL05	Coastal Alluvium (Sand/Silt/Clay) -East Coast	Quaternary	16	14	18
5	Alluvium	AL05	Coastal Alluvium (Sand/Silt/Clay) - West Coast	Quaternary	10	8	12
6	Alluvium	AL06	Valley Fills	Quaternary	22	20	24
7	Alluvium	AL07	Glacial Deposits	Quaternary	22	20	24
8	Laterite	LT01	Laterite / Ferruginous concretions	Quaternary	7	6	8
9	Basalt	BS01	Basic Rocks (Basalt) - Vesicular or Jointed	Mesozoic to Cenozoic	13	12	14
9	Basalt	BS01	Basic Rocks (Basalt) - Weathered	Mesozoic to Cenozoic	7	6	8
10	Basalt	BS01	Basic Rocks (Basalt) - Massive Poorly Jointed	Mesozoic to Cenozoic	2	1	3
11	Basalt	BS02	Ultra Basic - Vesicular or Jointed	Mesozoic to Cenozoic	13	12	14
11	Basalt	BS02	Ultra Basic - Weathered	Mesozoic to Cenozoic	7	6	8
12	Basalt	BS02	Ultra Basic - Massive Poorly Jointed	Mesozoic to Cenozoic	2	1	3
13	Sandstone	ST01	Sandstone/Conglomerate	Upper Palaeozoic to Cenozoic	12	10	14
14	Sandstone	ST02	Sandstone with Shale	Upper Palaeozoic to Cenozoic	12	10	14
15	Sandstone	ST03	Sandstone with shale/ coal beds	Upper Palaeozoic to Cenozoic	12	10	14
16	Sandstone	ST04	Sandstone with Clay	Upper Palaeozoic to Cenozoic	12	10	14
17	Sandstone	ST05	Sandstone/Conglomerate	Proterozoic to Cenozoic	6	5	7
18	Sandstone	ST06	Sandstone with Shale	Proterozoic to Cenozoic	6	5	7
19	Shale	SH01	Shale with limestone	Upper Palaeozoic to Cenozoic	4	3	5
20	Shale	SH02	Shale with Sandstone	Upper Palaeozoic to Cenozoic	4	3	5

Sl.No	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
21	Shale	SH03	Shale, limestone and sandstone	Upper Palaeozoic to Cenozoic	4	3	5
22	Shale	SH04	Shale	Upper Palaeozoic to Cenozoic	4	3	5
23	Shale	SH05	Shale/Shale with Sandstone	Proterozoic to Cenozoic	4	3	5
24	Shale	SH06	Shale with Limestone	Proterozoic to Cenozoic	4	3	5
25	Limestone	LS01	Miliolitic Limestone	Quaternary	6	5	7
27	Limestone	LS02	Limestone / Dolomite	Upper Palaeozoic to Cenozoic	6	5	7
29	Limestone	LS03	Limestone/Dolomite	Proterozoic	6	5	7
31	Limestone	LS04	Limestone with Shale	Proterozoic	6	5	7
33	Limestone	LS05	Marble	Azoic to Proterozoic	6	5	7
35	Granite	GR01	Acidic Rocks (Granite, Syenite, Rhyolite etc.) - Weathered, Jointed	Mesozoic to Cenozoic	7	5	9
36	Granite	GR01	Acidic Rocks (Granite, Syenite, Rhyolite etc.) - Massive or Poorly Fractured	Mesozoic to Cenozoic	2	1	3
37	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Weathered, Jointed	Proterozoic to Cenozoic	11	10	12
38	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	2	1	3
39	Schist	SC01	Schist - Weathered, Jointed	Azoic to Proterozoic	7	5	9
40	Schist	SC01	Schist - Massive, Poorly Fractured	Azoic to Proterozoic	2	1	3
41	Schist	SC02	Phyllite	Azoic to Proterozoic	4	3	5
42	Schist	SC03	Slate	Azoic to Proterozoic	4	3	5
43	Quartzite	QZ01	Quartzite - Weathered, Jointed	Proterozoic to Cenozoic	6	5	7
44	Quartzite	QZ01	Quartzite - Massive, Poorly Fractured	Proterozoic to Cenozoic	2	1	3
45	Quartzite	QZ02	Quartzite - Weathered, Jointed	Azoic to Proterozoic	6	5	7
46	Quartzite	QZ02	Quartzite - Massive, Poorly Fractured	Azoic to Proterozoic	2	1	3
47	Charnockite	CK01	Charnockite - Weathered, Jointed	Azoic	5	4	6
48	Charnockite	CK01	Charnockite - Massive, Poorly Fractured	Azoic	2	1	3
49	Khondalite	KH01	Khondalites, Granulites - Weathered, Jointed	Azoic	7	5	9
50	Khondalite	KH01	Khondalites, Granulites - Massive, Poorly Fractured	Azoic	2	1	3
51	Banded Gneissic Complex	BG01	Banded Gneissic Complex - Weathered, Jointed	Azoic	7	5	9
52	Banded Gneissic Complex	BG01	Banded Gneissic Complex - Massive, Poorly Fractured	Azoic	2	1	3

Sl.No	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
53	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Weathered, Jointed	Azoic to Proterozoic	7	5	9
54	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Massive, Poorly Fractured	Azoic to Proterozoic	2	1	3
55	Gneiss	GN02	Gneiss -Weathered, Jointed	Azoic to Proterozoic	11	10	12
56	Gneiss	GN02	Gneiss-Massive, Poorly Fractured	Azoic to Proterozoic	2	1	3
57	Gneiss	GN03	Migmatitic Gneiss - Weathered, Jointed	Azoic	7	5	9
58	Gneiss	GN03	Migmatitic Gneiss - Massive, Poorly Fractured	Azoic	2	1	3
59	Intrusive	IN01	Basic Rocks (Dolerite, Anorthosite etc.) - Weathered, Jointed	Proterozoic to Cenozoic	7	6	8
60	Intrusive	IN01	Basic Rocks (Dolerite, Anorthosite etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	2	1	3
61	Intrusive	IN02	Ulrra Basics (Epidiorite, Granophyre etc.) - Weathered, Jointed	Proterozoic to Cenozoic	7	6	8
62	Intrusive	IN02	Ulrra Basics (Epidiorite, Granophyre etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	2	1	3

5.14.3 Norms for Canal Recharge

Unlike other norms, the Recharge factor for calculating Recharge due to canals is given in two units viz. ham/million m² of wetted area/day and cumecs per million m² of wetted area. As all other norms are in ham, the committee recommends the norm in ham/million m² of wetted area for computing the recharge due to canals.

There is a wide variation in the values of the recharge norms proposed by GEC 1997. The Canal seepage norm is approximately 150times the other recharge norms. In the absence of any field studies to refine the norms it is decided by the committee to continue with the same norms. The committee strongly recommends that each state agency must conduct one field study at least one in each district before completing the first assessment using this methodology. The committee also suggests a recommended value and minimum and maximum values as in the case of other norms. Where specific results are available from case studies in some states, the adhoc norms are to be replaced by norms evolved from these results.

The Norms suggested in Table 9 below are nothing but the rationalization and redistribution of norms suggested by GEC-1997 methodology and hence people are encouraged to conduct field studies and strengthen the Norms database.

TABLE9: NORMS RECOMMENDED FOR THE RECHARGE DUE TO CANALS

Formation	Canal Seepage factor ham/day/million Square meters of wetted Area		
	Recommended	Minimum	Maximum
Unlined canals in normal soils with some clay content along with sand	17.5	15	20
Unlined canals in sandy soil with some silt content	27.5	25	30
Lined canals in normal soils with some clay content along with sand	3.5	3	4
Lined canals in sandy soil with some silt content	5.5	5	6
All canals in hard rock area	3.5	3	4

5.14.4 Norms for Recharge Due to Irrigation

The Norms Suggested by GEC-1997 gives for only three ranges of water levels and it creates a problem in the boundary conditions. For instance, as a result of the variation in water level from 24.9 to 25.1m bgl in the adjoining blocks, change occurs in the return flow from irrigation in the range of 10% to 15%. Hence to reduce the discrepancy it is recommended to have linear relationship of the norms in between 10m bgl water level and 25m bgl water level. It is proposed to have the same norm of 10m bgl zone for all the water levels less than 10m. Similarly, the norm recommended for 25m may be used for the water levels more than 25m as well. The Recommended Norms are presented in Table 10.

For surface water, the recharge is to be estimated based on water released at the outlet. For ground water, the recharge is to be estimated based on gross draft. Where continuous supply is used instead of rotational supply, an additional recharge of 5% of application may be used. Where specific results are available from case studies in some states, the adhoc norms are to be replaced by norms evolved from these results.

TABLE10: NORMS RECOMMENDED FOR THE RECHARGE FROM IRRIGATION

DTW m bgl	Ground Water		Surface Water	
	Paddy	Non Paddy	Paddy	Non Paddy
<=10	45	25	50	30
11	43.3	23.7	48.3	28.7
12	41.7	22.3	46.7	27.3
13	40	21	45	26

14	38.3	19.7	43.3	24.7
15	36.7	18.3	41.7	23.3
16	35	17	40	22
17	33.3	15.7	38.3	20.7
18	31.7	14.3	36.7	19.3
19	30	13	35	18
20	28.3	11.7	33.3	16.7
21	26.7	10.3	31.7	15.3
22	25	9	30	14
23	23.3	7.7	28.3	12.7
24	21.7	6.3	26.7	11.3
>=25	20	5	25	10

5.14.5 Norms for Recharge due to Tanks & Ponds

As the data on the field studies for computing recharge from Tanks & Ponds are very limited, it is recommended to follow the same norm as followed in GEC 1997 in future assessments also. Hence the norm recommended by GEC-2015 for Seepage from Tanks & Ponds is 1.4 mm / day.

5.14.6 Norms for Recharge due to Water Conservation Structures

Even though the data on the field studies for computing recharge from Water Conservation Structures are very limited, it is recommended that the Recharge from the water conservation structures is 40% of the Gross Storage based on the field studies by Non Government Organizations. Hence, the norm recommended by GEC-2015 for the seepage from Water Conservation Structures is 40% of gross storage during a year which means 20% during monsoon season and 20% during non-monsoon Season.

5.14.7 Norm for Per Capita Requirement

As the option is given to use the actual requirement for domestic needs, the Requirement Norm recommended by the committee is 60 lpcd for domestic needs. This can be modified if the actual requirement is known.

5.14.8 Norm for Natural Discharges

The Discharge Norm used in computing Unaccounted Natural Discharge is 5% if water table fluctuation method is used or 10% if rainfall infiltration factor method is used for assessing the Rainfall recharge. This committee recommends to compute the base flow for each assessment unit. Wherever, there is no assessment of base flow, earlier norms recommended by GEC 1997 i.e. 5% or 10% of the Total Annual Ground Water Recharge as the Natural Discharges may be continued.

5.14.9 Unit Draft

GEC-1997 methodology recommends to use well census method for computing the ground water draft. The norm used for computing ground water draft is the unit draft. The unit draft can be computed by field studies. This method involves selecting representative abstraction structure and calculating the discharge from that particular type of structure and collecting the information on how many hours of pumping is being done in various seasons and number of such days during each season. The Unit Draft during a particular season can be computed using the following equation:

$$\text{Unit Draft} = \text{Discharge in } m^3/hr \times \text{No. of Pumping hrs in a day} \times \text{No. of days} \quad 38$$

One basic drawback in the methodology of computing unit draft is that there is no normalization procedure for the same. As per GEC-1997 guidelines, the recharge from rainfall is normalized for a normal rainfall. It means that even though the resources are estimated in a surplus rainfall year or in a deficit rainfall year, the assessment is normalised for a normal rainfall which is required for planning. For recharge from other sources, average figures/ values are taken. If the average figures are not available for any reason, 60% of the design figures are taken. This procedure is very much essential as the planning should be for average resources rather than for the recharge due to excess rainfall or deficit rainfall. But the procedure that is being followed for computing unit draft does not have any normalization procedure. Normally, if the year in which one collects the draft data in the field is an excess rainfall year, the abstraction from ground water will be less. Similarly, if the year of the computation of unit draft is a drought year the unit draft will be high. Hence, there is a requirement to devise a methodology that can be used for the normalization of unit draft figures. The following are the two simple techniques, which can be followed. If the unit draft values for one rainfall cycle are available for at least 10 years second method shown in equation 40 is to be followed or else the first method shown in equation 39 may be used.

$$\text{Normalized Unit Draft} = \frac{\text{Unit Draft} \times \text{Rainfall for the Year}}{\text{Normal Rainfall}} \quad 39$$

$$\text{Normalized Unit Draft} = \frac{\sum_{i=1}^n \text{Unit Draft}_i}{\text{Number of Years}} \quad 40$$

Although GEC-1997 methodology recommends a default value for the unit drafts, each State is using its own values, generally after conducting field studies, even though without a

documentation. Hence, it is felt that this norm may be computed by the state agency, which is going to assess the norms before commencement of the assessment. But it is strongly recommended that the field studies should be documented and submitted along with the results of the assessment.

5.15 SUMMARY REPORT OF GROUND WATER ASSESSMENT

A summary for each unit adopted for ground water assessment is to be presented in the formats given in the following tables. These tables should also be accompanied by one graphical plot showing the ground water level trend during pre monsoon and post monsoon seasons for each of the sub unit assessed. The committee also recommends that there should be two reports for each state one with the results of the Dynamic Ground Water Resources which can be used for planning for future ground water management. Whereas the other report should contain the Total Availability of the resources which will indicate the ground water mining taking place in the country for sensitizing stakeholders about the damage being done to the environment and for planning the remedial measures there upon for rectifying the damage.

**TABLE 11: SUMMARY REPORT IN RESPECT OF THE DYNAMIC
GROUND WATER RESOURCES OF EACH GROUND WATER
ASSESSMENT UNIT**

A. Dynamic Ground Water Resources of Unconfined Aquifer:

1. Command and Non - command Areas

S. No.	Description of item	Non - command area		Command area	
		in hectare metres	in mm	in hectare metres	in mm
1	Recharge from 'Rainfall' during monsoon season				
2	Recharge from 'Other Sources' during monsoon season				
3	Resultant Ground Water Inflow during monsoon season				
4	Recharge from 'Rainfall' during non - monsoon season				
5	Recharge from 'Other Sources' during non - monsoon season				
6	Resultant Ground Water Inflow during non-monsoon season				
7	Annual ground water recharge [(1) + (2) + (3) + (4)+(5)+(6)]				
8	Estimated Base Flow Restricted to ecological Flow				
9	If Base flow is estimated separately, Estimated Evapotranspiration Losses				
10	If Base flow is not estimated separately Unaccounted annual natural discharges				
11	Total Natural Discharges [(8)+(9)) or (10)				
12	Annual Extractable Ground Water Resource [(7) - (11)]				
13	Current annual gross ground water extraction for 'All Uses'				
14	Current annual gross ground water extraction for 'Domestic				

S. No.	Description of item	Non - command area		Command area	
		in hectare metres	in mm	in hectare metres	in mm
	Use'				
15	Current annual gross ground water extraction for 'Irrigation'				
16	Current annual gross ground water extraction for 'Industrial use'				
17	Annual ground water allocation for domestic water supply as on 20 25.				
18	Net annual ground water availability for 'Future Use' [(12) - (15) - (16) -(17)]				

S. No.	Description of item	Non - command area	Command area
19	Stage of ground water Extraction as a percentage [$((13)/(12)) * 100$]		
20	Quantity Categorisation for future ground water development (Safe / Semi-Critical/ Critical / Over exploited)		
21	Quality Tagging (if any)		
22	Does the water table during pre and post monsoon seasons show a significant falling trend (Yes / No)		
23	Validation of Assessment Using Ground Water level trends (Valid/ To Be Reassessed)		

2. Poor Ground Water Quality Area

S. No.	Description of item	in hectare metres	in mm
1	Recharge from 'Rainfall' during monsoon season		
2	Recharge from 'Other Sources' during monsoon season		
3	Resultant Ground Water Inflow during monsoon season		
4	Recharge from 'Rainfall' during non - monsoon season		
5	Recharge from 'Other Sources'		

S. No.	Description of item	in hectare metres	in mm
	during non - monsoon season		
6	Resultant Ground Water Inflow during non-monsoon season		
7	Annual ground water recharge [(1) + (2) + (3) + (4) + (5) + (6)]		
8	Estimated Base Flow Restricted to Ecological Flow		
9	If Base flow is estimated separately, Estimated Evapotranspiration Losses		
10	If Base flow is not estimated separately Unaccounted annual natural discharges		
11	Total Natural Discharges [(8)+(9)) or (10)]		
12	Annual Extractable ground water Resource [(7) - (11)]		
13	Current annual gross ground water extraction for 'All Uses'		
14	Current annual gross ground water extraction for 'Domestic Use'		
15	Current annual gross ground water extraction for 'Irrigation'		
16	Current annual gross ground water extraction for 'Industrial use'		
17	Annual ground water allocation for domestic water supply as on 20 25.		
18	Net annual ground water availability for 'Future Use' [(12) - (15) - (16) - (17)]		

S. No	Description of item	Poor Ground Water Quality Area
19	Stage of ground water Extraction as a percentage [((13) / (2) * 100)	
20	Quantity Categorisation for future ground water development (Safe / Semi-Critical/ Critical /	

S. No	Description of item	Poor Ground Water Quality Area
	Over exploited)	
21	Quality Tagging	
22	Does the water table during pre and post monsoon interval show a significant falling trend (Yes / No)	
23	Validation of Assessment Using Ground Water level trends (Valid/ To Be Reassessed)	

3. Potential Resources (If any)in Ground Water Assessment Unit

a.	Potential resource due to Springs in hectare meters	=	
b.	Potential resource in waterlogged and shallow water table areas in hectare metres	=	
c.	Potential resource in flood prone area in hectare metres	=	
d.	Total potential recharge in hectare metres [(a) + (b) + (c)]	=	

B. Dynamic Ground Water Resources of Confined/ Semi-Confined Aquifers: (If the aquifer is being exploited)

S.No	Aquifer Number & Name	Type	Dynamic Ground Water Resources in ham
1			
2			
3			

TABLE 12: SUMMARY REPORT IN RESPECT OF THE TOTAL GROUND WATER AVAILABILITY OF EACH GROUND WATER ASSESSMENT UNIT

A. In storage Ground Water Resources of Unconfined Aquifer in Ground Water Assessment Unit

a.	In storage / Static ground water resource in hectare metres	=	
----	---	---	--

B. In storage Ground Water Resources of Confined/ Semi-Confined Aquifers:

S.No	Aquifer Number & Name	Type	In storage Ground Water Resources in ham
1			
2			
3			

C. Total Extractable Ground Water Availability in the Assessment Unit

S.No	Aquifer Number & Name	Type	Extractable Ground Water Resources in ham
1			
2			
3			

(Note: For Unconfined Aquifer - it is Annual Extractable Ground Water Resources and for other aquifers it is the dynamic resources computed)

D. Total Ground Water Availability in the Assessment Unit

1	Total Extractable Ground Water Resources in ham	:	
2	Total In storage Ground Water Resources in ham	:	
3	Total Ground Water Availability in ham	:	

Apart from this, it is recommended to create a GIS based village wise database of all primary information and data related to estimation of ground water resources. The final output is recommended to be depicted on maps and should be accessible using web based interactive tools.

* * *

6

PROPOSED DATABASE FOR THE ESTIMATION

The database for ground water resource assessment has two components which are equally important viz., data elements like water level, rainfall etc. and the norms like specific yield, rainfall infiltration factor etc. The committee studied the database maintained by the various states. Most of the states maintain their database either in MS-Excel or in MS-Access format. The database capabilities of MS-Excel are limited for handling such a huge database especially for a State or country. Hence it is recommended to use MS-Access for future Ground Water Resources Estimation exercise in all levels from an assessment unit to the country.

6.1 DATA ELEMENTS USED IN THE ASSESSMENT

The detailed guidelines published as an annexure to the GEC 1997 report has meticulously described each of the data element used in the methodology. This helped to clarify the concept behind the computations. However the document failed to specify the structure of data elements and their required precision. There is no common structure of the data elements in GEC 1997 report. Hence it is difficult to combine the data sets to make it a national dataset. The central level expert group during 2009 assessment suggested certain annexure for making a unified database, still the required level of uniformity in the data elements could not be achieved. There is a need to devise the data structure of all the elements with its name, type of data and its precision. The broad data elements used in the ground water resource estimation are given in Table 13:

TABLE 13. BROAD DATA ELEMENTS USED IN THE GROUND WATER RESOURCES ESTIMATION

Component	Parameter	Unit	Data type	Source
Assessment Sub Units	Total Geographic Area	Hectares	Integer	Revenue Census
	Hilly Area	Hectares	Integer	DEM/ Geomorphological Maps
	Poor Ground Water Quality	Hectares	Integer	SGWD

Component	Parameter	Unit	Data type	Source
	Area			
	Command Area	Hectares	Integer	Irrigation Department
	Non Command Area	Hectares	Integer	Irrigation Department
Ground Water Extraction	Well Census	Number	Integer	MI Census
	Number of days	Number	Integer	Field Studies
	Cropping Pattern	Acres	Float(7,2)	Agriculture Department/ Block Office
	Power Consumed	Kilo Watt Hours	Integer	Electricity Department
Base Flow & Recharge From Streams	River Stage	Meters	Float(7,2)	Central Water Commission & Irrigation Department
	River Discharge	Cumecs	Float(7,2)	Central Water Commission & Irrigation Department
	Ground Water Level Heads	Meters	Float(7,2)	CGWB/SGWD
	Transmissivity	Square meters/day	Float(7,2)	CGWB/SGWD
Lateral Flows	Ground Water Level Heads	Meters	Float(7,2)	CGWB/SGWD
	Transmissivity	Square meters/day	Float(7,2)	CGWB/SGWD
	Width of the Seepage Face	Meters	Integer	Field Studies
Vertical Flows	Ground Water Level Heads	Meters	Float(7,2)	CGWB/SGWD
	Hydraulic Conductivity of the Aquitard	meters/day	Float(7,2)	CGWB/SGWD
	Thickness of the Aquitard	Meters	Float(7,2)	Field Studies
Evaporation	Evaporating Area	Hectares	Integer	Field Studies
	Evaporation rate	mm/day	Float(6,2)	IMD
Transpiration	Transpiring Area	Hectares	Integer	Field Studies
	Transpiration rate	mm/day	Float(6,2)	IMD/ Agricultural Universities
Canal Seepage	Reach Length	Meters	Integer	Irrigation Department
	Full Supply Depth	Meters	Float(5,2)	Irrigation Department
	Side Angle	Degrees	Float(5,2)	Irrigation Department
	Base Width	Meters	Float(5,2)	Irrigation Department
	Number of Days	No	Integer	Irrigation Department
Recharge Due	Cropping	Acres	Float(7,2)	Agriculture

Component	Parameter	Unit	Data type	Source
to Ground Water Irrigation	Pattern			Department / Block Office
Recharge Due to Surface Water Irrigation	Design Discharge of the Outlet	Cumecs	Float(6,2)	Irrigation Department
	Number of Days	Number	Integer	Irrigation Department
	Cropping Pattern	Acres	Float(7,2)	Irrigation Department/ Agriculture Department / Block Office
Recharge Due to Tanks/Ponds	Water Spread Area	Hectares	Float(7,2)	Irrigation Department/Remote Sensing
	Number of Days	Number	Integer	Irrigation Department/Remote Sensing
Recharge Due to Water Conservation Structures	Gross Storage	Hectare meters	Float(7,2)	Irrigation Department/Watershed Management
	Number of Refills	Number	Float(3,1)	Irrigation Department/Watershed Management/ Field Studies
Rainfall Infiltration Factor Method	Rainfall	millimeter	Float(5,1)	IMD/Revenue Department
Water Table Fluctuation Method	Water Level	Meter	Float(6,2)	CGWB/SGWD
Allocation	Population as on base year	Number	Integer	Population census
	Population Growth rate	Percent	Float(5,2)	Population census
	Dependency on Ground Water	Ratio	Float(5,2)	Water Supply Departments
Ground Water Level Trend	Water Level	Meters	Float(6,2)	CGWB/SGWD
Apportioning	Block areas	Hectares	Integer	SGWD
In Storage Resources of Unconfined Aquifer	Area	Hectares	Integer	CGWB/SGWD
	Bottom of Dynamic Zone	Meters above MSL	Float(7,2)	CGWB/SGWD
	Bottom of unconfined Aquifer	Meters above MSL	Float(7,2)	CGWB/SGWD
Dynamic Resources of Confined/ semi	Area	Hectares	Integer	CGWB/SGWD
	Pre monsoon Piezometric	Meters above	Float(7,2)	CGWB/SGWD

Component	Parameter	Unit	Data type	Source
confined Aquifer	head.	MSL		
	Post monsoon Piezometric head.	Meters above MSL	Float(7,2)	CGWB/SGWD
In storage Resources of Confined/ semi confined Aquifer	Area	Hectares	Integer	CGWB/SGWD
	Pre monsoon Piezometric head.	Meters above MSL	Float(7,2)	CGWB/SGWD
	Post monsoon Piezometric head.	Meters above MSL	Float(7,2)	CGWB/SGWD
	Bottom of Top Confining Layer	Meters above MSL	Float(7,2)	CGWB/SGWD

Note: The number in the bracket indicates total number of digits and number of required decimals.

6.2 STANDARDIZATION OF DATA ELEMENTS USED IN THE GROUND WATER RESOURCES ESTIMATION

Considering the existing limitations, the committee recommends the following standards and precisions for data elements. This standardization is envisaged to maintain uniformity in reporting and improve comparability of the assessment figures.

6.2.1 Region Specific Data Elements (Chapter - I)

S.No	Parameter	Type	Size	Decimals
1	Predominant Rock Terrain	Text	30	
2	Predominant Monsoon	Text	30	
3	Type of Assessment Unit	Text	10	
4	Ground Water Year	Text	20	
5	Monsoon Season	Text	20	
6	Non Monsoon Season	Text	20	
7	Pre-Monsoon Monitoring Month	Text	10	
8	Post-Monsoon Monitoring Month	Text	10	

6.2.2 Data Elements Pertaining To Sub Units (Chapter - II)

S.No	Parameter	Type	Size	Decimals
1	Toposheet Numbers	Text	50	
2	Starting Latitude	Text	10	
3	Ending Latitude	Text	10	
4	Starting Longitude	Text	10	
5	Ending Longitude	Text	10	
6	Total Area	Number	7	0
7	Hilly Area	Number	7	0
8	Recharge Worthy Area	Number	7	0
9	Poor Ground Water Quality Area	Number	7	0
10	Command Area	Number	7	0
11	Non Command Area	Number	7	0

6.2.3 Data Elements Pertaining to the Estimation of Ground Water Extraction Using Unit Draft Method (Chapter - III)

S.No	Parameter	Type	Size	Decimals
1	Type of Structure	Text	50	
2	Assessment Sub Unit	Text	20	
3	Draft Per day	Number	3	0
4	Monsoon Days	Number	3	0
5	Non Monsoon Days	Number	3	0
6	Monsoon Unit Draft	Number	5	2
7	Non Monsoon Unit Draft	Number	5	2
8	Annual Unit Draft	Number	5	2
9	Extraction Type	Text	10	0
10	Total No. of Structures	Number	5	0
11	Total No. of Structures in Use	Number	5	0
12	Total Structure Monsoon Extraction	Number	7	2
13	Total Structure Non Monsoon Extraction	Number	7	2
14	Total Structure Annual Extraction	Number	7	2
15	Total Sub Unit Monsoon Extraction	Number	7	0
16	Total Sub Unit Non Monsoon Extraction	Number	7	0
17	Total Sub Unit Annual Extraction	Number	7	0
18	Total Sub Unit Domestic Monsoon Extraction	Number	7	0
19	Total Sub Unit Domestic Non Monsoon Extraction	Number	7	0
20	Total Sub Unit Domestic Annual Extraction	Number	7	0
21	Total Sub Unit Irrigation Monsoon Extraction	Number	7	0
22	Total Sub Unit Irrigation Non Monsoon Extraction	Number	7	0
20	Total Sub Unit Irrigation Annual Extraction	Number	7	0
21	Total Sub Unit Industrial Monsoon Extraction	Number	7	0
22	Total Sub Unit Industrial Non Monsoon Extraction	Number	7	0
23	Total Sub Unit Industrial Annual Extraction	Number	7	0
24	Total Sub Unit All Uses Monsoon Extraction	Number	8	0
25	Total Sub Unit All Uses Non Monsoon Extraction	Number	8	0
26	Total Sub Unit All Uses Annual Extraction	Number	8	0
27	Total Sub Unit All Uses Monsoon Extraction m	Number	5	3
28	Total Sub Unit All Uses Non Monsoon Extraction m	Number	5	3
29	Total Sub Unit All Uses Annual Extraction m	Number	5	3

6.2.4 Data Elements Pertaining to the Estimation of Ground Water Extraction Using Crop Water Requirement Method (Chapter - III)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Crop Type	Text	10	
3	Crop Name	Text	20	
4	Crop Season	Text	10	
5	Crop Acreage	Number	8	2
6	Crop Water Requirement	Number	6	2
7	Extraction for the Crop During Monsoon	Number	7	2
8	Extraction for the Crop During Non Monsoon Season	Number	7	2
9	Annual Extraction for the Crop	Number	7	2

S.No	Parameter	Type	Size	Decimals
10	Draft Type	Text	10	0
11	Total Sub Unit Extraction During Monsoon	Number	8	0
12	Total Sub Unit Extraction During Non Monsoon	Number	8	0
13	Total Sub Unit Annual Extraction	Number	8	0

6.2.5 Data Elements Pertaining to the Estimation of Ground Water Extraction Using Power Consumption Method (Chapter - III)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Domestic Power consumption in Monsoon Season	Number	8	0
3	Domestic Power Consumption in Non Monsoon Season	Number	8	0
4	Annual Domestic Power Consumption	Number	8	0
5	Irrigation Power consumption in Monsoon Season	Number	8	0
6	Irrigation Power Consumption in Non Monsoon Season	Number	8	0
7	Irrigation Domestic Power Consumption	Number	8	0
8	Domestic Extraction For Unit Power Consumption During Monsoon Season	Number	7	2
9	Domestic Extraction For Unit Power Consumption During Non Monsoon Season	Number	7	2
10	Irrigation Extraction For Unit Power Consumption During Monsoon Season	Number	7	2
11	Irrigation Extraction For Unit Power Consumption During Non Monsoon Season	Number	7	2
12	Domestic Extraction using Power Consumption During Monsoon	Number	8	0
13	Domestic Extraction using Power Consumption During Non Monsoon	Number	8	0
14	Irrigation Extraction using Power Consumption During Monsoon	Number	8	0
15	Irrigation Extraction using Power Consumption During Non Monsoon	Number	8	0

6.2.6 Data Elements Pertaining to the Estimation of Ground Water Extraction Using Consumptive Use Method (Chapter - III)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Population as on base year	Number	6	0
3	Growth Rate of Population per year	Number	5	0
4	Population as the Assessment Year	Number	6	0
5	Per capita daily requirement for Domestic Needs	Number	3	0
6	Fractional Load on Ground Water	Number	4	2
7	Domestic extraction During Monsoon Season	Number	8	0
8	Domestic extraction During Non Monsoon Season	Number	8	0
9	Annual Domestic extraction	Number	8	0

6.2.7 Data Elements Pertaining to the Estimation of Ground Water Extraction Using Consumptive Use Pattern Method (Chapter - III)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	

S.No	Parameter	Type	Size	Decimals
2	Type of Industry	Text	20	
3	No of Such Units	Number	4	0
4	Ground Water Requirement of the Industry During Monsoon	Number	6	0
5	Ground Water Requirement of the Industry During Non Monsoon	Number	6	0
6	Annual Ground Water Requirement of the Industry	Number	6	0
7	Fractional Load on Ground Water	Number	4	2
8	Industrial Extraction For the Type of Industry During Monsoon Season	Number	8	0
9	Industrial Extraction For the Type of Industry During Monsoon Season	Number	8	0
10	Annual Industrial Extraction For the Type of Industry	Number	8	0
11	Industrial Extraction For the Sub Unit During Monsoon Season	Number	8	0
12	Industrial Extraction For the Sub Unit During Monsoon Season	Number	8	0
13	Annual Industrial Extraction For the Sub Unit	Number	8	0

6.2.8 Data Elements Pertaining to Estimation of Recharge from Canals (Chapter - IV)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Name of Canal Segment	Text	50	
3	Type of Canal	Text	10	
4	Canal Length	Number	6	0
5	Starting Latitude	Text	10	
6	Ending Latitude	Text	10	
7	Starting Longitude	Text	10	
8	Ending Longitude	Text	10	
9	Full Supply Depth	Number	5	2
10	Base Width	Number	5	2
11	Side Slope	Number	4	1
12	Wetted Perimeter	Number	6	2
13	Wetted Area million sq m	Number	8	5
14	Lining	Text	10	
15	Soil Type	Text	10	
16	Canal Seepage factor	Number	4	1
17	Monsoon Days	Number	3	0
18	Non Monsoon Days	Number	3	0
19	Monsoon Canal Recharge	Number	7	2
20	Non Monsoon Canal Recharge	Number	7	2
21	Total Sub Unit Monsoon Canal Recharge	Number	7	0
22	Total Sub Unit Non Monsoon Canal Recharge	Number	7	0
23	Total Sub Unit Annual Canal Recharge	Number	7	0

6.2.9 Data Elements Pertaining to the Estimation of Recharge from Surface Water Irrigation (Chapter - V)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Name of Outlet	Text	50	
3	Name of the Canal	Text	50	
4	Latitude	Text	10	
5	Longitude	Text	10	
6	Design Discharge	Number	6	3
7	Monsoon Days	Number	3	0
8	Non Monsoon Days	Number	3	0
9	Monsoon Water Released	Number	7	2
10	Non Monsoon Water released	Number	7	2
11	Total Sub Unit Monsoon Water Released	Number	7	0
12	Total Sub Unit Non Monsoon Water Released	Number	7	0
13	Total Sub Unit Annual Water Released	Number	7	0
14	Name of the Observation Well	Text	50	
15	Previous Post Monsoon Water level	Number	6	2
16	Current Pre Monsoon Water level	Number	6	2
17	Current Post Monsoon Water level	Number	6	2
18	Average Previous Post Monsoon Water level	Number	6	2
19	Average Current Pre Monsoon Water level	Number	6	2
20	Average Current Post Monsoon Water level	Number	6	2
21	Water level During Monsoon	Number	6	2
22	Water level During Non Monsoon	Number	6	2
23	Name of the Crop	Text	20	
24	Area of Crop Monsoon	Number	7	2
25	Area of Crop Non Monsoon	Number	7	2
26	Total Area of Paddy Monsoon	Number	8	2
27	Total Area of Paddy Non Monsoon	Number	8	2
28	Total Area of Non Paddy Monsoon	Number	8	2
29	Total Area of Non Paddy Non Monsoon	Number	8	2
30	Type of Irrigation Water Monsoon	Text	10	
31	Return Flow Factor Paddy Monsoon	Number	5	2
32	Return Flow Factor Non Paddy Monsoon	Number	5	2
33	Weighted Average Return Flow Factor Monsoon	Number	5	2
34	Type of Irrigation Water Non Monsoon	Text	10	
35	Return Flow Factor Paddy Non Monsoon	Number	5	2
36	Return Flow Factor Non Paddy Non Monsoon	Number	5	2
37	Weighted Average Return Flow Factor Non Monsoon	Number	5	2
38	Total Sub Unit Monsoon Recharge due to SWI	Number	7	0
39	Total Sub Unit Non Monsoon Recharge due to SWI	Number	7	0
40	Total Sub Unit Annual Recharge due to SWI	Number	7	0

6.2.10 Data Elements Pertaining to the Estimation of Recharge from Ground Water Irrigation (Chapter - VI)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Ground Water Applied Monsoon	Number	7	2
3	Ground Water Applied Non Monsoon	Number	7	2
4	Name of the Observation Well	Text	50	
5	Previous Post Monsoon Water level	Number	6	2
6	Current Pre Monsoon Water level	Number	6	2
7	Current Post Monsoon Water level	Number	6	2
8	Average Previous Post Monsoon Water level	Number	6	2
9	Average Current Pre Monsoon Water level	Number	6	2
10	Average Current Post Monsoon Water level	Number	6	2
11	Water level During Monsoon	Number	6	2
12	Water level During Non Monsoon	Number	6	2
13	Name of the Crop	Text	20	
14	Area of Crop Monsoon	Number	7	2
15	Area of Crop Non Monsoon	Number	7	2
16	Total Area of Paddy Monsoon	Number	8	2
17	Total Area of Paddy Non Monsoon	Number	8	2
18	Return Flow Factor Paddy Monsoon	Number	5	2
19	Return Flow Factor Non Paddy Monsoon	Number	5	2
20	Weighted Average Return Flow Factor Monsoon	Number	5	2
21	Return Flow Factor Paddy Non Monsoon	Number	5	2
22	Return Flow Factor Non Paddy Non Monsoon	Number	5	2
23	Weighted Average Return Flow Factor Non Monsoon	Number	5	2
24	Total Sub Unit Monsoon Recharge due to GWI	Number	7	0
25	Total Sub Unit Non Monsoon Recharge due to GWI	Number	7	0
26	Total Sub Unit Annual Recharge due to GWI	Number	7	0

6.2.11 Data Elements Pertaining to the Estimation of Recharge from Tanks & Ponds (Chapter - VII)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Name of Tank	Text	50	
3	Latitude	Text	10	
4	Longitude	Text	10	
5	Year of Construction	Text	9	
6	Monsoon Water Spread Area	Number	5	0
7	Non Monsoon Water Spread Area	Number	5	0
8	Monsoon Days	Number	3	0
9	Non Monsoon Days	Number	3	0
9	Monsoon Recharge TP	Number	7	2
10	Non Monsoon Recharge TP	Number	7	2
11	Total Sub Unit Monsoon Recharge TP	Number	7	0
12	Total Sub Unit Non Monsoon Recharge TP	Number	7	0
13	Total Sub Unit Annual Recharge TP	Number	7	0

6.2.12 Data Elements Pertaining to the Estimation of Recharge from Water Conservation Structures (Chapter - VIII)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Name of Water Conservation Structure	Text	50	
3	Type of Water Conservation Structure	Text	20	
4	Latitude	Text	10	
5	Longitude	Text	10	
6	Year of Construction	Text	9	
7	Storage Capacity	Number	5	0
8	No Fillings	Number	3	1
9	Gross Storage	Number	6	0
10	Monsoon Recharge WCS	Number	7	2
11	Non Monsoon Recharge WCS	Number	7	2
12	Total Sub Unit Monsoon Recharge WCS	Number	7	0
13	Total Sub Unit Non Monsoon Recharge WCS	Number	7	0
14	Total Sub Unit Annual Recharge WCS	Number	7	0

6.2.13 Data Elements Pertaining to the Estimation of Recharge from Other Sources (Chapter - IX)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Total Sub Unit Monsoon Canal Recharge	Number	7	0
3	Total Sub Unit Non Monsoon Canal Recharge	Number	7	0
4	Total Sub Unit Annual Canal Recharge	Number	7	0
5	Total Sub Unit Monsoon Recharge due to SWI	Number	7	0
6	Total Sub Unit Non Monsoon Recharge due to SWI	Number	7	0
7	Total Sub Unit Annual Recharge due to SWI	Number	7	0
8	Total Sub Unit Monsoon Recharge due to GWI	Number	7	0
9	Total Sub Unit Non Monsoon Recharge due to GWI	Number	7	0
10	Total Sub Unit Annual Recharge due to GWI	Number	7	0
11	Total Sub Unit Monsoon Recharge TP	Number	7	0
12	Total Sub Unit Non Monsoon Recharge TP	Number	7	0
13	Total Sub Unit Annual Recharge TP	Number	7	0
14	Total Sub Unit Monsoon Recharge WCS	Number	7	0
15	Total Sub Unit Non Monsoon Recharge WCS	Number	7	0
16	Total Sub Unit Annual Recharge WCS	Number	7	0
17	Total Sub Unit Monsoon Recharge Other Sources	Number	8	0
18	Total Sub Unit Non Monsoon Recharge Other Sources	Number	8	0
19	Total Sub Unit Annual Recharge Other Sources	Number	8	0

6.2.14 Data Elements Pertaining to Estimation of Lateral Flow (Chapter - X)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Through Flow section ID	Text	20	
3	Average Hydraulic gradient Through seepage face During monsoon Season	Number	7	2
4	Average Hydraulic gradient Through seepage face During Non-Monsoon Season	Number	7	2

5	Transmissivity of the Aquifer	Number	8	2
6	Length of Seepage Section	Number	8	2
7	Through flow During Monsoon Season	Number	8	0
8	Through flow During Non-Monsoon Season	Number	8	0
9	Sub Unit Resultant Through flow During Monsoon Season	Number	8	0
10	Sub Unit Resultant Through flow During Non-Monsoon Season	Number	8	0

6.2.15 Data Elements Pertaining to Estimation of Vertical Flow (Chapter -XI)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Leakage section ID	Text	20	
3	Average Head in the Aquifer During monsoon Season	Number	7	2
4	Average Head in the Aquifer During Non-Monsoon Season	Number	7	2
5	Average Head in the Top/Bottom Aquifer During Monsoon Season	Number	7	2
6	Average Head in the Top/Bottom Aquifer During Non-Monsoon Season	Number	7	2
7	Hydraulic Conductivity of the Aquitard	Number	8	2
8	Thickness of the Aquitard	Number	8	2
9	Seepage Effected Area	Number	7	0
10	Vertical flow During Monsoon Season	Number	8	0
11	Vertical flow During Non-Monsoon Season	Number	8	0
12	Sub Unit Resultant Vertical flow During Monsoon Season	Number	8	0
13	Sub Unit Resultant Vertical flow During Non-Monsoon Season	Number	8	0

6.2.16 Data Elements Pertaining to Estimation of Base Flow(Chapter - XII)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	River Segment ID	Text	20	
3	Stream Flow	Number	8	2
4	Base Flow	Number	8	2
5	Total Base flow During Monsoon Season	Number	9	2
6	Total Base flow During Non-Monsoon Season	Number	9	2
7	Sub Unit Base flow During Monsoon Season	Number	9	2
8	Sub Unit Base flow During Non Monsoon Season	Number	9	2

6.2.17 Data Elements Pertaining to Estimation of Recharge from Streams (Chapter - XIII)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Flow section ID	Text	20	
3	Average Head in the Aquifer During monsoon Season	Number	7	2
4	Average Head in the Aquifer During Non-Monsoon Season	Number	7	2
5	Average Stage in the Stream During Monsoon Season	Number	7	2
6	Average Stage in the Stream During Non-Monsoon Season	Number	7	2
7	Transmissivity of the Aquifer	Number	8	2

8	Length of Recharge Section During Monsoon Season	Number	8	2
9	Length of Recharge Section During Non-Monsoon Season	Number	8	2
10	Recharge Due to Streams During Monsoon Season	Number	8	0
11	Recharge Due to Streams During Non-Monsoon Season	Number	8	0
12	Sub Unit Resultant Recharge Due to Streams During Monsoon Season	Number	8	0
13	Sub Unit Resultant Recharge Due to Streams During Non-Monsoon Season	Number	8	0

6.2.18 Data Elements Pertaining to Evaporation & Transpiration (Chapter - XIV)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Evaporating Area During Monsoon Season	Number	7	0
3	Evaporating Area During Non Monsoon Season	Number	7	0
4	Evaporation Rate During Monsoon Season	Number	7	2
5	Evaporation Rate During Non Monsoon Season	Number	7	2
6	Sub Unit Evaporation During Monsoon Season	Number	8	0
7	Sub Unit Evaporation During Monsoon Season	Number	8	0
8	Transpiring Area During Monsoon Season	Number	7	0
9	Transpiring Area During Non Monsoon Season	Number	7	0
10	Transpiration Rate During Monsoon Season	Number	7	2
11	Transpiration Rate During Non Monsoon Season	Number	7	2
12	Sub Unit Transpiration During Monsoon Season	Number	8	0
13	Sub Unit Transpiration During Non Monsoon Season	Number	8	0

6.2.19 Data Elements Pertaining to the Estimation of Rainfall Recharge By Rainfall Infiltration Factor Method (Chapter - XV)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Name of Raingauge	Text	50	
3	Latitude	Text	10	
4	Longitude	Text	10	
5	No. of Years Data Available	Number	3	0
6	Start Year	Number	4	0
7	End Year	Number	4	0
8	Normal Monsoon Rainfall	Number	7	2
9	Normal Non Monsoon Rainfall	Number	7	2
10	Normal Annual Rainfall	Number	7	2
11	Average Normal Monsoon Rainfall	Number	7	2
12	Average Normal Non Monsoon Rainfall	Number	7	2
13	Average Normal Annual Rainfall	Number	7	2
14	Percentage of Non Monsoon rainfall	Number	5	2
15	Predominant Rock Terrain	Text	30	
16	Geographic location	Text	20	
17	Hard rock type	Text	30	
18	Watershed Development Activity Present	Logical		
19	Rainfall Infiltration Factor	Number	5	2
20	Area	Number	7	0
11	Total Sub Unit Monsoon RF Recharge RFIF	Number	8	0
12	Total Sub Unit Non Monsoon RF Recharge RFIF	Number	8	0

S.No	Parameter	Type	Size	Decimals
13	Total Sub Unit Annual RF Recharge RFIF	Number	8	0
14	Total Sub Unit Monsoon RF Recharge RFIF m	Number	7	3
15	Total Sub Unit Non Monsoon RF Recharge RFIF m	Number	7	3
16	Total Sub Unit Annual RF Recharge RFIF m	Number	7	3

6.2.20 Data Elements Pertaining to the Estimation of Rainfall Recharge by Ground Water Level Fluctuation Method (Chapter - XVI)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Name of Raingauge	Text	50	
3	Current year Monsoon Rainfall	Number	7	2
4	Average Current Year Monsoon Rainfall	Number	7	2
5	Name of Observation well	Text	50	
6	Current year Pre Monsoon WL	Number	6	2
7	Current year Post Monsoon WL	Number	6	2
8	Average Current Year Pre Monsoon WL	Number	6	2
9	Average Current Year Post Monsoon WL	Number	6	2
10	Average Current Year WL Fluctuation	Number	6	2
11	Predominant Rock Terrain	Text	30	
12	Soil Type	Text	20	
13	Hard rock type	Text	30	
14	Specific Yield	Number	5	2
15	Area	Number	7	0
16	Total Sub Unit Monsoon Recharge Other Sources	Number	8	0
17	Total Sub Unit All Uses Monsoon Draft	Number	8	0
18	Total Sub Unit Monsoon Change in GW Storage	Number	8	0
19	Total Sub Unit Monsoon RF Recharge WTFM	Number	8	0
20	Ground Water year	Number	4	0
21	Monsoon Rainfall m	Number	7	3
22	Corresponding Monsoon RF Recharge WTFM THam	Number	7	3
23	Deviation Monsoon RF with Normal	Number	5	2
24	Normal RF Recharge $Y=mX$	Number	7	3
25	Average Normal RF Recharge $Y=mX$	Number	7	3
26	Rainfall Square	Number	7	3
27	Product of Rainfall and Recharge	Number	7	3
28	Sum Rainfall	Number	7	3
29	Sum Recharge	Number	7	3
30	Sum Rainfall Square	Number	7	3
31	Sum Product	Number	7	3
32	Number of Data Points	Number	2	0
33	Slope	Number	7	3
34	Intercept	Number	7	3
35	Normal RF Recharge $Y=mX+C$	Number	7	3
36	Percent Difference	Number	6	2
37	Noramalized RF Recharge	Number	7	0
38	Final RF Recharge Monsoon	Number	7	0
39	Final RF Recharge Monsoon m	Number	7	3
40	Final RF Recharge Non Monsoon	Number	7	0
41	Final RF Recharge Non Monsoon m	Number	7	3
42	Final RF Recharge Annual	Number	7	0
43	Final RF Recharge Annual m	Number	7	3

6.2.21 Data Elements Pertaining to the Estimation of Annual Extractable Ground Water Resources (Chapter - XVII)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Total Sub Unit Monsoon Recharge Other Sources	Number	8	0
3	Total Sub Unit Non Monsoon Recharge Other Sources	Number	8	0
4	Total Sub Unit Annual Recharge Other Sources	Number	8	0
5	Total Sub Unit Resultant Inflows During Monsoon Season	Number	8	0
6	Total Sub Unit Resultant Inflows During Non Monsoon Season	Number	8	0
7	Final RF Recharge Monsoon	Number	7	0
8	Final RF Recharge Non Monsoon	Number	7	0
9	Final RF Recharge Annual	Number	7	0
10	Total Annual Ground Water recharge	Number	8	0
11	Base Flows restricting to Ecological Flows	Number	8	0
12	Unaccounted Natural Discharges	Number	8	0
13	Annual Extractable Ground Water Resources	Number	8	0
11	Area	Number	7	0
12	Annual Extractable Ground Water Resources	Number	8	0

6.2.22 Data Elements Pertaining to the Estimation of Stage of Ground Water Extraction (Chapter - XVIII)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Annual Extractable Ground Water Resource	Number	8	0
3	Total Sub Unit All Uses Annual Extraction	Number	8	0
4	Stage of Ground Water Extraction	Number	6	2

6.2.23 Data Elements Pertaining to the Estimation of Ground Water Level Trends (Chapter - XIX)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Name of Observation Well	Text	50	
3	Latitude	Text	10	
4	Longitude	Text	10	
5	No of Years Data Available	Number	3	0
6	Start Year	Number	4	0
7	End Year	Number	4	0
8	Year	Number	4	0
9	Pre-Monsoon Water Level	Number	6	2
10	Post-Monsoon Water Level	Number	6	2
11	Year X	Number	2	0
12	WL	Number	6	2
13	Year X Square	Number	4	0
14	Product of Year and WL	Number	7	3
15	Sum Year X	Number	7	3
16	Sum WL	Number	7	3
17	Sum Year X Square	Number	7	3

18	Sum Product	Number	7	3
19	Number of Data Points	Number	2	0
20	Slope	Number	7	3
21	Intercept	Number	7	3
22	Trend	Text	20	
23	Stage of Ground Water extraction	Number	6	2
24	Validity	Text	10	

6.2.24 Data Elements Pertaining to the Categorization (Chapter - XX)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Stage of Ground Water Extraction	Number	6	2
3	Validity	Text	10	
4	Quantity Category	Text	20	
5	Quality Tag	Text	10	

6.2.25 Data Elements Pertaining to the Allocation (Chapter - XXI)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Population	Number	7	0
3	Year of Census	Number	4	0
4	Growth Rate	Number	5	2
5	Projected Population	Number	7	0
6	Dependency on GW	Number	3	2
7	Percapita requirement	Number	3	0
8	Annual Allocation	Number	8	0
9	Area	Number	7	0
10	Annual Allocation m	Number	7	3

6.2.26 Data Elements Pertaining to the Estimation of Net Ground Water Availability for Future Use (Chapter - XXII)

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Area	Number	7	0
3	Annual Extractable Ground Water Resource	Number	8	0
4	Total Sub Unit Irrigation Annual Extraction	Number	7	0
5	Total Sub Unit Industrial Annual Extraction	Number	7	0
5	Annual Allocation for Domestic needs	Number	8	0
6	Net Ground Water Availability For Future Use	Number	8	0
7	Net Ground Water Availability For Future Use m	Number	7	3

6.2.27 Data Elements Pertaining to the Estimation of Additional Potential Resources (Chapter - XXIII)

S.No	Parameter	Type	Size	Decimals
1	Assessment Unit	Text	20	
2	Spring discharge During Monsoon	Number	5	2
3	Spring Discharge During Non Monsoon	Number	5	2

4	Average Monsoon Days Spring Yields in the unit	Number	3	0
5	Average Non Monsoon Days Spring Yields in the unit	Number	3	0
6	Annual Spring Discharge in the Unit	Number	5	2
7	No of Such Springs in the Unit	Number	4	0
8	Potential resource Due to Spring Discharges	Number	8	0
9	Water Logged Area	Number	7	0
10	Average Depth to Water level	Number	6	2
11	Specific Yield	Number	5	2
12	Potential Resources Shallow WT	Number	8	0
13	Flood Prone Area	Number	7	0
14	No of Days Area is Submerged	Number	3	0
15	Potential Resources in Flood Prone Areas	Number	8	0
16	Total Potential Resources	Number	8	0

6.2.28 Data Elements Pertaining to the Dynamic Ground Water Resources of Confined/ Semi-Confined Aquifer (Chapter - XXIV)

S.No	Parameter	Type	Size	Decimals
1	Name of the Assessment Unit	Text	20	
2	Area of the Confined Aquifer	Number	7	0
3	Storativity	Number	10	8
4	Pre monsoon Piezometric head	Number	7	2
5	Post monsoon Piezometric head	Number	7	2
6	Total Dynamic Resource of Confined Aquifer	Number	8	0

6.2.29 Data Elements Pertaining to the Preparation of Summary Report (Chapter - XXV)

S.No	Parameter	Type	Size	Decimals
1	State	Text	50	
2	Assessment Unit	Text	20	
3	Type of Assessment Unit	Text	20	
4	Predominant Rock Terrain	Text	30	
5	Total Area	Number	7	0
6	Poor Ground Water Quality Area	Number	7	0
7	Command Area	Number	7	0
8	Non Command Area	Number	7	0
9	Ground Water Assessment year	Text	9	0
10	Final Monsoon Recharge Other Sources NC	Number	8	0
11	Final Non Monsoon Recharge Other Sources NC	Number	8	0
12	Base Flow During Monsoon NC	Number	8	0
13	Recharge Due to Streams Monsoon NC	Number	8	0
14	Lateral Flows During Monsoon NC	Number	8	0
15	Vertical Flows During Monsoon NC	Number	8	0
16	Evaporation During Monsoon NC	Number	8	0
17	Transpiration During Monsoon NC	Number	8	0
18	Recharge Due to Streams Non Monsoon NC	Number	8	0
19	Lateral Flows During Non Monsoon NC	Number	8	0
20	Vertical Flows During Non Monsoon NC	Number	8	0
21	Evaporation During Non Monsoon NC	Number	8	0
22	Transpiration During Non Monsoon NC	Number	8	0
23	Final RF Recharge Monsoon NC	Number	7	0

S.No	Parameter	Type	Size	Decimals
24	Final RF Recharge Non Monsoon NC	Number	7	0
25	Total Annual Ground Water recharge NC	Number	8	0
26	Unaccounted Natural Discharges NC	Number	8	0
27	Annual Extractable Ground Water Recharge NC	Number	8	0
28	Total Sub Unit All Uses Annual Extraction NC	Number	8	0
29	Stage of Ground Water Extraction NC	Number	6	2
30	Total Sub Unit Irrigation Annual Extraction NC	Number	8	0
31	Total Sub Unit Industrial Annual Extraction NC	Number	8	0
32	Annual Allocation NC	Number	8	0
33	Net Ground Water Availability For Future Use NC	Number	8	0
34	Final Monsoon Recharge Other Sources C	Number	8	0
35	Final Non Monsoon Recharge Other Sources C	Number	8	0
36	Recharge Due to Streams Monsoon C	Number	8	0
37	Lateral Flows During Monsoon C	Number	8	0
38	Vertical Flows During Monsoon C	Number	8	0
39	Evaporation During Monsoon C	Number	8	0
40	Transpiration During Monsoon C	Number	8	0
41	Recharge Due to Streams Non Monsoon C	Number	8	0
42	Lateral Flows During Non Monsoon C	Number	8	0
43	Vertical Flows During Non Monsoon C	Number	8	0
44	Evaporation During Non Monsoon C	Number	8	0
45	Transpiration During Non Monsoon C	Number	8	0
46	Final RF Recharge Monsoon C	Number	8	0
47	Final RF Recharge Non Monsoon C	Number	8	0
48	Total Annual Ground Water recharge C	Number	8	0
49	Unaccounted Natural Discharges C	Number	8	0
50	Annual Extractable Ground Water Recharge C	Number	8	0
51	Total Sub Unit All Uses Annual Extraction C	Number	8	0
52	Stage of Ground Water Extraction C	Number	6	2
53	Total Sub Unit Irrigation Annual Extraction C	Number	8	0
54	Total Sub Unit Industrial Annual Extraction C	Number	8	0
55	Annual Allocation C	Number	8	0
56	Net Ground Water Availability For Future Use C	Number	8	0
57	WTFM Used NC	Logical	1	
58	WTFM Used C	Logical	1	
59	Method For SY Determination NC	Text	20	
60	Method For SY Determination C	Text	20	
61	Declining Pre and Post WL NC	Logical		
62	Category NC	Text	15	
63	Validity NC	Text	10	
64	Declining Pre and Post WL C	Logical		
65	Category C	Text	15	
66	Validity C	Text	10	
67	Final Monsoon Recharge Other Sources PQ	Number	8	0
68	Final Non Monsoon Recharge Other Sources PQ	Number	8	0
69	Recharge Due to Streams Monsoon PQ	Number	8	0
70	Lateral Flows During Monsoon PQ	Number	8	0
71	Vertical Flows During Monsoon PQ	Number	8	0
72	Evaporation During Monsoon PQ	Number	8	0
73	Transpiration During Monsoon PQ	Number	8	0
74	Recharge Due to Streams Non Monsoon PQ	Number	8	0
75	Lateral Flows During Non Monsoon PQ	Number	8	0
76	Vertical Flows During Non Monsoon PQ	Number	8	0

S.No	Parameter	Type	Size	Decimals
77	Evaporation During Non Monsoon PQ	Number	8	0
78	Transpiration During Non Monsoon PQ	Number	8	0
79	Final RF Recharge Monsoon PQ	Number	7	0
80	Final RF Recharge Non Monsoon PQ	Number	7	0
81	Total Annual Ground Water Recharge PQ	Number	8	0
82	Unaccounted Natural Discharges PQ	Number	8	0
83	Annual Extractable Ground Water Recharge PQ	Number	8	0
84	Total Sub Unit Irrigation Annual Extraction PQ	Number	8	0
85	Total Sub Unit Industrial Annual Extraction PQ	Number	8	0
86	Net Ground Water Availability For Future Use PQ	Number	8	0
87	WTFM Used PQ	Logical	1	
88	Method For SY Determination PQ	Text	20	
89	Declining Pre and Post WL PQ	Logical		
90	Category PQ	Text	15	
91	Validity PQ	Text	10	
92	Potential Resources Due to Spring Discharges	Number	8	0
93	Potential Resources Due to Shallow WT	Number	8	0
94	Potential Resources Due to Flood Prone Area	Number	8	0
95	Total Potential Resources	Number	8	0

6.230. Data Elements Pertaining to the Apportioning (Chapter - XXVI)

S.No	Parameter	Type	Size	Decimals
1	State	Text	50	
2	Administrative Unit	Text	20	
3	Type of Administrative Unit	Text	20	
4	Toposheet Numbers	Text	50	
5	Starting Latitude	Text	10	
6	Ending Latitude	Text	10	
7	Starting Longitude	Text	10	
8	Ending Longitude	Text	10	
9	Total Area	Number	7	0
10	Hilly Area	Number	7	0
11	Recharge Worthy Area	Number	7	0
12	Poor Ground Water Quality Area	Number	7	0
13	Command Area	Number	7	0
14	Non Command Area	Number	7	0
15	Name of the Assessment Unit	Text	20	
16	Annual Extractable Ground Water Recharge NC	Number	8	0
17	Area of Assessment Sub Unit in the Admin Unit NC	Number	7	0
18	Annual Extractable Ground Water Recharge in Admin NC	Number	8	0
19	Total Area of Assessment Unit in the Admin Unit NC	Number	7	0
20	Total Annual Extractable Ground Water Recharge in Admin NC	Number	8	0
21	Total Annual Extractable Ground Water Recharge in Admin NC m	Number	8	3
22	Sub Unit All Uses Annual Extraction NC	Number	8	0
23	Sub Unit All Uses Annual Extraction in Admin NC	Number	8	0
24	Total Sub Unit All Uses Annual Extraction Admin NC	Number	8	0
25	Total Sub Unit All Uses Annual Extraction Admin NC m	Number	8	3
26	Sub Unit Irrigation Annual Extraction NC	Number	8	0
27	Sub Unit Irrigation Annual Extraction in Admin NC	Number	8	0
28	Total Sub Unit Irrigation Annual Extraction Admin NC	Number	8	0

S.No	Parameter	Type	Size	Decimals
29	Total Sub Unit Irrigation Annual Extraction Admin NC m	Number	8	3
30	Sub Unit Industrial Annual Extraction NC	Number	8	0
31	Sub Unit Industrial Annual Extraction in Admin NC	Number	8	0
32	Total Sub Unit Industrial Annual Extraction Admin NC	Number	8	0
33	Total Sub Unit Industrial Annual Extraction Admin NC m	Number	8	3
34	Sub Unit Allocation NC	Number	8	0
35	Sub Unit Allocation in Admin NC	Number	8	0
36	Total Sub Unit Allocation Admin NC	Number	8	0
37	Total Sub Unit Allocation Admin NC m	Number	8	3
38	Sub Unit Pretrend NC	Number	8	0
39	Sub Unit Pretrend in Admin NC	Number	8	0
40	Total Sub Unit Pretrend Admin NC	Number	8	0
41	Sub Unit Posttrend NC	Number	8	0
42	Sub Unit Pretrend in Admin NC	Number	8	0
43	Total Sub Unit Posttrend Admin NC	Number	8	0
44	Stage of Ground Water Extraction NC	Number	6	2
45	Annual Extractable Ground Water Resource C	Number	8	0
46	Area of Assessment Sub Unit in the Admin Unit C	Number	7	0
47	Annual Extractable Ground Water Resource in Admin C	Number	8	0
48	Total Area of Assessment Unit in the Admin Unit C	Number	7	0
49	Total Annual Extractable Ground Water Resource in Admin C	Number	8	0
50	Total Annual Extractable Ground Water Resource in Admin C m	Number	8	3
51	Sub Unit All Uses Annual Extraction C	Number	8	0
52	Sub Unit All Uses Annual Extraction in Admin C	Number	8	0
53	Total Sub Unit All Uses Annual Extraction Admin C	Number	8	0
54	Total Sub Unit All Uses Annual Extraction Admin C m	Number	8	3
55	Sub Unit Irrigation Annual Extraction C	Number	8	0
56	Sub Unit Irrigation Annual Extraction in Admin C	Number	8	0
57	Total Sub Unit Irrigation Annual Extraction Admin C	Number	8	0
58	Total Sub Unit Irrigation Annual Extraction Admin C m	Number	8	3
59	Sub Unit Industrial Annual Extraction C	Number	8	0
60	Sub Unit Industrial Annual Extraction in Admin C	Number	8	0
61	Total Sub Unit Industrial Annual Extraction Admin C	Number	8	0
62	Total Sub Unit Industrial Annual Extraction Admin C m	Number	8	3
63	Sub Unit Allocation C	Number	8	0
64	Sub Unit Allocation in Admin C	Number	8	0
65	Total Sub Unit Allocation Admin C	Number	8	0
66	Total Sub Unit Allocation Admin C m	Number	8	3
67	Sub Unit Pretrend C	Number	8	0
68	Sub Unit Pretrend in Admin C	Number	8	0
69	Total Sub Unit Pretrend Admin C	Number	8	0
70	Sub Unit Posttrend C	Number	8	0
71	Sub Unit Pretrend in Admin C	Number	8	0
72	Total Sub Unit Posttrend Admin C	Number	8	0
73	Stage of Ground Water Extraction C	Number	6	2
74	Annual Extractable Ground Water Resource PQ	Number	8	0
75	Area of Assessment Sub Unit in the Admin Unit PQ	Number	7	0
76	Annual Extractable Ground Water Resource in Admin PQ	Number	8	0
77	Total Area of Assessment Unit in the Admin Unit PQ	Number	7	0

S.No	Parameter	Type	Size	Decimals
78	Total Annual Extractable Ground Water Resource in Admin PQ	Number	8	0
79	Total Annual Extractable Ground Water Resource in Admin PQ m	Number	8	3
80	Sub Unit All Uses Annual Extraction PQ	Number	8	0
81	Sub Unit All Uses Annual Extraction in Admin PQ	Number	8	0
82	Total Sub Unit All Uses Annual Extraction Admin PQ	Number	8	0
83	Total Sub Unit All Uses Annual Extraction Admin PQ m	Number	8	3
84	Sub Unit Irrigation Annual Extraction PQ	Number	8	0
85	Sub Unit Irrigation Annual Extraction in Admin PQ	Number	8	0
86	Total Sub Unit Irrigation Annual Extraction Admin PQ	Number	8	0
87	Total Sub Unit Irrigation Annual Extraction Admin PQ m	Number	8	3
88	Sub Unit Industrial Annual Extraction PQ	Number	8	0
89	Sub Unit Industrial Annual Extraction in Admin PQ	Number	8	0
90	Total Sub Unit Industrial Annual Extraction Admin PQ	Number	8	0
91	Total Sub Unit Industrial Annual Extraction Admin PQ m	Number	8	3
92	Sub Unit Allocation PQ	Number	8	0
93	Sub Unit Allocation in Admin PQ	Number	8	0
94	Total Sub Unit Allocation Admin PQ	Number	8	0
95	Total Sub Unit Allocation Admin PQ m	Number	8	3
96	Sub Unit Pre trend PQ	Number	8	0
97	Sub Unit Pre trend in Admin PQ	Number	8	0
98	Total Sub Unit Pre trend Admin PQ	Number	8	0
99	Sub Unit Post trend PQ	Number	8	0
100	Sub Unit Post trend in Admin PQ	Number	8	0
101	Total Sub Unit Post trend Admin PQ	Number	8	0
102	Stage of Ground Water Extraction PQ	Number	6	2

6.2.31 Data Elements Pertaining to the Static/ In Storage Ground Water Resources of Unconfined Aquifer (Chapter - XXVII)

S.No	Parameter	Type	Size	Decimals
1	Name of the Assessment Unit	Text	20	
2	Static Resources Area	Number	7	0
3	Average Depth of Fluctuation	Number	6	2
4	Bottom of Aquifer	Number	7	2
5	Bottom of Aquifer for Computation	Number	7	2
6	Specific Yield	Number	5	2
7	Total Static Resources Unconfined	Number	8	0

6.2.32 Data Elements Pertaining to the In storage Ground Water Resources of Confined/ Semi-Confined Aquifer (Chapter - XXVIII)

S.No	Parameter	Type	Size	Decimals
1	Name of the Assessment Unit	Text	20	
2	Area of the Confined Aquifer	Number	7	0
3	Storativity	Number	10	8
4	Pre monsoon Piezometric head	Number	7	2
5	Post monsoon Piezometric head	Number	7	2

S.No	Parameter	Type	Size	Decimals
6	Bottom of Top Confined Layer	Number	7	2
6	Total In Storage Resource of Confined Aquifer	Number	8	0

6.2.33 Data Elements Pertaining to the Total Ground Water Availability (Chapter - XXIX)

S.No	Parameter	Type	Size	Decimals
1	Name of the Assessment Unit	Text	20	
2	Annual Extractable Ground Water Resource	Number	8	0
3	In storage Ground Water Resources of Unconfined Aquifer	Number	8	0
4	Total Ground Water Availability of Unconfined Aquifer	Number	8	0
5	Dynamic Ground Water Resources of Confined Aquifers	Number	8	0
6	In storage Ground Water Resources of Confined Aquifers	Number	8	0
7	Total Ground Water Availability of Confined Aquifers	Number	8	0
8	Dynamic Ground Water Resources of Semi-Confined Aquifers	Number	8	0
9	In storage Ground Water Resources of Semi-Confined Aquifers	Number	8	0
10	Total Ground Water Availability of Semi-Confined Aquifers	Number	8	0
11	Total Ground Water Availability of the Assessment Unit	Number	8	0

6.3 NORMS USED IN THE RESOURCE ESTIMATION

In assessing the ground water resources five categories of norms are being used as recommended by the current methodology. These are Storage Norms, Infiltration Norms, Abstraction Norms, Requirement Norms and Discharge Norms. The storage norm is represented as specific yield, which is expressed as a fraction or percent. The requirement norm for the domestic and industrial water requirement is expressed in litres per capita per day (lpcd). The abstraction norm is expressed in hectare metres (ham). The discharge norm is expressed as a percentage. The Infiltration norms which make a major chunk of the norms are expressed as percent as in the case of Rainfall Infiltration Factor, Return Flow Factor for irrigation and Seepage Factor for water conservation structures. In the case of Return Flow Factor for tanks and ponds it is expressed as mm/day and as ham/day/million m² of wetted area for the Canal Seepage Factor. The different norms proposed for ground water resource estimation is given in Table 14.

**TABLE14. TYPES OF NORMS USED IN THE GROUND WATER
RESOURCE ESTIMATION USING GEC-2015.**

Type Of Norm	Parameter	Unit
Storage Norm	Specific Yield	Percent
Infiltration Norms	Rainfall Infiltration Factor	Percent
	Canal Seepage	Ham/day/10 ⁶ m ² of wetted area
	Return Flow Factor For Irrigation	Percent
	Infiltration Factor For Tanks & Ponds	mm/day
	Seepage Factor For Water Conservation Structures	Percent
Requirement Norms	Per capita Requirement For Domestic and Industrial Needs	lpcd
Abstraction Norm	Unit Draft	Ham
Discharge Norm	Unaccounted Natural Discharges	Percent

* * *

7

FUTURE STRATEGIES***7.1 REFINEMENTS TO THE RECOMMENDED METHODOLOGY*****7.1.1 Introduction**

The methodology for ground water resource estimation as described in Chapter 5 is based on relatively sound scientific basis. It also meets the practical requirements for formulating rational ground water development strategies. This methodology commensurate with available human resources, their level of technical skills and infrastructure facilities available with the state level ground water organisations for formulating rational ground water development strategies. However, the methodology still has considerable scope for refinement and improvement which can be planned and achieved in a time bound and phased manner for future assessments. Some of these essential refinements are briefly described below.

7.1.2 Aquifer wise Assessment

One of the major recommendations in the present (GEC-2015) methodology is to assess the ground water resources aquifer wise. The major issues are estimating recharge for shallow aquifer, extraction for the deeper aquifer and categorization of assessment units based on the results so obtained. It is recommended that ground water resources may be assessed to a depth of 100m in hard rock areas and 300m in soft rock areas till the aquifer geometry is completely established throughout the country through aquifer mapping.

7.1.3 Switching Over to Watershed as an assessment unit in areas other than alluvium

As per the recommendations of GEC-97, watershed should be taken as the assessment unit in areas other than alluvium. However, even now many states dominated by hard rock areas are still assessing the resources administrative unit wise. Hence, GEC 2015 also recommends a switch over to watershed as the unit for resource assessment in the areas dominated by lithology other than Alluvium.

7.1.4 Employing Remote Sensing Techniques

Remote sensing techniques can be profitably employed for quantifying various components of the methodology described in Chapter 5. The Digital Elevation Models (DEM) DEM data can be utilized for delineating hilly areas where slope is more than 20%. If the temporal data of the area is available, these techniques can also be used for delineating the water spread area of tanks & ponds and the number of days water is available in such structures. Similarly the technique can also be used for assessing the cropped area and the mode of irrigation (either ground water or surface water) predominantly employed.

7.1.5 Computerization of the Ground Water Resource Estimation Methodology

In most states, the application of the methodology for ground water resource estimation is predominantly carried out using MS-Excel or MS-Access. Even though automated system like GWA Module in GEMS is available, it is not utilized to the fullest due to lack of basic knowledge of the system in a client-server environment and Oracle database. Hence, there is a need to develop a simple, user friendly application that can be used even in the basic models of personal computers.

7.1.6 Data monitoring

The availability of adequate data is the key to the successful application of GEC-2015 methodology of ground water resource estimation as given in Chapter 5. This will be achieved when a switch over is made to an aquifer wise assessment and all the components in the ground water balance equation are utilized. Following are the prerequisites:

- Aquifer mapping to establish aquifer geometry and aquifer parameters.
- Establishment of appropriate grid of observation wells for monitoring water table fluctuations and quality.
- Establishment of at least one rain gauge station in each assessment unit for monitoring daily rainfall.
- Establishment of at least one pan evaporimeter in each assessment unit for evaporation measurements.
- Establishment of one stream gauge at the mouth of the watershed with emphasis on base flow measurements.
- Adequate number of field level experiments are to be conducted for measurement of aquifer parameters, seepage losses, infiltration rates and other norms used in the estimation.

7.1.7 Norms for the Estimation of Recharge

Norms for Ground water resource estimation provided in section 5.14 may be used in situations where field studies could not be conducted. An attempt has been made in Chapter 5 to specify these norms in as realistic manner as possible most of which are the redistribution

of the norms suggested by GEC 1997 methodology. It is however, necessary that a proper mechanism be evolved through which these norms can be periodically evaluated and refined based on field level studies.

7.1.8 Distributed Parameter Modelling

The methodology described in Chapter 5 is essentially a lumped parameter system approach. Although the physical ground water unit has been categorised into a few distinct and relevant sub-units but spatial variations are not adequately represented. A need therefore arises to consciously employ computer based distributed parameter system approach using techniques like finite difference, finite element and boundary integral equation methods. Such application for a few selected hydrogeologic units should be undertaken in a phased and time bound manner.

7.2 ALTERNATIVE METHODOLOGY

The methodology described in Chapter 5 for ground water resource estimation for the unconfined aquifer is essentially a water balance approach in which:

- The physical system for which the water balance is carried out is a lumped system representing the ground water regime (below the water table). It has a number of input and output components. This is true even in aquifer wise resource estimation,
- Only one of the input components i.e. recharge from rainfall is considered to be unknown. All other components can be either directly estimated individually, or ignored due to some reasonably valid factor or accounted for in some indirect manner.
- The algebraic sum of all input and output components is equated to the change in storage within the ground water regime as reflected by the water table fluctuation. This in turn results in estimating the single unknown component i.e. recharge from rainfall.

There is a genuine need for an alternative methodology for computing the recharge from rainfall which does not make use of the water table fluctuation. This need has also been emphasised in the GEC 1997 methodology and the approach paper on the Hydrology Project. One direct advantage of the application of such an alternative methodology is that the recharge from rainfall thus estimated can be used to corroborate the estimate obtained by the water table fluctuation method and thereby gain confidence in the validity of the estimate. In case there is a discrepancy in the two estimates, it is also advantageous in the sense that it can motivate practicing hydrogeologists to look more closely into the discrepancies and seek

scientific explanations. This, in turn, can considerably enhance their understanding on all issues related to ground water resource estimation.

7.2.1 Soil Water Balance Method

The soil water balance method has been widely applied in many watersheds in North America, Europe and Israel. The main characteristics of the soil-water-balance method are briefly mentioned below:

- a) It is essentially a water balance approach similar to the methodology presented in Chapter 5. However, it significantly differs in the sense that the physical system for which the water balance is applied comprises of the zone above the water table. This system is again divided into two sub-units- an upper zone representing the vegetative surfaces, leaf litter and ground surface and a lower zone representing the vertical soil profile above the water table.
- b) The sub-system representing the upper zone has a number of input and output components. The algebraic sum of these components is equated to the change in soil moisture. Given a rainfall input P in mm/day and potential evapotranspiration E_p in mm/day, the output component of excess rainfall, PM in mm/day is obtained. PM contributes to surface runoff Q in mm/day and to replenishment to the lower zone, PEM in mm/day. Determination of Q requires the use of a suitable method such as SCS method.
- c) The lower zone also has a number of input and output components. The algebraic sum of these components is equated to the change in soil moisture within the lower zone. Given the value of PEM in mm/day, and the evaporation, E_a in mm/day, the output component of natural replenishment to the ground water system below, GW in mm/day is finally obtained. GW represents the recharge from rainfall to the ground water regime.
- d) The application of the method yields reliable results only if the water balance is carried out over a number of very small discrete time periods. The recommended time duration is one day. On the other hand, the methodology presented in Chapter 5 allows much larger duration of time period in which the water balance is carried out. For instance, one year has been divided into only two discrete time durations.
- e) The method also requires calibration of the water budget model with actual field data before it is applied.

The alternative methodology described above has significant advantages. However, given the limitations of lack of data on meteorological, hydrologic and soil characteristics on

a watershed basis obtained through a comprehensive system of field level instrumentation, it is probably not practical to immediately apply the method on a very wide scale. The state level ground water organisations may also not have the required infrastructure facilities. Under these circumstances, it is recommended that this method can be used as a validating process rather than the method for estimation.

7.3 R & D Studies

Norms given in the Chapter 5 may be used in the estimations of ground water resources for situations as GEC-2015 has made an attempt to specify the norms used for estimation of ground water resources in as realistic manner as possible. The norms can be used for situations where data from field studies is not available. To strengthen and to refine various parameters used for the ground water resources estimation special R & D studies must be carried out. Some of these broad areas where special R&D studies are to be done on priority include:

- Return flow from irrigation/ micro irrigation.
- Seepage from canals
- Flows across Command and non-command areas.
- Spring discharge and spring hydrology.
- Aquifers in waterlogged areas.
- Aquifers and soil water balance
- Confined aquifer systems.
- Coastal studies in different hydrogeological settings.
- Urban ground water balance.
- Aquifers of arid regions.

Urban Ground Water Balance Studies may be taken up in Lucknow and Hyderabad and study of spring discharge and spring hydrology may be taken up in the state of Sikkim.

8

BIBLIOGRAPHY

- Agricultural and Refinance Development Corporation, 1979, Report of the Ground Water Over-Exploitation Committee. New Delhi.
- Central Ground Water Board. 2009. Report of the working group on methodology for Assessment of development potential of deeper aquifers. Ministry of Water Resources, Govt. of India
- Central Ground Water Board. 2006. Dynamic Ground Water Resources of India (As on 31st March 2004), Ministry of Water Resources, Govt. of India
- Central Ground Water Board. 2011. Dynamic Ground Water Resources of India (As on 31st March 2009), Ministry of Water Resources, Govt. of India
- Central Ground Water Board. 2012. Aquifer Systems of India, Ministry of Water Resources, Govt. of India
- Central Ground Water Board. 2012. Specific Yield Studies For Planning & Designing Of Artificial Recharge Structures in Sub Urban Areas Of Chennai, Tamil Nadu PDS, (HP II) Infiltration Studies, Ministry of Water Resources, River Development and Ganga Rejuvenation, Govt. of India
- Central Ground Water Board. 2014. Determination of Rainfall Infiltration Factor using CRD Method, Machilipatnam, Krishna District, Andhra Pradesh, Ministry of Water Resources, River Development and Ganga Rejuvenation, Govt. of India
- Central Ground Water Board. 2014. Dynamic Ground Water Resources of India (As on 31st March 2011), Ministry of Water Resources, River Development and Ganga Rejuvenation, Govt. of India
- Central Ground Water Board. 2015. Report on Pilot Project on Aquifer Mapping & Management in Ramgarh Area, Thar Desert, Jaisalmer district, Rajasthan, Ministry of Water Resources, River Development and Ganga Rejuvenation, Govt. of India
- Central Ground Water Board. 2015. Report on Pilot Project on Aquifer Mapping in Ankasandra Watershed, Parts of Tiptur&C.N.Halli Taluks, Tumkur District, Karnataka, Ministry of Water Resources, River Development and Ganga Rejuvenation, Govt. of India.

- Central Ground Water Board. 2015. Report On Pilot Project On Aquifer Mapping in Baswa-Bandiqui Area, Dausa District, Rajasthan, Ministry of Water Resources, River Development and Ganga Rejuvenation, Govt. Of India
- Central Ground Water Board. 2015. Report on Pilot Project on Aquifer Mapping in Chandrabhaga Watershed (WGKKC-2), Nagpur District, Maharashtra, Ministry of Water Resources, River Development and Ganga Rejuvenation, Govt. of India
- Central Ground Water Board. 2015. Report on Pilot project on Aquifer mapping in Lower Vellar watershed, Cuddaloredistrict, Tamilnadu, Ministry of Water Resources, River Development and Ganga Rejuvenation, Govt. of India
- Central Ground Water Board. 2015. Report on Pilot Project on Aquifer Mapping in Maner-Khagaul Area, Patna District Bihar (Watershed -GNDK013), Ministry of Water Resources, River Development and Ganga Rejuvenation, Govt. of India
- Chatterjee, Rana and Ray, R.K. 2014. Assessment of Ground water Resources – A review of International Practices. Central Ground Water Board, Ministry of Water Resources, River Development and Ganga Rejuvenation, Govt. of India
- Jain, R.C., Bhatia, A.K., Biswas, K.B., Srivastava, C.P., Saha, D., Chatterjee, Rana, Marwah, S. 2013. First Approximation Report – Ground Water Resources in the Alluvial Aquifers of Indo-Gangetic Basin. Central Ground Water Board, Ministry of Water Resources, Govt. of India.
- Kaushik, Y.B., Nandkumaran, N., Keshri, A, Chatterjee, R. (ed.) 2010. Workshop on Ground Water Resources Estimation. Central Ground Water Board, Ministry of Water Resources, Govt of India
- Kulkarni, H., Dhiman, S.C., Garg, Sudhir, Vijay Sankar, P.S., Vijay Bhaskar, T.M., Kunar, S. et. al. 2011. Report of the Working Group on Sustainable Ground Water Management- report submitted to Planning Commission for XIIth Five Year Plan. Planning Commission, Govt. of India
- Ministry of Water Resources, 1984, Report of the Ground Water Estimation Committee. Govt. of India.
- Ministry of Water Resources. 1997. Ground Water Resource Estimation Methodology – 1997. Govt. of India
- Ministry of Water Resources. 1998. Detailed Guidelines on Ground Water Resources Estimation Methodology – 1997. Govt. of India
- Ministry of Water Resources. 2004. Methodology For Ground Water Resource Estimation Methodology in Hard Rock Terrain –2004. Govt. of India
- Ministry of Water Resources. 2012. National Water Policy. Govt. of India
- NABARD, 2006, Review of methodologies for estimation of Ground Water Resources in India.

9

PRINCIPAL CONTRIBUTORS

- 1 Dr. A.K. Gosain, Professor, Dept. of Civil Engineering, IIT Delhi.
- 2 Sh. A.K. Madhukar, Superintending Geophysicist, Central Ground Water Board, CHQ, Faridabad.
- 3 Dr. A.R. Khan, Dy. General Manager, National Bank for Agriculture, & Rural Development (NABARD),
- 4 Sh. A.V.S.S. Anand, Scientist-D Central Ground Water Board, RGNGWTRI, Raipur.
- 5 Sh. Amit Kumar, Director, Department of land resources, Ministry of Rural Development, New Delhi
- 6 Dr. B.C. Joshi, Scientist-D, Central Ground Water Board, CHQ, Faridabad
- 7 Sh. B.Jaya Kumar, Regional Director (Retd), CGWB, Pune
- 8 Sh. BimalJeet Bhandari, Executive Engineer (Agronomist), Director, Water Resources, Punjab, Sector-68, Mohali, Punjab
- 9 Sh. D.Venkateswaran, Scientist –D, CGWB, Nagpur
- 10 DDG & National Mission Head II, Geological Survey of India, Maharashtra
- 11 Sh. Dharamveer Singh Rathore, Directorate (Lucknow), A.E. (Mechanical), Ground water Department, Uttar Pradesh
- 12 Dr. Dipankar Saha, Member (SAM), Central Ground Water Board, CHQ, Faridabad.
- 13 Dr. E. Sampath Kumar, Member (SM&L), Central Ground Water Board, R.K Puram, New Delhi
- 14 Sh. G.C. Pati, Member (TT & WQ), Central Ground Water Board, CHQ, Faridabad
- 15 Sh. H.B.Shelat, Geologist, Gujarat Water Resources and Development Corporation Limited, Gandhi Nagar, Gujarat
- 16 Dr. Himanshu Kulkarni, Director, Advanced Centre for Water Resources Development and Management.
- 17 Dr. J.S.Mehta, Director, Geological Survey India, New Delhi.
- 18 Dr. Jyoti P. Patil, Scientist C, NIH, Roorkee
- 19 Dr. K. Venugopal, Director, AP Ground Water Department
- 20 Sh. K.B. Biswas, Chairman, Central Ground Water Board, CHQ, Faridabad
- 21 Sh. K.C. Naik, Member (RGI), Central Ground Water Board, CHQ, Faridabad
- 22 Sh.. K.S.Sastry, Deputy Director, APSGWD, Govt. of Andhra Pradesh, Visakhapatnam
- 23 Dr. N.C.Ghosh, Scientist ‘G’ and Head, Groundwater Hydrology division, NIH,

Roorkee

- 24 Prof. N.J. Raju School of Environmental Sciences, Jawaharlal Nehru University, New Delhi.
- 25 Sh. N.Srinivasu, Deputy Director, APSGWD, Govt. of Andhra Pradesh, Hyderabad
- 26 Dr. Nandakumaran.P., Regional Director, Central Ground Water Board, CHQ, Faridabad.
- 27 Er. P.S. Bhogal, Director, Water Resources & Environment Directorate, Govt. of Punjab, Chandigarh.
- 28 Ms. Parveen Kaur, Scientist B, Central Ground Water Board, CHQ, Faridabad
- 29 Dr. Prahlad Ram, Asstt. Hydrogeologist, Central Ground Water Board, CHQ, Faridabad.
- 30 Sh. R.S.Garkhal, DDG, Geological Survey of India, New Delhi
- 31 Sh. Rana Chatterjee, Scientist D, Central Ground Water Board, Jamnagar House, New Delhi
- 32 Sh. Ranjan Kumar Ray, Scientist-C, Central Ground Water Board, CHQ, Faridabad.
- 33 Sh. Ravi Kant Singh, Senior Hydrogeologist, Ground water Department, Uttar Pradesh.
- 34 Ms. Rumi Mukherjee, Scientist-C, Central Ground Water Board, CHQ, Faridabad.
- 35 Dr. S. Suresh, Scientist D, Central Ground Water Board, CHQ, Faridabad
- 36 Sh. S.K. Sinha, Scientist-D, Central Ground Water Board, CHQ, Faridabad.
- 37 Dr. S.K. Srivastava, Head, Geoinformatics Department, IIRS, Dehradun
- 38 Sh. S.K.Sahni, Joint Director, Ground Water Department, Uttar Pradesh, Lucknow.
- 39 Sh. Sanjay Marwaha, Regional Director, Central Ground Water Board, CHQ, Faridabad.
- 40 Sh. Sushil Gupta, Ex Chairman, Central Ground Water Board, CHQ, Faridabad
- 41 Ms. Uma Kapoor, OIC, CGWB,SUO, Delhi
- 42 Sh. V.Shanmugam, Chief Engineer, State Ground & Surface Water Resources Data Centre, PWD(WRO), Chennai, Tamilnadu.
- 43 Sh. Vimal Kumar Chaurasia, SE, Ground Water Survey Circle, Madhya Pradesh, Bhopal
- 44 Sh. Vivek P Kapadia, Managing Director, Gujarat Water resources and development Corporation, Gandhinagar, Gujarat.

ANNEXURE I

(TO BE PUBLISHED IN THE GAZETTE OF INDIA PART-I, SECTION -II)

File No. T-13014/4/2014-GW -M

Government of India

Ministry of Water Resources, River Development & Ganga Rejuvenation
(Ground Water Desk)

Shram Shakti Bhawan, Rafi Marg

New Delhi- 110 001

Dated: 6th January, 2015**RESOLUTION****Sub: Constitution of Ground water estimation Committee to review and revise the Ground Water Estimation Methodology 1997 (GEC-97).**

The ground water resources assessment of the country is being carried out jointly by Central Ground Water Board and State Ground Water Departments based on methodology recommended by "Ground Water Estimation Committee 1997" (GEC 1997) at regular interval with the objective to identify and prioritize the areas for ground water management interventions. The ground water assessments in 2004, 2009 and 2011 were done as per GEC-97.

2) The Central Ground Water Board, State Ground Water Organisation, Universities and other organisations have carried out number of studies on assessment of ground water resources since the GEC-97 was adopted. Results of the studies were presented and deliberated in various consultative meetings and workshops. A need was felt to review and revise the GEC-1997 methodology to incorporate new advancements/practices/tools like ground water modelling and also refining the various parameters being used in assessment.

3) Composition of the Committee:

In the view of above, Ministry of Water Resources, River Development & Ganga Rejuvenation, Government of India hereby constitutes a committee to review and revise the Ground water Estimation Methodology (GEC-97) and look into related issues. The Committee will consist of following Members:

1.	Chairman, Central Ground Water Board	Chairman
2.	Joint Secretary (WSM), Ministry of Rural Development, Government of India, New Delhi.	Member
3.	General Manager, National Bank for Agriculture, & Rural Development (NABARD), Sterling Centre, Shiv Sagar Estate, Dr. Annie Besant Road, Post Box No. 6552, Mumbai - 400 018	Member
4.	Dy. Director General, Geological Survey of India, CGPB Secretariat, Geological Survey of India, Pushpa Bhawan, A-Block, 2nd Floor, Madangir Road, New Delhi - 110062.	Member
5.	Director, State Water Investigation Directorate, Government of West Bengal, Sectt. Bhawan (3 rd Floor), Salt Lake, Kolkata - 700 091.	Member
6.	Chief Engineer (PWD), State Ground and Surface Water Resources Data Centre, Water, Government of Tamil Nadu, IWS Campus, Tharamani, Chennai - 600 113.	Member
7.	Superintending Geohydrologist, Government of Madhya Pradesh, Ground Water Survey Circle, Bhopal (MP).	Member

Contd..2..

8.	Managing Director, Gujarat Water Resources Development Corporation Ltd., Government of Gujarat, Sector-10 A, Near Bij Bhawan, Gandhinagar - 382043.	Member
9.	Director, State Ground Water Department, Government of Andhra Pradesh, B.R.K.R. complex, 7 th and 8 th Floor, B-Block, Tank Bund Road, Hyderabad - 500063.	Member
10.	Director, Groundwater Survey and Development Agency, Government of Maharashtra, Bhujal Bhawan, Shivaji Nagar, Pune - 411 005.	Member
11.	Director, Water Resources & Environment Directorate, Government of Punjab, SCO- 32-34, Sector-17C Chandigarh.- 160017	Member
12.	Director, UP Ground Water Department, Government of Uttar Pradesh, 9 th Floor, Indira Bhavan, Ashok Marg, Lucknow - 226 001.	Member
13.	Member(TT&WQ), CGWB, NH-IV, Faridabad	<i>Member Secretary</i>

3.1) Special Invitees:-

1.	Commissioner (SP), Government of India, MOWR,RD&GR, Shram Shakti Bhawan, New Delhi - 110 001.
2.	Head, Ground Water Hydrology Division, National Institute of Hydrology, Jalvigyan Bhawan, Roorkee - 247667
3.	Professor Dr. N. J. Raju, School of Environmental Sciences, Jawaharlal University, New Delhi
4.	Professor Dr. A.K. Gosai, Department of Civil Engineering, IIT Delhi
5.	Dr. S. K. Srivastav, IIRS, Dept. of Space, Govt. of India, Kalidas Road, Dehradun - 248 001
6.	Dr. Himanshu Kulkarni, Advanced Centre for Water resources development and Management, Pune, Maharashtra
7.	Member(SAM), Central Ground Water Board, NH-IV, Faridabad
8.	Member (SML) and Member Secretary, CGWA, R.K. Puram, New Delhi

3.2) Sh. Rana Chatterjee, Scientist-D, CGWB, will assist the Committee.

3.3) The committee may co-opt any other Member(s), if necessary.

4) Terms of reference

The terms of reference of the Committee are as follows:

1. Firming up / updating various parameters and their values currently used in the assessment of ground water resources based on the scientific work carried out by various organizations.
2. To look into the details of the methodology recommended by Ground Water Estimation Committee (1997) and to suggest aspects which call for a revision. The Committee may, if considered necessary, update the existing or recommend a new methodology for the assessment of ground water resources in different hydrogeological situations and climatic zones.
3. To recommend the smallest assessment unit for assessment of ground water resources based on hydrogeological/hydrological and/or administrative division.
4. To recommend a methodology for assessment of ground water resource in urban areas/specific areas.
5. Suggest alternative approaches for real time assessment of ground water resources.

Contd..3..

6. Committee should suggest modality and methodology for incorporating quality consideration in assessment of ground water resources.
7. Review and recommend methodology for assessment of Total Ground Water Availability.
8. Any other aspects relevant to the terms referred to above.

5) Time frame:

The Committee may submit its report within 6 month from the date of issue of resolution.

6) Expenditure

Expenditure on account of TA/DA to official Members of the Committee will be met from the source from which they draw their salaries and that of non-official Members (if any), will be borne by the Central Ground Water Board, subject to the directions indicated in MoF OM No. 19030/3/2008-E.IV dated 23.09.2008 and directions issued by MoF from time to time in relation to austerity, travel restrictions etc.

This issues with the approval of the Hon'ble Minister (WR,RD&GR).


(R.K. Gupta)
Director (GW)

ORDER

Ordered that the above RESOLUTION be published in the Gazette of India for general information.

Ordered also that a copy of the Resolution published be communicated to this Ministry.


(R.K. Gupta)
Director (GW)

To

**The Manager,
Government of India Press,
Faridabad (Haryana).**

Copy to:

1. PS to Minister(WR,RD&GR)
2. PS to MoS (WR,RD&GR)
3. Sr. PPS to Secretary (WR,RD&GR).
4. PS to Additional Secretary (WR,RD&GR).
5. All Wing Heads, Ministry of Water Resources, New Delhi
6. All Organization Heads of Ministry of Water Resources, New Delhi
7. Chairman, Central Ground Water Board, Faridabad.
8. All concerned Committee members.

Copy also to:

NIC for uploading on the Ministry's website.


(R.K. Gupta)
Director (GW)

ANNEXURE II



No 40/CGWB/M(TT &WQ)/RES/2014-1819
 Govt. of India
 Ministry of Water Resources, RD & GR
 Central Ground Water Board
 Bhujal Bhawan
 Faridabad
 Haryana
 0129-2477108
 Date: 04/03/2015



To,

As per addresses overleaf

Subject: Constitution of Sub-Groups to review and revise the ground water resources estimation methodology

Sir,

Kindly refer to the minutes of the first meeting (copy enclosed for ready reference) of the Ground Water Estimation Committee to review and revise the ground water estimation methodology 1997 (GEC-97) held on 10.02.2015 at CGWB, Jamnagar House, New Delhi. As decided in the meeting, in order to facilitate the working of the Committee and to ensure timely completion of the Terms of References of the Committee, the deliverables of the committee have been divided into three sub-heads: i) Refinement of ground water resource assessment methodology, ii) Database used for estimation of ground water resources and iii) Alternative approach for assessment involving advanced technologies. Accordingly the following three sub-groups have been formed. The Groups would be spearheaded by a Convener and would be assisted by a Resource Person. Sub-Group wise broad scope of deliverables are proposed as follows

- **Sub-Group I** (Refinement of ground water resource assessment methodology): Refinement in ground water assessment methodology incorporating the concept of sustainable yield (NWP, 2012), small assessment unit, quality consideration, assessment in urban/ specific areas, total groundwater availability. Framing of Standard Operational Procedure for Groundwater Assessment including – Institutional involvement and Protocol for collection and validation of data, Detailed Guidelines on ground water resources assessment
- **Sub-Group II** (Database used for estimation of ground water resources): Database used in resources estimation – Preparation of a comprehensive data bank on information pertaining to parameters to be made use of in ground water resource estimation obtained from all ground water assessment studies / research studies made by government agencies, research institutions, universities, non-governmental organisations etc.; Guidelines on methodologies for estimation of various parameters; and Benchmarking of the data elements to be used for Ground Water Resources Assessment

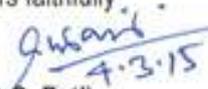
- **Sub-Group III** (Alternative approach for assessment involving advanced technologies): Alternate approach for real time assessment of ground water resources using advanced tools like remote sensing, ground water flow modelling, Application of advance techniques in validation of database, parameter estimation and ground water recharge and discharge estimation etc. used in ground water resources estimation.

Sub-Group I (Refinement of ground water resource assessment methodology)	Sub-Group II (Database used for estimation of ground water resources)	Sub-Group III (Alternative approach for assessment involving advanced technologies)
Dr. Himanshu Kulkarni Director, Advanced Centre for Water resources Development and Management - Convener	Dr. A.R. Khan, Dy General Manager, NABARD – Convener	Dr. A.K. Gosain, Professor, IIT, Delhi - Convener
Member (SM&L), CGWB, Faridabad	Member (RGI), CGWB, Faridabad	Member (SAM), CGWB, Faridabad
Dr. N.J. Raju, Professor, School of Environmental Sciences, JNU	Dr. S.K. Srivastava, Head Geoinformatics Department, IIRS, Dehradun	Dr. N.C. Ghosh, Scientist 'G' and head groundwater hydrology division, NIH, Roorkee.
Dr. K. Venugopal, Director, AP Ground Water Department	DDG and National Mission Head II, Geological Survey of India Maharashtra	Sh. Vivek P. Kapadia, MD, GWRDC, Govt. of Gujarat
Sh. P. S. Bhogal, Director, Water Resources, Punjab	Sh. Vimal Chaurasia, SE, Ground Water Survey Circle, Bhopal	Er. V. Shanmugam, Chief Engineer, SG&SWRDC, Tamil Nadu
Sh. S.K. Sahni, Joint Director, Ground Water Department, UP	Dr. S. Suresh, Scientist-D CGWB, Faridabad	Shri S.K. Sinha, Scientist-D CGWB, Faridabad
Resource Person: Sh. Rana Chatterjee, Scientist 'D', Central Ground Water Board, Jaipur	Resource Person: Sh. A.V.S.S. Anand, Scientist 'C', RGNWTRI, Raipur	Resource Person: Sh. Ranjan Kumar Ray, Scientist 'C', Central Ground Water Board, Faridabad

Each Sub-Group will submit its recommendations to the Chairman of the Committee within two months from issue of this letter for finalization of consolidated report of the Committee.

This issues with approval of the Chairman.

Yours faithfully,


(G.C. Pati)
7.3.15
Member (TT&WQ)

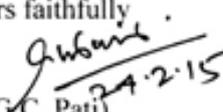
ANNEXURE III

No. 40/CGWB/M (TT&WQ) RES/2014-
 Central Ground Water Board
 Ministry of Water Resources,
 River Development & Ganga Rejuvenation
 Government of India
 Bhujal Bhawan, NH-IV
 Faridabad-121001, Haryana
 Email: mtt-cgwb@nic.in

Subject: Minutes of 1st meeting of Ground Water estimation Committee to review and revise the Ground Water Estimation Methodology 1997 (GEC-97) held on 10th February, 2015 at Jamnagar House, New Delhi-reg.

With reference to the above cited subject, please find enclosed herewith minutes of 1st meeting of Committee held on 10th February, 2015 at Jamnagar House, New Delhi for further necessary action.

This issues with approval of Chairman, CGWB

Yours faithfully

 (G.C. Pati)
 24.2.15
 Member (TT&WQ)

To

1. All Members/ Special invitees of Committee to review and revise the Ground Water Estimation Methodology 1997 (GEC-97).
2. TS to Chairman, CGWB, Bhujal Bhawan, NH-IV, Faridabad
3. TS to Member (SAM), CGWB, Bhujal Bhawan, NH-IV, Faridabad
4. TS to Member (SML), CGWA, R.K. Puram, New Delhi
5. All Regional Directors, CGWB
6. Special invitees/participants

Minutes of the 1st meeting of Experts to review and revise the Ground Water Estimation Methodology 1997 (GEC-97) held on 10.02.2015 at Jamnagar House, New Delhi

The meeting of members of Committee, constituted by Ministry of Water Resources, River Development & Ganga Rejuvenation, Government of India to review and revise the Ground Water Estimation Methodology 1997 (GEC-97) was held under the chairmanship of Shri K. C. Naik, Member (TT&WQ), Central Ground Water Board at 1100hrs on 10/02/2015 at CGWB, Jamnagar House, New Delhi. At the onset, Chairman welcomed all the members of the Committee and other invitees. He apprised the members that assessment of Ground Water Resources of India is being carried out at an interval of two years with the objective to identify and prioritize the areas for ground water management interventions. However there is need to review and revise the GEC-1997 methodology to incorporate new advancements/practices/tools like ground water modelling and also refining the various parameters being used in assessment.

Shri Rana Chatterjee, Scientist-D, CGWB made a presentation wherein various aspects of the present assessment using GEC-97 were described including its strengths and weaknesses. The best international practices followed worldwide were touched upon and the key issues to be considered by the committee were highlighted. He pointed out that the bottom-line of the entire exercise would be to develop a robust but executable solution which is scientific and simple & easy to understand for common people.

Dr. K. Venugopal, Director Ground Water Department, Government of Andhra Pradesh opined that the declining water levels are not always the best indicator of the depletion of ground water resources and safe blocks not necessarily indicate good potential. So it is necessary to change nomenclature of safe. He recommended that measuring yield of the wells/aquifer should be introduced in resource assessment along with measurement of ground water level. Effect of micro irrigation on ground water draft needs to be also considered and the parameter which is used for weathered / hard rock i.e Specific Yield or Storativity needs to be defined clearly.

Dr. A.R. Khan, Deputy General Manager, NABARD, Mumbai emphasized that unit draft of ground water structures should be measured accurately. He also stated that the results of Micro level studies may be incorporated in Ground water resources assessment. A quality consideration is necessary in resource assessment. There should be interlinking of assessment and management and state specific/region specific parameters. He also stressed that software should be developed to keep updating data regarding parameters/database that is being used.

Climate change issues need to be considered as water is the most vulnerable sector. Dr. Khan also suggested that if in the next meeting the results of some of the micro level studies is presented, then it will be very informative.

Er. P. S. Bhogal, Director, Water Resources & Environment Directorate, Government of Punjab pointed out that in Punjab in some cases adjoining blocks show significant differences in stage of ground water development though they have similar hydrogeological characteristics. He opined that the vertical variation in hydrogeological properties should be accounted for in recharge estimation. Methodology should be region wise as there is huge variation in geology for alluvial areas and hard rock areas. There should be clear demarcation between dynamic and static ground water resources. Depth of dynamic ground water resources should be fixed to some extent region wise. Water level be the criterion for categorization of assessment units. He also stated that instead of stage of ground water development, it should be stage of ground water withdrawal for convenience of common man.

Shri Vivek P. Kapadia, Managing Director, Gujarat Water Resources and Development Corporation Limited, Government of Gujarat stressed that quality consideration should be taken into account for assessment of ground water resources. He also suggested that the monitoring stations should be increased.

Shri S. K. Sahani, Joint Director, Ground Water Department, Uttar Pradesh stated that assessment unit should be Nyaya Panchayat particularly for over-exploited areas.

Sri V Shanmugam , Chief Engineer ,SG & SWRDC Ground water Department, Tamil Nadu opined that specific yield and rainfall recharge factors need to be revised. Actual field tests need to be carried out to estimate region wise parameters.

Dr. A K Gosain, Professor, IIT Delhi felt that the for resource assessment, macro picture has to be in place before micro level studies are undertaken. He stressed the need for a plan for using advanced techniques and for real time assessment.

Dr. N C Ghosh, Head, Hydrology Division ,NIH Roorkee stressed that management needs to be incorporated ,parameters should be revised and modeling studies may be incorporated which can be carried out by Central Agencies/Research institutes like IIT/NIH .There is also need for capacity building on advanced techniques.

Dr S K Srivastava ,Scientist , Indian Institute of Remote Sensing, Dehradun felt that GEC needs to be strengthened with improved data base and geomorphological factors may also be

incorporated. Alternate methodologies of resource estimation need to be used. Ground water flow modeling and GEC'97 should be done simultaneously for some areas.

Dr. N. Janardhana Raju, Prof. from JNU, New Delhi, emphasized the need to incorporate ground water quality considerations in the methodology.

On the suggestion from Er. P. S. Bhogal, Director, Water Resources & Environment Directorate, Punjab that the 2013 estimation should be based on new methodology instead of GEC'97 methodology, Sri S.K.Sinha, Scientist 'D', CGWB clarified that 2013 estimation cannot be postponed. The states may refine the parameters to bring out a more realistic picture.

After the deliberations, it was decided that three subgroups namely for (i) Refinement of ground water resource assessment methodology (ii) database used in resource assessment and (iii) alternative approach for assessment involving advanced technologies would be constituted to facilitate the working of the committee and to ensure timely completion of the Terms of Reference. The Sub-Groups members would be from the members and special invitees of the Committee. It would be spearheaded by a convener and assisted by a resource person from CGWB.

The meeting ended with the vote of thanks.

ANNEXURE IV

No.40/CGWB/M(TT&WQ)/Res./ 2015
Central Ground Water Board
Ministry of Water Resources, River
Development & Ganga Rejuvenation
BhujalBhawan, Faridabad
Dated: 16.07.2015

To
(As per the list)

Sub: Minutes of the Meeting on “Revision of GEC-97 Methodology” held under the Chairmanship of Chairman CGWB, at Jamnagar house, New Delhi on 3rd July, 2015 at 12.00 hrs

Kindly find enclosed herewith a the Minutes of the Meeting on “Revision of GEC-97 Methodology” held under the Chairmanship of Chairman CGWB, at Jamnagar House, New Delhi on 3rd July, 2015 at 12.00 hrs.

This is for your kind information and necessary action.

Encl.: As above

Yours faithfully

(G.C. Pati)
Member (TT & WQ)

MINUTES OF THE MEETING ON “REVISION OF GEC-97 METHODOLOGY” HELD UNDER THE CHAIRMANSHIP OF CHAIRMAN CGWB, AT JAMNAGAR HOUSE, NEW DELHI ON 3rd JULY, 2015 AT 12.00 HRS

Shri K.B.Biswas, Chairman, Central Ground Water Board (CGWB) and Chairman of the committee to review and revise the GEC-97 Methodology welcomed all the Members of the committee and informed that the revised GEC Methodology needs to be very precise taking into consideration the public information and ground water regulation. Shri G.C. Pati, Member (TT & WQ), CGWB informed that the three subgroups constituted to facilitate the working and timely completion of terms of references of the committee to review and revise the GEC-97 Methodology were supposed to submit their report by 06.07.2015. The meeting was called to discuss upon the progress of work done by the subgroups and what new parameter/factors can be used for refinement of GEC-97 methodology.

With the permission of the Chair, Dr.Himanshu Kulkarni, Executive Director, ACWADAM, and convener of the Sub Group-I, AVSS Anand, Scientist C RGNGWT & RI and Resource Person for Subgroup-II and Ranjan K Ray, Scientist C and Resource Person for Subgroup III made presentations on work done for the revision of the GEC Methodology.

List of participants is annexed.

Following points emerged from the deliberations during the meeting:

1. The subgroups will submit a base report on their recommendation for revision of GEC-97 Methodology to the Chairman within one month from the date of issue of the minutes of the meeting.
2. Another meeting may be held to discuss and finalize the Base Report.
3. Pilot studies may be taken up to test the implementation of the recommendations of the three subgroups.
4. After finalization of the methodology, the detailed guidelines for implementation of the methodology will be prepared.

Meeting ended with vote of thanks.

1641

List of Participants

SI.No	Participants
1.	Chairman, Central Ground Water Board, CHQ, Faridabad
2.	Member (SAM), Central Ground Water Board, CHQ, Faridabad
3.	Member (TT & WQ), Central Ground Water Board, CHQ, Faridabad
4.	Member (RGI), Central Ground Water Board, CHQ, Faridabad.
5.	Member (SM&L), Central Ground Water Board, R.K Puram, New Delhi
6.	Dr.Himanshu Kulkarni, Director, Advanced Centre for Water Resources Development and Management.
7.	Dr.A.R.Khan, Dy. General Manager, NABARD
8.	Dr. A.K. Gosain, Professor, IIT Delhi.
9.	Shri. A.K. Madhukar, Superintending Geophysicist, Central Ground Water Board, CHQ, Faridabad.
10.	Dr. S. Suresh, Scientist D, Central Ground Water Board, CHQ, Faridabad.
11.	Shri S.K. Sinha, Scientist D, Central Ground Water Board, CHQ, Faridabad.
12.	Shri. Rana Chatterjee, Scientist D, Central Ground Water Board, Jamnagar House, New Delhi
13.	Dr. B.C. Joshi, Scientist D, Central Ground Water Board, CHQ, Faridabad
14.	Shri AVSS Anand, Scientist C, Central Ground Water Board, RGNGWTRI, Raipur.
15.	Shri. Ranjan Kumar Ray, Scientist C, Central Ground Water Board, CHQ, Faridabad.
16.	Ms. Rumi Mukherjee, Scientist C, Central Ground Water Board, CHQ, Faridabad.
17.	Ms. Parveen Kaur, Scientist B, Central Ground Water Board, CHQ, Faridabad

ANNEXURE V

No.40/CGWB/M(TT&WQ)/Res./ 2015
Central Ground Water Board
Ministry of Water Resources, River
Development & Ganga Rejuvenation
BhujalBhawan, Faridabad
Dated: 22.09.2015

To
(As per the list)

Sub: Minutes of the Meeting on “Revision of GEC-97 Methodology” held under the Chairmanship of Chairman CGWB, at Jamnagar house, New Delhi on 18th Sept, 2015 at 2.30 P.M

Kindly find enclosed herewith the Minutes of the Meeting on “Revision of GEC-97 Methodology” held under the Chairmanship of Chairman CGWB, at Jamnagar House, New Delhi on 18th Sept, 2015 at 2.30 P.M

This is for your kind information and necessary action.

Encl.: As above

Yours faithfully

(G.C. Pati)
Member (TT & WQ)

MINUTES OF THE MEETING ON “REVISION OF GEC-97 METHODOLOGY” HELD UNDER THE CHAIRMANSHIP OF CHAIRMAN CGWB, AT JAMNAGAR HOUSE, NEW DELHION 18TH SEPT, 2015 AT 2.30 P.M

Shri K.B.Biswas, Chairman, Central Ground Water Board (CGWB) and Chairman of the committee to review and revise the GEC-97 Methodology welcomed all the Members of the committee and sought recommendation from the three subgroups. Shri G.C. Pati, Member (TT & WQ), CGWB informed that the report of the committee to review and revise the GEC-97 Methodology will be finalized on the basis of the recommendation of the three subgroups constituted to facilitate the timely completion of terms of references of the committee.

Dr.Himanshu Kulkarni, Executive Director, ACWADAM, and convener of the Sub Group-I, AVSS Anand, Scientist C RGNWGT & RI and Resource Person for Subgroup-II and Ranjan K Ray, Scientist C and Resource Person for Subgroup III made presentations on recommendations of the respective subgroups.

List of participants is annexed.

Following points emerged from the deliberations during the meeting:

1. As per the recommendations of the Subgroup I, the term Ground water development may be exchanged with Ground water exploitation.
2. Ground water resources assessment may be done once in 5 years.
3. Resource assessment is done quantitatively but simultaneously quality may also be added. It was decided to consider Stage of Ground water Exploitation for categorization of assessment units. Categorization of Assessment units which are affected by Arsenic or fluoride, the term respective Hazard Areas may be used. The assessment of for salinity affected areas in practice may continue.
4. Committee members agreed upon the recommendations of the subgroup II that Pilot studies need to be conducted to determine base flow factor in the proposed methodology.
5. Digital Elevation Models (DEM) may be used for determining the hilly area over a region which is considered not suitable for ground water recharge.
6. Recommendations of all the Subgroups were deliberated upon during the meeting and there was a broad agreement over these recommendations.
7. A committee is constituted to prepare the final report on the Revised GEC-Methodology and detailed Guidelines for calculation of Ground water Resources Assessment.

Following are the Member of the Committee:

Sl. No	Members
1	Shri. G.C. Pati, Member (TT & WQ), Central Ground Water Board, CHQ, Faridabad
2	Dr. B.C. Joshi, Scientist-D, Central Ground Water Board, CHQ, Faridabad
3	Shri AVSS Anand, Scientist-C, Central Ground Water Board, RGNGWTRI, Raipur.
4	Ms. Rumi Mukherjee, Scientist-C, Central Ground Water Board, CHQ, Faridabad.
5	Ms. Parveen Kaur, Scientist-B, Central Ground Water Board, CHQ, Faridabad

Meeting ended with vote of thanks.

List of participants:

Sl.No	Participants
1	Shri. K.B. Biswas, Chairman, Central Ground Water Board, CHQ, Faridabad
2	Shri. K.C. Naik, Member (SAM), Central Ground Water Board, CHQ, Faridabad
3	Shri G.C. Pati, Member (TT & WQ), Central Ground Water Board, CHQ, Faridabad
4	Dr. Dipankar Saha, Member (RGI), Central Ground Water Board, CHQ, Faridabad.
5	Dr. E. Sampath Kumar, Member (SM&L), Central Ground Water Board, R.K Puram, New Delhi
6	Dr. Himanshu Kulkarni, Director, Advanced Centre for Water Resources Development and Management.
7	Dr. A.R. Khan, Dy. General Manager, NABARD
8	Dr. A.K. Gosain, Professor, IIT Delhi.
9	Dr. J.S. Mehta, Director, Geological Survey India, New Delhi.
10	Shri. A.K. Madhukar, Superintending Geophysicist, Central Ground Water Board, CHQ, Faridabad.
11	Dr. S.K. Srivastava, Head, Geoinformatics Department, IIRS, Dehradun
12	Shri. Bimaljeet Bhandari, Executive Engineer (Agronomist), Director, Water Resources, Punjab, Sector-68, Mohali, Punjab
13	Shri. Rana Chatterjee, Scientist-D, Central Ground Water Board, Jamnagar House, New Delhi
14	Dr. B.C. Joshi, Scientist-D, Central Ground Water Board, CHQ, Faridabad
15	Shri AVSS Anand, Scientist-C, Central Ground Water Board, RGNGWTRI, Raipur.
16	Dr. Jyoti P. Patil, Scientist C, NIH, Roorkee
17	Shri. Ranjan Kumar Ray, Scientist-C, Central Ground Water Board, CHQ, Faridabad.
18	Ms. Rumi Mukherjee, Scientist-C, Central Ground Water Board, CHQ, Faridabad.
19	Ms. Parveen Kaur, Scientist-B, Central Ground Water Board, CHQ, Faridabad

ANNEXURE VI

No.40/CGWB/M(TT&WQ)/Res./ 2015
Central Ground Water Board
Ministry of Water Resources, River
Development & Ganga Rejuvenation
BhujalBhawan, Faridabad
Dated: 10.12.2015

To
(As per the list)

Sub: Minutes of the Meeting on “Revision of GEC-97 Methodology” held under the Chairmanship of Chairman CGWB, at Jamnagar house, New Delhi on 3rd Dec, 2015 at 11.30 A.M

Kindly find enclosed herewith the Minutes of the Meeting on “Revision of GEC-97 Methodology” held under the Chairmanship of Chairman CGWB, at Jamnagar House, New Delhi on 3rdDec, 2015 at 11.30 A.M

This is for your kind information and necessary action.

Encl.: As above

Yours faithfully

(G.C. Pati)
Member (TT & WQ)

MINUTES OF THE MEETING ON “REVISION OF GEC-97 METHODOLOGY” HELD UNDER THE CHAIRMANSHIP OF CHAIRMAN CGWB, AT JAMNAGAR HOUSE, NEW DELHI ON 3rd DEC, 2015 AT 11.30 A.M

Shri K.B.Biswas, Chairman, Central Ground Water Board (CGWB) and Chairman of the committee to review and revise the GEC-97 Methodology welcomed all the Members of the committee. Shri G.C. Pati, Member (TT & WQ), CGWB informed that the drafting committee has prepared the final draft report on GEC-2015. Shri AVSS Anand, Scientist D RGNGWT & RI and Resource Person for Subgroup-II made presentation on highlights of the final draft report for discussion.

List of participants is annexed.

Following points emerged from the deliberations during the meeting:

1. As per the recommendations of the committee, the term ‘Ground water development’ will be replaced with the term ‘Ground water extraction’.
2. The GEC-2015 recommends aquifer wise ground water resource assessment of both Replenishable ground water resources or Dynamic Ground Water Resources and In-storage Resources or Static Resources for all aquifers after a period of 3 years. However, the presently used assessment units may continue till the aquifers are fully deciphered. Only the report on Dynamic Ground Water Resources assessment will be shared with the States or with public.
3. The Ground water resources worked out Aquifer wise may be apportioned and presented on administrative units such as block/taluka/mandal/ firka as well as higher administrative units like Districts/State.
4. Water year is to be considered as the base for ground water resources assessment.
5. The GEC-2015 recommends classification of assessment units into 4 categories i.e. Safe, Semi-Critical, Critical, Over-Exploited on the basis of Stage of Ground water extraction. The criteria for categorization of Assessment units will be: 0 to ≤ 65 Safe; >65 to ≤ 85 Semi-critical; >85 to ≤ 100 Critical and >100 Over Exploited. The results will be validated using the Long term ground water level trends.
6. The Quality aspect of Ground water will also be considered during the resources assessment and assessment units with poor ground water quality will be tagged for salinity, Fluoride and Arsenic Hazard.

7. Special studies need to be taken up for refinement of norms on various factors such as return flow from irrigation taking into account the micro irrigation, seepage from canal, spring discharge, aquifer and soil water balance. Immediate studies may be taken up in Lucknow, Sikkim and Hyderabad for different hydrogeological terrains.

Over all there was a broad consensus on the recommendations of the report on GEC-2015. It was deliberated that there is a need to conduct R & D studies for refinement of various parameters used for resource assessment.

List of participants:

Sl.No	Participants
1.	Shri. K.B. Biswas, Chairman, Central Ground Water Board, CHQ, Faridabad
2.	Shri. K.C. Naik, Member (RGI), Central Ground Water Board, CHQ, Faridabad
3.	Shri. G.C. Pati, Member (TT & WQ), Central Ground Water Board, CHQ, Faridabad
4.	Dr. Dipankar Saha, Member (SAM), Central Ground Water Board, CHQ, Faridabad.
5.	Dr. E. Sampath Kumar, Member (SM&L), Central Ground Water Board, R.K Puram, New Delhi
6.	Dr. Himanshu Kulkarni, Director, Advanced Centre for Water Resources Development and Management.
7.	Dr. A.R. Khan, Dy. General Manager, National Bank for Agriculture, & Rural Development(NABARD),
8.	Dr. Nandakumaran. P., Regional Director, Central Ground Water Board, CHQ, Faridabad.
9.	Shri. Sanjay Marwaha, Regional Director, Central Ground Water Board, CHQ, Faridabad.
10.	Professor N.J. Raju School of Environmental Sciences, Jawaharlal University, New Delhi.
11.	Dr. S.K. Srivastava, Head, Geoinformatics Department, IIRS, Dehradun
12.	Shri. S.K. Sinha, Central Ground Water Board, CHQ, Faridabad.
13.	Dr. S. Suresh, Scientist D, Central Ground Water Board, CHQ, Faridabad
14.	Shri. Ravi Kant Singh, Senior Hydrogeologist, Ground water Department, Uttar Pradesh.
15.	Shri. Dharamveer Singh Rathore, Directorate (Lucknow), A.E. (Mechanical), Ground water Department, Uttar Pradesh

16.	Dr. B.C. Joshi, Scientist-D, Central Ground Water Board, CHQ, Faridabad
17.	Shri AVSS Anand, Scientist-D Central Ground Water Board, RGNGWTRI, Raipur.
18.	Shri. Ranjan Kumar Ray, Scientist-C, Central Ground Water Board, CHQ, Faridabad.
19.	Ms. Parveen Kaur, Scientist-B, Central Ground Water Board, CHQ, Faridabad

Gaurav