


पंजाब के जल गुणवत्ता मुद्दे और चुनौतियां

Water Quality Issues and Challenges in Punjab

केंद्रीय भूमि जलबोर्ड
Central Ground Water Board

जल संसाधन मंत्रालय
Ministry of Water Resources

भारत सरकार
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सुशील गुप्ता
Sushil Gupta

अध्यक्ष
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Chairman
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प्रस्तावना

पंजाब राज्य अपने प्राकृतिक संसाधनों और समृद्ध जैव विविधताओं से सम्पन्न है । यह राज्य हमारे देश में गेहूं के सबसे अधिक उत्पादक राज्यों में से एक है। राष्ट्रीय खाद्य सुरक्षा के लक्ष्यों को प्राप्त करने के उद्देश्य से राज्य में बेहतर फसल की पैदावार के लिए उर्वरक और कीटनाशकों की अत्यधिक मात्रा का उपयोग करते हुए गहन कृषि पद्धतियों को अपनाया गया। इसके परिणामस्वरूप राज्य के कुछ हिस्सों में सतही और भूमिजल संसाधनों में गिरावट आई है।

पिछले कुछ वर्षों में इस राज्य में भूमि उपयोग पद्धति में उल्लेखनीय परिवर्तन देखा गया है। राज्य के बड़े हिस्से में गैर कृषि उपयोग क्रियाकलाप किए जा रहे हैं जिनमे उद्योग, आवास परिवहन आदि शामिल हैं, जिसके परिणामस्वरूप सतही जल के साथ-साथ भूजल भी संदूषित हुआ है।

पर्यावरण की सुरक्षा और गुणवत्ता में सुधार करने के उद्देश्य से सरकार द्वारा उत्सर्जन एवं निर्वहन संबंधी मानकों का निर्धारण, खतरनाक अपशिष्ट के प्रबंधन तथा सार्वजनिक स्वास्थ्य सुरक्षा और कल्याण जैसी गतिविधियों के माध्यम से उल्लेखनीय कार्रवाई की गयी है। हालांकि जल गुणवत्ता प्रबंधन योजना तैयार करने के लिए सशक्त उपचारी प्रौद्योगिक तथा विभिन्न हितधारकों द्वारा इन्हे अपनाया जाना भी अनिवार्य हैं। केंद्रीय भूमि जल बोर्ड ने प्रबंधन कार्यनीति के रूप भूजल के कृत्रिम पुनर्भरण पर प्रदर्शनात्मक स्कीमों सहित भूजल मानीटरिंग और प्रबंधन संबंधित विभिन्न गतिविधियों को आरंभ किया है ।

यह रिपोर्ट जल गुणवत्ता की वर्तमान स्थिति पर प्रकाश डालने और इस क्षेत्र में उभरती चुनौतियों की पहचान करने के साथ-साथ संभावित सुधारात्मक उपायों को रेखांकित करने के लिए केंद्रीय भूमि जल बोर्ड और पंजाब में विभिन्न सहभागी संगठनों से एकत्र आंकड़ों का एक संकलन है । मुझे आशा है यह संकलन जल संसाधन और जल गुणवत्ता प्रबंधन के क्षेत्र में काम कर रहे प्रशासकों, आयोजकों, प्रबंधकों, व्यावसायिकों, शिक्षाविदों और अन्य हितधारकों के लिए अत्यन्त उपयोगी सिद्ध होगा ।

इस रिपोर्ट को तैयार करने के लिए आंकड़ों का संकलन कर इसे इतने उपयोगी रूप में प्रकाशित करने की दिशा में केंद्रीय भूमि जल बोर्ड, उत्तर पश्चिमी क्षेत्र, चंडीगढ़ तथा अन्य राज्य अभिकरणों के अधिकारियों द्वारा किए गए सार्थक प्रयास अत्यंत ही सराहनीय हैं ।

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CONSERVE WATER - SAVE LIFE

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Preface

The State of Punjab is blessed with enormous amount of natural resources and rich bio-diversity. The state is one of the largest producers of wheat in the country. In order to achieve National Food Security the State adopted intensive agricultural practices using large quantity of fertilizers and pesticides for better crop yields. This has resulted in the deterioration of both surface and groundwater resources in certain areas of the State.

Over the last few years, the State has experienced a tremendous transformation in the land use patterns. A large part of the State being put to non-agricultural uses also industries, housing, transport etc. leading to contamination of surface as well as ground water.

Government is taking proactive steps to protect and improve the quality of the environment by setting standards for emission and discharges, management of hazardous wastes, and protection of public health and welfare. However, formulation of Water Quality Management plan calls for persuasive remediation technologies and their adoption by various stakeholders. Central Ground Water Board has taken up various ground water monitoring and management related activities including demonstrative schemes on artificial recharge to ground water as a management strategy.

This report is a compilation of data gathered from Central Ground Water Board and various participating organizations in Punjab to highlight the prevailing status of water quality and identify the challenges along with possible remedial measures. I am sure that this compilation will be of immense use amongst the administrators, planners, managers, professional, academicians and other stakeholders working in the field of Water Resource and Water Quality Management.

The sincere efforts made by the officers from Central Ground Water Board North Western Region, Chandigarh and other State Agencies in compiling the data and bringing it in this form are highly appreciated.

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CONSERVE WATER - SAVE LIFE

अनुक्रमणिका

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कार्यकारी सारांश

पंजाब राज्य में जनसंख्या में तीव्र वृद्धि के साथ–साथ कृषि पद्धतियों, शहरीकरण और औद्योगीकरण के कारण कई अवरोध पैदा हो गए हैं। यह राज्य राष्ट्रीय खाद्य सुरक्षा को प्राप्त करने की दिशा में हरित क्रांति का सूत्रपात करने में सबसे आगे था और इस राज्य में गहन कृषि पद्धतियों को अपनाया गया। अत्यधिक कृषि गतिविधियों के परिणामस्वरूप, बेहतर फसल की उपज के लिए खाद और कीटनाशकों का भारी मात्रा में उपयोग किया गया। इसके कारण दिक्काल में भूजल और सतही जल दोनों की प्रदूषित हुए हैं। हाल ही में कई संगठनों और आम लोगों द्वारा राज्य के विभिन्न हिस्सों में जल की गुणवत्ता में हो रही गिरावट पर गंभीर चिंता व्यक्त की गई है। जल गुणवत्ता की समस्या के कारण स्वास्थ्य संबंधी गंभीर आपदाएं उत्पन्न हुई हैं और लोग जल जनित रोगों से प्रभावित हैं। इस समस्या को कम करने के लिए, विभिन्न केन्द्रीय और राज्य विभाग, अनुसंधान एवं विकास संस्थान जल की गुणवत्ता के आकलन और मानीटरिंग के कार्य में सक्रिय रूप से लगे हुए हैं। इन विभागों द्वारा उत्सृजित आकड़ें एक ही स्थान पर उपलब्ध न होने के कारण उपयुक्त निवारक और उपचारात्मक उपायों के लिए इनका उचित प्रचार–प्रसार नहीं हो रहा है। इस स्थिति को ध्यान में रखते हुए केंद्रीय भूमिजल बोर्ड द्वारा विभिन्न विभागों के आकड़ों को शामिल कर जल की गुणवत्ता और उभरते मुद्दों पर स्थिति रिपोर्ट संकलित करने का प्रयास किया गया है।

पंजाब, भारत का एक छोटा राज्य परंतु सबसे अधिक समृद्ध राज्यों में एक है। यह राज्य अपार प्राकृतिक संसाधनों और प्रचुर जैव विविधताओं से भरा है। यह अपनी आधुनिक कृषि पद्धतियों के साथ तेजी से विकसित अर्थव्यवस्था के लिए जाना जाता है। इस राज्य में पिछले पचास वर्षों में जनसंख्या में 62% की वृद्धि देखी हुई है। वर्ष 2011 की जनगणना के अनुसार राज्य की जनसंख्या लगभग 277 लाख है।

पंजाब राज्य का विस्तार 50362 वर्ग कि.मी. में फैला हुआ है जोकि देश के कुल क्षेत्रफल का लगभग 1.6% है। देश के कुल क्षेत्रफल के मात्र 1.6% भूमि विस्तार सहित पंजाब सबसे छोटे राज्यो में से एक है परंतु देश के 42% चावल, 55% गेहूं, और 24% कपास के उत्पादन में इसका योगदान है। राज्य में निवल सिंचित क्षेत्र की तुलना में सकल बुवाई क्षेत्र वर्ष 1970–71 के दौरान 71% से वर्ष 2008–09 के दौरान 97.4% तक बढ़ गया है।

राज्य में भूमि उपयोग पैटर्न में उल्लेखनीय परिवर्तन आया है। हाल के वर्षों के दौरान, औद्योगिक स्थलो, आवास, परिवहन व्यवस्था, मनोरंजन प्रयोजनों, सिंचाई प्रणाली, आदि के रूप में गैर कृषि उपयोग क्षेत्र में वृद्धि हुई है।

सामानतया राज्य की मृदा में विशेष रूप से बठिंडा, फिरोजपुर और फरीदकोट के मोटे बनावट की मिट्टी में फास्फोरस की कमी है। पंजाब में विभिन्न जिलों से आवधिक रूप से एकत्र मिट्टी के नमूनों के विश्लेषण से यह ज्ञात हुआ है कि जस्ता (Zn) की कमी में सुधार हुआ है और लोहा (Fe), मैंगनीज (Mn) की कमी की दर में और अधिक वृद्धि हुई है। फसल की उच्च पैदावार पर अत्यधिक जोर देने वाली वर्तमान शोषण प्रधान कृषि पद्धति के परिणामस्वरूप मृदा में सूक्ष्म पोषक तत्वों की कमी हुई है तथा इस कमी को कार्बनिक और अकार्बनिक उर्वरकों के माध्यम से पूरा किया जा रहा है।

राज्य में कुल 14.54 एमएएफ़ सतही जल उपलब्ध है जो इस राज्य के कुल सिंचित क्षेत्र का मात्र 29% है। नहरों के माध्यम से जल की उपलब्धता लगभग 1.45 एम एचएम है जो 1.6 एचएएम के क्षेत्र को सिंचाई प्रदान करता हैं। नहर क्षमता में कमी के कारण वर्ष 1990 तक नहर सिंचित क्षेत्र में 35% से अधिक की कमी हुई है। वर्ष 1970–71 के 1.92 लाख की तुलना में वर्तमान में 12.32 लाख ट्यूबवेल (एमआई जनगणना, 2001) हैं और कुल नलकूपों का 75% बिजली से संचालित हैं तथा शेष डीजल संचालित हैं। भूजल द्वारा सिंचाई किए जा रहे क्षेत्र की प्रतिशतता कुल सिंचित क्षेत्र के 55% से बढ़कर 73% हो गई है।

भूजलवैज्ञानिकी दृष्टि से, राज्य को चार इकाइयों में विभाजित किया जा सकता है जैसे (i) शिवालिक के साथ, सामान्यतः एक संकीर्ण बेल्ट में उपस्थित गिरिपाद अवसाद जिन्हें "कंडी" के रूप में जाना जाता है (ii) जलोढ़ मैदान (iii) राज्य के दक्षिणी पश्चिमी भाग में जमा होने वाली वातज और (iv) रोपड़ जिले के आनंदपुर साहिब में अंतरापर्वतीय घाटी।

विशाल सिंधु–गंगा के जलोढ़ मैदान भूजल संसाधनों का बहुत अच्छा भंडार है। पंजाब में भूजल परिरूद्ध एवं अपरिरूद्ध स्थितियों में पाया जाता है। जलभृत पार्श्विक एवं उर्ध्वाधरं रूप से गहन एवं स्थायी हैं। अन्य भागों की तुलना में दक्षिणी पश्चिमी भाग में, शुद्ध जल जलभृत की मोटाई काफी कम है क्योंकि यह क्षेत्र खारा/खारे जल से आच्छादित है। कई स्थानो पर, शुद्ध जलभृत की मोटाई 10 मी. से भी कम है।

राज्य की निवल वार्षिक भूजल उपलब्धता का अनुमान 21.44 बीसीएम के रूप में किया गया है। राज्य का अनुमानित निवल वार्षिक ड्राफ्ट 31.16 बीसीएम है। राज्य में वर्तमान भूजल विकास 145% है। 137 ब्लॉको में से, 103 ब्लॉक अति दोहित, 5 ब्लॉक गंभीर, 4 ब्लॉक अर्द्ध गंभीर और केवल 25 ब्लॉक सुरक्षित श्रेणी में हैं।

पश्चिमी जिलों में निचले क्षेत्रों के अतिरिक्त पूरे राज्य, जहां जल जमाव और मृदा लवणता देखी गई है, में जल स्तर तेजी से घट रहा है। प्रभावित क्षेत्रों में विस्तार और जल निकासी व्यवस्था में सुधार के कारण वर्ष 1998 के 4.7% की तुलना में जल भराव क्षेत्र वर्ष 2004 में तेजी से घटकर राज्य के कुल क्षेत्रफल का 0.3% तक आ गया है।

सघन कृषि गतिविधियों के कारण उर्वरकों, कीटनाशकों, शाकनाशी के अत्यधिक उपयोग से सतही और भूजल दोनों प्रदूषित हुए है। राज्य में, इस्तेमाल कीटनाशकों के लगभग 75 प्रतिशत का इस्तेमाल मालवा क्षेत्र (कपास बेल्ट) में होता है।

आंकड़ों के मिलान और विश्लेषण से यह पता चलता है कि नहर कमान क्षेत्रों में जल स्तर में लगातार वृद्धि हुई है और यह नई नहर प्रणाली की शुरूआत के बाद और अधिक उल्लेखनीय हो गया है। राज्य के फरीदकोट, मुक्तसर, फिरोजपुर, बठिंडा, होशियारपुर, गुरदासपुर और रोपड़ जिलो सहित दक्षिणी पश्चिमी, पूर्वोत्तर और पूर्वी हिस्सों में मानसून पूर्व और पश्चात अवधि में बढ़ते जल स्तर की प्रवृत्ति देखी गई है।

जल जमाव क्षेत्रो में बढ़ोतरी का रूझान बहुत कम है। ऐसे क्षेत्र जहां जल स्तर की गहराई (5–10 मीटर) हैं, मुख्यतया बठिंडा जिले के कुछ हिस्सों में 70–80 सेमी/की दर से वृद्धि देखी गई है।

राज्य के मध्यम और उत्तर पश्चिमी हिस्सों में मानसून पूर्व एवं बाद की अवधि में जल स्तर में गिरावट आई है। 59% क्षेत्र के जल स्तर में मानसून बाद गिरावट का रुझान दिखाई दिया है, जबकि मानसून पूर्व में 66% क्षेत्रों पर जल स्तर में गिरावट का रुझान मिला है।

प्राकृतिक वातावरण में प्रवाहित औद्योगिक अपशिष्ट के कारण जल प्रदूषित हो रहा है। इसके अलावा, शहरी गंदगी का एक बड़ा हिस्सा बिना उपचार फैलाया जा रहा है। राज्य के 5 बड़े शहरों यानी लुधियाना, जालंधर, अमृतसर, बठिंडा और पटियाला में कुल ठोस अपशिष्ट का 73% उत्पन्न किया जा रहा है।

घग्गर नदी, सतलुज और ब्यास नदियों में औद्योगिक और नगर निगम के कचरों के कारण लगभग सभी स्थानों पर जल गुणवत्ता में ह्रास हुआ है। जल में सूक्ष्म जीवों की उपस्थिति के कारण मोगा, जालंधर, बरनाला, एसएएस नगर जैसे स्थानों में आंत्रशोध / जल जनित रोगों की घटनाएं सामने आई हैं।

लुधियाना, अमृतसर, मंडी गोबिंदगढ़, कपूरथला आदि के औद्योगिक केन्द्रों के आसपास भूजल में सीसा, क्रोमियम, कैडमियम, तांबा, साइनाइड, निकल आदि भारी धातुओं की उच्च सांद्रता है।

सेलेनियम की उच्च सान्द्रता होशियारपुर, नवांशहर जिलों में पायी गई है और आर्सेनिक की उच्च सांद्रता अमृतसर, गुरदासपुर, होशियारपुर, कपूरथला और रोपड़ जिलों में पायी गई है। 1.5 मिलीग्राम / एल से अधिक फ्लोराइड की सांद्रता बठिंडा, फिरोजपुर, मनसा और पटियाला जिले में पायी गई है। एल्युमीनियम की उच्च सांध्रता गुरदासपुर, नवांशहर, होशियारपुर, पटियाला, रोपड़ और मोगा जिलों में देखी गई है। राज्य के फिरोजपुर, मोगा, बरनाला, भटिंडा और संगरूर जिले के पूरे दक्षिण पश्चिमी बेल्ट में भूजल में यूरेनियम की उच्च मात्रा है।

आईसीएमआर (भारतीय चिकित्सा अनुसंधान परिषद) के सहयोग से राज्य सरकार द्वारा किए गए अध्ययन में विशेष रूप से मालवा क्षेत्र में कैंसर रोग के संकेत मिले हैं। यह देखा गया है कि राज्य में कैंसर की दर 30.5/लाख है जबकि बठिंडा और मुक्तसर जिलों में यह 75/लाख है।

जल गुणवत्ता प्रबंधन आयोजना के लिए सतही और भूजल गुणवत्ता को प्रभावित करने वाले सभी प्रदूषण एवं जल संदूषण की स्रोतों की सूची के माध्यम से विभिन्न हितधारियों द्वारा प्रभावी उपचारी प्रौद्योगिकी तैयार कर इन्हें अपनाया आवश्यक है। केन्द्र सरकार ने भू जल का कृत्रिम पुर्नभरण जैसी उपयुक्त जल संसाधन प्रबंधन नीति के माध्यम से जल प्रदूषण को रोकने के लिए कदम उठाए हैं और केंद्रीय भूमि जल बोर्ड की केन्द्रीय क्षेत्र योजना के तहत पंजाब राज्य में प्रदर्शनात्मक योजनाओं को वित्त घोषित किया गया है।

राष्ट्रीय जल नीति (2002) के प्रावधानों में केन्द्र सरकार को पर्यावरण की सुरक्षा एवं सुधार के लिए अपशिष्ट के उत्सर्जन एवं विसर्जन संबंधी मानक निर्धारण करने, उद्योगों की अवस्थिति का निर्धारण करने, खतरनाक अपशिष्टों के प्रबंधन तथा सार्वजनिक स्वास्थ्य एवं कल्याण की सुरक्षा हेतु सभी उपाय करने की शक्ति प्रदान की गई है।

सभी निगरानी एजेंसियों, विभागों, प्रदूषण नियंत्रण बोर्ड और अन्य ऐसी एजेंसियों द्वारा जल गुणवत्ता निगरानी तंत्र की प्रक्रिया में एकरूपता बनाए रखने के लिए पर्यावरण एवं वन मंत्रालय ने जल गुणवत्ता मूल्यांकन प्राधिकरण (2001) का गठन किया गया ताकि विश्वसनीय आंकड़ों के आधार पर जल से संबंधित कार्य योजना तैयार की जा सके। केन्द्र और राज्य प्रदूषण नियंत्रण बोर्ड ने दावाधारकों की सक्रिय भागीदारी के साथ सुरक्षा, विनियमन और उपायों के लिए पर्यावरण कानूनों के प्रभावी कार्यान्वयन की कार्य योजना तैयार की है।

इस रिपोर्ट के संकलन में सहभागी संगठनों द्वारा सृजित प्रचुर आकड़ों का उपयोग किया गया है। यह सतही और भूजल की गुणवत्ता, इसकी वर्तमान स्थिति और मानव स्वास्थ्य पर इसके प्रभाव संबंधी बहुमूल्य जानकारी प्रदान करता है। विभिन्न राज्य/केन्द्रीय विभागों, शैक्षणिक संस्थानों, शोधकर्ताओं और अन्य दावा धारकों के लिए यह संग्रह प्रदूषण कम करने के लिए कार्यनीति तैयार करने की दिशा में मार्गदर्शी सिद्ध होगा।

EXECUTIVE SUMMARY

Rapid population increase coupled with agricultural practices, urbanization and industrialization has brought in many interventions in the State of Punjab. The State was at the forefront of ushering in green revolution to achieve national food security and adopted intensive agricultural practices. The intense agricultural activity has prompted usage of large quantity of fertilizers and pesticides for better crop yield. This has resulted in both ground water and surface water pollution over space and time. Of late, many Organizations and people at large have expressed serious concern about deterioration of water quality in different parts of the State. Water quality problem has posed serious health hazards and people are affected by various water borne diseases. To mitigate this problem, various Central and State departments, R&D institutions are actively engaged in water quality assessment and monitoring. The large volume of data generated by these departments is not available in a single platform for proper dissemination to take up suitable preventive and remedial measures. This has necessitated Central Ground Water Board to make an effort to compile a status report on water quality and its emerging issues incorporating the data contributed by various departments.

Punjab is a small but one of the richest State in India. The State is bestowed with vast natural resources and rich bio-diversity. It is recognized for its fast developing economy with modern agricultural practices. The State has witnessed a population growth of 62% in the last fifty years. The population of the State as per 2011 census is about 277 millions.

The State of Punjab has an aerial extent of 50,362 sq.km, which is about 1.6% of total area of the Country. Punjab is a one of the smallest State with a total land area of 1.6% of the country yet it contributes to 42% rice, 55%wheat, and 24% cotton production in the country. The net irrigated area to gross area sown has increased from 71% during 1970-71 to 97.4% during 2008-09.

Land use pattern has undergone a tremendous transformation in the State. During the recent years, there has been an increase in the area put to non-agricultural uses such as industrial sites, housing, transport systems, recreational purposes, irrigation systems, etc.

The soils in the State are generally deficient in Phosphorus, especially the coarse textured soils of Bathinda, Ferozepur and Faridkot. The analysis of soil samples collected from various Districts in Punjab, over a period revealed that, the deficiency of Zinc (Zn) has decreased and that of Iron (Fe) and Manganese (Mn) has increased. The present exploitive agriculture laying emphasis on high crop yields has resulted in the depletion of micronutrients in soil and is being supplemented with both organic and inorganic fertilizers.

There is a total of 14.54 MAF surface water which cover only 29% of the total irrigated area of the State. The availability of water through canals is of the order of 1.45 M ham. and provide irrigation to an area of 1.6 M ham. There has been a reduction of over 35 % in canal irrigated area since 1990 due to reduction in canal capacity. At present, there are 12.32 lac tube wells (MI census, 2001) as compared to 1.92 lac in 1970-71 and about 75% of the total tube wells are electric operated and rest are diesel operated. The area under irrigation by ground water has increased from 55 to 73% of total irrigated area.

Hydrogeologically, the State can be divided into four units i.e. (i) Piedmont deposits occurring along a narrow belt along the Siwaliks, commonly known as “Kandi” (ii) Alluvial plains: (iii) Aeolian deposits occurring in the southwestern part of the State and (iv) Intermontane valley at Anandpur Sahib of Ropar district.

The vast Indo-Gangetic alluvial plain forms an excellent repository of ground water resources. Ground water in Punjab occurs under both confined and unconfined conditions. The aquifers are laterally and vertically extensive and persistent in nature. In southwestern parts, the thickness of fresh water aquifer is much less as compared to the other parts because area is underlain by brackish/saline water. At places, the thickness of fresh water bearing aquifer is even less than 10 m.

The estimated Net Annual Ground Water Availability of State has been assessed to be 21.44 bcm. Net annual draft of the State has been estimated to be 31.16 bcm. The present ground water development in the State is 145%. Out of 137 blocks, 103 blocks are *overexploited*, 5 blocks are *critical*, 4 blocks are *semi critical* and only 25 blocks are in *safe* category.

The water table is depleting at an alarming rate in the entire State except in the low-lying pockets in southwestern Districts of the State, where water logging and soil salinity is noticed. The waterlogged areas have come down sharply to 0.3% of total area of State in 2004 as compared to 4.7% in the year 1998 due to expansion and improvement in drainage system in the affected areas.

The intensive agricultural activity has prompted excessive use of fertilizers, pesticides, insecticides, herbicides causing pollution of both surface and ground water. The Malwa region (cotton belt) accounts for nearly 75 percent of pesticides used in the State.

The collation and analysis of data shows that there is continuous rise in water levels in the canal command areas and it has become more significant after the introduction of new canal system. Areas showing rising water level trend both in pre & post-monsoon period are in the southwestern, northeastern and eastern parts of the State, covering parts of Faridkot, Muktsar, Ferozepur, Bathinda, Hoshiarpur, Gurdaspur and Ropar Districts.

In the waterlogged areas, the magnitude of rising trend is very less. The areas where water levels are deep (5-10m), the rate of rise even up to 70-80 cm/yr has been observed mainly in parts of Bathinda District.

Areas experiencing declining water level trends in both Pre and Post-monsoon period are in the central and northwestern parts of the State. About 66% of area shows declining water level trends in pre-monsoon while 59% of the area shows declining water level trends in post-monsoon.

The industrial effluents discharged into the natural environment are causing water pollution. Besides, a huge amount of municipal wastes is being generated and disposed off without any treatment. 73% of the total municipal solid waste is being generated in the 5 mega towns in the State i.e Ludhiana, Jalandhar, Amritsar, Bathinda and Patiala.

Water quality is deteriorated nearly at all locations in river Ghaggar followed by Satluj and Beas rivers due to disposal of industrial and municipal wastes into them. Incidences of Gastroenteritis/water borne diseases has been reported from a number of places like Moga, Jalandhar, Barnala, SAS Nagar due to the presence of micro organisms in water.

Ground water at few places has higher concentrations of heavy metals such as Lead, Chromium, Cadmium, Copper, Cyanide, Nickel etc. around the industrial hubs like Ludhiana, Amritsar, Mandi Gobindgarh, Kapurthala etc.

Higher concentration of Selenium has been reported from Hoshiarpur, Nawanshahr Districts and higher concentrations of Arsenic have been found in Amritsar, Gurdaspur, Hoshiarpur, Kapurthala and Ropar districts. Fluoride having concentrations more than 1.5 mg/l have been reported from Bathinda, Ferozepur, Mansa and Patiala Districts. High concentration of Aluminium has been observed in Gurdaspur, Nawanshahr, Hoshiarpur, Patiala, Ropar and Moga districts. The entire southwestern belt of the State comprising of Ferozepur, Moga, Barnala, Bathinda and Sangrur Districts have high incidence of Uranium in groundwater.

A study by the State government in collaboration with ICMR (Indian Council of Medical Research) has indicated the high incidence of cancer disease, especially in Malwa region. It is also observed that rate of cancer incidences in the State is 30.5/lakh population where as the rate is as high as 75/lakh in Bathinda and Muktsar Districts.

The formulation of Water Quality Management plan calls for effective clean remediation technologies and their adoption by various stakeholders through inventory of all sources of pollution and water contamination affecting the surface and ground water quality. The Central Government has taken steps to contain the water pollution by taking up suitable water resource management strategies like Artificial Recharge to Ground Water and the Central Sector Scheme of CGWB under which demonstrative schemes in the State of Punjab has been funded.

As envisaged in National Water Policy (2002), the Central Government is empowered to take measures necessary to protect and improve the quality of the environment by setting standards for emission and discharges, regulating the location of industries, management of hazardous wastes, and protection of public health and welfare.

Ministry of Environment and Forest has constituted Water Quality Assessment Authority (2001) in order to maintain the uniformity in the procedure for water quality monitoring mechanism by all monitoring agencies, departments, Pollution Control Boards and other such agencies so that water related action plans may be drawn up on the basis of reliable data. The Central and State Pollution Control Board have formulated action plan for effective implementation of environmental laws for protection, regulation and remediation with active involvement of stakeholders.

The large volume of data generated by the participating organizations has been used in compilation of this report. This provides a wealth of information on surface and ground water quality, its present status and its bearing on human health. This compendium will form a base for formulating the road map for pollution mitigation by various Central/State departments, academic Institutions, researchers and other stakeholders.

1. BACK DROP

Punjab is one of the richest States in India. It is a State bestowed with rich biodiversity, lush green fields and fertile soil. It has made long strides on it's path to bring prosperity to the State. The State of Punjab in administratively divided into four divisions and 20 districts, 142 blocks (Plate 1.1). Punjab has witnessed 62% growth in population in the last fifty years.As per 2011 census, there are 12673 inhabited villages and 157 towns in Punjab State. The total population of the State is 27704236 (2011) constituting 2.29% of the total population of the country. 62.51% people live in the rural area and 37.49% live in urban localities. One major feature of the State's demography is the high rate of increase in urban population (25.72%) in the previous decade indicating rural-urban migration. The urban population is further expected to increase to 45% by 2020 A.D. Population wise Ludhiana is the biggest city with 3487882 persons, followed by Amritsar- 2490891 and Gurdaspur 2299026 persons. The percent increase in population for last three dacades in the State is 20.26% (1981-1991) and 19.76% (1991-2001) and 13.73% (2001-2011) indicating more or less a stabilized population growth situation. The population density of the State is 550 persons per km^2 which is higher than National average 382 per km^2 and in 2001 density of Punjab was 484 per km^2.

Agriculture is the backbone of Punjab's economy and the State's agriculture has reached it's highest production level with available natural resources. The Central Govt. encouraged the strategy of enhancing food grain production in the State, particularly wheat and rice, for meeting emergent food demand in the country after the outbreak of famine in early sixties. Thereafter, the green revolution ushered in the State of Punjab during 1960's to 1970's to achieve the food security of India.

The State of Punjab was at the forefront of ushering in Green revolution in 1969. The target of achieving National Food Security also involved the use of large quantity of fertilizer, pesticides, insecticides, weedicides, use of hybrid varieties of seeds and excessive extraction of ground water. Thus, Punjab became the hub of agricultural activity. Over the years, the agricultural practices have changed the cropping pattern on an extensive scale which has made the agro-ecosystem of the State extremely fragile in the context of water depletion, soil health, weeds and pest, human health and overall living environment. Large dam with extensive canal network were constructed on the major rivers in Punjab State which has reduced the flood events drastically and stopped the influx of fresh soil and nutrients from the catchment area resulting into the reduction of fertility of soil. To improve the yield from these soils and increase the food production, farmers have introduced excessive use of fertilizer and pesticides which has led to large scale contamination of soil and successively sub-soil water.

With passage of time, rapid industrialization and urbanization took place which triggered usage of large quantity of ground water as well as surface water for various purposes. There was also increase in disposal of solid waste from urban agglomerates and industrial hubs which has posed a threat for environmental degradation due to haphazard discharges into natural rivulets/nallahas and indiscriminate dumping in the agricultural fields. The intensive irrigation coupled with rapid industrialization and urbanization has brought in water quality degradation vis-a-vis development of water resources with space and time.

With the advent of green revolution, there were many interventions in the field of agriculture to achieve National food security for the country which has prompted farmers to grow high yield paddy with advanced agriculture practices. As a result, over the years, many such problems in the field of water quality have emerged due to large scale usage of pesticides, herbicides, weedicides, etc. Of late, it has raised serious concern for various Central/State Government departments, R & D institutions and NGO's and people at large. At many places, water quality problem has posed serious health hazards and people are affected by various water borne diseases. Many Government organizations have been working to assess the water quality and have taken some remedial measures. The large volume of data generated by various departments is not available on a single platform and not being properly shared amongst the concerned agencies to devise suitable measures to mitigate the problems. Against this backdrop, it calls for an immediate action plan to be evolved involving various departments so that the data generated could be shared in an appropriate forum for taking up suitable preventive and remedial measures. To assess the present status of water quality in the State of Punjab, it has necessitated Central Ground Water Board to make an effort to compile this report. The report embodies the various emerging issues and challenges in the State of Punjab especially with respect to water quality and the data contributed by all the participating departments like Central Ground Water Board, Government Of India. Department of Environment, Punjab University, Chandigarh, Department of Health and Family Welfare, Government of Punjab, Department of Water Supply and Sanitation, Government of Punjab Farmers/NGO, Punjab Pollution Control Board, Government of Punjab, School of Public Health and Community Medicine, PGIMER, Chandigarh and Water Resource and Environment Directorate, Government of Punjab has helped in compilation of this report.

Plate 1.1

2. WATER QUALITY AND HEALTH ISSUES

The concentration of most potentially harmful impurities in natural waters are normally very low but there are many compounds used in agriculture, in the home and in industry, which can find their way into surface and ground waters. Because of the essential role played by water in supporting human life it has also, if contaminated, great potential for transmitting a wide variety of diseases and illness. The effect of these substances depends on the quantity of water consumed per day and their concentration in water. Likewise, the quality of irrigation water for agricultural use should be such, that it does not impair plant growth or adversely affect the productivity of the land. The water quality standards as laid down in BIS standard (IS-10500, 1991) and WHO (2008) standards are summarized Annexure I to IX.

2.1 Impact on Human Health

The water quality for various uses should be as per specification of water required for particular use. The chemical parameters above the permissible limit have adverse effect on human health. Hardness, measured as CaCO3, when present more than 600 mg/l may affect water supply system (Scaling), lead to excessive soap consumption, calcification of arteries. There is no conclusive proof but it may cause urinary concretions, diseases of kidney or bladder and stomach disorder. Iron in traces is essential for nutrition and high Iron concentration (> 1.0mg/l) in water, though not having major effect on human health, gives bitter sweet astringent taste, causes staining of laundry and porcelain.Nitrate at very high concentration may cause infant methaemoglobinaemia (blue babies), causes gastric cancer and affects adversely central nervous system and cardiovascular system.Fluoride less than 1.0 mg/l is desirable in drinking water as it prevents dental carries but with very high concentration may cause crippling skeletal fluorosis. Copper is essential and beneficial element in human metabolism. Deficiency results in nutritional anaemia in infants. Large amount gives astringent taste, causes liver damage, central nervous system irritation and depression. In water supply it enhances corrosion of aluminium in particular. The desirable limit of Lead in drinking water is 0.05 mg/l . It is toxic in both acute and chronic exposures. Burning in the mouth, severe inflammation of the gastro-intestinal tract with vomiting and diarrhoea, chronic toxicity nausea, severe abdominal pain, paralysis, mental confusion, visual disturbances, anaemia etc are some of its manifestations when present in higher concentrations.The probable effects of the water quality, for drinking uses beyond the prescribed limits by IS:10500, 1991are summarised in the Annexure II.

Common symptoms of mercury poisoning include peripheral neuropathy (presenting as paresthesia or itching, burning or pain), skin discoloration. Other symptoms may include kidney dysfunction (e.g. Fanconi syndrome) or neuropsychiatric symptoms such as emotional lability, memory impairment, or insomnia.

Long term exposure to Cyanide affects the thyroid and central nervous system adversely. In drinking water the maximum permissible limit for cyanide is 0.05 mg/l and there is no relaxation in this value as beyond this limit water becomes toxic.

Arsenic is a recognized carcinogenic element. The gastrointestinal tract, nervous system, respiratory tract and skin can be severely affected. Chronic poisoning is manifested by general muscular weakness, loss of appetite and nausea, leading to inflammation of mucous membrane in the eye, nose and larynx, skin lesions may also occur. Neurological manifestations and even malignant tumours in vital organs may also be observed. Humans residing in seleneferious areas of Punjab show loss of hair, malformation of finger and toe nails and progressive deterioration in human health. Animals consuming Se rich fodder exhibit typical symptoms of Selenium poisoning. The most consistent clinical manifestations are loosing body condition and loss of hair, necrosis of tail, reluctance to move, stiff gate, and overgrowth of hooves followed by cracks gradually leading to detachment from main hoof.

Water containing low amounts of uranium is usually safe to drink. Because of it's nature, uranium is not likely to accumulate in fish or vegetables and uranium that is absorbed will be eliminated quickly through urine and faeces. Uranium concentrations are often higher in phosphate-rich soil, but this does not have to be a problem, because concentrations often do not exceed normal ranges for uncontaminated soil. It is possible that intake of a large amount of uranium might damage the kidneys. There is also a chance of getting cancer from any radioactive material like uranium. Natural and depleted uranium are only weakly radioactive and are not likely to cause cancer from their radiation. The provisional guideline by WHO (2004) of Uranium for drinking water is 15 µg/l. The guideline value is designated as provisional because of outstanding uncertainties regarding the toxicology and epidemiology of Uranium.

The pesticides have deleterious effects on health. Several of the pesticides are carcinogenic and cause long term harmful effect on health, in case contaminated water is continuously used for long term for human consumption). The organo-chlorine pesticides are more persistent and most toxic, therefore some of these pesticides are banned or regulated. The organo-phosphorous compound have short life span in the environment and these break down rapidly and pose less danger to wild life and contamination to ground water in comparison to organo-chlorine pesticides. Pesticides in drinking waters of Punjab indicate genotoxic effects which are not yet manifesting but are in the pre-carcinogenic phase.

Besides causing acute and chronic toxicity, pesticides are affecting the immune system in general and other sensitive systems leading to immuno suppression, immuno potentiation and hypersensitivity of the host against infectious and non infectious diseases as well as causing glomerulonephritis, rheumatoid arthritis, carcinogenicity, reduced fertility, increased cholesterol, high infant mortality, varied metabolic and genetic disorders and reduced lifespan in humans and livestock populations in India.There is abundant evidence that many pesticides produce their acute toxic action by inhibiting enzymes. The excessive use of chemical fertilizer like urea, DPK, NPK, etc and pesticides (insecticides and weedicides) in Punjab have resulted in the disorders of endocrine glands e.g., thyroid, parathyroid, pituitary, kidneys and adrenals (Kheti Virasat,NGO).

The main cause of water borne diseases and enteric diseases like cholera, typhoid, para-typhoid, bacillary, dysentery, gastro-enterititis etc. are due to the contamination of source with intestinal pathogenic micro-organisms. The contamination of drinking water by human/animal excreta faecal matter constitutes the most common mechanism for transmission of these organisms to healthy human being not only directly but also indirectly.

2.2 Impact on Livestock

The concentration of specific constituent of parameter that renders water unfit for livestock are subject to a number of variables which include age, sex, species, water intake, diet, the chemical form of the toxin and temperature of the environment. Probable effects of some of the parameters on livestock as prescribed by BIS are summarized in Annexure III.

Saline water with total soluble salts above 3000 mg/l cause diarrhoea, is a risk to pregnant/lactating animals and increases mortality while cadmium above 0.05 mg/l may cause permanent sterility, reduced longevity and malformation of foetus. Maximum permissible limit prescribed by BIS for animals is 0.01 mg/l and it is not readily absorbed in animal tissue. High concentration of Lead (>0.1 mg/l) may be poisonous while nitrate above 100 mg/l may lead to methaemoglobinaemia, erosion and haemorrhage of gastric mucosa leading to death. Cause reduction in plasma and vitamin A in liver. Fluoride above 2.0 mg/l may cause tooth mottling and is also transferred into milk and eggs. Maximum permissible limit of pesticides in water consumed by livestock is 0.001 mg/l and non-lethal doses may affect growth rate, egg production and viability of the young.

2.3 Impact on Plant Growth

The electrical conductivity is the measure of salt contents in the water. The effects of salinity are stunted plants growth, low yield, discoloration and even leaf burns at margin or top. High sodium in water affects the permeability of soil and causes infiltration problems. This is because sodium when present in the soil in exchangeable form replaces calcium and magnesium adsorbed on the soil clays and causes dispersion of soil particles

Other problems to the crop caused by an excess of Na is the formation of crusting seed beds, temporary saturation of the surface soil, high pH and the increased potential for diseases, weeds, soil erosion, lack of oxygen and inadequate nutrient availability.

Bicarbonate hazard, expressed as RSC, when above 2.5 meq/l results in increase of sodium causing adverse effect. When water having high bicarbonates and low calcium and magnesium is used for irrigation purpose, precipitation of calcium and magnesium as carbonate takes place, changing the residual water to high sodium water with sodium bicarbonate in solution.

Boron is an essential plant nutrient but concentration above 4.0 mg/l is toxic to plant.Copper, Lead and Zinc are essential plant nutrients but very high concentration may be toxic and reduce root growth. Chromium above 1.0 mg/l is toxic to plants. Very high concentration may reduce growth, produce iron deficiency in plants and reduce the yields. High concentration of Cadmium (>0.5 mg/l) reduces plant growth, bio-accumulates in plants and reduces yields. Iron is an important and essential element. Deficiency caused by excess of lime in soils, results in chlorosis. Excess iron contributes to soil acidification. Excess of Nickel in irrigation water causes stunted growth of plants when concentration is above 0.5 mg/l. It is toxic to barley, beans, Oats, when more than 2.0 mg/l.

The BIS prescribed limits and possible effects of water quality parameters in irrigation waters on plant growth are listed in Annexure IV.

2.4 Impact on Industries

The quality requirements for industrial water supplies range widely and almost every industrial application has it’s own standards. However, the threshold values of some of the important water quality parameters and their probable effects in industries prescribed by IS:10500:1991 are given in Annexure V.

Low pH increases corrosion of concrete; pH 7 is required for most industries, pH 6.7-7.2 is advised for carbonated beverage industry. Total dissolved solids above 3000 mg/l cause foaming in boilers and solids interfere with cleanliness, colour or taste of finished products. Low TDS values are required in most industries, high TDS leads to corrosion. Recommended value of Iron for food processing units is 0.2mg/l, for paper and photographic industry iron of 0.1 mg/l is recommended, iron less than 0.1 mg/l is recommended in cooling waters. Fluoride above 1.0 mg/l is harmful in industries involved in production of food, beverages, pharmaceuticals and medical items while nitrate above 30 mg/l is injurious to dyeing of wool and silk fabrics and harmful in fermentation process for brewing. Nitrate in some water protects metals in boilers from inter-crystalline cracking. Copper is undesirable in food industry as it has colour reactions and imparts fishy taste to finished products. Affects smoothness and brightness of metal deposits in metal plating, baths. No guidelines have been given for Chromium, Zinc and Lead for water to be used for industrial purposes.

3. WATER AND LAND USE

Punjab has a vast expanse of flat alluvial land while the Shivalik hills in the north have fluvial carvings and deposits of the three rivers, namely, the Ravi, Beas and Satluj, which flow through central Punjab, and the sand dunes in the southwest. It is endowed with some forests, abundant water and fertile land resources, whereas its earth resources (mines, fossil fuel) are negligible. Agriculture is the mainstay of the State. However, in recent years, due to the increase in population and other economic activities, serious concern has been expressed that both land and water resources have been overexploited, while their conservation has been slow and inadequate, so much so that there is fear that both land and water may become inadequate to support future development activities.

Inter-relationship and inter-dependence among water, land, vegetation and animal resources determine the nature and kind of livelihood support systems. The degeneration of natural resources such as land and water due to anthropogenic activities is assuming alarming proportions. It is, therefore, pertinent to evolve strategies for sustainable natural resource management. It is also imperative to observe the changes taking place in the land-use pattern in general and in the agricultural sector in particular, which will have wide ranging implications on availability of fresh water.

3.1 PHYSIOGRAPHY & DRAINAGE

The physiographic set up of an area plays a vital role in assessment of availability of water in space and time. The State of Punjab represents complex physiographic set up. The State can be divided into 7 major physiographic units namely, Hills (Shiwalik), Eroded hills with flat land, Intermontane valleys, Piedomont Plains, Sirowal Zone, Alluvial Plains and Sand Dunes. (Plate 3.1) .The unit wise physiographic setup of the State is given as under:

Hills (Shiwalik): The low lying Siwalik hills of the Himalayas occupy the north eastern part of the State. These hills traverse NW – SE direction and forms the boundary with neighbouring State of Himachal Pradesh and occupy northern and northeastern part of Gurdaspur, Hoshiarpur, Nawanshahr and Ropar (Roopnagar) districts.

Eroded hills with flat land: Eroded Upper Siwalik formations forming flat land are locally known as 'Beet' meaning waterless. These flat surface land (plate or tablelands) occur in Hoshiarpur district and forms fertile land to support agricultural activities.

Intermontane valleys: A longitudinal intermontane Sutlej valley extend 40 km from Nangal to Ropar along the Satluj river with an average width of 5 km. The thickness of valley fill is limited to an average of 50 m below ground level.

Piedmont areas: The transitional area between the alluvial plains and mountainous range of the Himalayan foothills is occupied by the Piedmont plains. These piedmont plains are alluvial fans deposits which have been dissected by hill torrents and small perennial streams are also known as "Kandi". The width of 'Kandi belt' varies from 6-10 km.

Sirowal Zone: Sirowal Zone lies further southwest of Kandi belt. The zone has gentle topographic gradient as compared to Kandi and presents very low relief.

Alluvial Plains: Alluvial Plains forms the dominant physiographic unit and consist of alluvium deposited by Rivers such as Indus, Ravi, Satluj, Beas and Ghaggar rivers. The plains have altitude of less than 300 m above m.s.l. These are represented as recent Flood Plains, Abandoned Flood Plains, and Bar Upland Areas.

Sand Dunes: These occupy southwestern part of the State which experiences semiarid type of climate and constitute about 28% of the area and cover parts of Ferozepur, Mansa, Bathinda, Muktsar, Kapurthala, Sangrur, Faridkot and Patiala districts. These dunes are mostly isolated type and vary in size and height.

PRSC made a study to understand the change in geomorphological setup in the State with respect to time i.e1987 to 2004 based on the satellite data. The results of the study show that anthropogenic interferences have modified the landforms to a great extent (Plates 3.2 & 3.3).

The physiographical set up of any area is dependent on geological set up. Geologically, the area in Punjab State is underlain by Siwaliks and Alluvium deposits of Middle Miocene to Recent age. The Siwaliks including upper, middle and lower are varying in age from (Middle Miocene to Pleistocene) form hilly tract running in Northern and North-eastern part of the State and the alluviul deposits (Pleistocene to Recent) constitute the alluvial plains of Punjab.

Hydrogeologically, the State can be divided into four units i.e.(i) Piedmont deposits occurring along a narrow belt along the Siwaliks, commonly known as “Kandi”; (ii) Alluvial plains; (iii) Aeolian deposits occurring in the south-western part of the State and (iv) an intermontane valley at Anandpur Sahib of Ropar district.

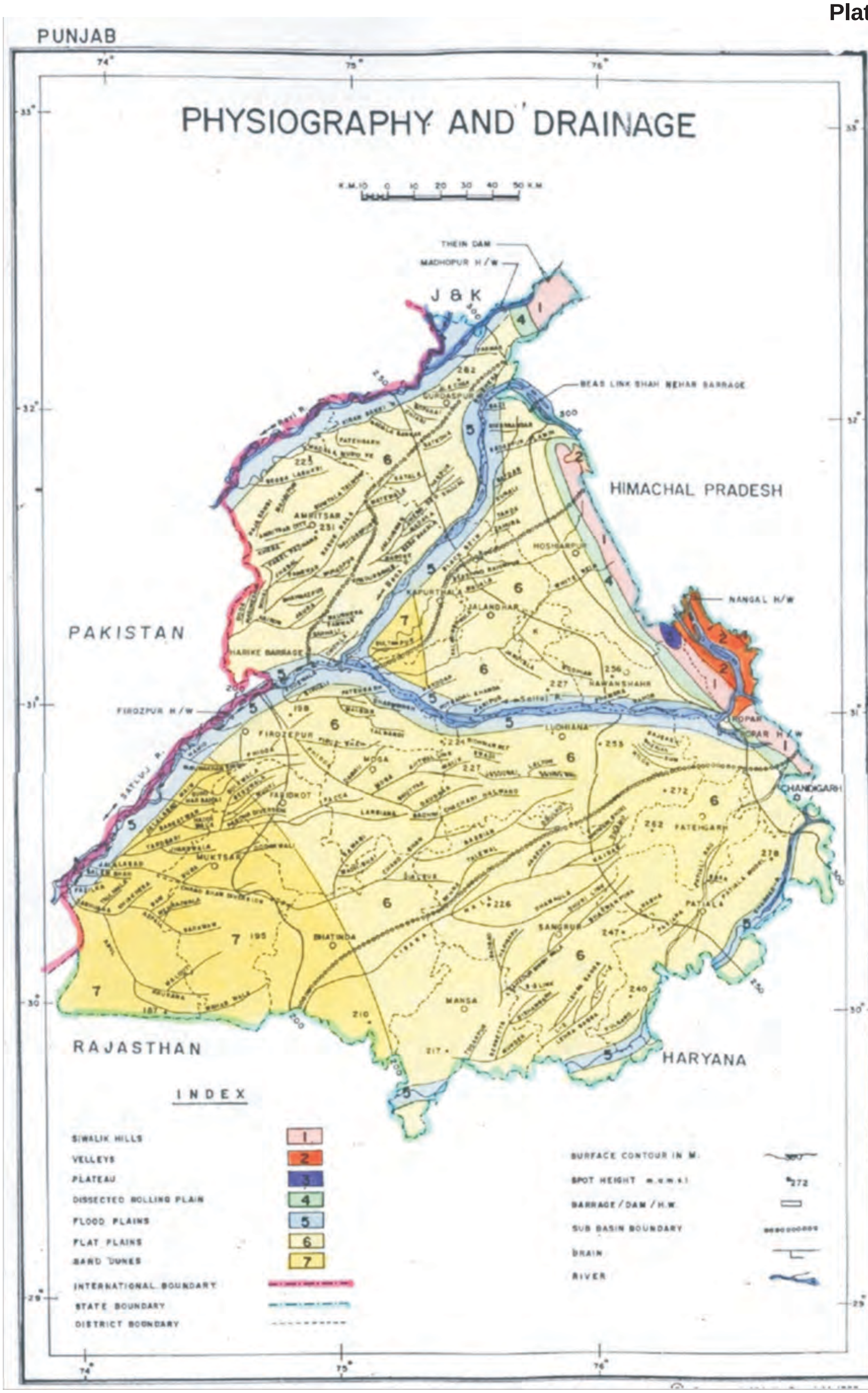
Pediment deposits “kandi” forms a poor to moderate aquifer with deep water levels distributed over a very limited area mainly along the foot hills. Aeolian deposits are overlaying the alluvial deposits occupying only the south western part of the State and rarely form an aquifer. Only perched ground water aquifer exist occurring only an isolated patches.

Alluvial deposits including inter maintain valley fill deposits forms the potential aquifers those are extensively developed.

The alluvial plain is divided into Newer alluvium occurring along active flood plains of rivers and older alluvium confined to abandoned flood plains. (Plate: 3.12). Ground water exploration has been carried out by CGWB down to a depth of 450m or even more, reveals existence of thick aquifers (Plate 3.13).

These aquifers are laterally and vertically extensive and persistent in nature. However, in south western parts, the thickness of fresh water aquifer is much less as compared to the other parts because area is underlain by brackish / saline water. At places, the thickness of fresh water bearing aquifer is even less than 10 m. Fresh ground water sediments are depicted through a Fence diagram (Plate 3.14)

Plate 3.1


PUNJAB
PHYSIOGRAPHY AND DRAINAGE
J & K
HIMACHAL PRADESH
PAKISTAN
RAJASTHAN
HARYANA
THEIN DAM
MADHOPUR H/W
BEAS LINK SHAH NEHAR BARRAGE
NANGAL H/W
HARIKE BARRAGE
FIROZPUR H/W
AMRITSAR
GURDASPUR
HOSHIARPUR
KAPURTHALA
JALANDHAR
NAWANSHAHR
LUDHIANA
ROPAR
CHANDIGARH
FIROZEPUR
MOGA
FARIDKOT
MUKTSAR
BHATINDA
SANGRUR
PATIALA
FATEHGARH
MANSA
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VELLEYS 2
PLATEAU 3
DISSECTED ROLLING PLAIN 4
FLOOD PLAINS 5
FLAT PLAINS 6
SAND DUNES 7
INTERNATIONAL BOUNDARY
STATE BOUNDARY
DISTRICT BOUNDARY
SURFACE CONTOUR IN M.
SPOT HEIGHT
BARRAGE/DAM/H.W.
SUB BASIN BOUNDARY
DRAIN
RIVER

Plate 3.12

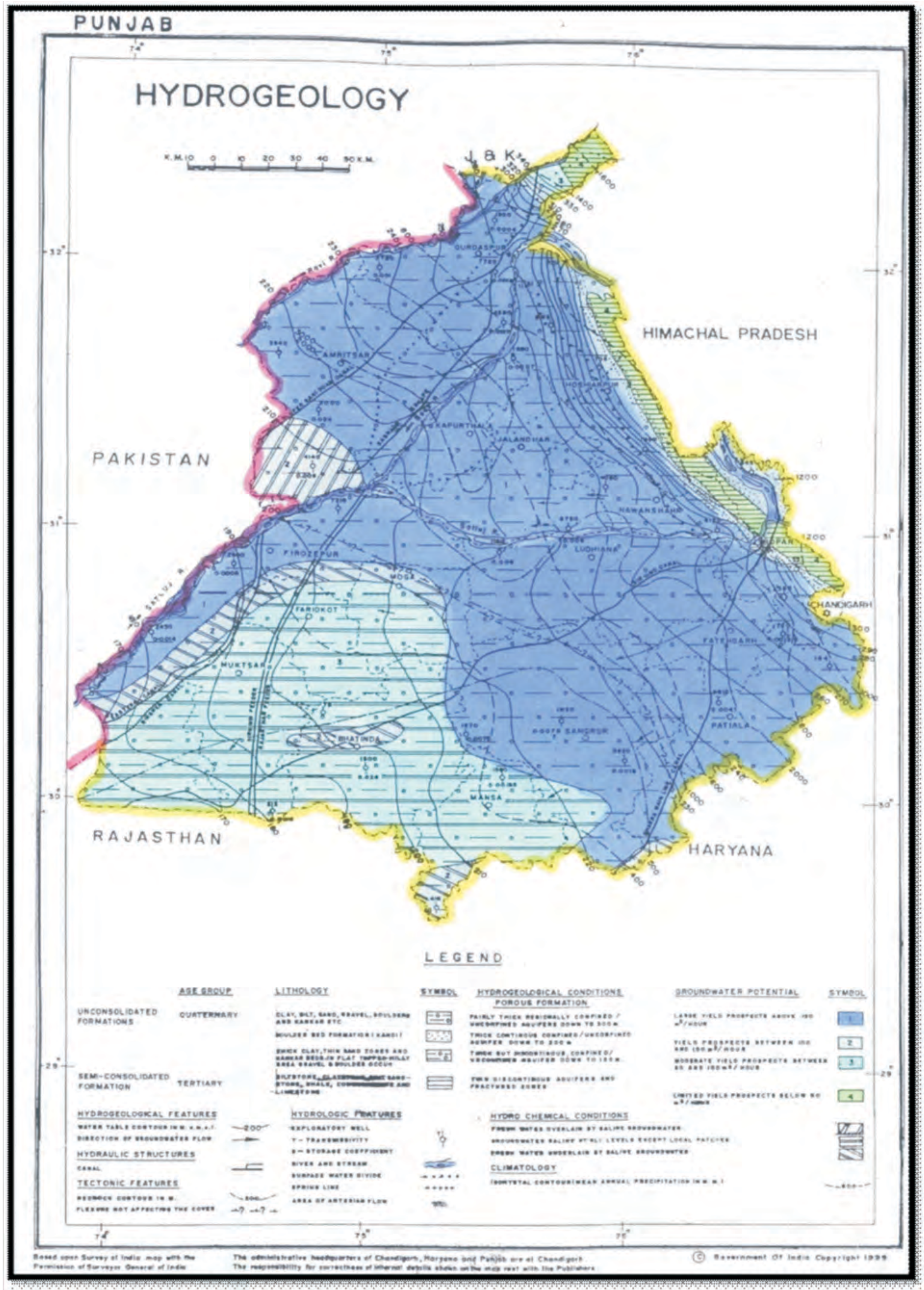
PUNJAB
HYDROGEOLOGY
PAKISTAN
HIMACHAL PRADESH
RAJASTHAN
HARYANA
J & K
AMRITSAR
GURDASPUR
HOSHIARPUR
KAPURTHALA
JALANDHAR
NAWANSHAHR
LUDHIANA
FIROZEPUR
FARIDKOT
MOGA
MUKTSAR
BHATINDA
MANSA
SANGRUR
PATIALA
FATEHGARH
CHANDIGARH
LEGEND
AGE GROUP
LITHOLOGY
SYMBOL
HYDROGEOLOGICAL CONDITIONS
POROUS FORMATION
GROUNDWATER POTENTIAL
UNCONSOLIDATED FORMATIONS
QUATERNARY
SEMI-CONSOLIDATED FORMATION
TERTIARY
HYDROGEOLOGICAL FEATURES
HYDRAULIC STRUCTURES
TECTONIC FEATURES
HYDROLOGIC FEATURES
HYDRO CHEMICAL CONDITIONS
CLIMATOLOGY
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Plate 3.13

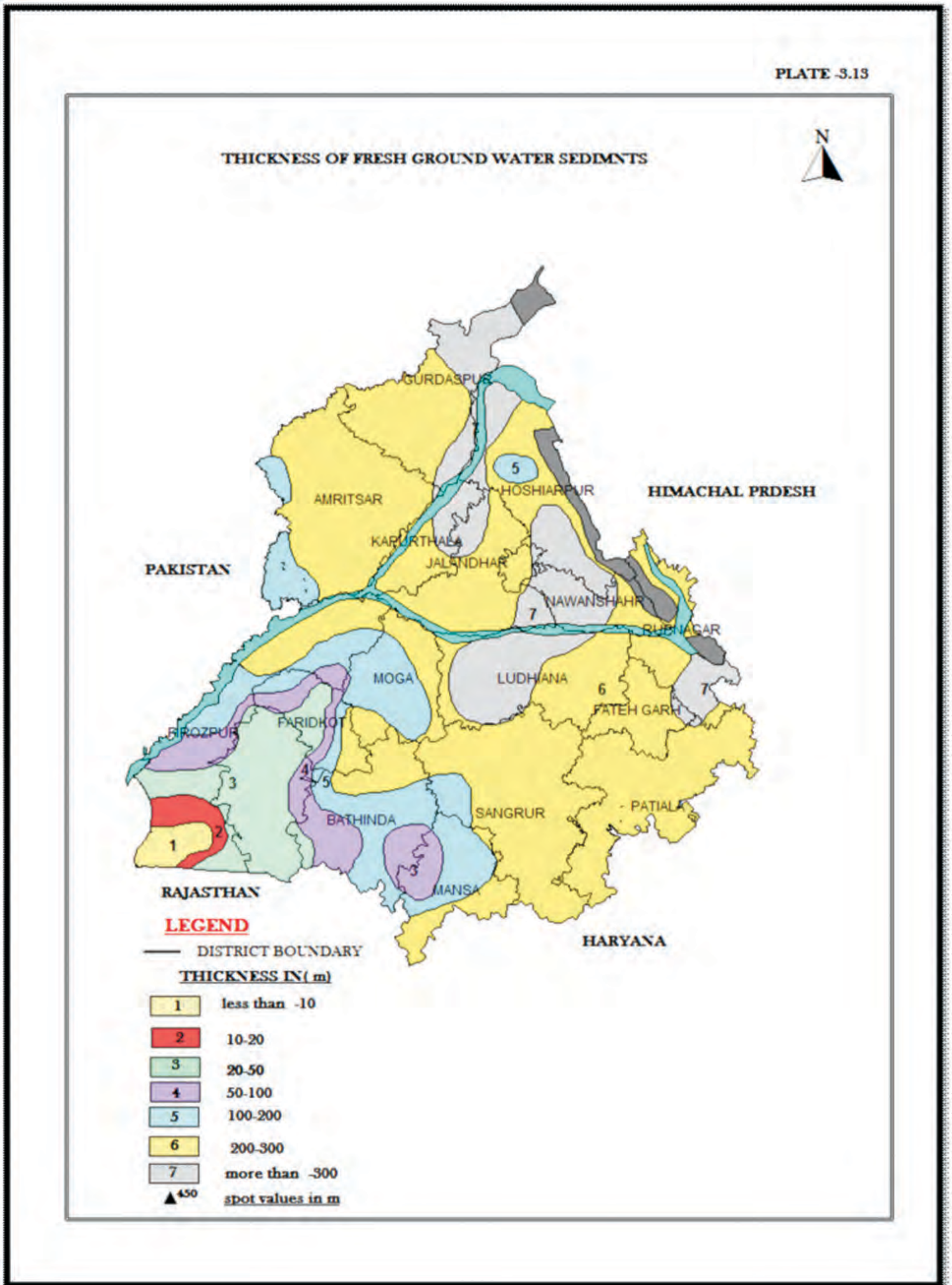
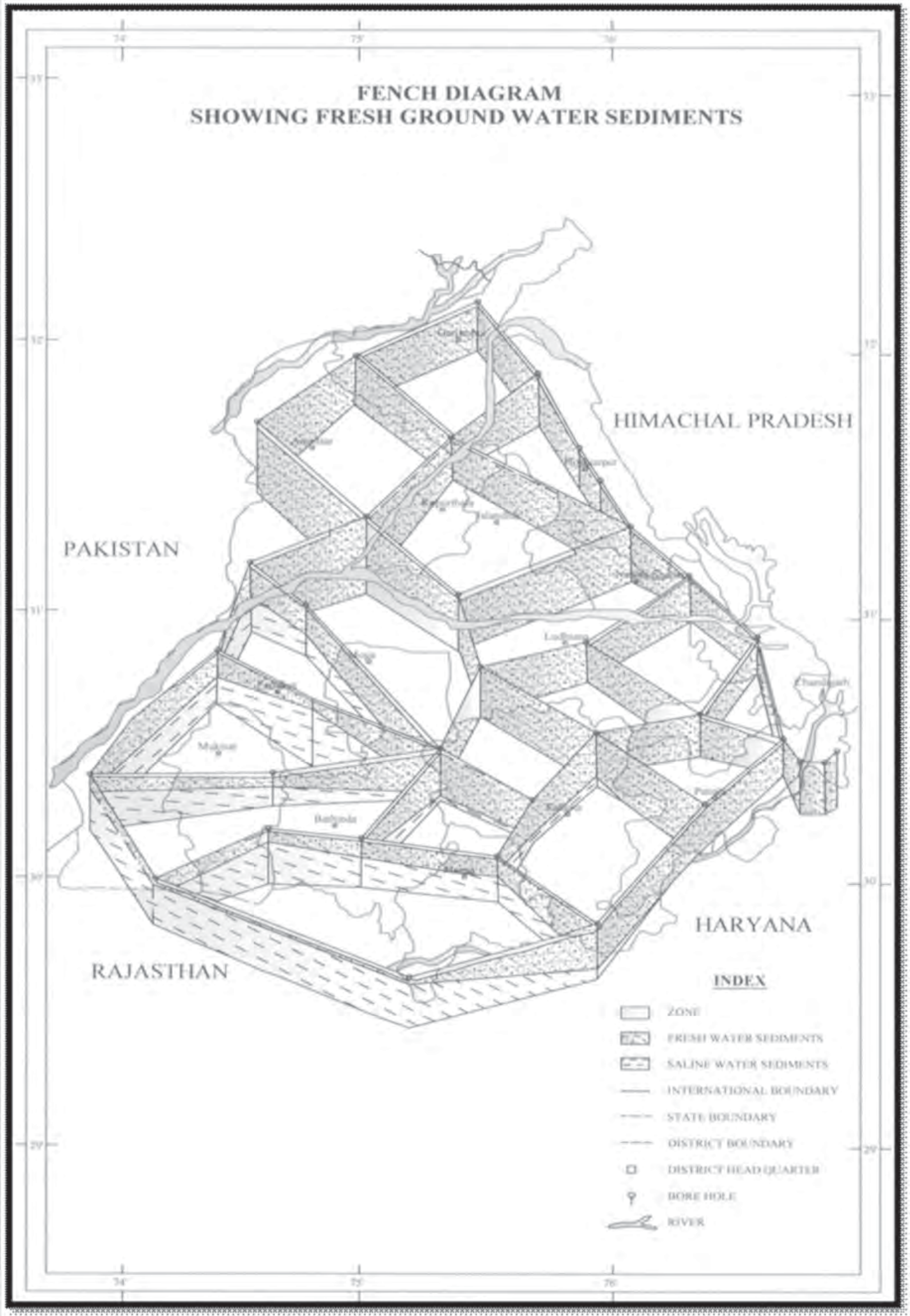


PLATE -3.13
THICKNESS OF FRESH GROUND WATER SEDIMNTS
N
GURDASPUR
AMRITSAR
HOSHIARPUR
HIMACHAL PRDESH
KAPURTHALA
JALANDHAR
PAKISTAN
NAWANSHAHR
RUPNAGAR
MOGA
LUDHIANA
FATEH GARH
FIROZPUR
FARIDKOT
BATHINDA
SANGRUR
PATIALA
MANSA
RAJASTHAN
HARYANA
LEGEND
DISTRICT BOUNDARY
THICKNESS IN(m)
1 less than -10
2 10-20
3 20-50
4 50-100
5 100-200
6 200-300
7 more than -300
450 spot values in m

Plate 3.14



FENCH DIAGRAM
SHOWING FRESH GROUND WATER SEDIMENTS
HIMACHAL PRADESH
PAKISTAN
HARYANA
RAJASTHAN
INDEX
ZONE
FRESH WATER SEDIMENTS
SALINE WATER SEDIMENTS
INTERNATIONAL BOUNDARY
STATE BOUNDARY
DISTRICT BOUNDARY
DISTRICT HEAD QUARTER
BORE HOLE
RIVER

Plate 3.2

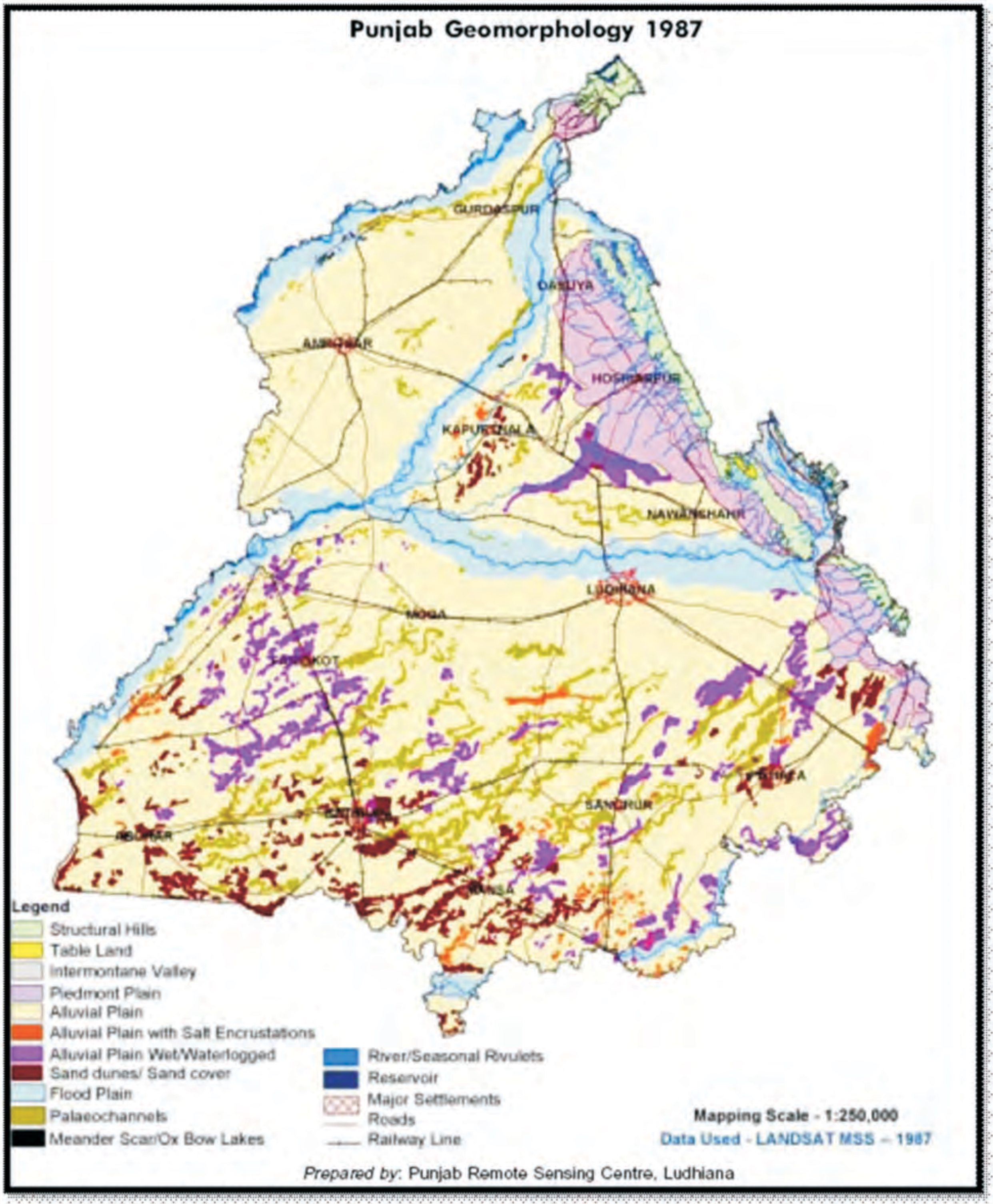
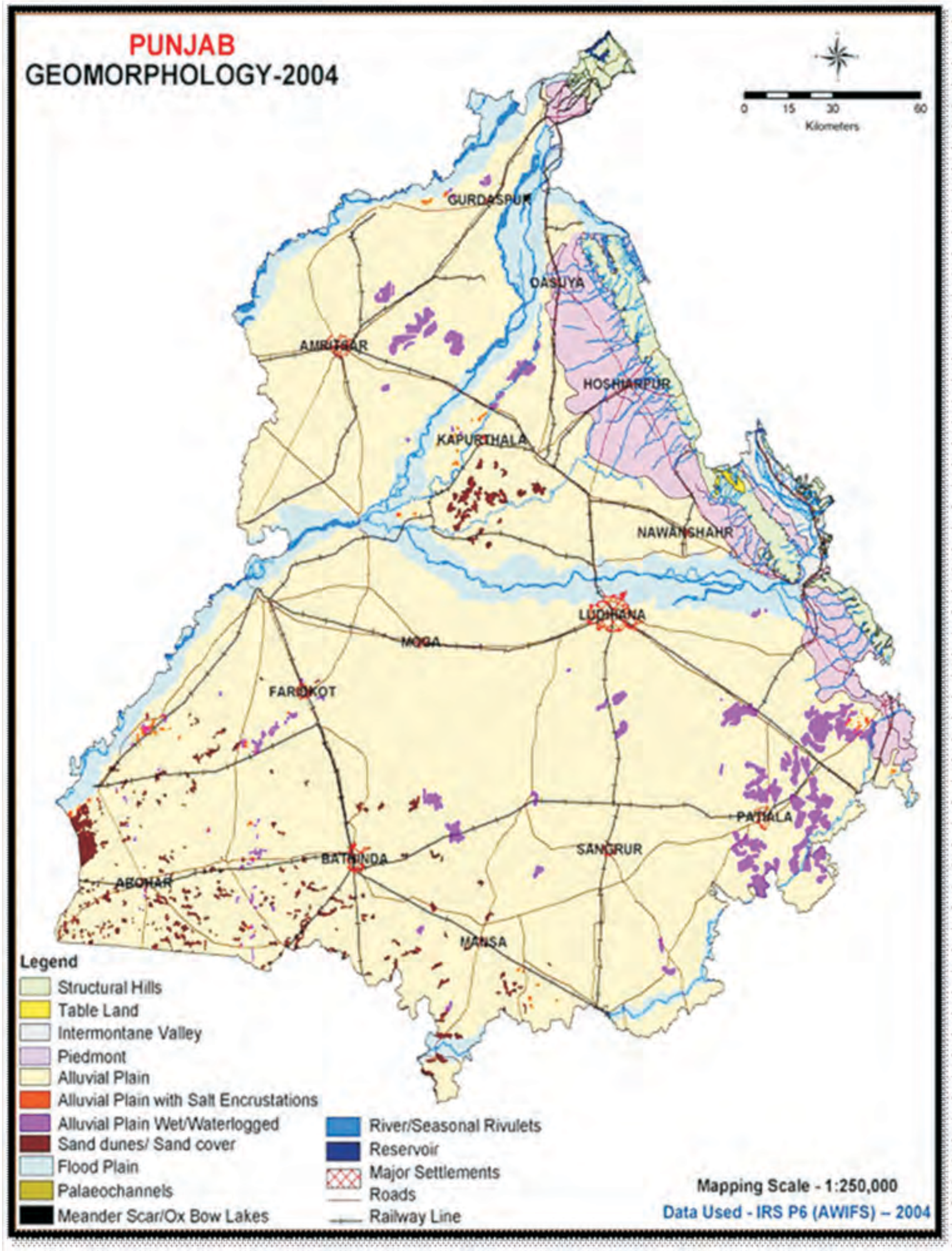

Punjab Geomorphology 1987
GURDASPUR
DASUYA
HOSHIARPUR
KAPURTHALA
NAWANSHAHR
LUDHIANA
MOGA
SANGRUR
MANSA
Legend
Structural Hills
Table Land
Intermontane Valley
Piedmont Plain
Alluvial Plain
Alluvial Plain with Salt Encrustations
Alluvial Plain Wet/Waterlogged
Sand dunes/ Sand cover
Flood Plain
Palaeochannels
Meander Scar/Ox Bow Lakes
River/Seasonal Rivulets
Reservoir
Major Settlements
Roads
Railway Line
Mapping Scale - 1:250,000
Data Used - LANDSAT MSS – 1987
Prepared by: Punjab Remote Sensing Centre, Ludhiana

Plate 3.3



There has been change in the spread of palaeochannels, sand dunes, salt- affected and wet/ waterlogged areas in the last seventeen years. Sand dunes with a spread of 1498 sq km (2.97% of Total Geographic Area) during 1987 have reduced to 413 sq km (0.80% of TGA) due to levelling and being brought under irrigated agriculture. The geomorphogical Plate (1987) shows a number of palaeochannels with a spread of 2142 sq km (4.25% to TGA) which reduced to 122 sq km (0.24% of TGA) during 2004. Wetland/waterlogged areas occupied 2183 sq km (4.33% of TGA) during 1987 which has reduced to 853 sq km (1.69% of TGA). Alluvial plain with salt accumulation has reduced from 371 sq km (0.74% of TGA) during 1987 to 40 sq km (0.08% of TGA) in 2004 as a result of reclamation and management of these lands for bringing them under productive use.

The drainage system of the State is mostly controlled by perennial rivers like the Satluj, Beas Ravi and the Ghaggar & its tributaries. About 8000 km long drainage system exists in the State which helps in quick runoff and prevents occurrences of water logging. The doab wise drainage system developed in the State is given below:

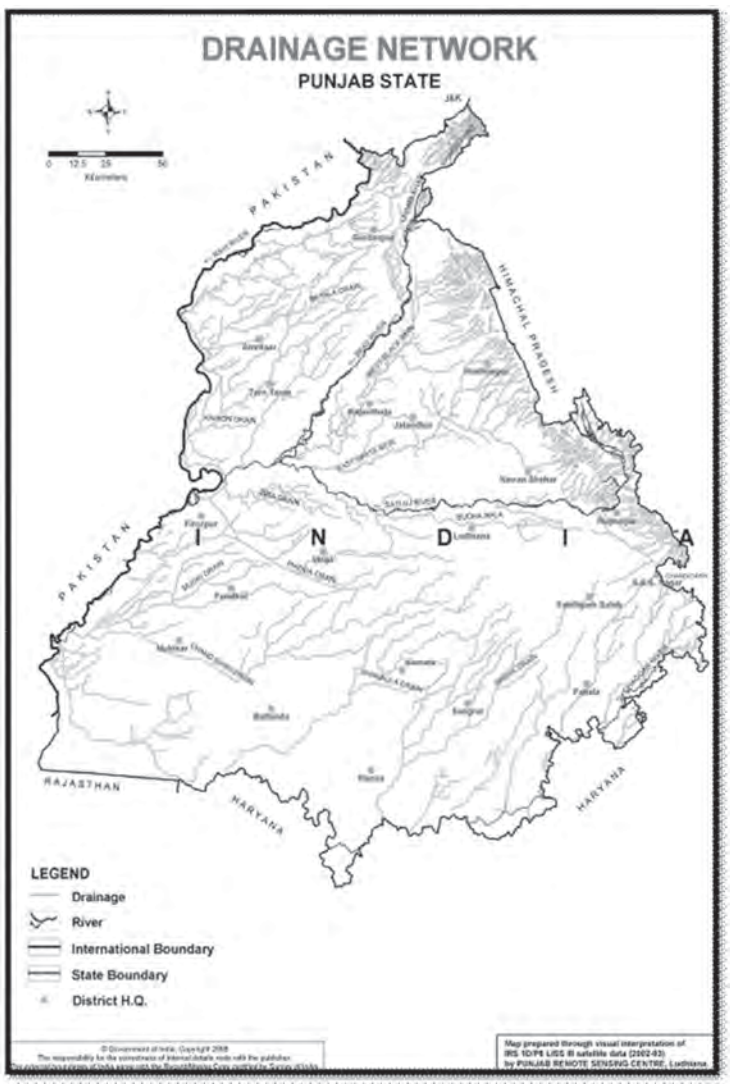
Bari doab

The drains between Ravi and Beas are Sakki Kiran Nallah, Hudiara Nallah, Kasur Nallah and Patti Nallah. In Upper Bari Doab tract, Chakki Khad a perennial tributary of the Beas, drains mainly the ‘kandi’ belt. The Naumuni and Kiran are two tributaries of the Ravi and drain north western parts of this tract. The Patti nala drains the southwestern part of the area and joins the Satluj river

Bist Doab

Two Beins (rivulets) flow between Beas and Satluj i.e. the East/Kali Bein and West/Safed Bein. Other major drains falling in river Satluj are Jalalabad drainage system and Budha Nallah(Plate 3.4). The Bist Doab tract is traversed by about 85 hill torrents known as choes, which debouch into plains. There are two main drainage patterns in this tract i.e Eastern or White Bein and The Western or Black Bein and both are perennial.

Plate 3.4



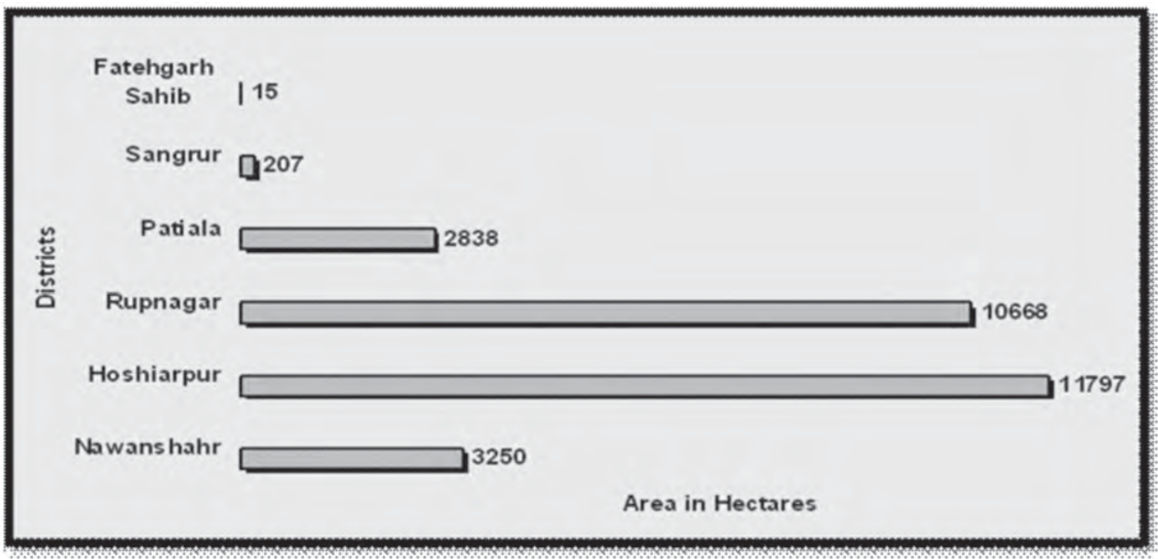
Ghaggar basin

The southeastern part of the State is drained by Ghaggar river which is perennial. Tangri nadi, Budha nala and Lissara nala are the main seasonal streams in the area. In south western part, some of the important drains are the Phidda drain, Chand Bhan drain and Jallalabad drain.

Choes in Punjab

Several seasonal rivers/rivulets known as 'Choes' are also found in the Shiwalik area . These are mainly responsible for soil erosion in Hoshiarpur, Nawanshar & Ropar districts. As many as 93 'choes' are reported to flow in Hoshiarpur district alone. It has been reported that these seasonal rivulets used to bring down approximately 35 tonnes/ha/annum of soil. This has been reduced to about 18 tonnes/ha/annum with the efforts of Soil Conservation and Forests Departments. The districtwise area under choes is represented by Fig 3.1.

Fig 3.1 District Wise Area Under Choes In Punjab



Source: Director of Land Records, Punjab as cited in Tiwana*et a*l., 2005

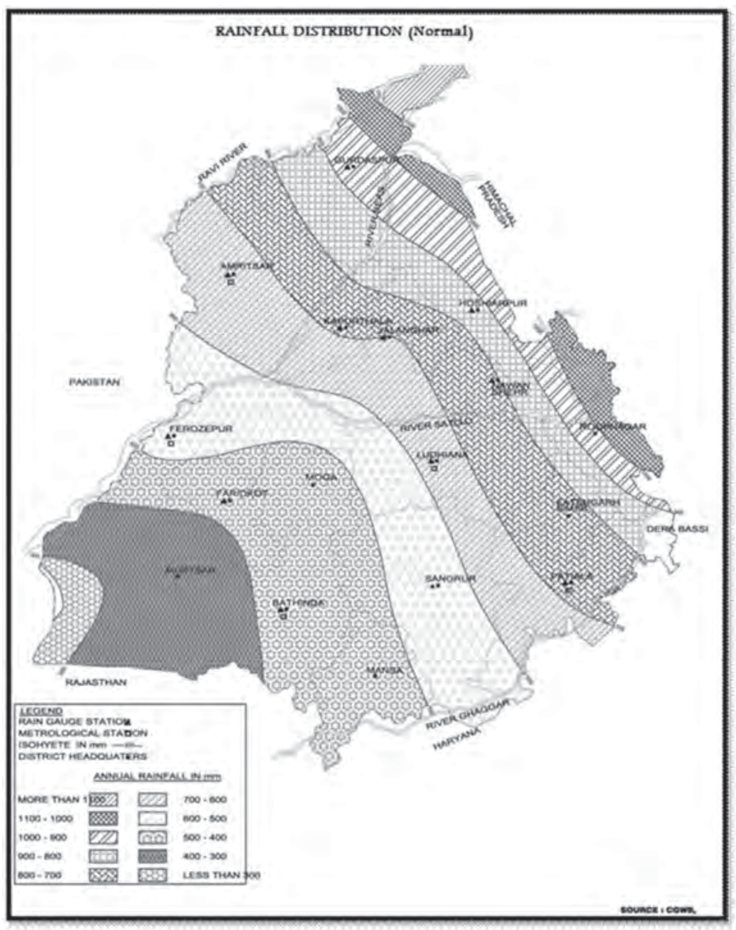
3.2 CLIMATE AND RAINFALL

The climate of the State is sub tropical with hot summers (temperature reaching upto 47^{0}C in some areas) and cold winters (with lowest temperature around 1^{0}C). The State experiences four seasons in a year namely, winter from November to March, summer from April to June, monsoon season from July to September and transition season from September till the beginning of November. State receives about 648.8 mm of Normal annual rainfall, 80% of which received during monsoon season from July to September. Rainfall in the State varies from 260 mm in extreme southwest parts to 720 mm in northern regions of the State. Districts lying north of Gurdaspur receive the maximum rainfall and districts southwest of Ferozepur receive the minimum amount of rainfall (Plate 3.5). Monsoon reaches eastern part by last week of June which is the normal onset date of monsoon season and covers entire State by first week of July. Withdrawal of southwest monsoon season begins from western parts of the State in the first week of September. During winters

(November-March) State receives about 100 mm of average rainfall due to passage of western disturbance which are quite crucial for agriculture operations.

Weather tends to be humid during July –September due to increased moisture contents in the air. Winds are generally of low speed during the post-monsoon season and winter season. They strengthen during monsoon season and summer. Winds are predominantly from south-easternly and easternly during monsoon season and summer while rest of the year winds are mostly from northwest and west direction. The lowest mean wind speed of 3.8 km/hr is marked from November to December and the highest speed of 8 km/hr is recorded in May and June. The relative humidity is generally high through out the year except during months of April to June. The average humidity remains about 32% in May and 73% during August. Day temperature is more or less uniform over the plains except during winter and monsoon season. In general the night temperature is lower in higher attitudes except during the post monsoon when they are more or less uniform. June is the hottest month with mean maximum temperature of 41^0 C in plains with 2^0 to 5^0 C lower temperatures at elevated places. Highest temperature recorded in the plain is 45^0C. January is the coldest month with mean minimum temperature for the State as a whole is 5.5^0C, varying from 4^0 to 5^0C in the west to 6^0 to 7^0C in the east. Lowest temperature recorded in the Punjab was 1^0C.

Plate 3.5



3.3 SOILS & MICRONUTRIENTS

The soils of Punjab have largely been developed on the alluvium deposited by the rivers. Soils have been affected dominantly by changes in climatic conditions over a long period of time. The soils types are divided into eight types and presented in Plate 3.6.

Flood Plain or Bet Soils covering 7% of total area in the State and occupy mainly the flood plain areas of various rivers, streams or choes. A more mature bet soils i.e old flood plain occurs in a wide belt along the west bank of river Satluj from Ropar town to Fazilka town.

Loamy Soils covers nearly 25% area of the State and are the most fertile and productive soil group. These soils occur mainly in Nawanshahr district, larger parts of Nakodar tehsil of Jalandhar district, Phagwara and central parts of Kapurthala district.

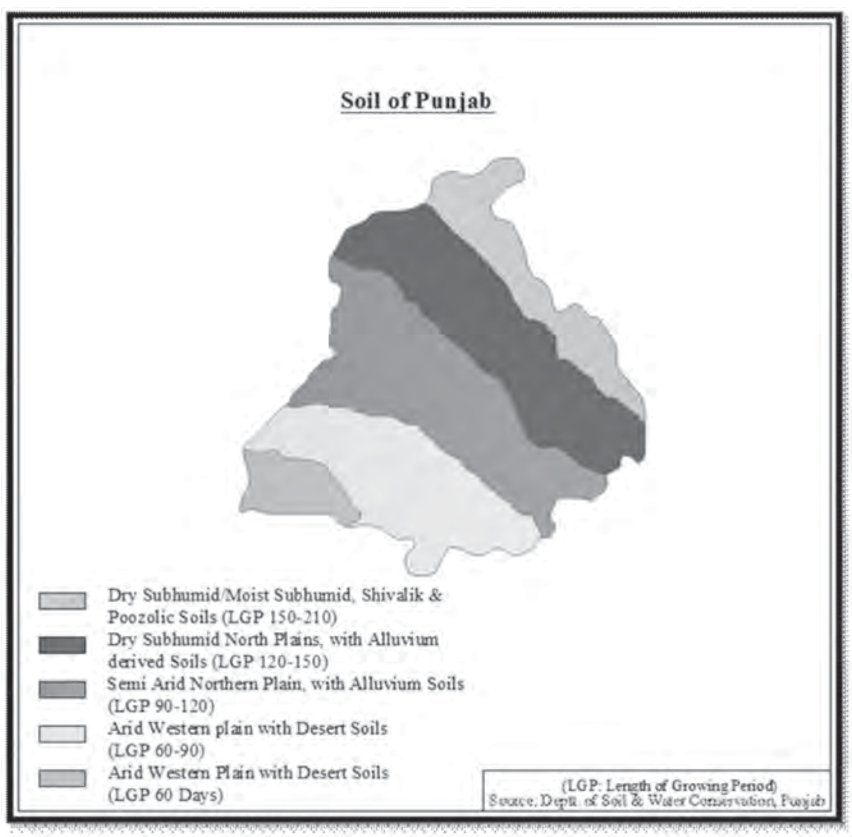
Sandy Soils are arid soils of south-western and south central Punjab covering 11% of the area and the districts of Bathinda, Mansa, southern parts of Ferozepur and Mukatsar districts, larger parts of Sangrur, south -central parts of Patiala district and some patches of Ludhiana district.

Desert Soils occur in the arid zone and cover more than 11% of the total area of the State. These soils mostly cover south-western parts of the State in Ferozepur, Mukatsar, large parts of Bathinda and Mansa and few patches in Sangrur and Ludhiana district.

Kandi Soils are found in Pathankot tehsil of Gurdaspur, parts of Hoshiarpur, Nawanshahr and Ropar districts and cover 23% of the total area. These have been deposited by numerous choes originating from Siwaliks hills.

Sierozems are grey soils covering nearly 25% of the area in semi arid parts of Punjab State and found in eastern part of the Malwa plain in Ludhiana districts, northern and central parts of Sangrur district, Fatehgarh Sahib district and Patiala district, western parts of Patiala district and partly in Faridkot district.

Plate 3.6



Grey Brown Podozolic & Forest Soils are the stony, gravelly and sandy soils occurring in parts of Gurdaspur district and Siwalik hill zone of Hoshiarpur, Nawanshahr and Ropar districts.

Sodic & Saline Soils occupy the areas in Bikaner canal, Abohar, Bathinda, Ghagghar and Kotla branches of Sirhind canal and Bhakra canal command areas. Large tracts of Malwa plain Fazilka, Jalalabad, Guru Harsahai, Talwandi Bhai in Ferozepur district, northern parts of Faridkot and Mukatsar districts, eastern parts of Mansa district, Govindgarh, Khokhar area of Sangrur district and Samana of Patiala district are also covered by this soil.

The soils of Punjab are generally low in Nitrogen (N) content, low to medium in Phosphates (P) and medium to high in Potassium (K) except in Kandi belt which has low to medium K content (Department of Agriculture, Punjab). During past two to three decades, intensive agricultural practices have put a tremendous pressure on the soils and resulted in steady decline in its fertility (nutrient availability), both with respect to macro and micronutrients. Even with recommended rate of fertilization in this cropping pattern, a negative balance of primary nutrients still exists (Benbi *et.al*., 2006). Moreover, partial factor productivity of NPK in Punjab has also dropped from 80.9 in 1966-67 to 16.0 in 2003-04. To overcome this, farmers in the State have been applying higher and higher doses of major nutrients, especially nitrogen for sustaining adequate production levels. Organic carbon content has been reduced to very low and inadequate levels in the State, because of very low or limited application of organic manures and non-recycling of crop residues (Johl *et al.,* 2002)

The soils in the State are generally deficient in Phosphorus, especially the coarse textured soils of Bathinda, Ferozepur and Faridkot. The decreased consumption of the phosphatic fertilizers as evidenced by widening N:P ratio together with increase in the area under rice-wheat system may be the reason for decline in soil P status (Source: Benbi *et al.*, 2006). With respect to available Potassium the Punjab soils have generally been categorized as medium (138-338 kg K_2O/ha) to high (more than 338 kg K_2O/ha. The percentage samples in the three categories remained remarkably similar over the years. Benbi *et al.*, (2006) reported that maintenance of K status of soils over the years may be ascribed to the presence of micaceous minerals in the soils and addition of substantial amounts of K through irrigation water.

The present exploitive agriculture laying emphasis on high crop yields has been depleting soils of their limited micro-nutrient reserves leading to the emergence of deficiencies of micor-nutrients in different soils of the State. Maintenance of soil fertility is essential to sustain agricultural production. The extent and nature of this deficiency varies in different soils and crops. Results of soil samples collected from various districts in Punjab, (PAU by Nayyar *et al.,* 1990) over a period of time revealed that deficiency of Zinc (Zn) has decreased & that of Iron (Fe) and Manganese (Mn) has increased.

Awareness amongst the farmers about Zinc deficiency has resulted in increased use of Zinc Sulphate and subsequently, the extent of Zinc deficiency has improved throughout State. As far as Fe and Mn are concerned, the increase in deficiency may be due to shift in cropping pattern towards rice particularly in coarse textured soils. (Source: Benbi *et al.,* 2006). Changes in micronutrient Status in various Districts of Punjab (1970-2004) is presented in Table: 3.1.

Table: 3.1 Changes in Micronutrient Status, Punjab (1970-2004)

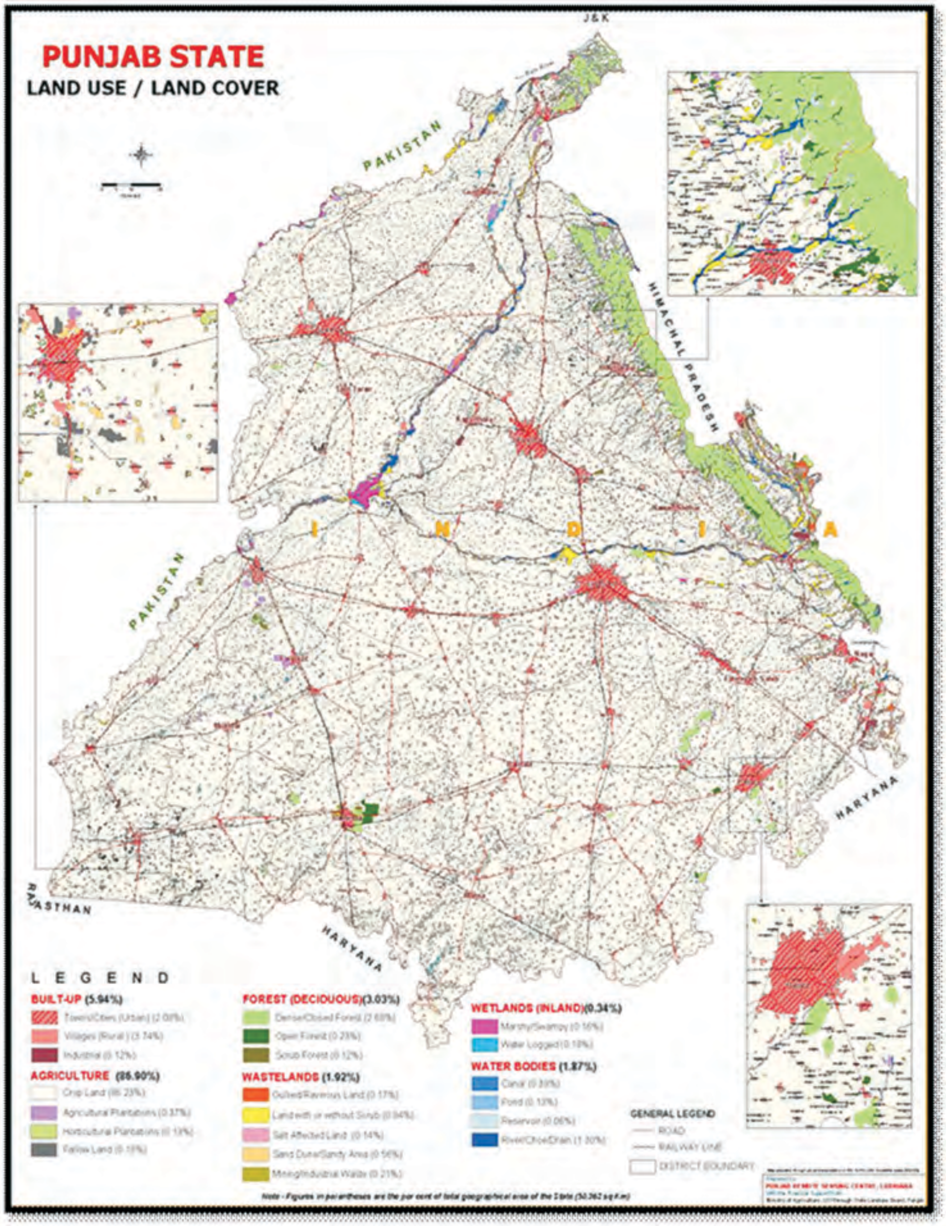
District	Year	Percent Sample Deficient			
		Zinc	Copper	Iron	Manganese
Ludhiana	1970	56	-	-	2
	1988	12	2	1	5
	2004	7	2	7	22
Jalandhar	1977	45	6	0	0
	1998	14	0	13	39
Sangrur	1977	71	4	7	0
	2000	14	0	18	35
Patiala	1980	23	1	4	2
	2004	12	1	5	5
Gurdaspur	1982	52	2	2	1
	2000	42	1	1	5
Kapurthala	1983	45	1	4	0
	1992	15	0	8	3
Amritsar	1984	47	0	0	0
	2004	36	0.5	4	5
Hoshiarpur	1985	59	1	13	6
	2004	31	6	24	25
Mukatsar	1992	70	2	61	7
	2004	37	5	31	8

Source: Sharma *et al.*, 2004 as cited in SOE, Punjab-2007

3.4 LAND USE

Major land use activities like agriculture, water resources developmental pastures, forests, urbanization, industrialization and commercial purpose like transportation, etc. are practiced in this State (Plate 3.7).

Plate 3.7

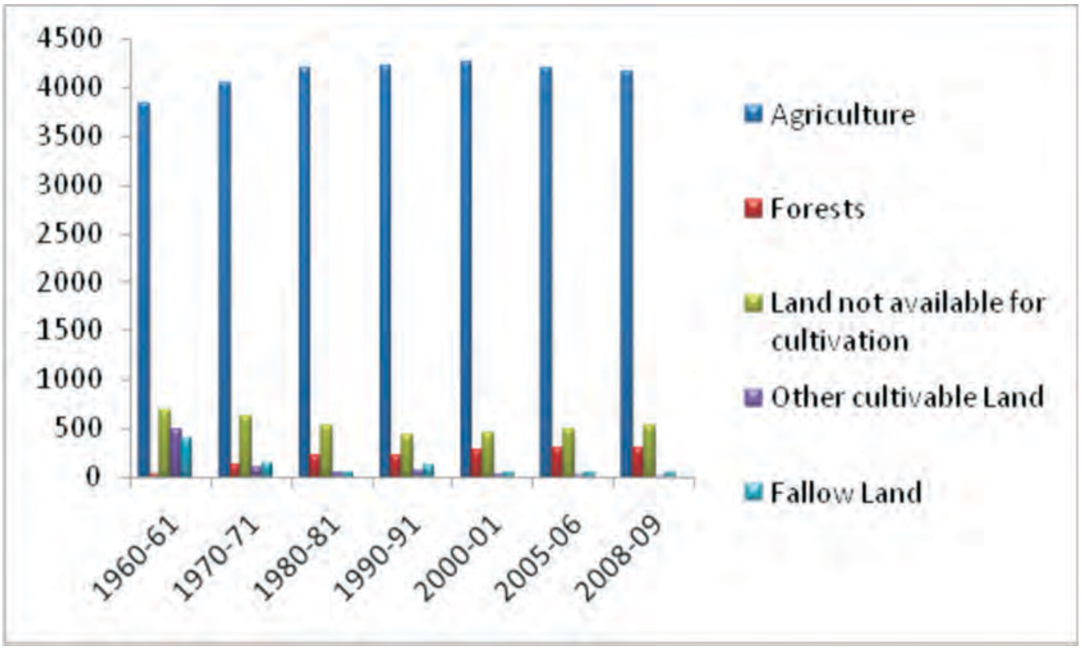


Land use usually depends upon the soil types in an area e.g. loamy soils support agricultural activities where as areas which are sandy and rocky are usually suitable for this activities.

Land use pattern has undergone a tremendous transformation in the State due to changes in agriculture cropping pattern, urbanization and industrialization. During the recent years, there has been an increase in the area put to non-agricultural uses, as expected, because as a result of increase in the development activities, more & more land is being used for industrial sites, housing, transport systems, recreational purposes, irrigation systems, etc. The change in the land use pattern brings associated ecological changes in the State.

In Punjab, the proportion of land under non-agricultural uses is higher than the all India average. Punjab land utilization is depicted in Fig-3.2.

Fig. 3.2 Land Utilization in Punjab (in Thousand Hac.)



Agriculture land:

82.77% of the total land of Punjab is under agricultural activities and classified as net area sown. This percentage is about double of the average percentage of the country as a whole (40.38%). The semi hill districts like Gurdaspur, Hoshiarpur, Nawanshahr and Roopnagar have comparatively lower percentage of net area sown which is 56% to 82%. South- western districts Mansa, Bathinda, Faridkot, Muktsar and Ferozepur have higher percentage of net area sown than average for Punjab. It is between 85% and 90%. The north central and central districts have high percentage of net area sown ranging between 82% and 90%. Kapurthala, because of sand dunes and sand bars cover has also a moderate (81%) area of net area sown.

Forests:

Area covered under forest is about 5.88% of the total area of the State and is very less as compared to agricultural land. It is about one fourth of the average percentage for the country (20.8%). A large part of the forest area lies in the district of Hoshiarpur, Gurdaspur, Roop Nager, SAS Nagar and Nawanshahr. The others districts have very Limited area under the forestcover.

Land Not Available For Cultivation

This class of land includes absolutely barren and uncultivable land like mountains, deserts, swamps, water bodies, etc. It also includes land covered by buildings, roads, railways, and water or otherwise appropriated for non-agricultural purposes. Such land covers about 10.27% of the total area of the State. Ludhiana, Bathinda, Sangrur and Patiala districts have each more than 30,000 ha. of land under this class; while Fatehgarh Sahib, Barnala, Mansa, Nawanshahr districts have each 11,000to 14,000 Hectare area of the State in this class. The other districts have very small area under this class.

Other Un-cultivable Land

Uncultivated land which is available for cultivation but, presently not been under cultivation. It includes culturable waste, permanent pastures, other grazing land and land under miscellaneous tree crops and grooves. Only very small area which is 0.20% of State's total geographical area falls under this category.

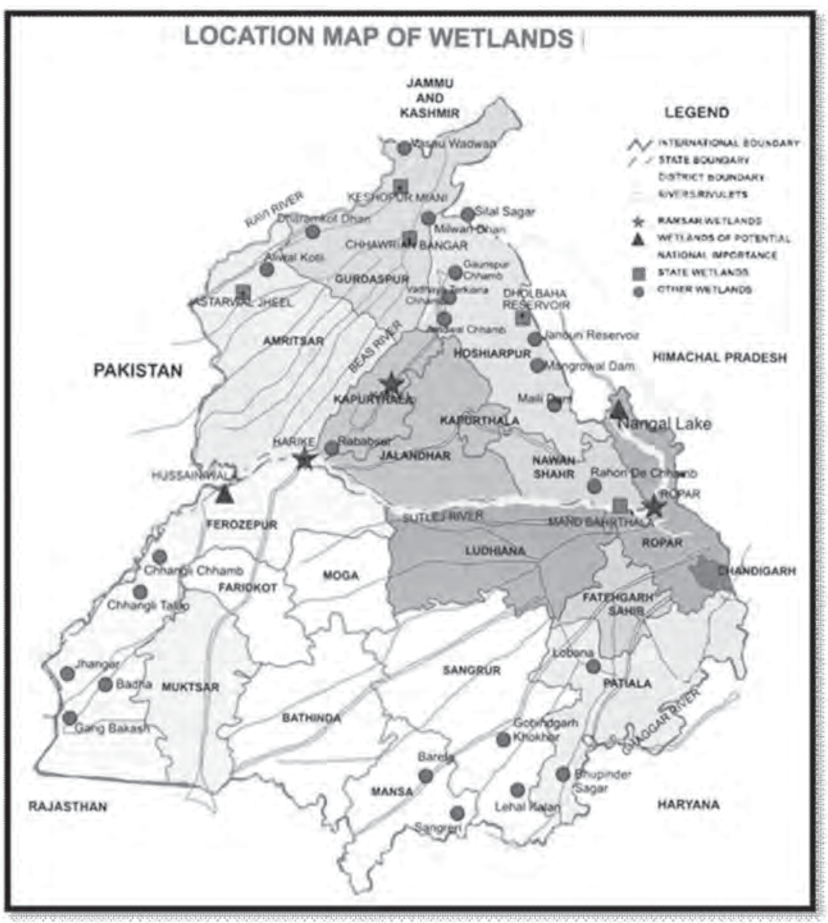
Fallow Land

It is the cultivable land which remains uncultivated over a long period and is also called "old fallow". The land kept uncultivated during the current year called "current fallow". It is 0.78% of the total area of the State. Fallow land of the State has been decreasing over the years due to extension of cultivated land.

Wetlands

The State has three wetlands of international importance with its three Ramsar sites (Harike, Kanjli and Ropar). The State has 12 natural and 9 manmade wetlands (covering more than 15,500 ha area). About 0.31% of the State's area is under natural and manmade wetlands. The twelve important natural wetlands cover a total area of 8.44 sq km and 9 manmade wetlands cover an area of 101.35 sq km. (Plate 3.8).

Plate 3.8



3.5 AGRICULTURAL PRODUCTIVITY

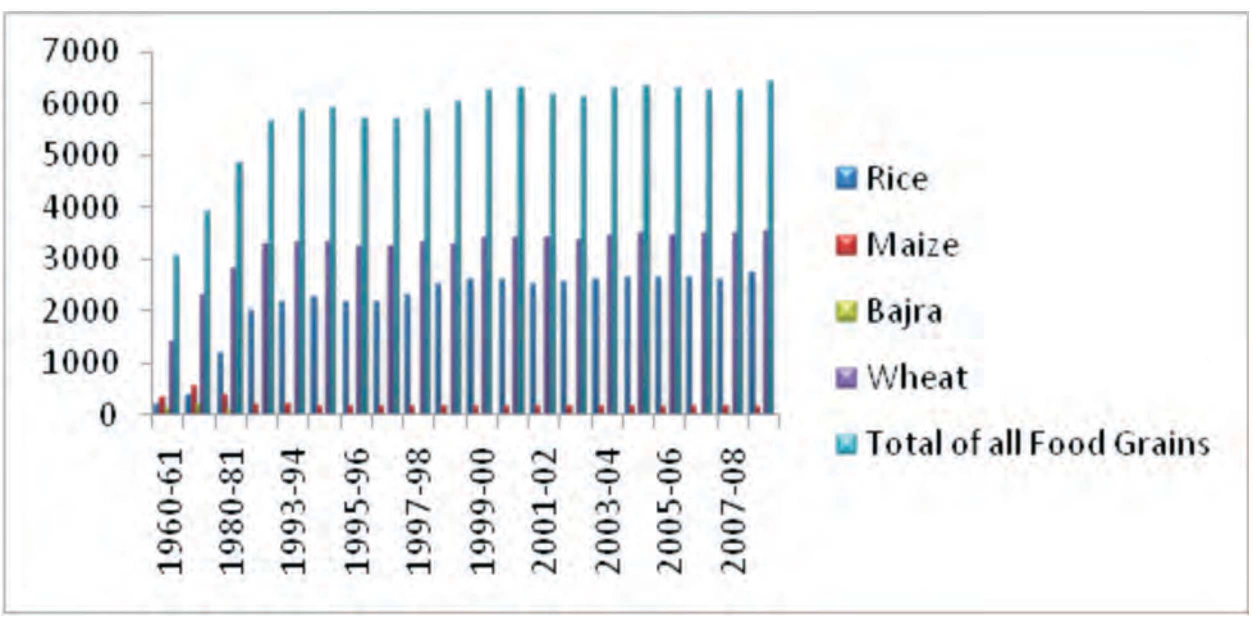
Punjab has made tremendous progress in the field of agricultural growth between 1953-55 to 1963-65, the index of agricultural production of all crops experienced a growth rate of 4% compared to 2.2% at the all India level. A Green Revolution started in Punjab during the mid-sixties (1965-66) with the introduction of modern technologies to boost food grain production. These inputs were introduction of high yielding varieties of seeds, use of chemical fertilizers, pesticides, insecticides, weedicides, mechanisation of farm tools such tractors, threshers, pump sets/motors, combine harvesters/reapers and others.

Assured irrigation system was the major input to build capacity and to adopt the new technology. Between 1965-66 & 1970-71 the per hectare yield of wheat doubled from 1104 kg to 2238 kg per hectare. In the mid 1980s, except for the southern parts of Punjab, the State began to follow a wheat-paddy rotation pattern in cultivation and as a consequence, Punjab became the food bowl of the country. It became the largest contributor to the central pool of procurement of food grains and made India, a country self sufficient in food grains.

The inputs have increased tremendously to increase the productivity and by bringing more & more area under wheat & paddy crops. The use of N & NPK fertilizers has increased to 8 times during 1970-71 to 2006-09. Consumption of chemical inputs has also shown increase over the decades. A very high proportion of the land is under cultivation because of the suitability of the land and overcoming the deficiency of rainfall by irrigation facilities, food grain production has increased from 3162 thousand metric tons in 1960-61 to 27326 thousand metric tons in 2006-09.

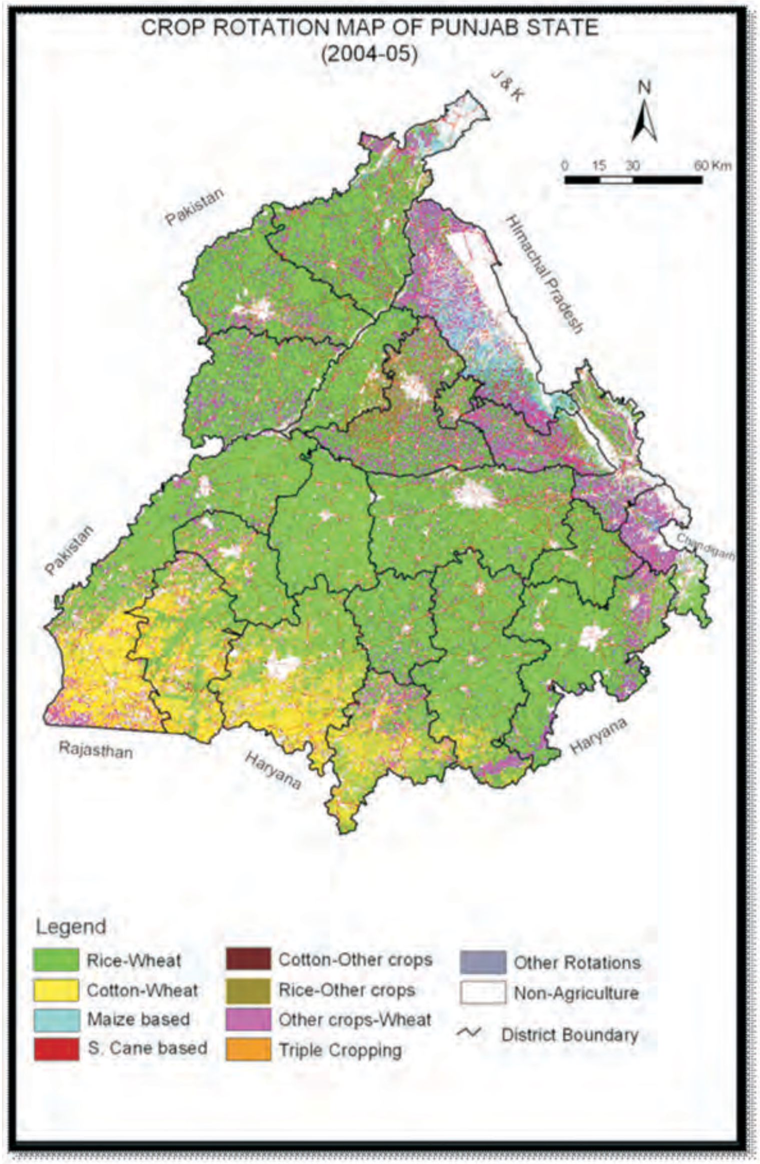
Though Punjab is a one of the smallest State with a total land area of 1.6% of the country yet it contributes to 42% rice, 55%wheat, and 24% cotton production in the country. Fig-3.3 indicates a considerable change in areas under cultivation & production of various crops.

Fig-3.3 Change In Area Under Major Crops In Punjab



Thus, the area under high water intensive rice crop has increased tremendously while the less water consuming crops of maize and bajra has largely reduced during the last three decades. Similarly, the area under groundnut and bajra, which are also, less water consuming crops has declined enormously. The crop rotation Plate (Plate 3.9) has confirmed that wheat-rice and cotton-wheat are the major rotations followed in the State.

Plate 3.9



The increase in the area under crops sown more than once has been achieved in the State primarily due to the availability of assured ground water resource for irrigation. The tremendous growth in tube well construction for irrigation has ultimately contributed to the increase in food grain production of the State. The production of rice in the State has increased from 688 thousand metric tons in the years 1970-71 to 11000 thousand metric tons in the year 2008-09. This is being achieved through increasing the yield per hectare from 1765 to 4,019 kg per hectare. Similarly, the production of wheat in the State has increased from 5145 to 15,733 thousand metric tons between the year 1970-71 to 2008-09 through increasing the yield per hectare from 2238 to 4507 kg per hectare. The histogram showing the Productivity of rice and wheat is given in Table 3.2 & 3.4 and figure 3.3 & 3.5.

Table: 3.2 Production of Rice

Year	RICE (area under cultivation'000H)	RICE PRODUCTION ('000M.TONS)
1960-61	227	229
1970-71	390	688
1980-81	1183	3233
1990-91	2015	6506
2000-01	2612	9157
2005-06	2647	10217
2008-09	2735	11000

Fig. 3.4 Production Of Rice Vs Area Under Rice Cultivation

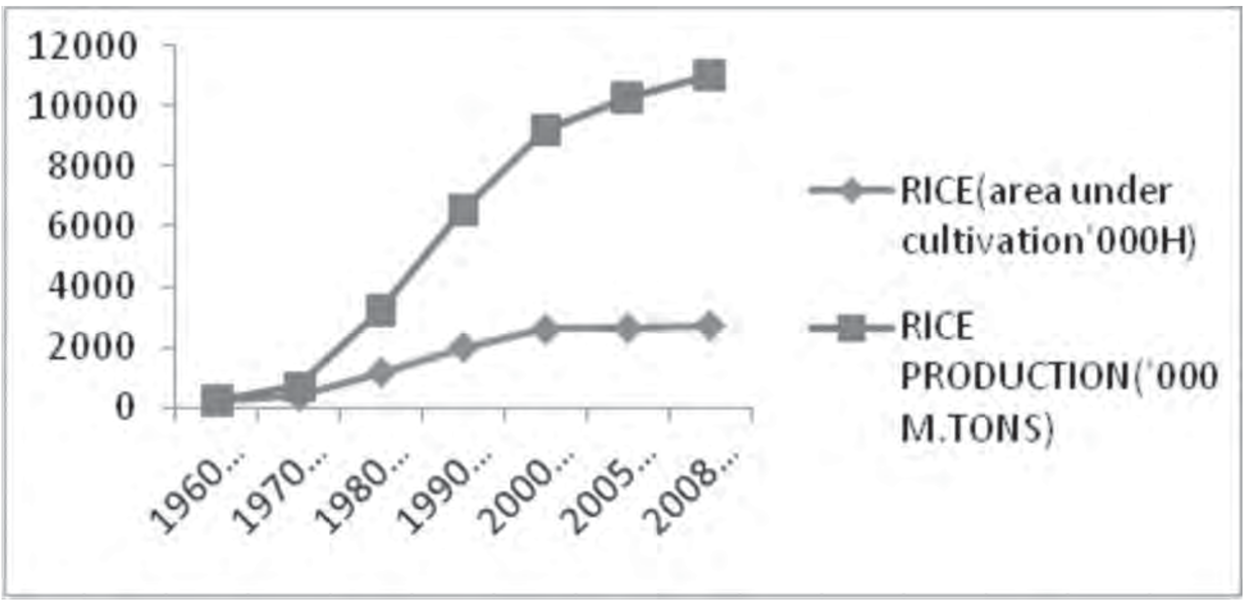
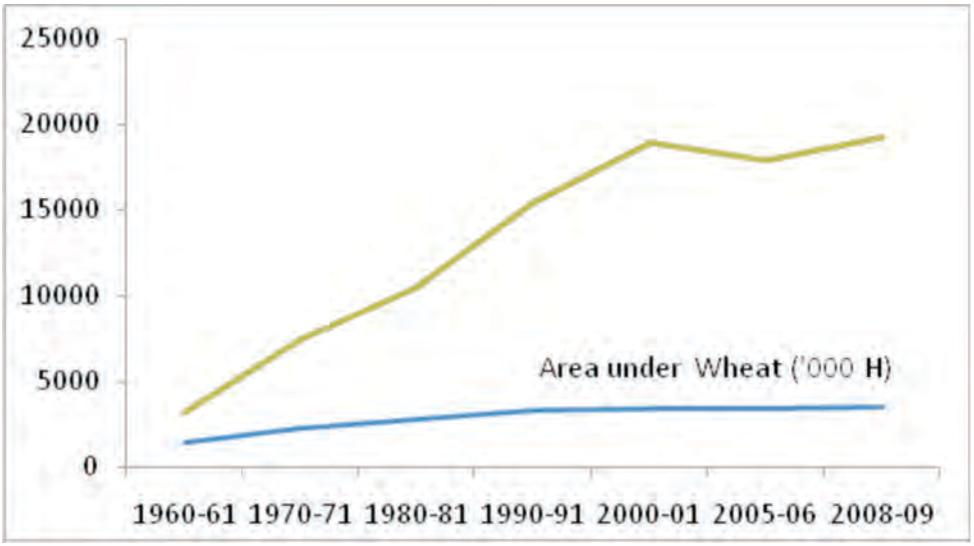


Table: 3.3 Production of Wheat

Year	Wheat (area under cultivation'000H)	Wheat Production ('000M.TONS)
1960-61	1400	1742
1970-71	2299	5145
1980-81	2812	7677
1990-91	3273	12159
2000-01	3408	15499
2005-06	3464	14476
2008-09	3526	15733

Fig. 3.5 Production Of Wheat Vs Area Under Rice Cultivation



The change in cropping pattern has put a tremendous pressure on the water resources as water requirement for rice is much more than other crops. Water requirements for different crops are as follows (Table 3.4):

Table 3.4 Water Requirements for Different Crops

S.No.	Rabi Crops	No. Of Irrigation Required	Remarks
1.	Wheat	4-5 for indegeneous varieties 5-7 for high yielding varieties	
2.	Barley	1-2	
3.	Toria	1-2	
4.	Sarson	1-2	
5.	Lein Seeds	3-4	
6.	Grams	One Irrigation before rain	
7.	Barseem	12-15	
8.	Oats	2-3	
9.	Garlic	18	
	Kharif Season		
1.	Rice	15-20	After Transplantation
2.	Cotton (American)	4-6	Depending on rain
3.	Cotton (Desi)	3-4	Depending on rain
4.	Sugarcane	8-9 2-8	Irrigation pre monsoon After Monsoon
5.	Groundnut	2-3	Depending on rain
6.	Soya Beans	2-3	Depending on rain
7.	Bajra	2-3	Depending on rain
8.	Maize	3	Depending on rain
9.	Jowar	1-2	Depending on rain

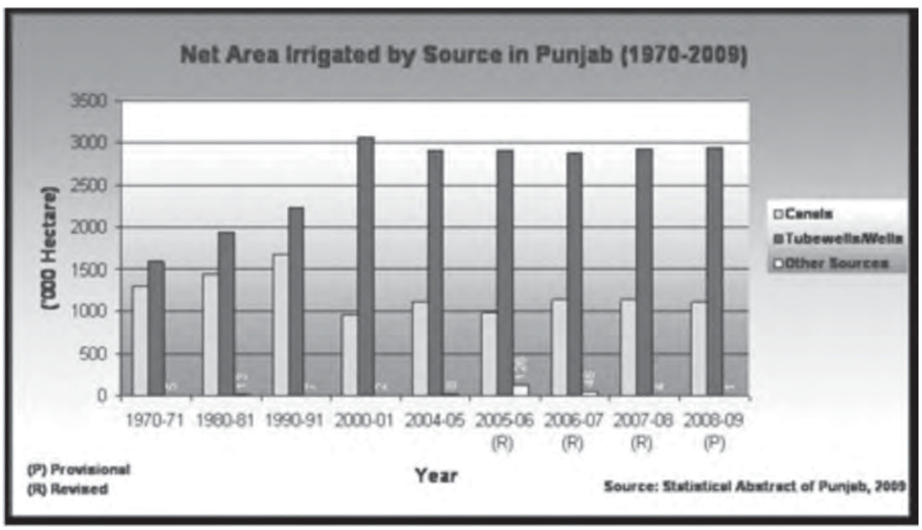
Source: Department Of Agriculture Punjab

3.6 IRRIGATION FACILITIES

Punjab has a intensive network of irrigation facility. Both the surface and ground water sources are being used for irrigation. The share of surface water of its rivers is limited to 14.54 MAF and remaining is fulfilled with groundwater. Further, the data pertaining to surplus Ravi-Beas waters during the flow series 1981-2002 reveals that the mean flow has got reduced to 14.37 MAF instead of 17.17 MAF as assessed based on flow series 1921-60. The average annual rainfall of the State has also decreased during the last two decades by 45% from 755 mm in the year 1990 to 418 mm in the year 2006. Even various reports have shown that the snow cover/glacier in the catchment area of rivers of the State is decreasing due to global warming. As such, the surface run-offs have decreased which along with canalization of rivers and fewer floods have decreased the natural recharge to ground water resources, so stressing the groundwater to meet the agriculture demand (Takshi & Chopra, 2010).

The net area irrigated to gross area sown has increased from 71% during 1970-71 to 97.4% during 2008-09 (Fig: 3.6).

Fig: 3.6 Net irrigated area by different sources.



About 94% net sown area in Punjab has irrigation facilities as compared to 40.5% national average. The districtwise gross irrigated area to gross cropped area during 2008-2009 is presented in Table: 3.5.

Table: 3.5 Gross Cropped & Irrigated Area (000' Hectare) in Punjab 2008-2009

District	Gross Cropped Area	Gross Irrigated Area	Gross Irrigated Area to Gross Cropped Area (%age)
Gurdaspur	506	439.4	86.7
Amritsar	422	421.5	100.0
Tarn Taran	397	397.0	100.0
Kapurthala	275	274.7	100.0
Jalandhar	421	420.2	99.8
Nawanshahr (S.B.S.Nagar)	184	173.2	94.1
Hoshiarpur	365	319.0	87.4
Roopnagar	143	111.1	77.7
S.A.S.Nagar	120	101.5	84.6
Ludhiana	595	595.1	100.0
Ferozepur	876	874.6	99.8
Faridkot	252	251.8	99.9
Mukatsar	449	446.1	99.3
Moga	383	383.5	100.0
Bathinda	556	554.3	99.7
Mansa	369	365.2	99.0
Sangrur	620	620.5	100.0
Barnala	249	248.6	100.0
Patiala	536	532.6	99.4
Fatehgarh Sahib	194	193.7	100.0

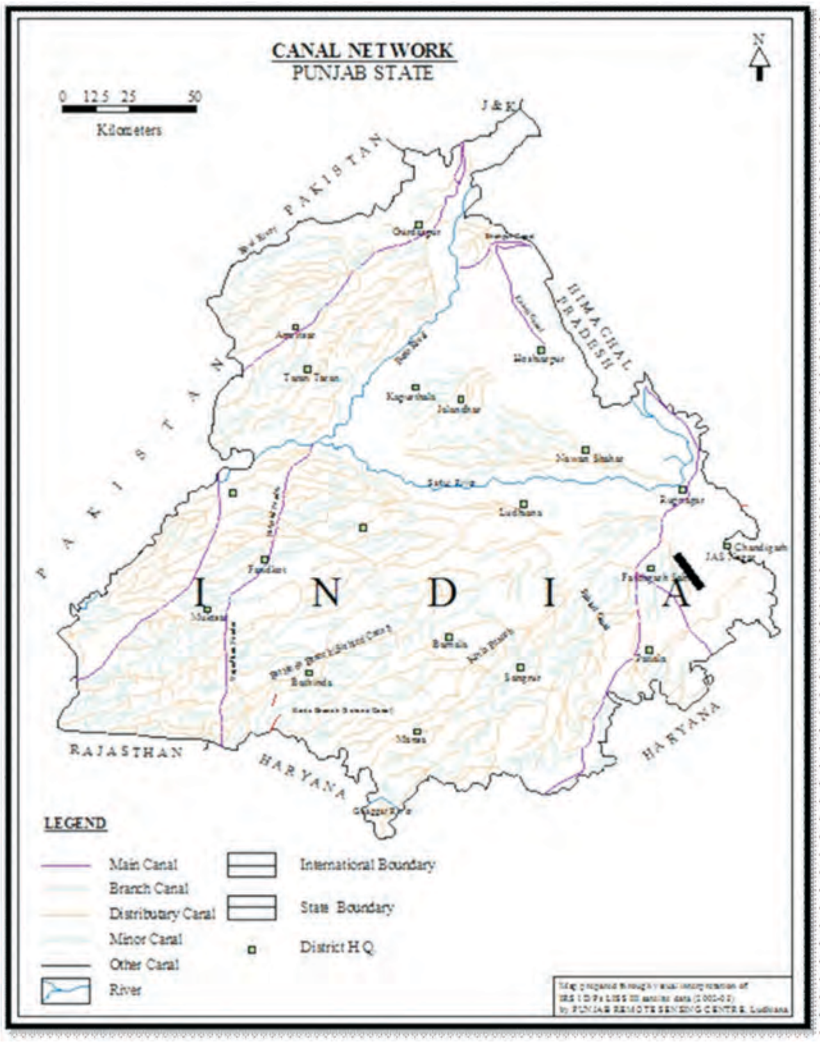
3.7 WATER RESOURCES

3.7.A Surface Water Resources

Irrigation had been practiced in Punjab since pre-historic times. The Persian Wheel became popular in the 13^{th} Century and 'Shah Nahar' was built in 17^{th} Century extending irrigation benefit to Majha&Bist Doab regions. Upper Bari Doab Canal (UBDC) in 1859 and Sirhind Canal System were commissioned in 1884. This transformed the so-called jungles into the most productive regions of Punjab. These canal colonies had the world's most extensive irrigation system and soon these colonies became the main granaries of India as canal irrigation made production more assured and the average yield increased considerably. Further, it enabled the farmers to substitute more valuable crops, which could not be grown otherwise in un-irrigated land. In the post-independence period, canal irrigation was further developed by the State gradually. Bhakra Canal System was constructed during 1948 to 1963 and by 1966 net-sown area irrigated in Punjab had gone upto 54% against the national average of 19.5%. Out of this, 57.8% was canal irrigated, 41% was irrigated by wells/tubewells and remaining 2.7% by ponds, rivers and Persian wells.

The State has an extensive and fully developed network of planned irrigation system consisting of about 14,500 kms of canal / distributaries / minors and about 1,00,000 kms of water courses (Plate 4.5.1) providing assured irrigation to an area of about 16 lac Ha. However, over the period, the area irrigated by government canals dwindled from 12,860 sq km in 1970-71 to 11100 sq km in year 2008-09. Thus, presently the surface water resources cover only 29% of the total irrigated area of the State. Most of the canals were constructed/upgraded after independence and/or reorganization of the State (Plate 3.10).

Plate 3.10



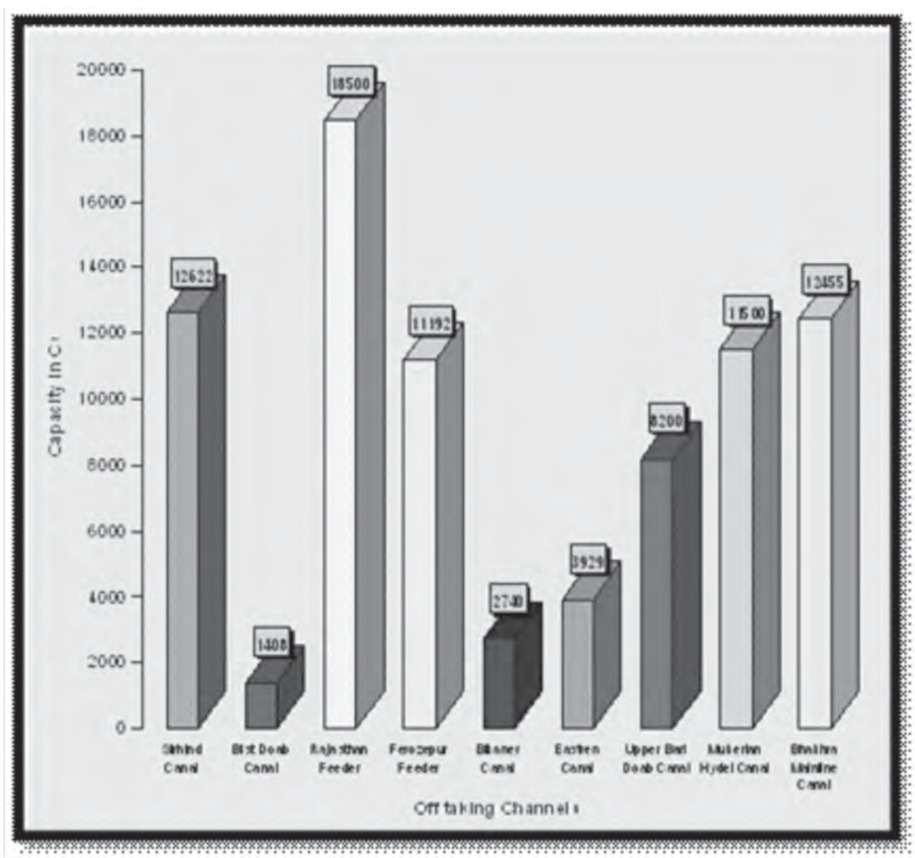
The main canals from River Satluj are Anandpur Hydel Channel and Bhakhra Main Line (BML). BML further bifurcates into Narwana branch and Bhakhra main branch. At Ropar again two main canals, Sirhind canal and Bist Doab canal originate. At Harike, Satluj feeds water to Rajasthan feeder canal and Ferozepur feeder canal. The Bikaner canal (Gang Canal) originates at Hussainiwala, one main canal from Beas originates at Shah Nehar Barrage called Shah Nehar or MukerianHydel Channel. The major irrigation canal originating from Ravi at Madhopur is Upper Bari Doab Canal (UBDC). The total stretch of canals & distributaries (including minor distributaries) is approx. 14,500 km. The Rajasthan feeder canal has the maximum capacity of 18,500 Cusecs. The main canals in Punjab and their discharge presented in Table 3.6 and detailed capacity of various canals is given in the fig. 3.7. Sirhind canal system has the maximum Culturable Command Area of 1.36 million ha.

Table 3.6 Main Canals In Punjab

S.No	Name of Canal	Discharge in Cusecs	Length in Km
1	Sirhind Canal	12622	59.44
2	Nangal Hydel Channels	14500	20.12
3	Combind Branch	7635	3.22
4	Sidhwan Branch	1751	88.01
5	Abohar Branch	3029	109.75
6	Bathinda Branch	2890	152.40
7	Ferozepur Feeder	10192	51.42
8	Sirhind Feeder	5264	136.53
9	Rajasthan Feeder	18500	149.43
10	Abohar Branch Lower	1692.50	46.37
10	Bikaner Canal	*2720/3027*	102.01
12	Eastern Canal	3929	8.02

Total C.C.A 30.88 lacs Hectare Source:Department of Irrigation, Punjab

Fig: 3.7 Detailed Capacity of Various Canals



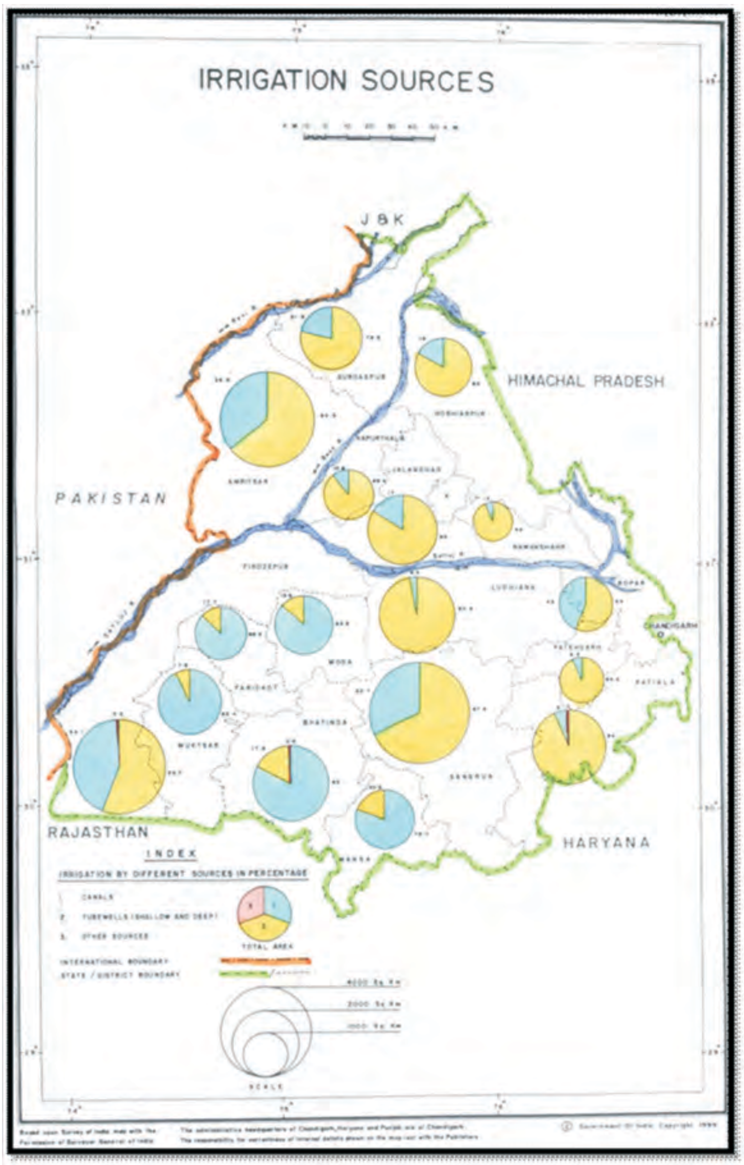
Source: Department of Irrigation, Government of Punjab as cited in Tiwana *et.al*.,2005

3.7B Ground Water Resources

The practice of irrigation through tubewells is not very old in Punjab and unlike canal irrigation; its development was due to the initiative and enterprise of the individual farmers. Before 1960, about one-third of the total irrigation was done through open wells and tubewells. Irrigation by ground water in the State is done mainly through shallow and deep tube wells. The shallow tube wells having depth in the range of 50 to 100 meters are owned by farmers, whereas deep tube wells of depth upto 300m are constructed by the State Government for direct irrigation and drinking purposes.

At present, there are 12.32 lacs tubewells (MI Census, 2001) as compared to 1.92 lacs in 1970-71 and about 75% of total tubewells are electric-operated while the rest are operated with diesel engines. As such, the percentage of net area irrigated to net area sown has shown a tremendous increase from 71 to 97.4% during 1970-71 to 2006-09. Out of the total irrigated area, the area under irrigation by groundwater through tubewells has increased from 55 to 73% during this period. Various irrigation sources in Punjab are presented in Plate 3.11.

Plate 3.11



There is a substantial increase in number of tube wells in the State since 1970 as presented in Table 3.7.

Table: 3.7 Status of Tube Wells in Punjab (1970-2009)

Year	Diesel Operated	Electric Operated	Total (Lakhs)
1970-1971	1.01	0.91	1.92
1980-1981	3.20	2.80	6.00
1990-1991	2.00	6.00	8.00
1997-1998	1.75	7.35	9.10
1998-1999	1.70	7.45	9.15
1999-2000	1.70	7.55	9.25
2001-2002	2.85	7.88	10.73
2003-2004	2.88	8.56	11.44
2004-2005	2.88	8.80	11.68
2005-2006	2.88	9.05	11.93
2006-2007(P)	2.80	9.52	12.32
2007-08	2.75	9.71	12.46
2008-09 (P)	2.80	9.96	12.76

(P) Provisional

(R) Revised

Source: Director of Land Records, Punjab as cited in Statistical Abstract of Punjab,2009

In the 12 districts, where ground water irrigation is done in more than 50% of the area, are Hoshiarpur (82%), Gurdaspur (78.5%), Amirtsar (64.5%), Kapurthala (89.4%), Jalandhar (83%), Patiala (94%), Fatehgarh Sahib (93.5%), Ludhiana (95.6%), Ferozepur (55.7%), Nawanshahr (93%), Ropar (54%) and Sangrur (67.3%).

The following zones have been demarcated in the State based on the yield characteristics of the various aquifers.

i) Local and discontinuous, fairly thick aquifers having fresh water down to 150 metres with average yield of wells below 50m^3/h exist in an area of about 12,350 sq.km. covering Muktsar, Faridkot, Moga, Bathinda, Mansa, southern parts of Sangrur and Ferozepur districts. The interpretations indicate the predominance of sand of various grades associated with kankar. Its percentage is as high as 70% in many areas. Although there are local concentrations of fine-grained sediments of considerable thickness, individual strata are generally lenticular and have little horizontal or vertical continuity. The unconsolidated sediments can broadly be divided under three groups.

ii) The division is rather clear in the South Western part, where the material in the depth range of 165 – 290 m is more argillaceous and some units can be traced from one borehole to another. It is underlain by gravel horizon composed of sub-angular milky white quartzitic grains. This in turn rests on possible Tertiary sediments.

iii) In a narrow strip extending from south of Fazilka to north of Moga and also in the north eastern parts of Gurdaspur, Hoshiarpur, Nawanshahr, Patiala, Ropar districts and Anandpur Sahib valley of Ropar district, comprising an area of about 6900 sq.kms., aquifers are regionally extensive and fairly thick down to 300 metres with an average yield of wells between 50 – 150 m^3/hours.

iii) In an area of about 29,280 sq.km. covering whole of Amritsar, Kapurthala, Fatehgarh Sahib, Ludhiana, Patiala districts and parts of Sangrur, Gurdaspur, Ferozepur, Patiala, Nawanshahr, Jalandhar and Ropar districts, regionally extensive and fairly thick aquifers down to 300 meters with an average yield of wells above 150 m^3/hour are occurring. The disposition, interrelationship of granular zones, nature, geometry and extension of aquifers of the entire Upper Bari Doab area embodies a number of granular layers alternating with thick or thin clay lenses. The major clay zones intervening these aquifer groups pinch out aquifer groups at a few places. Sand lenses also occur within these major clay zones. The first water table aquifer extends all over the area and is composed mainly of coarser sediments as compared to other groups. This aquifer is overlain by a thin clay layer of about 0.5 m to 2.5 m thick and is also underlain by clayey group which is about 3 to 6 m thick. It is revealed that in the north- eastern part of the area, there are 5-6 aquifers within 300 m depth and ranges in thickness from 20 to 65 m. These granular zones are laterally extensive in nature. The aquifer material is mainly composed of medium to coarse sand with beds of gravel at places. In the central part, five to six prominent granular zones have been encountered within a depth range of 300 to 375 m below land surface. The thickness of granular zones varies from 20 to 95 m and within the granular zones thin streaks of clay do occur. The thickness of clay beds varies from 3 to 14 m.

iv) Hilly terrain of about 11050 sq.km. in parts of Ropar, Gurdaspur, Hoshiarpur and Nawanshahr districts is underlain by semi-consolidated formations having limited yield potentials below 50 m^3/hour except plateau area (beet area) in Garhshankar block of Hoshiarpur district which has yield potential of 100m to 200 m^3/hr. The hydrogeological formations are mainly composed of thick beds of sand, boulders with alternating thin layers of clay. The hydraulic conductivity value ranges from 76 to 106 m/day indicating that the aquifers are highly transmissive. The value of 'T' for the aquifers tapping 40 to 43 m thickness of water bearing zones have been worked out to be 3300 and 3406 m^2/day. The wells constructed down to 178 and 192 m yield 2500 lpm discharge for 6 to 6.7 m drawdown. The water level in the area is deep seated and varies from 72 – 165 m below land surface which is due to surface elevation differences. The water table elevation in the area is 350 m above mean sea level.

v) Auto flow area – Free flow of ground water to the land surface due to artesian conditions exists in some areas. Auto flow zones in Punjab fall mostly in Gurdaspur district covering an area of about 100 sq.km. The flowing artesian aquifers also exist on left bank of the Beas river in Mukerian block of Hoshiarpur district and Anandpur Sahib block of Ropar district. The artesian aquifers occurs below 40 metres depth and along left bank of Ravi river upto 155 m.bgl. The free flow discharge ranges between 1 to 72 m^3/hour. The chemical quality of free flow water is fit for both irrigation and drinking purposes.

Ground Water Level Behaviour:

The Central Ground Water Board is monitoring 238 Ground water observation wells (161 dug wells and 77 piezometrers) in Punjab State to assess the phreatic ground water levels. In addition to above, deeper aquifers are also being monitored by way of 35 piezometers. About 80% of the Ground water observation wells fall in the command areas of various canal systems. The areas falling out of the major command include major part of Hoshiarpur and Ropar districts, parts of Gurdaspur, Jalandhar and Ludhiana districts.

In general, the depth to water level in Punjab State varies from 0.20 m bgl in Ferozepur district to 45.00 m bgl in Ludhiana district during November 2009 and May, 2010 respectively. The maximum and minimum water levels recorded in pre and post monsoon season is given below

	May 2010 (Pre-monsoon)	**November 2010 (Post-Monsoon)**
Minimum	1.18 m bgl (Ferozepur district)	0.20 m bgl (Ferozepur district)
Maximum	45.00 m bgl (Ludhiana district)	32.28 m bgl (Fatehgarh Sahib district)

It is observed that shallowest water level conditions prevail in southwestern parts mainly in Muktsar and Ferozepur districts, while deepest water level conditions exist in the central area in Ludhiana and Fatehgarh Sahib districts. The pre and post monsoon- behaviour of water level in the State is described as below.

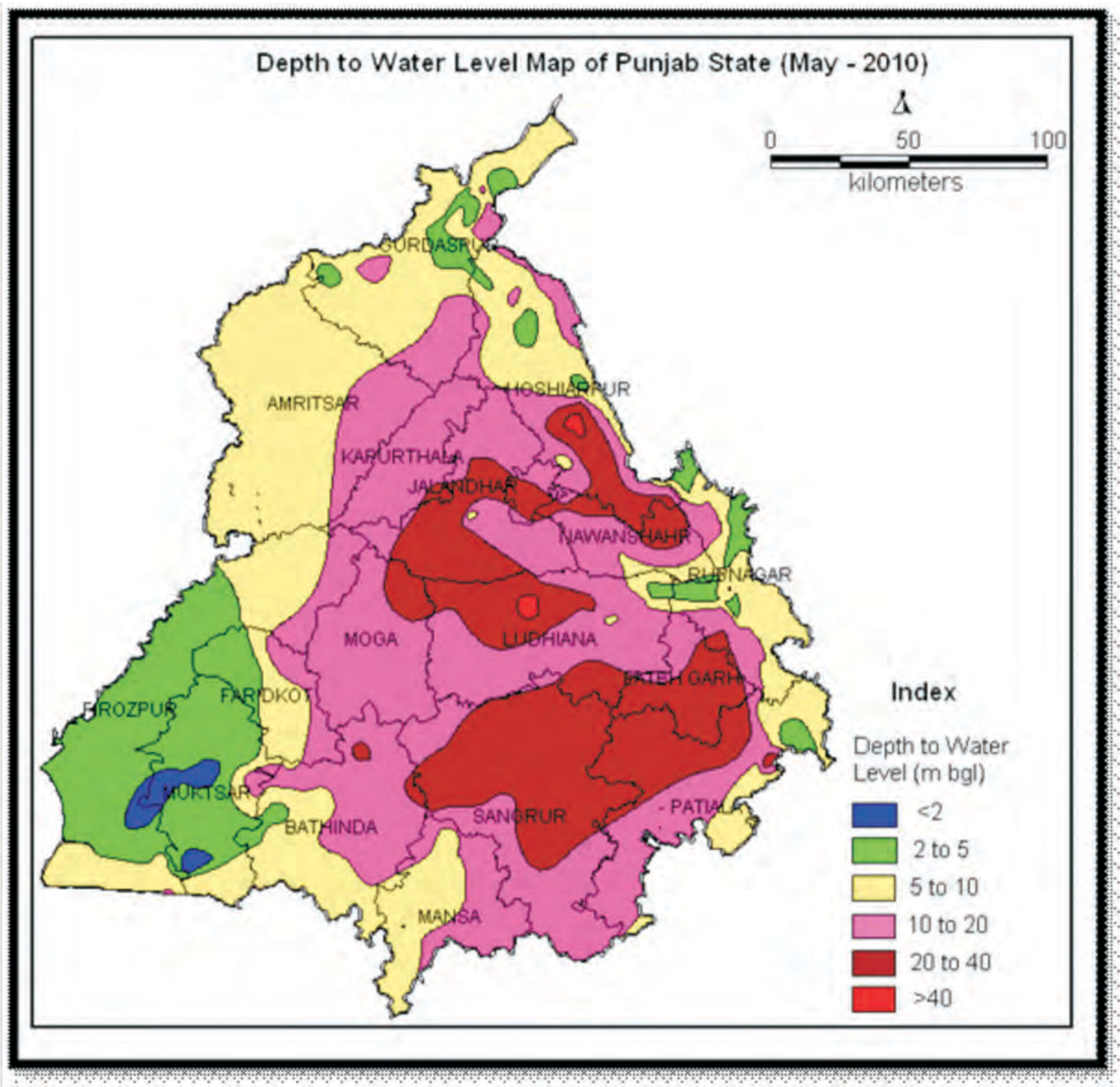
Pre-monsoon Depth to Water Level (May 2010)

The pre-monsoon depth to water level map reveals that 48% of the wells fall within the range of 10m and 36% of the wells show water level within 10-20 mbgl. Deeper water level conditions in the range of 20-40mbgl is observed in 15.17% of the observation wells. The water level data of May 2010 when compared with decadal mean (May 2000 to May 2009) reveals that about 76.70% of the wells analysed have shown fall in water level. Out of this 38.64% of the wells are showing fall in the range of 0-2 m, 19.89% wells are showing fall in the range of 2-4 m and 18.18% of the wells are showing fall of more than 4 m.

The remaining 23.30% of the wells analysed showing rise in water level, majority of this i.e. 19.89% of the wells are observed in the range of 0-2 m while 2.27% of the wells showing rise in the range of 2-4 m (Plate 3.15). The district wise area falling in the different water level depth range is given in Table 3.8.

The Water Resources & Environment Directorate also monitors the ground water levels in the State. The depth to water map has been prepared using the integrated data of CGWB and State organization for the month of May 2010 (Plate 3.16) reveals that there is no significant change in area falling in specific water level ranges as per the data of CGWB compared with the data of Water Resources & Environment Directorate.

Plate 3.15

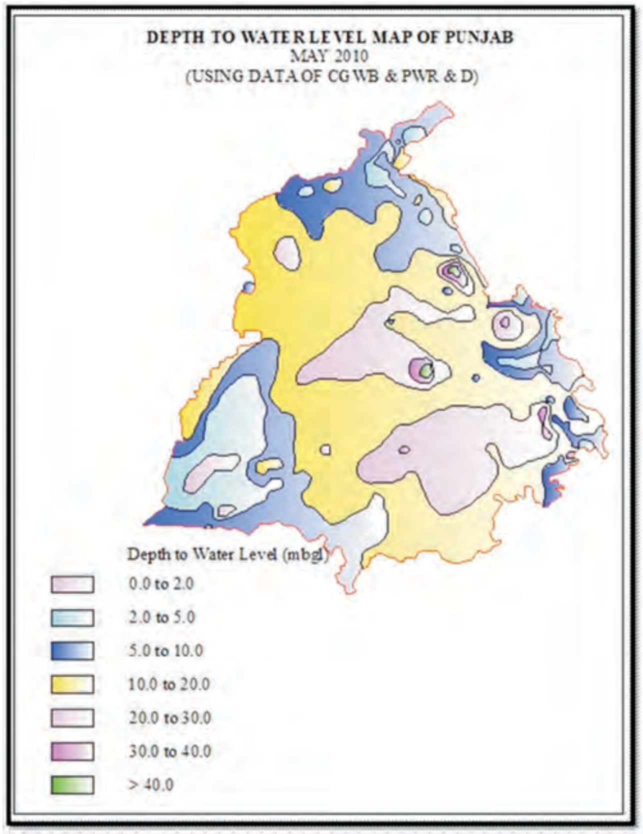


Depth to Water Level Map of Punjab State (May - 2010)
0
50
100
kilometers
GURDASPUR
AMRITSAR
HOSHIARPUR
KAPURTHALA
JALANDHAR
NAWANSHAHR
RUPNAGAR
MOGA
LUDHIANA
FATEH GARH
FIROZPUR
FARIDKOT
MUKTSAR
BATHINDA
SANGRUR
PATIALA
MANSA
Index
Depth to Water Level (m bgl)
<2
2 to 5
5 to 10
10 to 20
20 to 40
>40

Table: 3.8 DISTRICTWISE DEPTH TO WATER LEVEL RANGES IN PUNJAB (CGWB, MAY 2010)

		Depth to water level ranges/ area (Km^2) under various water level ranges/ %age area														
		0 to 2		2 to 5		5 to10		10 to 20		20 to 30		30 to 40		<40m		
	District/ Region	area	%age	area	%age	area	%age	area	%age	area	%age	area	%age	area	%age	total area
1	Amritsar	-	0.00	5	0.20	346	13.79	1769	70.51	389	15.50	-	0.00	-	0.00	2509
2	Gurdaspur	-	0.00	484	13.40	2176	60.23	953	26.38	-	0.00	-	0.00		0.00	3613
3	TaranTaran	-	0.00	0	0.00	21	0.82	2515	98.70	12	0.47	-	0.00		0.00	2548
	Upper Bari Doab	-	0.00	489	5.64	2543	29.33	5237	60.40	401	4.63	-	0.00	-	0.00	8670
4	Hoshiarpur	-	0.00	169	4.99	1587	46.90	1213	35.85	267	7.89	148	4.37	-	0.00	3384
5	Jalandhar	-	0.00	-	0.00	125	4.75	1294	49.16	1213	46.09	-	0.00	-	0.00	2632
6	Kapurthala	-	0.00	-	0.00	195	11.85	1245	75.68	205	12.46	-	0.00	-	0.00	1645
7	NawanShahr	-	0.00	25	1.95	173	13.53	694	54.26	357	27.91	27	2.11		0.00	1276
	Bist Doab	-	0.00	194	2.17	2080	23.27	4446	49.75	2042	22.85	175	1.96	-	0.00	8937
8	Barnala	-	0.00	-	0.00	-	0.00	565	39.90	837	12.00	14	0.99	-	0.00	1416
9	Ropar	-	0.00	417	30.02	612	44.06	347	24.98	13	0.94	-	0.00	-	0.00	1389
10	Patiala	-	0.00	16	0.48	417	12.50	1721	51.59	1145	34.32	37	1.11	-	0.00	3336
11	Fatehgarh Sahib	-	0.00	-	0.00	39	3.37	442	38.17	635	54.84	42	3.63	-	0.00	1158
12	Mohali	-	0.00	57	5.27	508	46.99	516	47.73	-	0.00	-	0.00	-	0.00	1081
13	Ludhiana	-	0.00	49	1.32	160	4.32	2378	64.27	887	23.97	226	6.11		0.00	3700
14	Sangrur	-	0.00	-	0.00	-	0.00	1394	38.78	2201	61.22	-	0.00		0.00	3595
	Upper Malwa	-	0.00	539	3.44	1736	11.07	7363	46.97	5718	36.48	319	2.04	-	0.00	15675
15	Mansa	-	0.00	-	0.00	1131	51.67	1058	48.33	-	0.00	-	0.00	-	0.00	2189
16	Bathinda	-	0.00	143	4.21	1387	40.83	1792	52.75	75	2.21	-	0.00	-	0.00	3397
17	Ferozepur	151	2.86	1092	20.65	2003	37.88	1939	36.67	103	1.95	-	0.00	-	0.00	5288
18	Faridkot	-	0.00	458	31.39	621	42.56	390	26.73		0.00	-	0.00	-	0.00	1469
19	Moga	-	0.00	-	0.00	-	0.00	1530	68.61	700	31.39	-	0.00	-	0.00	2230
20	Muktsar	395	14.99	1697	64.40	427	16.20	116	4.40	-	0.00	-	0.00	-	0.00	2635
	Lower Malwa	546	3.17	3390	19.70	5569	32.36	6825	39.66	878	5.10	-	0.00	-	0.00	17208
	State Total	546	1.08	4612	9.13	11928	23.62	23871	47.28	9039	17.90	494	0.98	-	0.00	50490

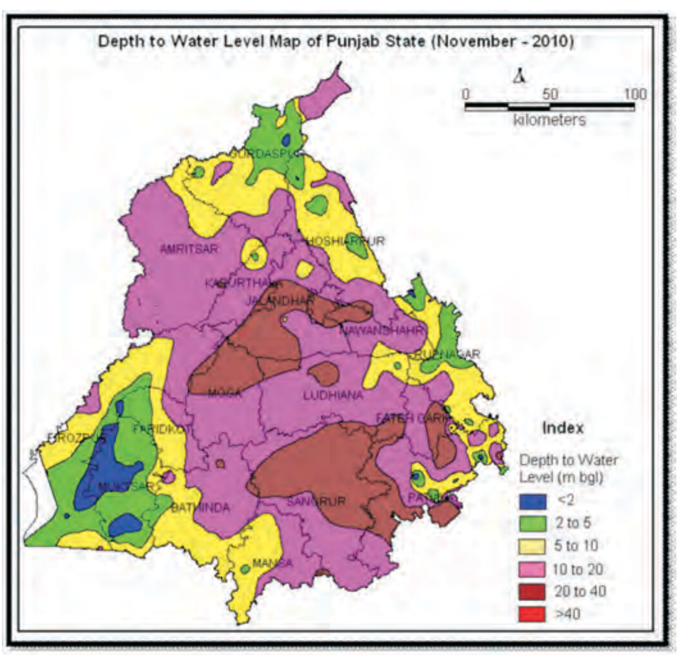
Plate 3.16



Depth to Water Level- November 2010

The post monsoon water depth to level of November 2010, reveals that 46.27% of the wells analysed have shown water level lying within 10mbgl whereas 38.31% wells are in the range of 10-20mbgl. Deeper water level conditions in the range of 20-40 m bgl are observed in 15.42% of the wells analysed (Plate 3.17).

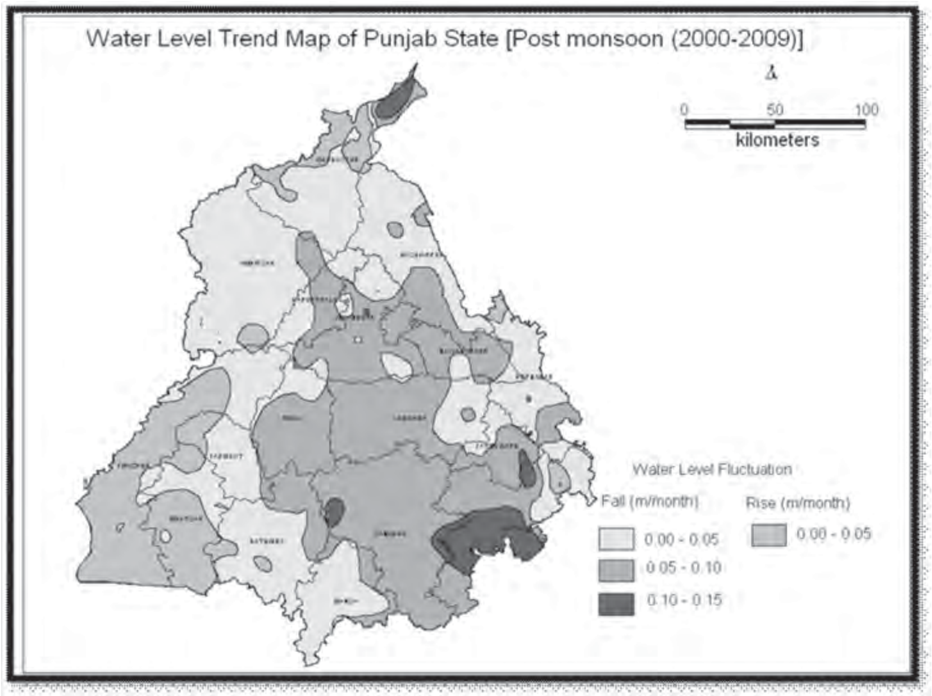
Plate 3.17



Long Term Water Level Fluctuation

The long term water level fluctuation map (1991-2010) depicted in Plate 3.18, shows rise and fall in water levels seemingly related to the amount of withdrawal of ground water. The areas where there are less number of tube wells, ground water is saline/alkaline and there is a general rise of water levels. The water levels have shown considerable decline wherever the ground water development has been more.

Plate 3.18

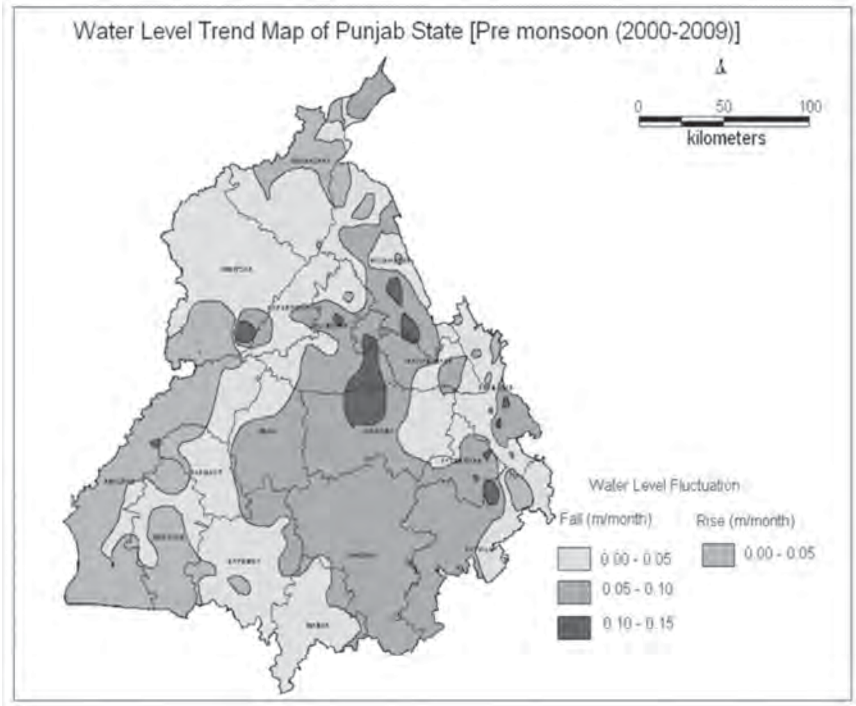


In major part of the State covering about 28,000 sq.km. area, the water levels have registered fall of more than 4 metres in past 20 years. The major parts of Nawanshahr, Jalandhar, Kapurthala, Moga, Patiala, Ropar, Fatehgarh Sahib, Sangrur, Mansa, Bathinda, Hoshiarpur, Gurdaspur,and Amritsar districts have registered a fall of >4 m during period of 20 years. Besides, about.8540 sq.km.area has experienced fall between 2 m to 4m and about 5630 sq. kms has experienced fall of less than 2m in various part of districts. The rise in water levels has been experienced in south western parts besides some part of Hoshiarpur district of the State and about 1675 sq. km area has experienced >4 m rise. The rise in water levels is attributed to the continuous seepage of water from network of unlined canals and distributaries and due to the negligible draft from groundwater in the area. The areas which shows fall in water level may be attributed to heavy withdrawal of ground water through various ground water abstraction structures.

Ground Water Level Trend [Pre monsoon (2000 – 2009)]

Perusal of the water level Trend map (Plate 3.19) of Pre-monsoon Season between May 2000 to May 2009 shows that in general there is a declining trend in water level as shown by 76.60% of the wells analysed. About 59.7% of the wells have declining trend in the range of 0 to 0.05 m per month while 31.9% of the wells have falling trend in the range of 0.05-0.10 m per month and 8.3% in the range of 0.10-0.15 m per month. The remaining wells i.e. 23.40% have shown rising trend in the range of 0-0.05 m per month.

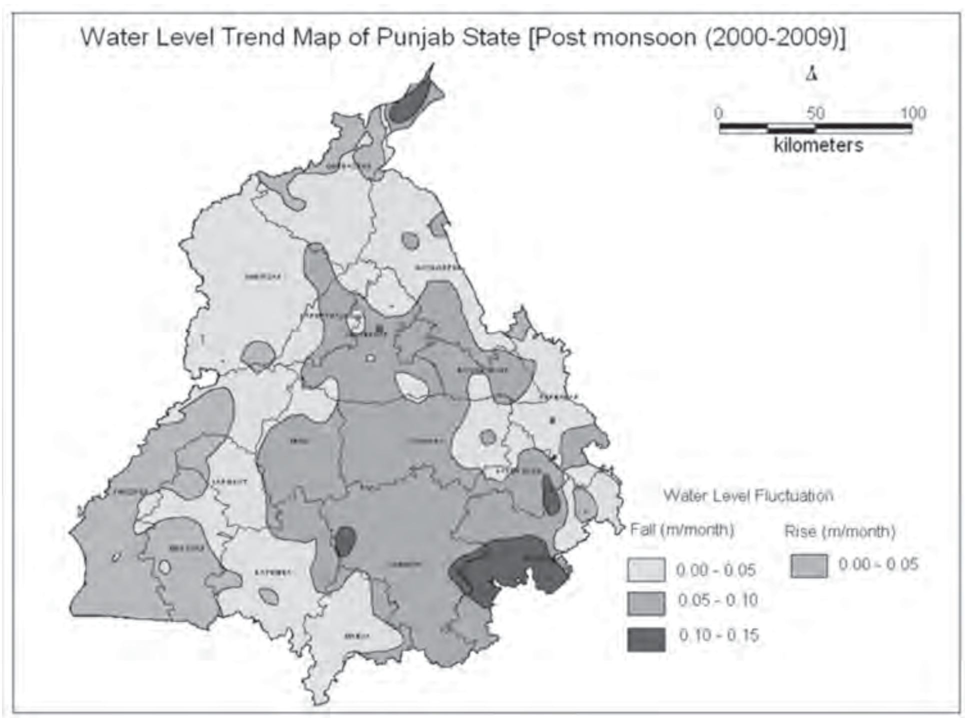
Plate 3.19



Ground Water Level Trend [Post monsoon (2000 – 2009)]

Perusal of the water level Trend map (Plate 3.20) of Post-monsoon Season between November 2000 to November 2009 shows that in general there is declining trend in water level as shown by 78.64% of the wells analysed. About 58.2% of the wells have declining trend in the range of 0 to 0.05 m per month while 37.0% of the wells have falling trend in the range of 0.05-0.10 m per month and 4.5% in the range of 0.10-0.15 m per month.The remaining wells i.e. 21.35% have shown rising trend in the range of 0-0.05 m per month.

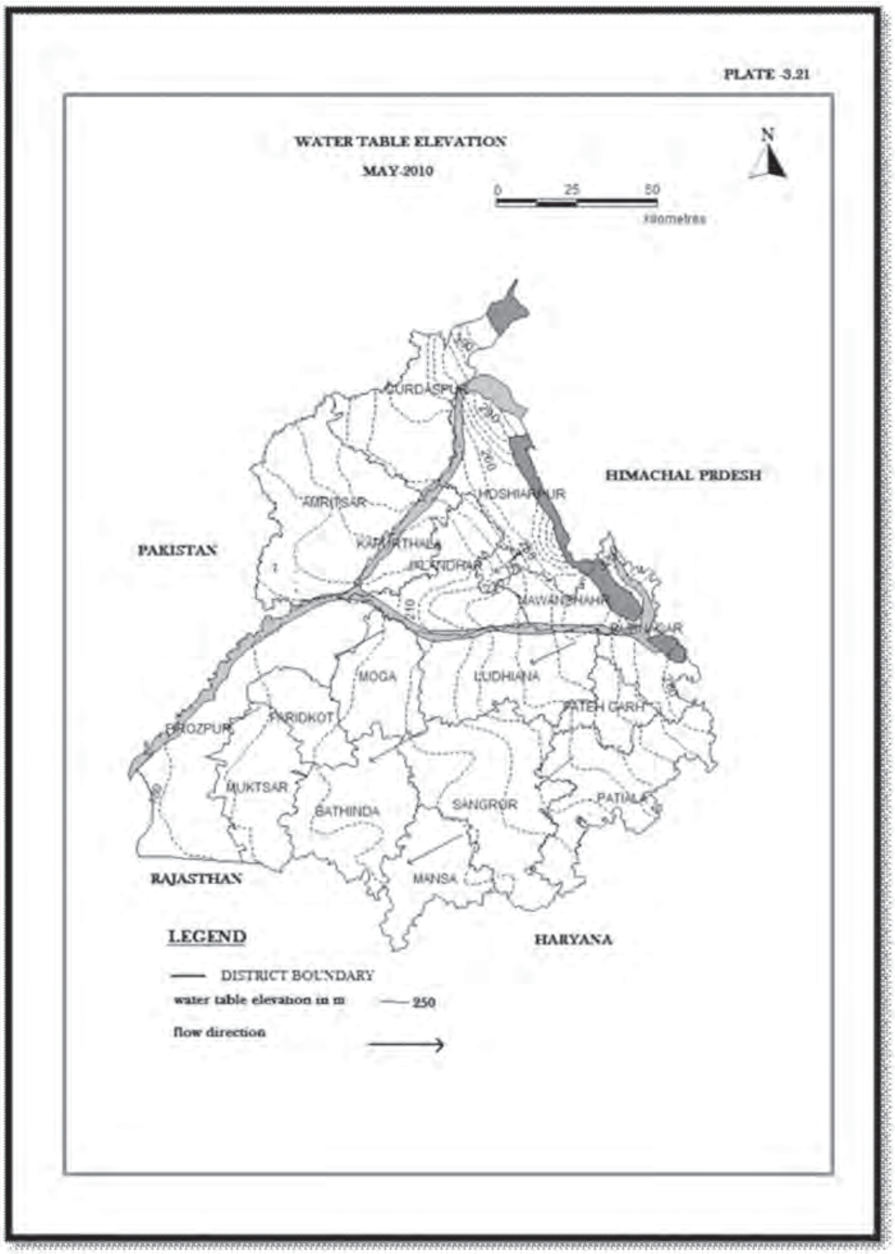
Plate 3.20



Ground Water Movement

The study of the water table elevation map (Plate 3.21) revealed that a water divide runs in NE-SW direction roughly passing through Sirhind, Kotkapura, Muktsar and Abohar. The maximum value of water table elevation above m.s.l. is in the NE part having value more than 330 m above mean Sea level and the lowest value is 165 m above m.s.l in the extreme SW part. The hydraulic gradient in the NE part is steep and ranges from 3.30 m to 5.0 m/km and in the central part it is 0.33 m/km.The steep gradient has been observed around Bathinda which may be due to the low values of lateral hydraulic conductivity and predominant clayey formations. Inother parts, ground water elevation contours are widely spaced indicating slow groundwater movement. Near Ferozepur, it is 0.2 m/km and in the South-western part, around Bathinda, it is again steep and is about 1.5 m/km around Pathankot. It is also evident from the Plate that the area of outflow lies towards the west and south west of the tract.Both the rivers i.e. Sutlej and Ghaggar are effluent in nature.

Plate 3.21



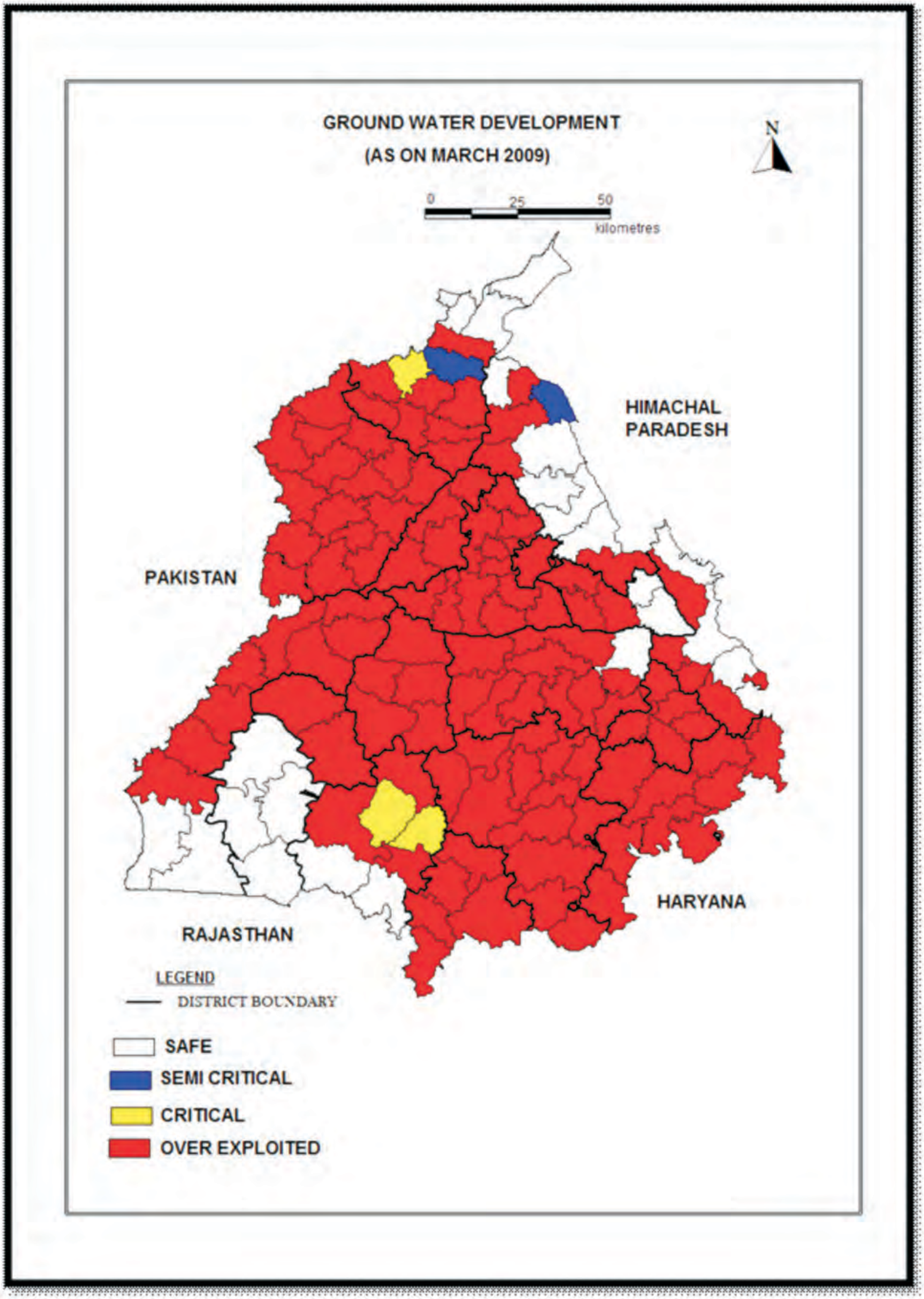
Ground Water Resources Development

Ground water resources of State has been estimated as on 31.03.2004. The Net annual ground water availability of State has been assessed to be 21.44 bcm. Net annual draft of the State has been estimated to be 31.16 bcm. Out of 137 blocks assessed, 103 falls under 'Over exploited' category, 5 in 'critical', 4 as 'Semi critical' and 25 as 'safe category'. Spatial distribution of the block with their category has been depicted in Plate 3.22. The district-wise categorization of blocks is also listed in Table: 3.9. The reason for this stage of ground water development are excessive withdrawal of ground water mainly to meet growing demands of agriculture in addition to industrial and domestic sectors. Surface water resources in the State are limited and are decreasing due to overexploitation. Thus stress is more and more on ground water.

Table: 3.9, District wise categorisation of blocks of Punjab State as on 31-03-2004

S. No	District	No. of blocks	Over-exploited	Critical	Semi-critical	Safe
1.	Amritsar	16	16	-	-	-
2.	Bathinda	07	04	-	-	03
3.	Faridkot	02	02	-	-	-
4.	Fatehgarh sahib	05	05	-	-	-
5.	Ferozepur	10	07	01	-	02
6.	Gurdaspur	14	07	02	01	04
7.	Hoshiarpur	10	02	-	02	06
8.	Jalandhar	10	10	-	-	-
9.	Kapurthala	05	05	-	-	-
10.	Ludhiana	11	10	01	-	-
11.	Mansa	05	05	-	-	-
12.	Moga	05	05	-	-	-
13.	Muktsar	04	-	-	-	04
14.	Nawanshahr	05	03	-	-	02
15.	Patiala	09	08	-	01	-
16.	Ropar	07	02	01	-	04

Plate 3.22


GROUND WATER DEVELOPMENT
(AS ON MARCH 2009)
N
0
25
50
kilometres
HIMACHAL PARADESH
PAKISTAN
RAJASTHAN
HARYANA
LEGEND
DISTRICT BOUNDARY
SAFE
SEMI CRITICAL
CRITICAL
OVER EXPLOITED

4. WATER POLLUTION & IT'S ENVIRONS

The quality of surface and groundwater may be impacted by naturally occurring processes as well as by the activities directly attributable to human interventions in different environs. The complex biodiversity, physiographic setup coupled with prevailing hydrogeological set up attribute to water pollution in various parts of the State. The magnitude of environmental impact associated with each of these processes is highly complicated and variable. Four general ways in which the chemical composition of water may be changed include natural processes, agricultural and urban runoff industrial effluents, waste disposal practices, and spills, leaks and other unintentional / intentional releases. In the natural way of contamination, the leaching of natural chemical deposits can also result in increased concentration of chlorides, sulfates, fluorides, Arsenic, nitrates, iron, and other inorganic chemicals,. In semi-arid and arid regions of the State this problem is further aggravated by high evapotranspiration losses from shallow water table.

The most significant and widespread source of contamination is discharge from agricultural and urban watersheds (EPA, 1983). These waters can have high concentration of nutrients, metals, pesticides, microorganisms and other organic chemicals. These are widespread and are not associated with a single identifiable source area, they are classified as nonpoint source contaminants. The third general source is activities associated with waste disposal practices. The last category of source of ground water contamination is also a direct result of human activities but is unrelated to waste disposal practices. These include accidental spills and leaks, agricultural activities, mining, salt water intrusion, etc

The nature of contamination impacts may be assessed in terms of the characteristics of the chemicals that are released and in terms of their distribution and difficulty of restoration or containment. In addition, impacts are directly related to potential human and ecological exposures and risk. Groundwater moves slowly, so it takes a long time for contamination to appear at potential receptor locations. It follows that it will take a correspondingly long time to remediate the initial release of contaminants. The primary chemicals of concern are classified as organic chemicals , metals and radionuclide, Other inorganic chemicals such as chloride, sulfates, nitrates and sodium from irrigation return flows and other sources are also significant.

Difficulty of remediation of ground water contamination depends on their mobility and the time duration since release to the subsurface environment. Some metals and radionuclide , such as lead, nickel, zinc, cesium, radium and thorium are immobile within the subsurface and are more significant as soil contaminants, rather than groundwater contaminants. For organic contaminants, the most significant chemical characteristics are the chemicals solubility (directly related to ions polarity) , and whether the chemical is released as an aqueous solution or as a non aqueous phase liquid. The sources of contamination of water are presented in Table 4.1.

Table: 4.1 Sources of Ground water Contamination

Category - I	**Category - II**	**Category - III**
Sources designed to discharge substances	Sources designed to store, treat, and /or dispose of substances: discharge through unplanned releases	Sources designed to retain substances during transport or transmission
Subsurface percolation (eg. Septic tanks, etc), injection wells, land applications	Landfills, open dumps, surface impoundments, waste tailings/ piles, above ground/ underground storage tanks, radioactive disposal sites	Pipelines, material transport and transfer
Category - IV	**Category - V**	**Category - VI**
Sources discharging as consequence of other planned activities	Sources providing conduit or inducing discharge through flow patterns	Natural occurring sources whose discharge is created and /or exacerbated by human activity
Irrigation practices, Pesticide applications, Fertilizers use, animal feedings, urban runoff, percolation of atmospheric pollutants, mining and mine drainage	Production wells, Other wells, Construction excavation	Groundwater-surface water interactions, natural leaching, salt water intrusion, upconing

Environmental pollution is an undesirable change in the physical, chemical and biological characteristics of the environment. Such changes are caused by substances that are introduced into the environment, by human interferences and natural causes also. Broadly, two types of pollution exist and these are as follows:

4.1 Geogenic Contamination

Deterioration of quality of ground water due to natural contamination from aquifers and overlaying soils is called geogenic contamination. This type of contamination occurs due to entrapped water reaction with the strata. Presence of high Fluoride, Selenium and Arsenic are usually a result of geogenic contamination as there are only a very few other source of these ions. The Contaminants, their Possible Sources is presented in Table 4.2.

Table : 4.2 Contaminants & their Possible Sources

S.No.	Contaminant	Possible source
1.	Salinity (as EC in µS/cm)	Long residence timeand geological formations
2.	Selenium (in mg/l)	Selenium rich sediments lying in Shiwalik Ranges as Selenites & selenates
3.	Fluoride (in mg/l)	Lime Stone, sandstone, granite as Fluorspar (CaF_2), cryolite (Na_3AlF_6), fluorite (CaF_2), fluorapatite $\{Ca_5F(PO_4)_3\}$ Insecticides, Disinfectants Preservatives Phosphatic fertilizers
4.	Arsenic (in mg/l)	1. Geothermal/Volcanic activities 2. Weathering of rocks & minerals- Arsenopyrite (FeAsS) Lollingite (FeAs2) Orpiment Realger Native Arsenic 3. Herbicides 4. Pesticides
5.	Uranium (in µg/l))	Siwalik classic sediments controlled by redox interface, porosity permeability barriers & reductants

The geogenic contaminants affecting the groundwater quality are:

Salinity

The saline ground water resource of Punjab State is 1351 MCM (1992) lying in the south-western part covering parts of Mansa, Bathinda, Faridkot, Moga, Ferozepur, Muktsar and Sangrur districts. The area is mostly underlain by saline / brackish ground water. The thickness of overlying fresh water zone is limited. The water is of mainly Na-Cl, $Na\text{-}Cl\text{-}SO_4\text{-}NO_3$ type and EC is generally above 4000 µS/cm, in some cases it exceeds 10000 µS/cm and renders it unusable for any purpose.

Selenium

The Se-toxic sites are located at dead ends of seasonal rivulets (choes) originating from upper Shiwalik ranges. It is most likely that Se rich sediments lying in Shiwalik ranges have been transported down along with flood water over a period of time and repeatedly being deposited in low lying areas at choe endings. Selenite complexes with common soil components such as ferric and aluminium sesquioxides, whereas selenate does not form such complexes and is easily leached from soil to groundwater.

The relative addition of Selenium through underground water has been computed and the results suggest that cultivation of rice in seleniferous region is aggravating Se toxicity problem as it needs to be irrigated extensively (Dhillon and Dhillon, 2003). Higher selenium has been observed in pockets of Hosiarpur and Nawansahr Districts.

Fluoride

Fluorine is so highly reactive that it is never found in its elemental gaseous State except in some industrial processes. It usually occurs as fluoride in a number of minerals of which fluorspar (CaF_2), cryolite (Na_3AlF_6), fluorite(CaF_2), and fluorapatite {$Ca_5F(PO_4)_3$} are the most common. As fluorspar, it is found in sedimentary rocks (lime stone and sand stone) and as cyrolite in igneous rocks (granite). These natural occurring fluorides are nearly insoluble in water. Hence, fluorides will be present in ground water only under conditions favoring their solution.

Fluoride is also contributed to ground water through anthropogenic activities. Usage of insecticides, disinfectants and preservatives containing fluoride are potential source of fluoride in ground water. Use of phosphatic fertilizers (including direct use of rock phosphate) may also contribute to high fluoride content in the ground water. The commonly used phosphate fertilizer contains nearly 1-3% of fluoride (as impurity), which enriches the soils, and on leaching percolates to the ground water. Fluorides are used in variety of industries such as plating and manufacturing of aluminium, brick and steel. Sewage effluents from municipalities using fluoridated drinking water may contribute fluoride into ground water. Fluoride is released form burning of coal in thermo-electric generating stations.

High concentrations of fluoride, often significantly above the safe limit of 1 mg/l, constitute a severe problem in some semi-arid areas of Punjab. Use of groundwater for drinking in these areas has resulted in the onset of widespread fluorosis symptoms, from mild form of dental fluorosis to crippling skeleton fluorosis. Floride having concentration more than 1.5 mg/l is found mainly in Bathinda, Ferozepur, Mansa and Patiala Districts.

Arsenic

The element is widely distributed and its abundance in the Earth's crust is about five grams per ton. Arsenopyrite, FeAsS, is among the most common of arsenic-bearing minerals.Arsenic is occasionally found uncombined. It is found generally in association with such metals as antimony and silver. Arsenic has a range of oxidation States from -3 to +5, but +3[As(III)] and +5[As(V)] are more dominants. As(V), as arsenate, AsO_4^{3-} is the stable form in aerobic waters. As(III), as arsenite, AsO_3^{3-} is dominant under anaerobic conditions. It is utilized in pesticides and in the manufacture of glass and as a preservative for hides. It comprises a major ingredient of insecticides, herbicides, and metal adhesives. Arsine (AsH_3), a colourless poisonous gas has been used as a doping agent for semi-conductors and as a military poison gas.

The exact source of arsenic contamination is to be established as the data collected so far is inadequate to provide plausible reason of mobilization of arsenic from sediments to ground water. Geochemical conditions, such as pH, oxidation–reduction, associated or competing ions, and evaporative environments, have significant effects on Arsenic concentration in groundwater (Hundal *et al.,* 2007). Moreover, studies have indicated that sand and clay deposited by rivers is generally rich in iron and arsenic and the peak arsenic concentration zone exists below 40 meters. Arsenic is a deadly poison, especially when present in high concentrations. People are exposed to Arsenic most of the time through drinking groundwater, usually unknowingly. Higher concentration of Arsenic more than permissible limit is found in parts of Amritsar, Gurdaspur, Hoshiarpur, Kapurthala and Ropar Districts.

Uranium

A compilation of various studies carried out by different agencies on the Uranium Content in water samples of Malwa Belt in Punjab was undertaken by PPCB. The studies by GNDU, Amritsar revealed that Uranium content in groundwater of Bathinda was higher than the prescribed safe limits. However, BARC, Mumbai Stated that concentration of Uranium in ground water were within permissible limit and there is nothing to worry. In order to study Uranium in Punjab State and effects of high concentration of Uranium on human health, a Joint core committee of various departments was constituted in December 2009. The Core committee members have submitted a Joint report of Chief Secretary Punjab. Higher concentrations of Uranium have been reported from several places in Bathinda, Mansa, Faridkot, Ferozepur and Moga Districts.

Various hypotheses regarding the causes of high uranium in ground water (Geogenic or anthropogenic) are summarised as follows:

1. Basement granite rocks as a source of uranium is advocated by GNDU, Amritsar.
2. Contamination of groundwater around flyash ponds, which is being investigated by PPCB in association with Physics department, P.U.
3. Some workers of GNDU attribute high concentration of uranium in ground water due to the air blown from Afganistan/nuclear reactors.
4. Phosphatic fertilizers are known to contain uranium ranging from 20 to 300 mg/kg. These ferilizers are used extensively in the State. This aspect needs to be investigated further (K.P. Singh, PSCS&T,2010)

The uranium mineralisation in the Siwaliks of the north western Himalaya occurs in the form of lenses having small extent mostly associated with poorly sorted immature grey sandstone, essentially along middle – upper Siwaliks transition zone and to a lesser extent along the transition zone between lower and middle Siwaliks. Uranium mineralisation in the Siwaliks is epegentic, remobilised and controlled by hydrodynamic gradient and organic matter in the zone of local and regional paleo ground water divide occurring in association with redox form. The redox interface is a prominient feature and carbonate waters are considered favourable for leaching of uranium as they are most effective complexing anions under high pH regime (Swarankar etal, 2009).

4.2 Anthropogenic contamination

(a) Agriculture Activities

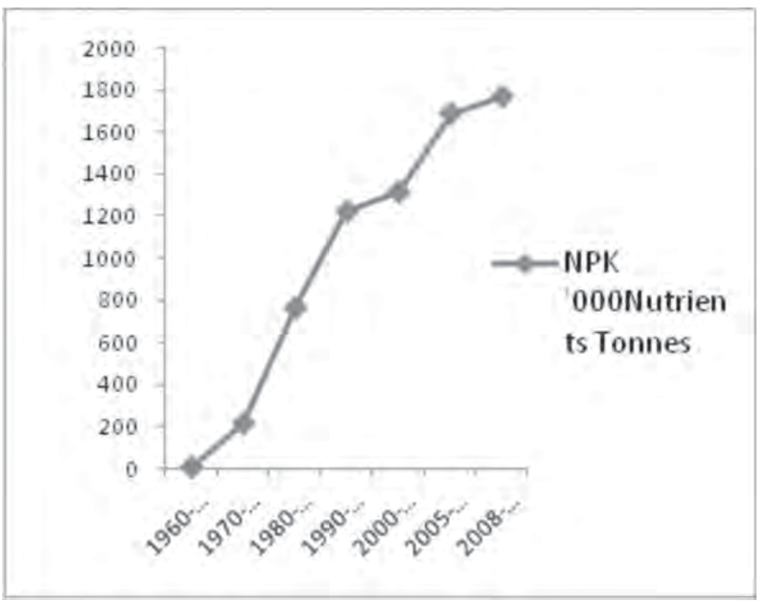
Fertilizers are an important input in the agriculture production. Initially organic fertilizers were mainly used in fields, however, later on use of chemical fertilizers have played a very important role in enhancing the agricultural production in the State. The food grain production in Punjab has increased from 3.16 million tons in 1960-61 to 27.326 million tons in 2008-2009 (Source: Statistical Abstract of Punjab, 1990 and 2009). It was initially due to increase in the area under cultivation and subsequently excess use of Chemical Fertilizers, pesticides and insecticides. The excess use of fertiliser, pesticides, insecticides, herbicides etc. is causing soil and ground water pollution in these areas.The main fertilizers used in the State are nitrogen based.

Use of fertilizers

Nitrogenous based fertilizer releases large amounts of NO_3^- which accumulate in the soil profile and is susceptible to leaching.High rates of leaching and nitrification in permeable or porous soils and relatively high use of fertilizer combine to make nitrate-leaching a serious problem in many irrigated soils (Aulakh and Malhi, 2005). In intensively cultivated semiarid subtropical region of Punjab, where average fertilizer N consumption increased from 56 to 188 kg N/ha/year during 1975 to 1988, NO_3^--N concentration in the shallow-well waters increased by almost 2 mg/l (Aulakh and Bijay-Singh, 1997). In some central districts of Punjab, fertilizer N levels exceed 300 kg N/ha/ year and on several farms, fertilizers are poorly managed (Aulakh and Pasricha, 1997).

The year wise consumption of the fertiliser was obtained from the State departments and analysis of the NPK fertiliser made. The year wise use of NPK is has been presented as Fig 4.1.

Fig.4.1 Consumption of NPK



Source-Statistical Abstract-2009

Animal wastes Disposal

Animal wastes appear to be the major contributors to high NO_3^--N in groundwater under village inhabitations and feedlots. The level of NO_3^--N in the water samples of 367 hand-pumps used in several villages and in 45 water samples collected beneath feedlots, was several folds higher than in 236 water samples of tube wells of adjoining areas, clearly illustrating that animal wastes and feedlots act as a point source of nitrates (Bajwa *et al.*, 1993). The wide variations in NO_3^--N concentration in groundwater is attributed to unscientific disposal of animal dung and urine around dairy sheds.

Use of Pesticides

The State of Punjab is one of the highest users of Chemical pesticides especially after the ushering in of green revolution. In Punjab this has increased from 3200 Metric tons (MT) in 1980-81 to 7300 MT in 1994-95 except in the year 2005-06 it came down to 5970 MT. Currently, the State consumes about 17 percent of total pesticides used in India. Out of these, more than 90 percent of the Pesticides are being used in the cultivation of Cotton, rice and vegetables. The Malwa region (Cotton belt) accounts for nearly 75 percent of pesticides used in the State. There has been a decrease in pesticide consumption since 2003-04 which can be attributed to the introduction of Bt cotton in the State (Which requires lesser number of sprays) as well as better awareness among farmers as State government is now promoting bio- pesticides.

Due to rampant use of pesticides for agricultural activity there have been numerous reports of pesticides residues in food and water. Residues of DDT and HCH (Hexachlorocyclohexane)/BHC (Benzanehexachloride) in Wheat Flour have been reported in a study carried out during 1974-76 by Joia *et al.* in random sampling from Jalandhar, Patiala, Sangrur, Ludhiana, Faridkot, Amritsar and Chandigarh. Pesticide contamination in vegetable oils and oil seed has also been reported by Battu *et al.* (1978) in products obtained from selected markets of Ludhiana, Mukatsar, Ferozepur, Sangrur and Khanna. Kalra and Chawla have reported presence of DDT and BHC in human milk. Study by Chahal *et al.*, carried out in span of eight years (1991 to 1998) revealed that 70 percent of vegetables were contaminated with different insecticides and about 27 percent of the samples contained residues above their respective limits.

(b) Industrial Pollution:

Organic and toxic wastes from industries cause water pollution (Table 4.3). Punjab Pollution Control Board has identified 13431 water polluting industries in the State under the provision of Water and Air Acts (Table 4.4).

Table 4.3 Major Water Polluting Industries in Punjab

Name of Industry	Major Pollutants
Metal Finishing	Low pH, toxicity, heavy metals like chromium, nickel and zinc etc.
Heat treatment	Cyanide, oil and grease
Arc Furnaces, Induction furnaces & Rolling mills	Oil and grease, traces of heavy metals, suspended particulates
Cotton dyeing	High pH, colour, high sodium BOD, toxic dyes
Synthetic/wool dyeing	High pH, Sulphide, toxic dyes, BOD, colour
Tanneries	Dissolved and suspended suspended solids, chlorides, sulphates, colour, BOD and chromium
Pulp & paper	Colour, dissolved and suspended solids, BOD and COD, fibre, lignin
Dairy products	High dissolved and colloridal solids, high BOD, grease, acids and alkalies

Name of Industry	Major Pollutants
Distilleries	Low pH, High organic matter, very high COD, high suspended and dissolved solids, high potassium
Fruit & vegetable canned products	High dissolved solids, colloidal and dissolved organic matter
Beer	High dissolved solids containing nitrogen and fermented starches and allied products
Yeast	High organic solids, high BOD
Soft drinks	High pH, high BOD, high suspended solids
Synthetic drugs and other pharmaceuticals	pH, high suspended and dissolved organic matter, COD toxicity
Pickling using acids	Low pH and total solids
Pesticides	High organic matter, pH, COD, toxicity
Thermal Plants	Traces of heavy metals, suspended particulates

Source: Tiwana et al., 2005

Table 4.4 Distribution of Industries in Punjab

Name of Industry group	No. of Units in Large/ Medium Scale Industries	No. of Units in Small Scale
Industries		
Food Products	106	9689
Beverages	18	174
Cotton/Woolen/Synthetic Textile/Dying, etc.	159	747
Hosiery & Garments	32	13840
Wooden Products	NA	11784
Paper Products & Printing	35	-
Paper & Printing	-	3579
Leather & leather Products	6	14518
Rubber & Plastic Products	17	4686
Chemical Products	75	4055
Non - Metallic Mineral Products	2	2640
Basic Metal Products	72	5722
Metal Products	13	20885
Machinery & Parts Except Electrical	9	10820
Electrical Machinery & Parts	36	4557
Transport Equipments& Parts	38	7015
Repairing & Servicing Units	NA	37462
Total SIDO units	NA	155248
Non-SIDO units	NA	46488
Misc. Industries	11	3075
Total	629	201736

Source: Economic Survey of Punjab 2003

Punjab Pollution Control Board has classified water polluting industries under Red (highly polluting) and Green Category(moderately , mild or non-polluting). There are 8804 industries under Red Category and 7868 industries Green Category (Table 4.5).

Table 4.5 Status of Water Polluting Industries in the State of Punjab

Years	Large & Medium (No. of Units)		Small Scale Industries (No. of Units)		Categories (No. of units)		
	With ETP	Without ETP	With ETP	Without ETP	Red	Orange	Green
2002-03	386	1	1847	751	7989	-	4916
2003-04	405	2	1787	540	8908	-	5188
2004-05	05	1997	472	9143	-	-	5707
2005-06	466	-	2145	301	7021	-	7528
2006-07	415	1	2021	117	8182	-	5249
2007-08	369	1	1915	92	7683	0	6073
2008-09	353	1	2101	96	8804	-	7868

ETP: Effluent Treatment Plant
Source: PPCB, Statistical Abstract of Punjab, 2009

(c) Urban Pollution (Municipal Waste):

Application of sewage sludge to agricultural fields and untreated industrial effluents alone, or in combination with ground/canal water, is a common practice in Punjab, especially in the vicinity of large cities, as these are considered reusable sources of essential plant nutrients and organic Carbon are causing pollution to the ground water.

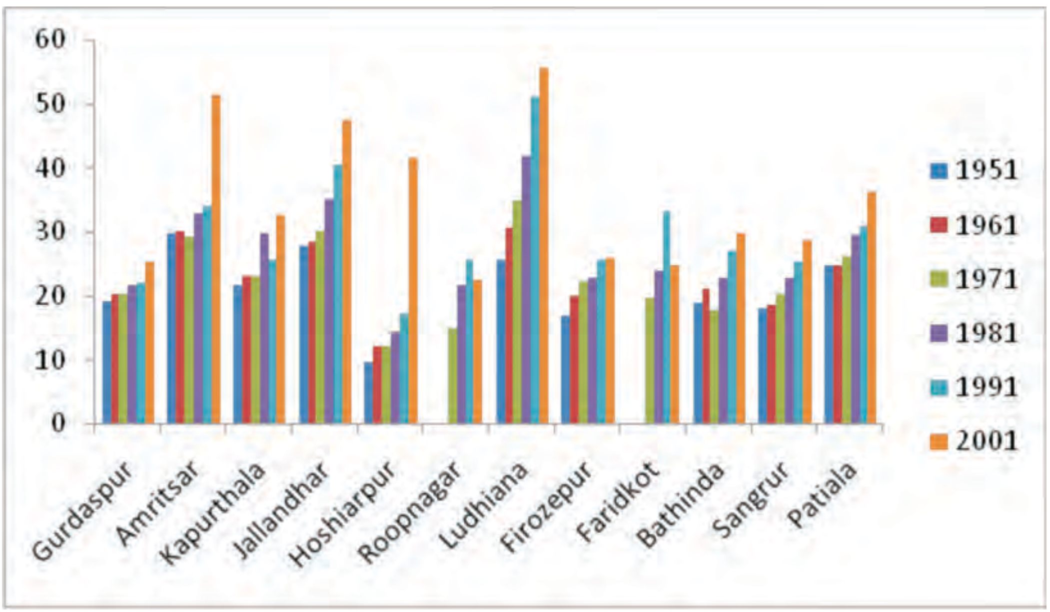
Discharge of partially/untreated water contributes to biological contamination of surface and groundwater. This can cause chronic diarrhoea and other water borne diseases. The list of major drains/nullahas/choes joininig the rivers, which carry untreated municipal wastes from parts of the State to water bodies are given (Table 4.6) below.

Table: 4.6 The List of Major Drains/Nallahas/Choes Joining The Rivers

Sutlej	Beas	Ravi	Ghaggar
Mehmoodpur drain	Chakki river	Naumani Nullaha	Patial Nadi
Charan drain	Ghural Nullaha	Saki nillaha	Jambhowal choe
Rahon Drain	Gazi drain	Hudiara Nullaha	Lehraghaga drain
Phambra drain	Nikasmansar drain		Dhanakasu nallaha
Theong drain	Khanuwan swamp drain		Sirhindchoe
Dhaini Drain	Tanda Ram Sahai drain		Mirapur choe
KotBadai khan drain	Sewa Nullaha		Jharmal nadi
BudhaNallaha	Sadarpur drain		
East Bein	Longer choe		
West Bein	Dasuya group of choes		
Chamkaur Macchiwara drain	Satiala drain		
Kishanpur drain	Dihrowal drain		
KasorNullah	Naushera drain		
	Patti nullaha		Source:PPCB,1989

All the 20 districts of the State are collectively generating about 999441.6 MT tons/day of municipal solid waste. The rapid increase in population due to urbanisation in various districts since 1951 has lead to proportionate increase in generation of municipal waste. This is clearly reflected by the percent increase in population of districts Amritsar, Ludhiana, Jallandhar and Patiala (Fig 4.2.) which is also reflected by 73% of the waste being generated in 5 Municipal Corporations i.e. Ludhiana, Jalandhar, Amritsar, Bathinda and Patiala alone (Statistical Abstract 2009). The physical composition of municipal solid waste generated in the State indicates that on an average, it contains 13% recyclables, 36.44% compostable matter and 40-50% inert material. The municipal authorities have identified landfill sites for all 137 local bodies but only 37 local bodies have land adequate to handle solid waste for 20 years. Further, many towns do not have proper collection and transportation facilities. The available infrastructure required for collection of municipal waste is grossly inadequate. The landfill sites have been selected randomly and not on scientific basis leading to leaching and contamination of the ground water sources.

Fig 4.2. District wise Percent Increase in Population



5. ORGANISATIONAL INTIATIVES AND SURVEILLANCE

5.1 Central Ground Water Board, Government of India

Water pollution is an environmental problem with multiple complex issues and challenges. At present there are various concerns being observed related to water quality issues due to impact of intensive agriculture development pattern and rapid industrialization and growth in urban sprawl. Over the years, the water quality problem has emerged as a National concern in the field of drinking water supply and sanitation. It has become imperative for all the concerned Central and State agencies to have a notice to present water quality status and devise suitable action plan for taking preventive and remedial measures. This has warranted taking up water quality monitoring and surveillance by various departments, R &D institutes, NGO's to address the issues in the State in a collective manner.In fact, several organisations are involved in monitoring water quality in the State of Punjab with different mandate and objectives. In the present endeavor, an attempt has been made by CGWB to collate the data and information as well as efforts being made by various Agencies to address the water quality related issues and problems in the State jointly. The monitoring programs executed by various organizations over the past 3 decades have generated huge volume of data in time and space and is being used to prepare various strategies and plans in isolation. However, the data/ information available with various organization those are involved in development of water/addressing health related issues/ R&D or monitoring the impact of use of water and quality concernes are to be integrated or brought to common platform To develop the stretegies for its future use.**Central Ground Water Board,** made all out efforts to collect and analyse the scitific data related to water quality issues.

Central Ground Water Board, under the Ministry of Water Resources is the National Apex Agency for investigations, evaluation and management of ground water resources. The mandate of the Board is to develop and disseminate technologies, and to monitor and implement national policies for the Scientific and Sustainable development and management of India's Ground Water Resources, including their exploration, assessment, conservation, augmentation, protection from geogenic pollution and distribution, based on principles of economic and ecological efficiency and equity.

Role in Water Quality Monitoring: The main activities of the Board include hydrogeological investigations,viz deciphering the aquifers shallow & deep for availablility of groundwater and nation-wide monitoring of the behavior of water table and water quality through a network of more than15,640 hydrograph stations. The data thus generated from these investigations provide a scientific base for preparation of ground water development schemes. In areas having problem of ground water pollution, sea-water ingress, groundwater depletion, etc., special studies are undertaken to assess the magnitude of the problem and suggest remedial measures., Board also undertakes research and development studies, water balance studies, conjunctive use studies and artificial recharge studies. The Board also organizes training programme for capacity building in the field of hydrogeology

5.2 Department of Environment Studies, Panjab University, Chandigarh

The University has been incorporated for the purpose, among others, of making provision for imparting education in Arts, Literature, Science and the learned professions and of furthering advancement of learning, the prosecution of original research, with power to appoint University Professors, Readers and Lecturers, to hold and manage educational endowments, to erect, equip and maintain University colleges, libraries, laboratories and museums, to making regulations relating to the residence and conduct of students and to do all such acts as tend to promote study and research".

To create awareness among the masses about management of our precious natural resources and for keeping our environment healthy, 2 year M.Sc. degree programme in Environment Science was planned and subsequently executed in 2002 under the Center for Environment and Vocational Studies. The Panjab University has bestowed upon the status of full-fledged Department from the year 2009 and now it is Department of Environment Studies. The results and findings of the studies carried out by these departments / Agencies are discussed in the following chapter.

Role in Water Quality Monitoring

The Department besides conducting postgraduate teaching programmes in various fields of Environment Science also aims to provide consultancy services to industries and other beneficiaries as the Laboratory of our Department has been approved by the Haryana Pollution Control Board. The department is collaborating with various central and State government organizations and institutions for excellence in this field. Various research Projects (Ongoing and successfully Completed) in the environmental field, having direct or indirect effects on human health, have been sponsored by different funding agencies.

5.3 Department of Health and Family Welfare, Government of Punjab

The Health and Family Welfare Department is committed to provide preventive, primitive and curative Health Services to the people of the State through a good network of medical institutions such as sub-centers, subsidiary health centers (dispensaries/Clinics etc.), primary health centers, community health centers, Sub-Divisional and Distt. Hospitals, Government Medical & Dental Colleges (attached hospitals).

Role in Water Quality Monitoring

The major programs initiated by the department is National Vector Borne Disease Control Programme and Integrated Disease Surveillance Programme. The other important activities being taken up by the department are

- Primary Health Care
- Secondary Level Health Care System
- Tertiary Level Health Care System
- Delivery of Family Planning Services

5.4 Department of Water Supply and Sanitation, Government of Punjab

Department of Water Supply and Sanitation has been educating and providing guidance to the public regarding water quality monitoring and surveillance; create awareness about the water borne diseases and other health hazards caused due to lack of sanitation and open defecation.

Role in Water Quality Monitoring

- Provide safe drinking water in adequate quantity to rural habitations on sustainable basis.
- Ensure permanent drinking water security in rural areas.
- Promote conjunctive use of ground water, surface water and rain water harvesting to achieve sustainability.
- Involve rural community in planning and execution of rural water supply schemes and to make the community capable of operation & maintenance of schemes on their own.
- Improve rural hygiene by providing individual toilets and sewerage system.
- Encourage the rural population to properly manage water supply and sanitation facilities to make villages Nirmal Gram.
- Installing Portable Filtration Plants is being adopted. Reverse Osmosis Plants / Defluoridation plants are also being installed for treatment of water at some places on pilots basis.
- Water Quality Monitoring and Surveillance
- Frequent Water Sampling
- Training to PRIs
- Mobile Water Testing Laboratory
- Strengthening of Water Testing facilities

5.5 Punjab Pollution Control Board, Government of Punjab

Punjab Pollution Control Board has been entrusted the task of implementation of environmental laws in the State of Punjab. PPCB is mandated to inspect industrial plants and manufacturing process, sewage or trade effluents, works and plants for the treatment of sewage and trade effluent or any control equipment, to review plans, specifications or other data relating to plants set up for effluent treatment or air pollution control devices, in connection with the issue consents for installation and operation of industrial plant and to give, such directions to such persons as it may consider necessary to take steps for the prevention and control or abatement of water or air pollution. Further the PPCB has to ensure that hazardous wastes generated by the industry are stored and disposed off without any detrimental effect to the environment. The major activities of the Board is given as under:-

Role in Water Quality Monitoring

Control pollution at the source with due regard to techno-economic feasibility for liquid effluents as well as gaseous emissions.

- Ensure that natural waters are not polluted by discharge of untreated city sewage.

- Maximize reuse / recycling of sewage and trade effluents and to use the treated effluent on land for irrigation and for industrial purpose after appropriate treatment.
- Minimize pollution control requirements by judicious location of new industries and relocation of industries wherever necessary.
- Effective control of water and air pollution and to maintain and restore the quality of water for various designated uses and of air.
- To identify pollution sources and initiate follow up action for abatement, prevention and control of pollution.
- To promote measures and assistance through incentives, guidelines, development of cost effective technologies and putting up demonstration plants.
- To persuade industry / local bodies to take preventive measures for the control of pollution.
- To strengthen the capacities for pollution control through training and laboratory development and strengthening of manpower and infrastructure.
- To create awareness about environmental pollution by educating the industry and local authorities.

5.6 School of Public Health and Community Medicine, PGIMER, Chandigarh

The Institute endeavors to provide the best health care, teaching, and research facilities in all branches of medicine, surgery, and public health. As a premiere national institute, PGIMER plays a leading role in the advancement of health care in the country. The PGIMER was also given the responsibility to broaden the horizons of medical knowledge by intensive research in the field of health.

Community Medicine Department has the dual purpose of evolving a feasible pattern of health care delivery to the rural people and for providing community health orientation to the resident doctors of the institute.

Role in Water Quality Monitoring

School of Public Health aims to conduct postgraduate teaching programmes and short term training courses in various fields of public health for national health programme managers to provide consultancy services to State and central health services on public health matters, and to carry out research by setting up model public health projects keeping in view national health policy guidelines and vision of health for all in 21st century.

5.7 Water Resources and Environment Directorate, Government of Punjab

The main objective of Water Resources Organization is to carry out the ground water and surface water studies for formulations of various schemes and policy matters for the judicious use of Water Resources in Punjab State.

Role in Water Quality Monitoring

The department is engaged in the following activities

- Ground Water monitoring and maintaining data base for ground water.
- Collection of rainfall data
- Collection of data on ground water & soil quality
- Carrying out hydrological, hydro-geological, hydro-chemical, geophysical, mathematical, statistical, agronomical, remote sensing and other studies.
- Deep ground water investigations to identify aquifer parameters
- Dynamic Ground Water Resource Estimation
- Framing of policy matters such as ground water legislations and State Water Policy

5.8 Farmers / NGO

One of the important NGO's working in Punjab for water is Kheti Virasat Mission (KVM). It is a civil society movement with compassion and concern for the nature, ecological sustainability, environmental health, safe food and livelihood of poor and socially and economically marginalized people.

Role in Water Quality Monitoring

As such the Kheti Virasat Mission also do not carry out monitoring of the water quality but takes up the activities for awareness, participatory programme, etc on regular basis. The major activities taken up by them include the following:-

- Environmental Health Action Group
- Women Action for Ecology
- KVM Global Initiative for Restoration of Ecology in Punjab
- Creativity for Environment - A forum of literary and creative artists
- Environment Justice Action Group - A forum for environmental laws
- Vatavaran Panchayat - Vatavaran Panchayat is a participatory forum and grass root level network for KVM activists, sympathisers, supports and partners, working for wider environmental and developmental issues.

6. WATER QUALITY TRENDS & IMPACTS

In this chapter, an attempt has been made to bring together the data / information available with different Agencies working on water quality and bring out the present status of water quality in the State. Though, the water quality in surface water sources and ground water are interlinked , the assesment and management of water quality in surface water sources and in ground water needs altogether a different approach. It is considered pertinent to discuss the status of water quality separately for surface water and ground water.

6.1 SURFACE WATER QUALITY

As discussed in previous chapter regarding different sources of pollution in Punjab and efforts made by various Agencies in monitoring and management of water quality, this chapter presents status of increased population, industrial wastes and agricultural chemicals that are contaminating our water sources. Monitoring waterways helps to identify changes in water quality, provide data for the design of pollution prevention or remediation programs, and respond to chemical spills and other emergencies.

River Water Quality

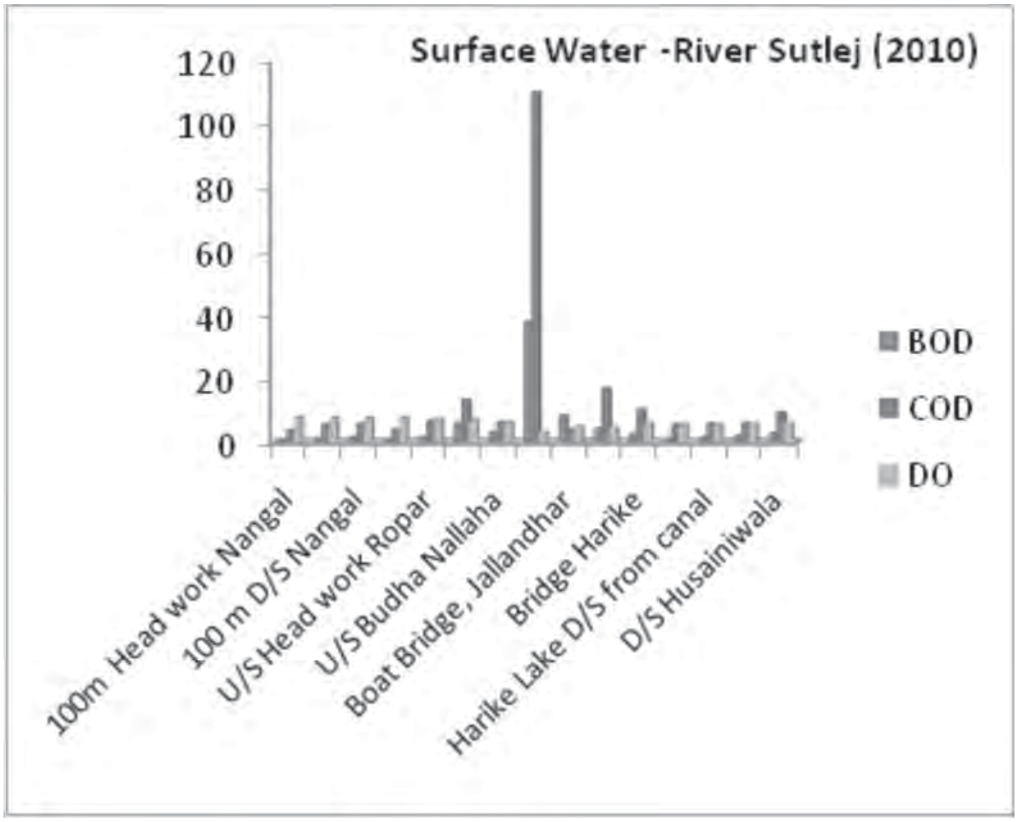
Water quality in the aquatic ecosystems of Punjab is being monitored by the Punjab Pollution Control Board at several locations. At each monitoring location, samples are collected every quarter i.e during the months of January, April, July.

River Sutlej

The pollution sources entering into River Sutlej and Sirhind Canal system were identified and are shown on the Plate 6.1. & 6.2 .Many important towns like Nangal, Ropar, Ludhiana and Ferozepur are situated along this river. Punjab Pollution Control Board (PPCB) is monitoring the quality of the river for physico-chemical parameters such as DO, BOD, COD, free ammonia, TDS and TFDS, pH, conductivity, alkalinity, hardness, calcium, magnesium, sodium, chloride, sulphate, nitrate and nitrite, etc. Monitoring of certain heavy metals like Nickel (Ni), Chromium (Cr), Cadmium (Cd), Copper (Cu), Zinc (Zn), Lead (Pb), Iron (Fe), Arsenic (As) and Mercury (Hg)) and pesiticides (DDT, Endosulfan, Aldrin and BHC) is being carried out at 12 places since 2002. The water quality of river Sutlej, in 2010, at various sampling points indicates that it's quality with respect to BOD, COD and DO starts deteriorating near Nangal and falls in 'C' category as per Designated Best Use (DBU) Classification but is of poor quality at Rishab Paper Mills (D Category) and is of extremely poor quality 100m downstream of Budha Nallaha (Fig 6.1).

Further, the feacal coliform bacteria in Sutlej indicate an increasing trend from 1988 onwards. The data for heavy metals and pesticides also indicate higher concentrations of Fe, Zn, Cr, Cu, Pb & Ni and pesticides like DDT, BHC, Endosulfan and Aldrin in water.

Fig 6.1



The Faecal Coliform is also extremely high near the entire length of Budha Nallaha upto the down stream of East Bein (Fig 6.2).

Fig 6.2

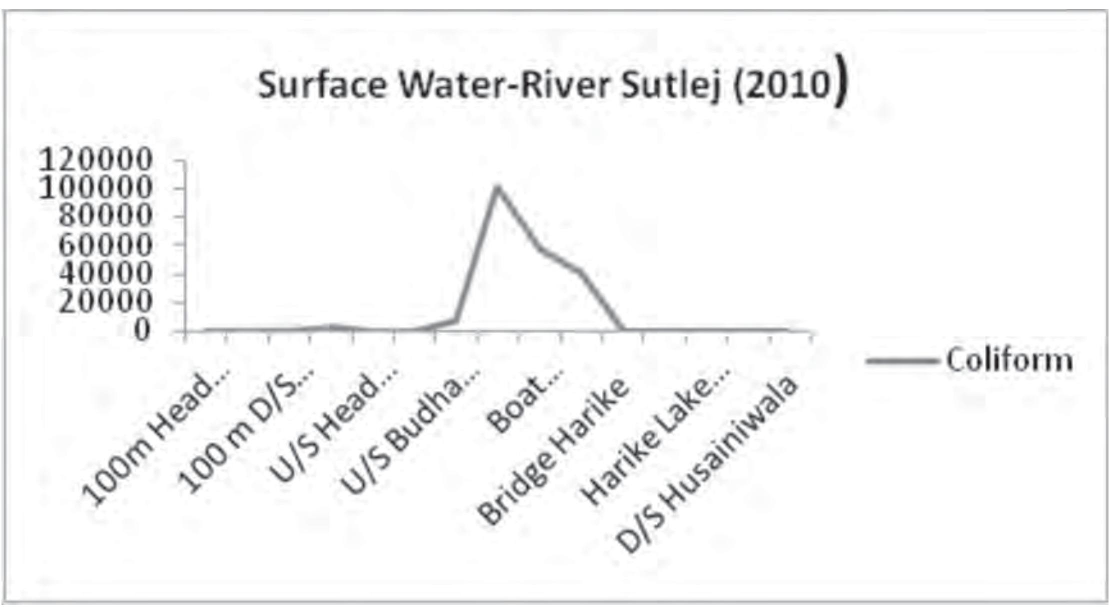


Plate 6.1

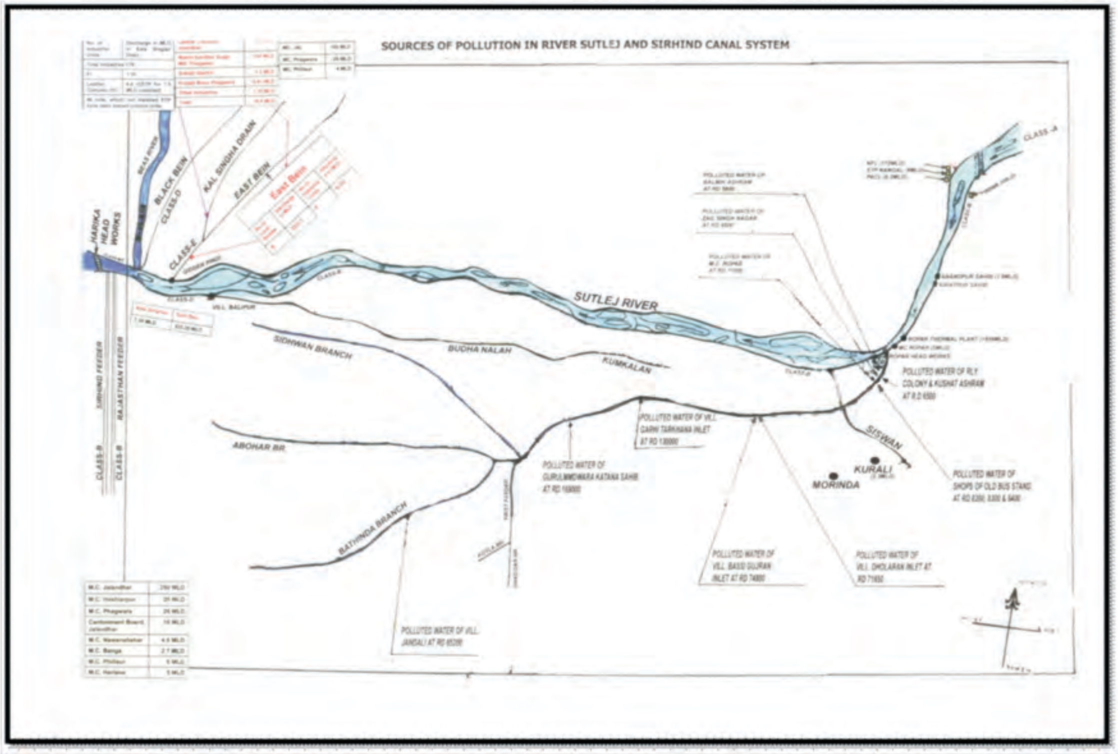
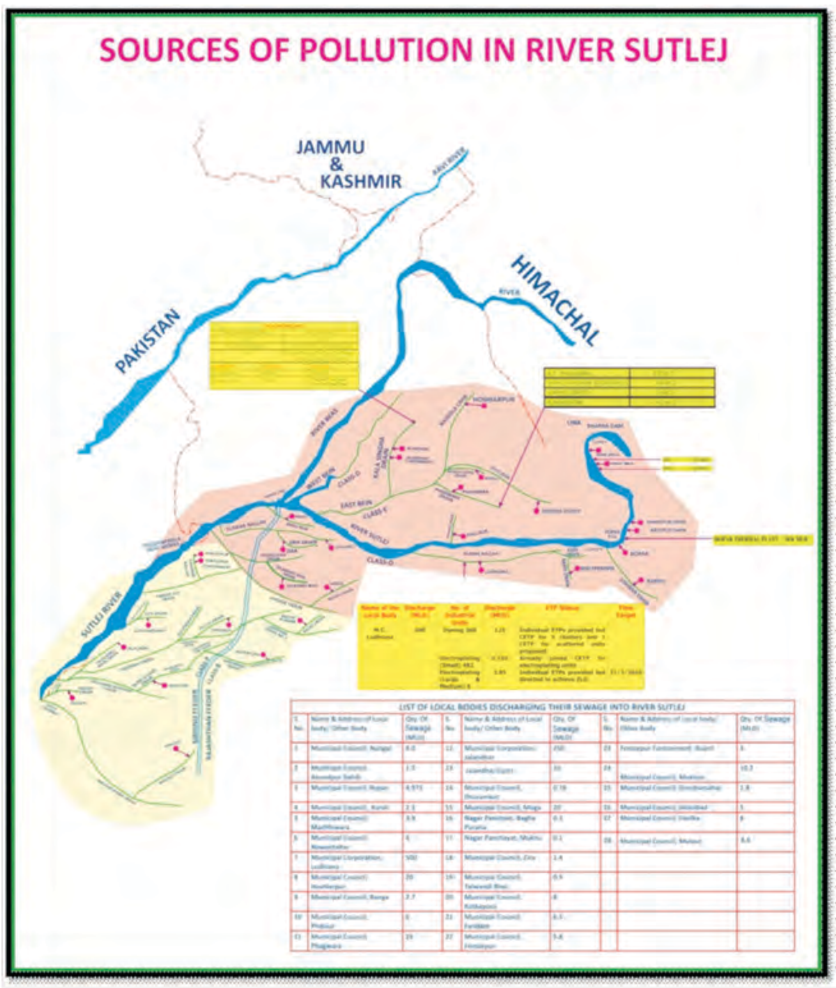


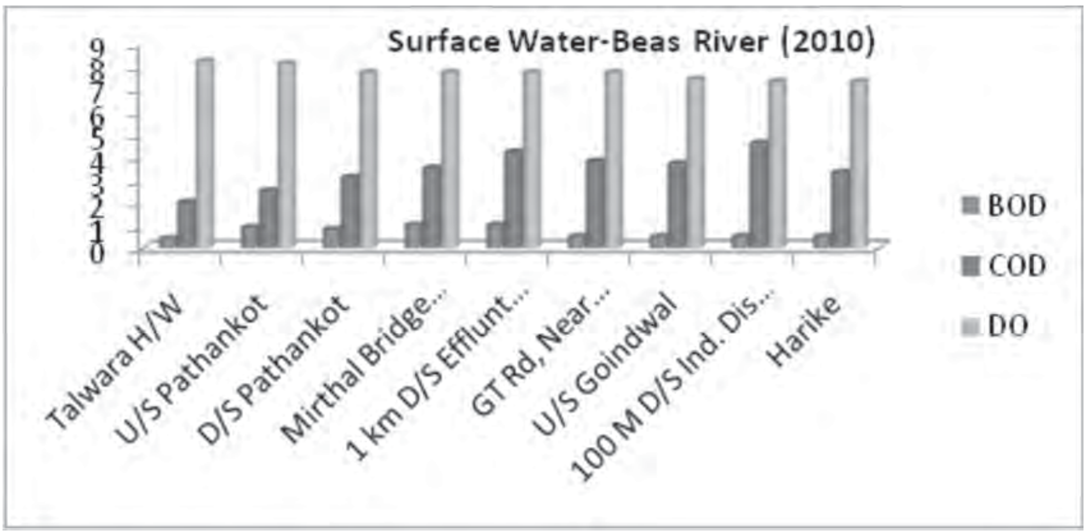
Plate 6.2



River Beas

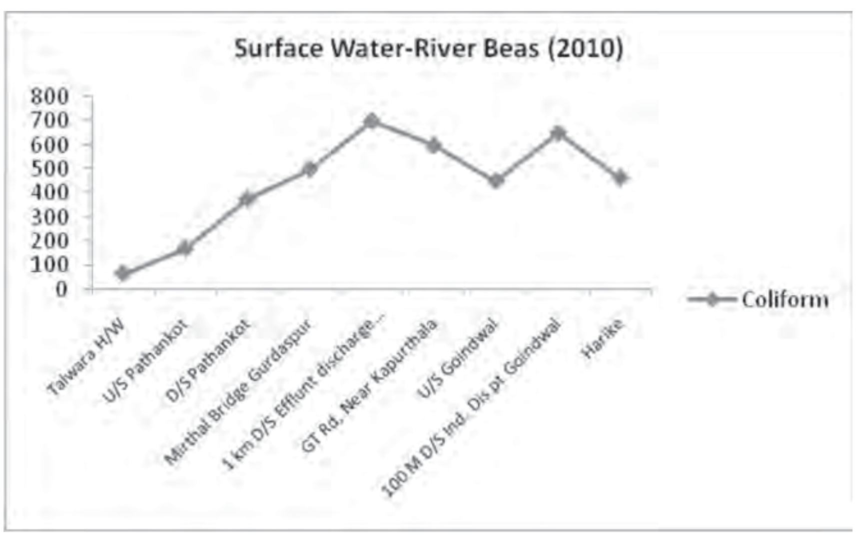
The Beas enters near the Rohtang Pass in Kulu at a height of 3,960 m and flows through a gorge from Larlji to Talwara and then enters the Punjab plains to meet the Sutlej at Harike. Its total length is 460 km and catchment area is 20,303 sq km. The important towns situated along the banks of river Beas are Talwara, Mukerian and Beas town. The sources of pollution in river Beas are presented in Plate 6.3. Data indicates that the quality of water of river Beas when it enters Punjab State at Talwara is fairly good. The river has sufficiently high dissolved oxygen content and a well buffered pH system at this point. The quality of water remains so till it receives effluents and sewage from Mukerian town where it drops down generally to Class C. Further downstream, the water quality is of Class C due to discharge of industrial effluents and sewage from Goindwal town and industrial complex. However, the quality of water improves to Class B once again by the time it reaches Harike. The water quality-2010 of Beas river is more or less the same with respect to BOD, COD and DO as depicted in Fig 6.3.

Fig 6.3



It is observed that water quality of Beas river with respect to Faecal coliform deteriorates at sampling point 1 km D/S Effluent discharge Mukerian and near Kapurthala (Fig 6.4). Further, the Faecal Coliform concentration is also low as compared to river Sutlej.

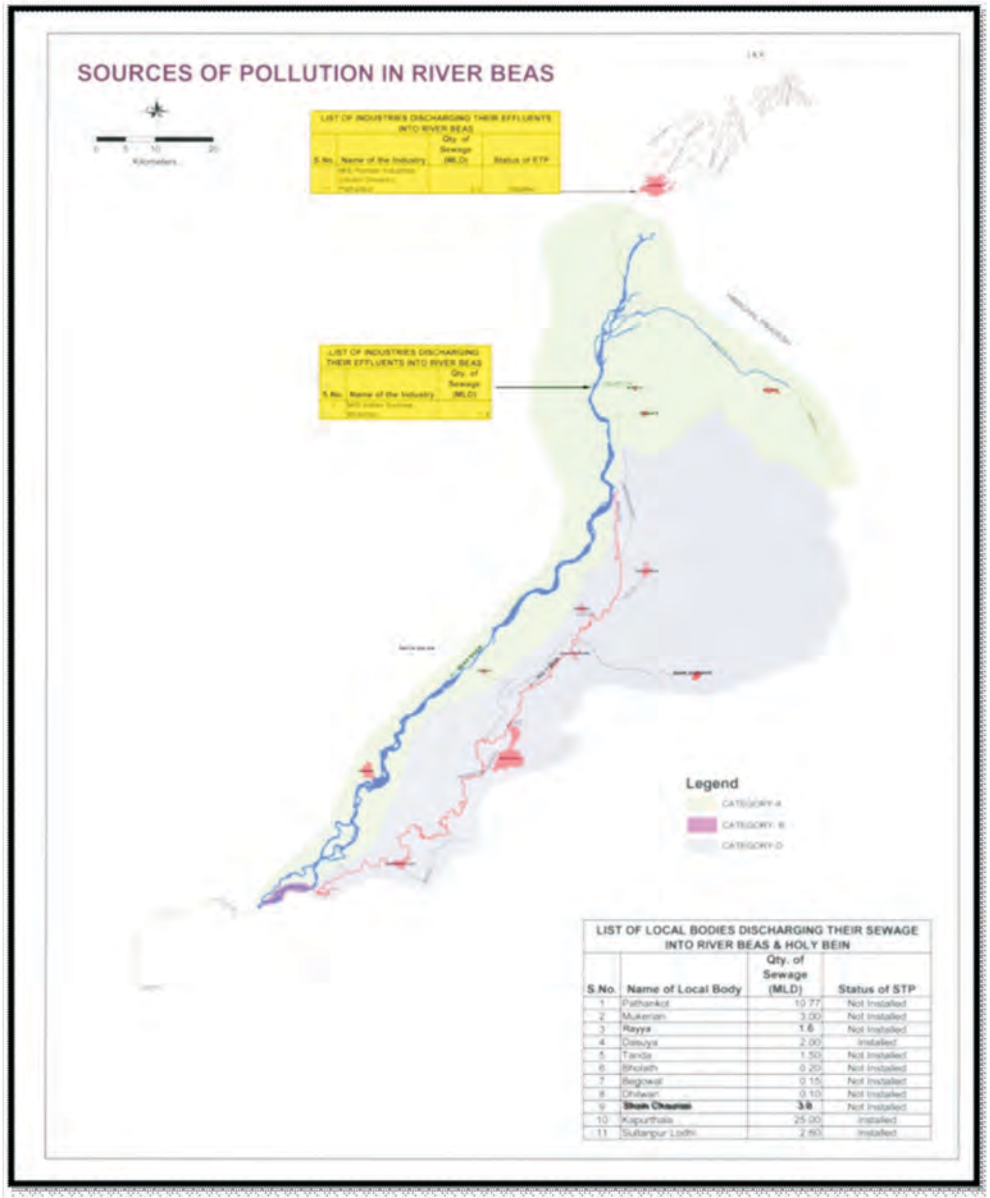
Fig 6.4



River Ravi

The Ravi rises in Kulu, flows westward through a triangle formed by the junction of the Pirpanjal and Dhaola Dhar ranges. It enters Punjab plains near Madhopur and later enters Pakistan 26 kms below Amritsar. Catchment area is only 14,442 sq km. The water quality in the river is comparatively clean along it's entire length since there is little human activity around it and it remains 'B' throughout the year.

Plate 6.3



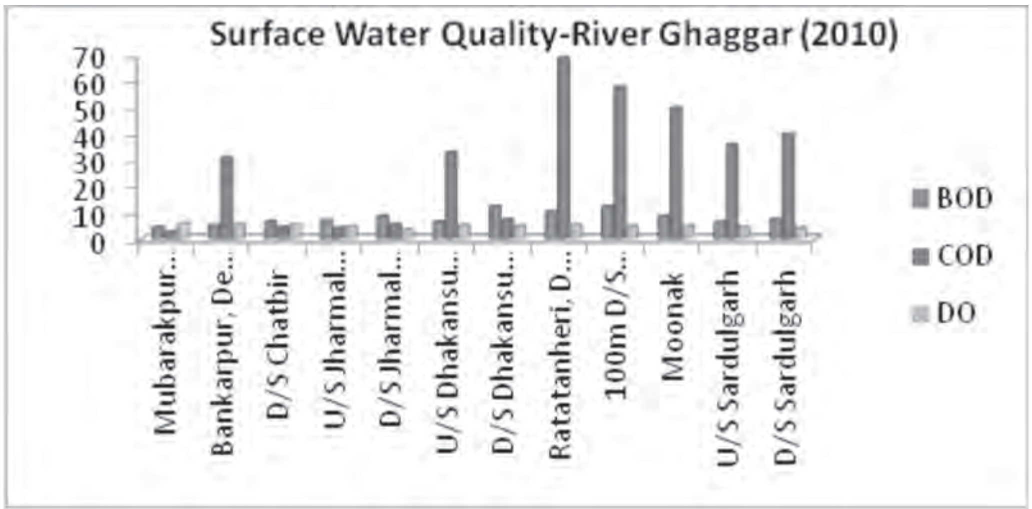
There is only one sampling station on the upstream side of Madhopur Head Works i.e, Gurdaspur on this river. The water quality of the river is more or less similar along its entire length. The water quality predominately conforms to A class as per designated best use classification of CPCB. The physico-chemical analysis of water at Madhopur suggests that the water is clean and almost free from pollution. The concentration of salts, ions and nutrients are well within permissible limits (Source:1993-1997 data as per CPCB). The water is slightly alkaline and well aerated. DO is high and BOD and COD contents are low. The total and faecal coliform are also low.

River Ghaggar

The Ghaggar originates from the feet of Shiwalik hills and runs towards North-East of Kalka. It enters Punjab in Dera Bassi block near village Kakrali and passes through Patiala, Sangrur and Bathinda districts of Punjab. It leaves Punjab near village Moonak after covering a distance of about 180 km in the Punjab territory.

There are 12 sampling locations (Plate 6.4) on the river. A general increasing trend in the BOD and COD values is observed since 1995 onwards indicating increase in pollution over the years. The surface water quality of entire stretch of Ghaggar river is of D category (Fig 6.5) but falls to E category of DBU classification downstream of Jahrmal Nadi. The COD values are high at Dera Bassi, from upstream of Dhakansu Nallaha till its tail end at Sardulgarh.

Fig 6.5



The feacal coliform values are also very high at times crossing the 5000 MPN/100ml limit specified for 'Class-C' quality water. The faecal coliform though high at all sampling points of Ghaggar river, increase sharply upstream of Dhakansu Nallaha till the last point downstream of Sardulgarh (Fig 6.6).

Fig 6.6

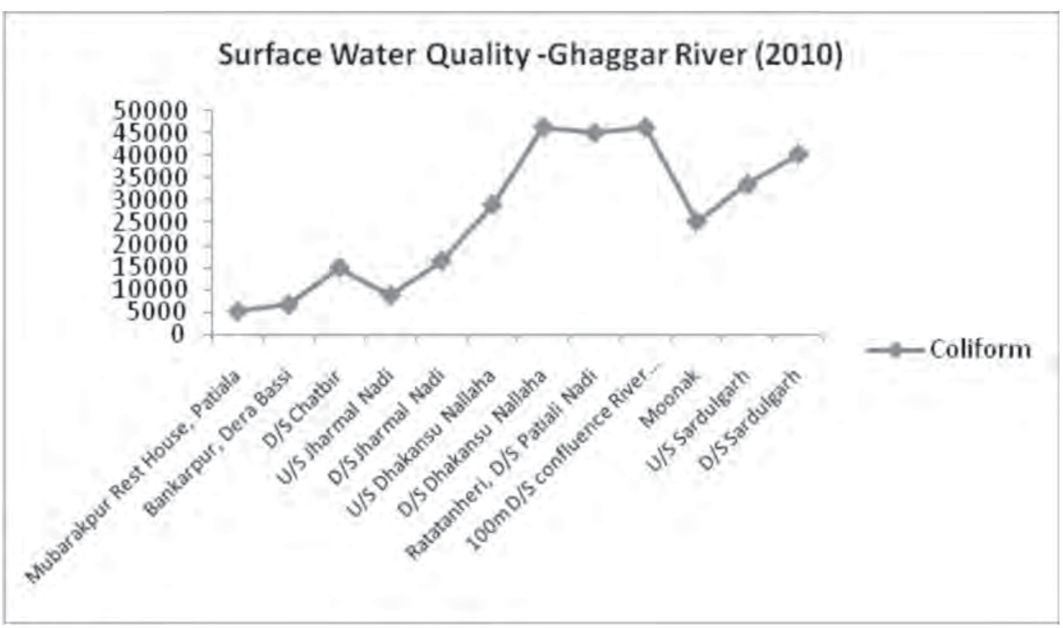
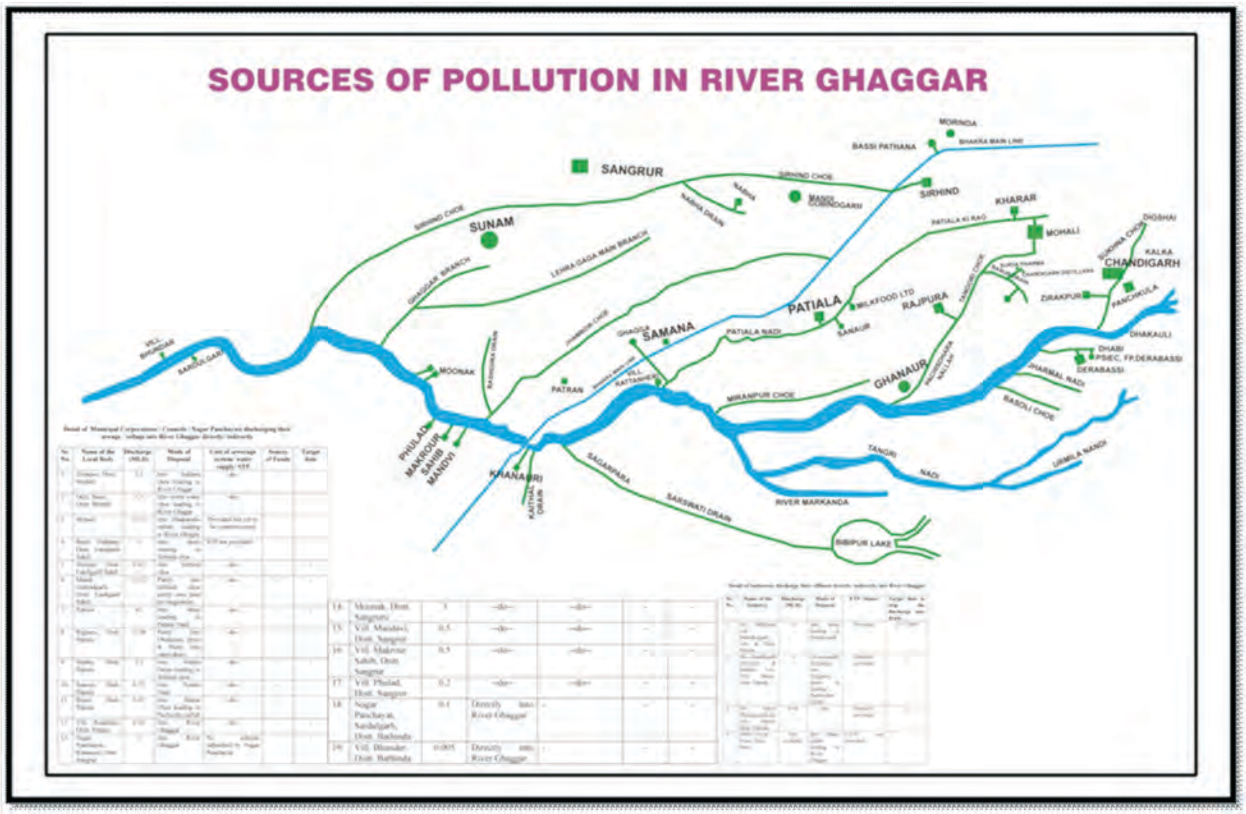


Plate 6.4



The heavy metal and pesticide monitoring in the river at three locations i.e. D/S Dhakansu nallah, D/S Ratanheri and D/S Khanauri and with regard to pesticides, high values have been reported at D/S Khanauri in the river water (PPCB, 2010).

Azad et al. (1984) studied the nature of potentially toxic elements and their concentration in the effluents emanating from two groups of industries - first involved in the manufacturing of metallic products, such as cycles, spare parts and electroplating; and the second group comprising processing of textiles, woolens and dyes. Analysis of these effluents revealed that, in general, lead (Pb), cadmium (Cd) and Nickel (Ni) were in higher concentration in effluents of industries manufacturing metallic products as compared with textile and woolen industries. The chemical analysis of sewage-water samples collected from different locations of an open drain, commonly known as “Budda Nullah,” downstream from entry into Ludhiana city, revealed that the concentration of metals in the drain increases manifold as it passes through Ludhiana city. This is because the number of industries pouring their untreated effluents increased as the distance downstream increased. This implies that the open Budda Nullah drain, which is a natural fresh-water stream before its entry into Ludhiana city, turns into a highly polluted sewage channel when it passes through the interior of the city, receiving effluents from various types of industries on its way.

Water Quality of Streams/Nallahas/Choes

The water quality studies carried out by PPCB (2006), for some streams, nallahs and choes are as follows:

Sukhna Choe: The value of BOD and COD of the water flowing in Sukhna Choe indicate that their concentration was found as 8 and 40 mg/l, respectively. The concentration of chloride, sulphate sodium and potassium was observed as 96, 40, 70 and 21 mg/l, respectively. The value of magnesium was estimated as and 50 mg/l, where as the concentration of zinc and lead was found to be as 0.2 and 0.04 mg/l, respectively. The reasons for high values of all parameters may probably be due to sewage brought by the choe of various residential settlements along or nearby Sukhna choe.

Dhankansu Nallah : The effluent flowing in the Dhankansu nallah was found contained BOD and COD as 135 and 228 mg/l, respectively. The reason for high values of substrate (organic matter) in the effluent may be probably due to discharge of domestic effluents. The mortality rate of fish was observed as 100% in 100% effluent after 96 hrs, which indicated that very low level of DO due to discharge of untreated sewage into the Dhankansu nullah.

Patiala Nadi : The wastewater samples collected from Patiala Nadi just before its confluence with river Ghaggar indicate the value of BOD, COD, sodium, sulphate, chloride and TSS as 160, 320, 188, 44, 140 and 28 mg/l, respectively. The value was zinc was found to be mg/l. The reasons for high values of various parameters may be due to the fact that Patiala Nadi mainly carries sewage of Patiala city.

Drain at Sardulagarh Town: First drain of Sardulgarh town which carrying sewage/ sullage of sardulgarh indicate the values of BOD, COD, TSS, TDS, chloride, sulphate, sodium, potassium, TKN, calcium, magnesium, phosphate, zinc, lead and copper were observed to be as 90, 188, 142, 1299, 118, 120, 136, 49, 37, 290, 110, 14, 0.09, ND and 0.06 mg/l, respectively. These results indicate that the sewage of Nagar Panchayat, Sardulgarh requires treatment before it's discharge into river Ghaggar. Waste water also contains pathogens to pose serious risk to human health.

Water Quality of Drains

In the district, Municipal Corporation of Amritsar is discharging waste in the drains, which is a potential source of pollution. The Saki and Hundiara nallah are also polluted. As per study of PPCB & PGI (2007) of Hundiara nallah and Tung Dhab drain (Plate 6.5 & 6.6) significantly higher association of envIronment pollution has been indicated due to heavy metals and pesticides. The Fluoride concentration was higher than the MPL (maximum permissible limit). Similarly Calcium, Magnesium and Ammonia were higher than the MPL. The mean BOD and COD values were higher in target area. Mercury, Lead, Chromium, Cadmium, Copper and Selenium were above the MPL in groundwater and surface water. Heptachlor, chloropyriphos, β-endosulphan, dimethoate and aldrin were more than MPL in groundwater samples of the target area.

Plate 6.5

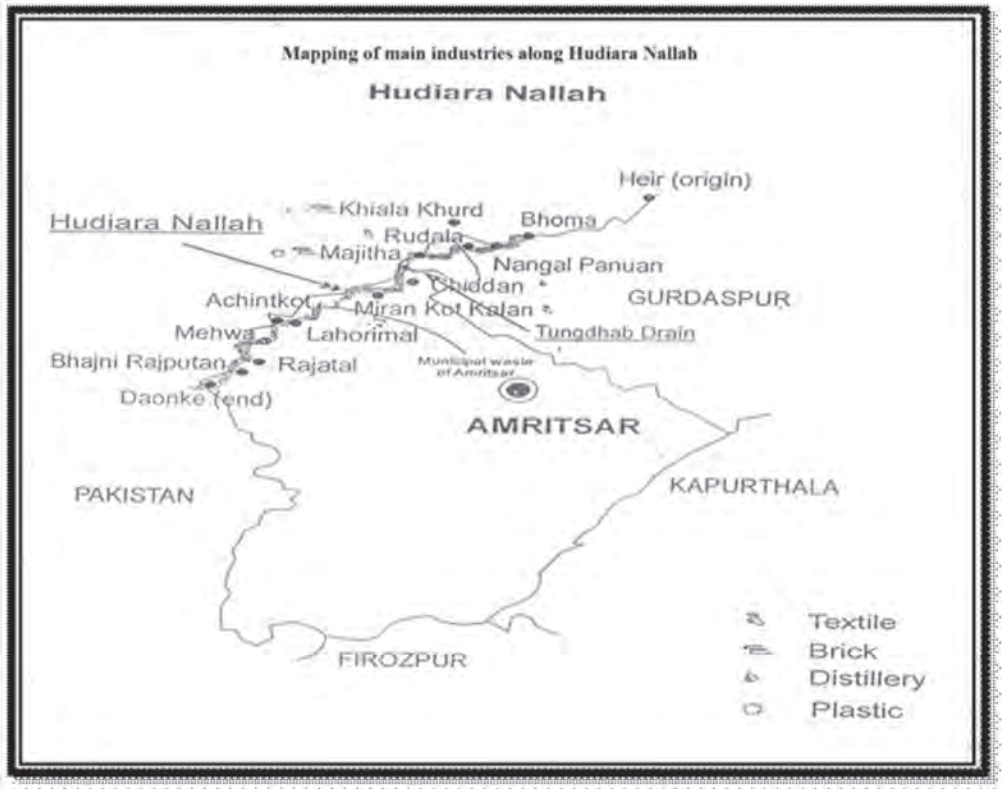
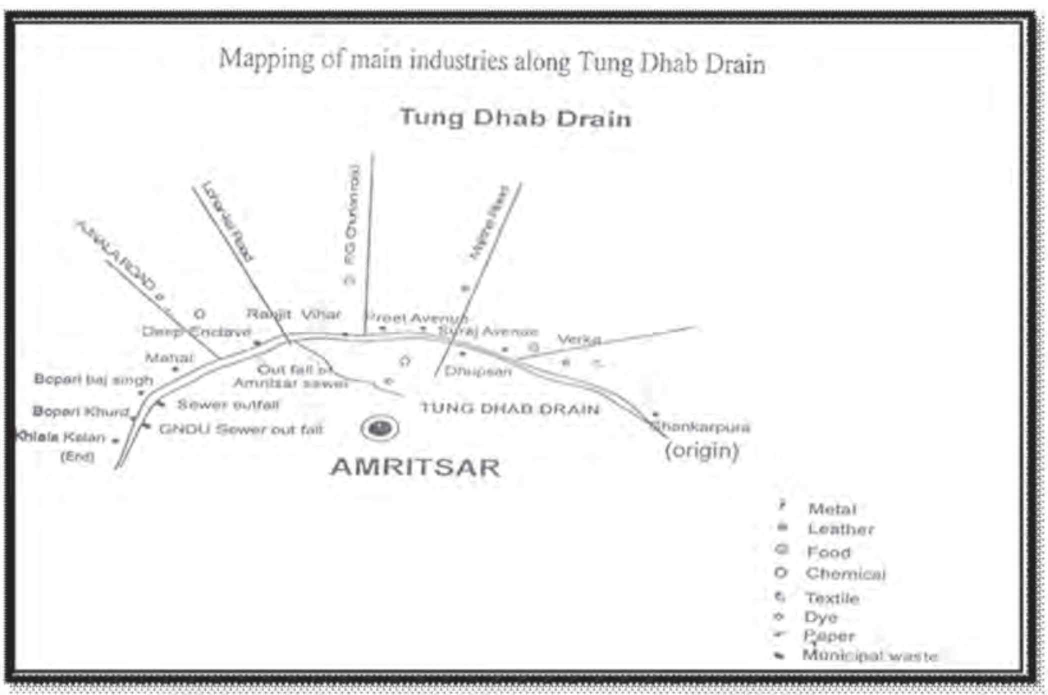


Plate 6.6



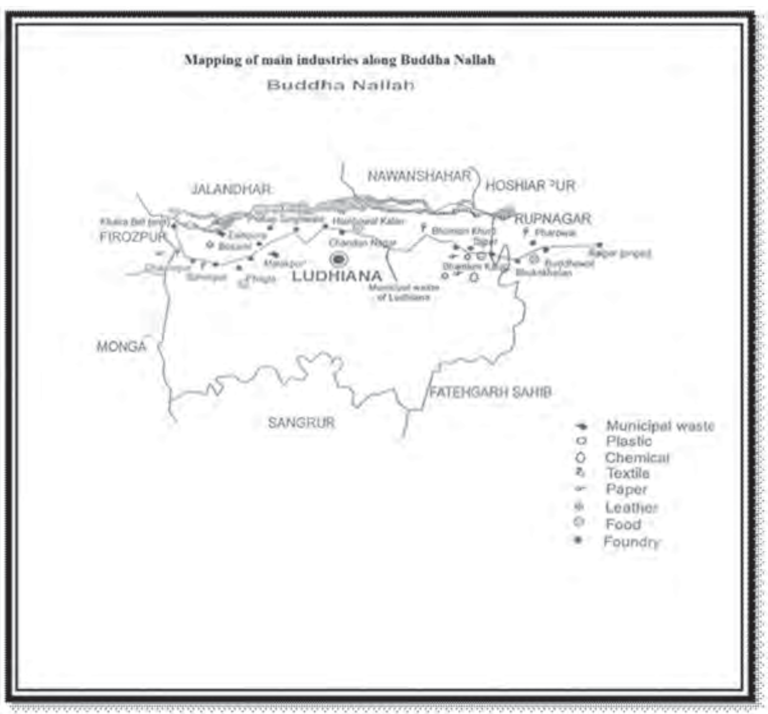
As per study of East Bein drain (Plate 6.7), significantly higher association of envIronment pollution has been indicated due to heavy metals and pesticides. Concentration of Cadmium, Copper, Selenium, Arsenic, COD, BOD were observed to be higher in mid stream area of East Bein drain in Khun Khun. Lead and Chromium were observed to be maximum downstream of drain. Effluent water had higher concentration of α and β endosulphan, Aldrin, α, β, γ-HCH, Heptachlor, 4,4' DDT, Malathion, Chloropyriphos and Mercury.

Plate 6.7

There are serious concerns over water quality aspects of the Budha nallah. As per study carried out by PPCB & PGI (2007) the overall concentration of Copper Selenium and Lead were found to be higher in midpoint of drain. Concentration of Chromium, Copper and Mercury were found above MPL in downstream of Nallaha (Plate 6.8). Effluent water of Khera Bet has high concentration of Heptachlor, β Endosulphan, Copper, Chromium and Nickel.The sampling sites are depicted in Plate 6.8.

In the district, Municipal Corporation of Bathinda is discharging waste in the drains, which is a potential source of pollution. The chances of pollution entering ground water are more as most of the district has shallow water levels and ground slope is very subtle thereby increasing the possibility of deposition of pollutants.

Plate 6.8



6.2 GROUND WATER QUALITY

CGWB is monitoring the water quality on an yearly basis since the seventies by collecting and analyzing water samples from various GWMS spread all over the State. These water-sampling points are mostly hand pumps of shallow depths, which are thoroughly in use for domestic purposes. 204 water samples were collected from all over the State, during May 2009, as per standard procedures laid in APHA from ground water monitoring stations (GWMS). Standard analytical methods (APHA, 1998) were employed for the determination of pH, electrical conductivity, total hardness, carbonate, bicarbonate, chloride, sulphate, nitrate, fluoride, calcium, magnesium, sodium and potassium.

Overall Water Quality Scenario of the State

The physico-chemical characteristics of the shallow waters of the State have indicated wide variations in mineral contents. About 60% of the well waters are fresh and of good quality. Such waters are generally found in northern and northeastern parts comprising of district of Amritsar, Fatehgarh sahib, Nawanshahr, Gurdaspur, Ropar, Hoshiarpur, Jalandhar, Ludhiana and Kapurthala. Nearly 30% of the well waters, generally found in central parts of the State comprising of Patiala, Moga, Mansa, and Ferozepur districts, are moderately saline and of marginal quality. About 10% of the well waters are saline and are not safe for use as the average EC of these waters is above 3000 mS/cm at 25°C. Such waters are generally found in isolated patches in southern and southwestern parts of the State comprising of districts of Faridkot, Muktsar, Bathinda and Sangrur. The District-wise Concentration Ranges of Chemical Constituents in Groundwater of Punjab are shown in Table: 6.1.

The overall status of different chemical parameters in the ground water with respect to the State is discussed below:

***pH** :* The ground water is slightly to moderately alkaline in nature. The pH values range from 6.89 at Nangal Bihala in Hoshiarpur district and Shahkot in Jallandhar district to 8.53 at Garh Shankar in Nawan shahr district.

***Salinity*: ** salinity of ground water is measured in terms of EC. The ground water is found to have low to very high salt content as the EC of well waters ranges from 280 mS/cm. at Brahmpur in district Ropar to 9630 mS/cm at Abohar in district Ferozepur. Grouping water samples based on EC values, it is found that 39.3 % of them have EC less than 750, 54.5 % have between 750 and 3000 and the remaining 6.1% of the samples have EC above 3000µS/cm. The Plate 6.9, showing aerial distribution of EC with intervals corresponding to limits assigned for desirable, permissible and unsuitable classes of waters indicates that desirable class of waters occur in northern parts comprising of Amritsar, Fatehgarh Sahib, Gurdaspur, Ropar, Hoshiarpur, Ludhiana, Nawanshahr and Kapurthala districts of the State. In the central parts comprising of Patiala, Jalandhar, Bathinda, Sangrur, Faridkot, Ferozepur, Mansa and Muktsar districts, the majority of the ground water falls in the permissible class and the ground water occurring in the southern and southwestern parts comprising of Faridkot, Muktsar, Bathinda, Mansa, Ferozepur and Moga districts is mostly saline and not suitable for drinking use.

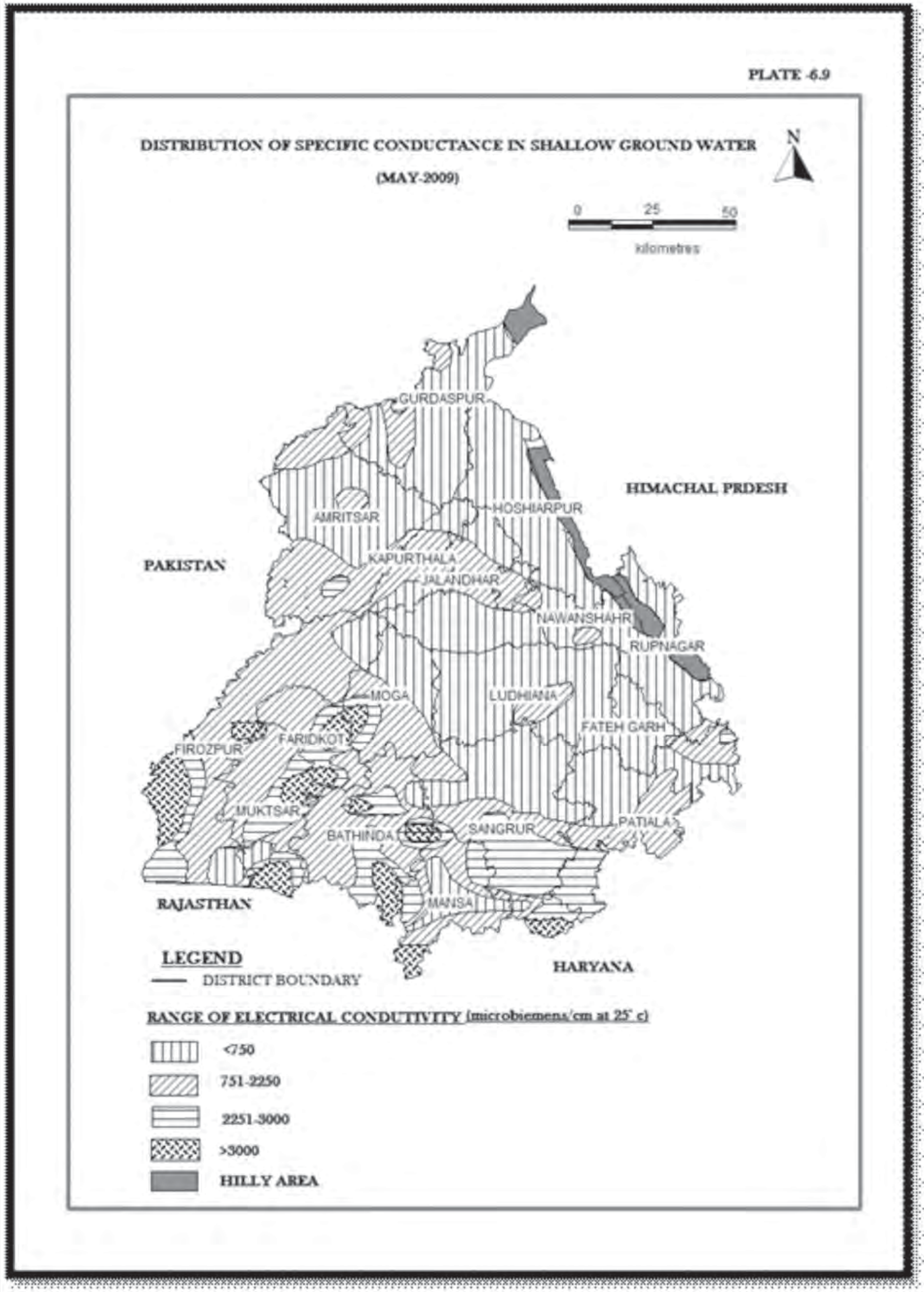


PLATE 6.9
DISTRIBUTION OF SPECIFIC CONDUCTANCE IN SHALLOW GROUND WATER
(MAY-2009)
N
0
25
50
kilometres
GURDASPUR
AMRITSAR
HOSHIARPUR
HIMACHAL PRDESH
PAKISTAN
KAPURTHALA
JALANDHAR
NAWANSHAHR
RUPNAGAR
MOGA
LUDHIANA
FATEH GARH
FIROZPUR
FARIDKOT
MUKTSAR
BATHINDA
SANGRUR
PATIALA
MANSA
RAJASTHAN
HARYANA
LEGEND
DISTRICT BOUNDARY
RANGE OF ELECTRICAL CONDUTIVITY (microsiemens/cm at 25° c)
<750
751-2250
2251-3000
>3000
HILLY AREA

TABLE: 6.1 DISTRICT-WISE CONCENTRATION RANGES OF CHEMICAL CONSTITUENTS IN GROUND WATER OF PUNJAB (2009)

Sr. No.	DISTRICT	No. of Samples	Range	pH	EC	CO_3 (<—	HCO_3	Cl	SO_4	NO_3 mg/l	F	Ca	Mg	Na	K —>)	TH as $CaCO_3$
1	Amritsar	13	Min	7.69	640		212	14	50	0	0.17	18	16	61	4.3	113
			Max	8.22	2170		622	190	252	172	2.48	54	68	322	32	383
2	Bathinda	23	Min	7.54	288		120	5.3	22	2.9	0.19	11	3.8	12	3.2	40
			Max	8.00	3490		918	471	500	380	7.25	216	228	570	325	1451
3	Faridkot	6	Min	7.59	319		109	12	50	2.2	0.29	34	9	17	3.2	122
			Max	8.26	4790		757	464	1200	130	4.2	89	89	1020	106	470
4	Fatehgarh Sahib	10	Min	7.27	595		220	10	0	0	0.04	15	5.6	37	4.0	155
			Max	7.94	790		469	60	80	87	0.64	65	57	124	14	349
5	Ferozepur	20	Min	7.45	520		244	10	25	0.3	0.06	25	26	23	5.3	190
			Max	8.28	9630		1763	1582	2520	240	4.4	228	213	1880	203	1447
6	Gurdaspur	25	Min	7.18	290		112	7.1	7	0	0.12	9	11	3.7	0.5	124
			Max	8.19	3290		647	274	620	340	1.21	90	98	372	524	552
7	Hoshiarpur	12	Min	6.89	315		130	13	0	0	0.07	16	4.9	11	1	112
			Max	7.61	1480		359	159	243	80	0.41	86	74	102	61	521
8	Jalandhar	14	Min	6.89	335		142	19	0	2.4	0.09	12	0	23	0.9	61
			Max	8.03	1440		483	317	139	80	2.4	105	78	166	9.8	582
9	Kapurthala	6	Min	7.59	340		62	14	36	0	0.18	18	23	29	3.7	147
			Max	8.13	1270		348	105	240	147	0.54	30	67	201	63	327
10	Ludhiana	16	Min	7.25	370		128	13	0	32	0.1	8	27	9.5	4.9	204
			Max	8.19	1460		768	76	171	90	2.15	69	59	237	27	408
11	Mansa	11	Min	7.90	340		142	26	10	4.0	0.55	10	16	5	3.0	91
			Max	8.25	4850		1393	698	1300	186	6	52	226	980	350	1007
12	Moga	2	Min	7.92	1090		254	34	230	0.6	0.74	6.4	0	202	1.6	16
			Max	8.2	1350		545	58	245	16	0.77	19	18	340	3.7	122
12	Muktsar	9	Min	7.85	850		197	105	78	30	0.26	13	6.4	58	7.6	58
			Max	8.18	6350		898	1040	920	660	13.8	207	213	990	865	1346
14	Nawanshahr	6	Min	7.01	360	0	171	13	0	0	0.12	16	27	13	2	194
			Max	8.53	1390	70	512	121	248	80	0.42	37	77	132	40	398
15	Patiala	22	Min	7.45	290		142	16	4	0	0.14	13	14	5	1	116
			Max	8.25	2670		882	381	490	85	2.58	67	147	440	81	749
16	Ropar	19	Min	7.00	280		128	13	0	4.1	0.14	16	12	7.2	0.5	163
			Max	8.21	1530		686	158	196	95	1.83	114	87	231	38	449
17	Sangrur	17	Min	7.55	295		133	29	5	0	0.1	8	22	5	2	149
			Max	8.25	2880		953	482	620	42	2.06	145	113	530	140	801

Depth wise studies of ground water quality conducted (Water Resources & Environment Directorate, Punjab) in this area reveal that ground water quality is saline / alkaline in nearly 50% of the area at a depth of 35 meters as against 18% at the depth of 10-meters.The ground water quality is fresh in over 60% of area at 10-meter depth while it is nearly 30% at 35-meter depth. Ground water quality problem is more severe in the districts of Moga, Mansa, Bathinda & Muktsar. The depth wise distribution of ground water quality in the region is given in Table 6.2 below:

Table 6.2 Distribution of Ground Water Quality in South-western Districts

Sr. No.	Quality of Ground water	% of Area at depth (m)				
		10	**15**	**20**	**25**	**35**
1.	Fresh	62.18	53.36	55.14	38.48	28.75
2.	Marginal	20.54	24.24	16.0	27.0	21.10
3.	Saline	16.28	22.40	27.86	34.52	50.15

Source: Water Resources and Environment Directorate, Punjab, Chandigarh (Total Study Area in S-W part of the State = 1.724 mha)

Calcium and Magnesium**:** The concentration of calcium ranges between 6.4 and 228mg/l. The lowest value is found at Darapur, district Moga whereas highest value is observed at Abohar, district Ferozepur. It is found to be a dominant cation (>50% of the sum of cations) in 17.2% samples. Magnesium concentration ranges between nil at Darapur, district Moga and 228 mg/l at Ghuda, district Bathinda. In majority of ground water samples, calcium concentration is less than 100 mg/l (93%). Calcium is very low in some districts, though it is very essential element for drinking and irrigation purposes. However, magnesium is less than the desirable limit of 30 mg/l in 38% samples and less than the maximum permissible limit of 100 mg/l for drinking waters (BIS 1991) in 98% samples. In more than half of well waters examined, Ca + Mg are the dominant cations having their concentration more than 50% of the total cation determined.

Sodium and Potassium**:** Sodium is the dominant cation in majority of ground waters of districts Barnala, Bathinda, Faridkot, Ferozepur, Mansa, Moga, Patiala and Sangrur. Its concentration varies widely from 3.7 mg/l at Khani Khui, district Gurdaspur to 1880 mg/l at Abohar in district Ferozepur. Sodium concentration is less than 100 mg/l in more than half of well waters under consideration. Potassium is found to be present in low concentration. In majority of the samples analyzed, the potassium content is less than 10 mg/l (64%). It ranges from 0.5 mg/l at Bhagowal, district Gurdaspur to 865 mg/l at Bhaliana, district Muktsar. High concentration of potassium (>100mg/l) is found in 9% samples. Its higher concentration indicates contamination of ground water from various point (industry, sewage) as well as non-point sources (agriculture).

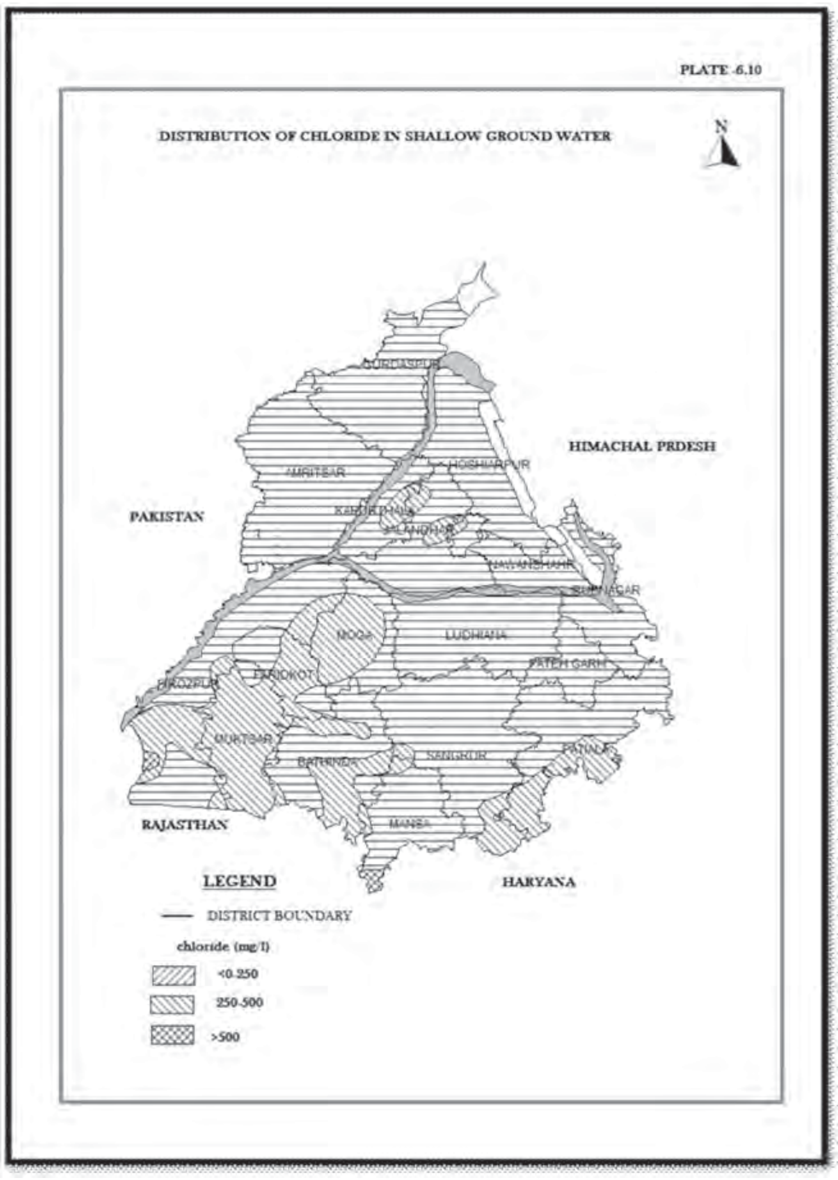
Carbonate and bicarbonate*:* Carbonate is found in a few samples and it varies from nil to 70 mg/l at Garh Shankar in district Nawanshahr. Bicarbonate is the dominant anion and it ranges from 62 mg/l at Bhatnura Khurd in district Kapurthala to 1763 mg/l at Deep Singhwala in district Ferozepur.

Chloride**:** The chloride concentration in ground water varies broadly between 5.3 mg/l at Dhapali, district Bathinda and 1582 mg/l at Abohar, district Ferozepur. Chloride content of ground water normally follows the distribution pattern of EC and it ranges from 5.3 mg/l to 1582 mg/l in the entire

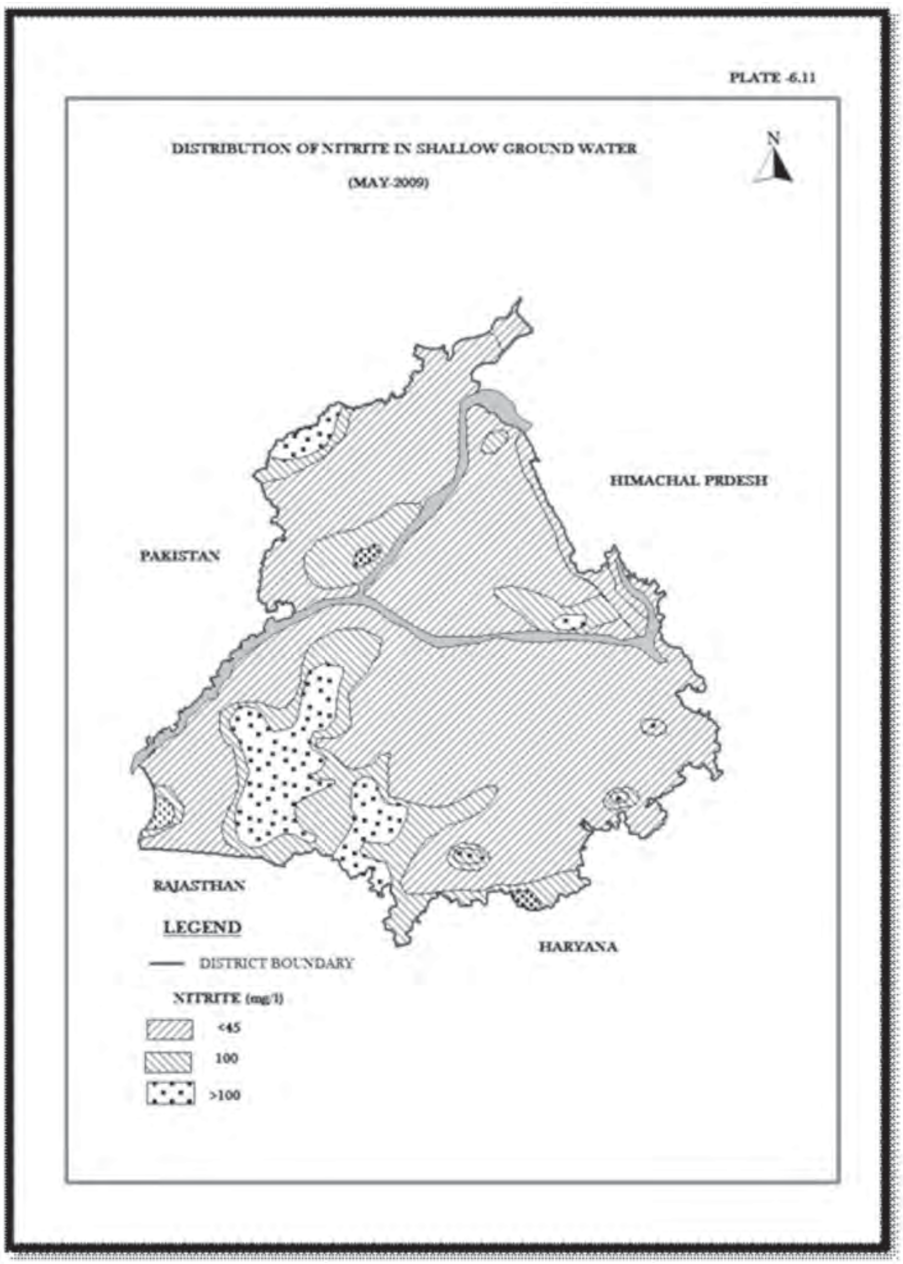
State. Chloride concentration above 400 mg/l gives salty taste to water and based on these aesthetic considerations, BIS has recommended a desirable limit of 250 mg/l for chloride in drinking water. This limit can be extended to 1000 mg/l in case of absence of a source with desirable concentration. Grouping of samples in these categories based on chloride content, it is found that Chloride is less than 250 mg/l in 81 % of the samples, between 250 and 1000 mg/l in 18.1 % samples and only 1% of the samples are found to have Chloride above 1000 mg/l. Map showing spatial distribution of Cl contents in ground water (Plate 6.10) indicates that Cl is below 250 mg/l in most of the districts, it is between 250 and 1000 mg/l in Patiala district and in southern and southwestern districts of the State. Cl is more than 1000 mg/l in isolated places in Ferozepur and Muktsar district.

***Sulphate*:** The sulphate (SO_4) content in ground water was found to be nil at a few places in district Hoshiarpur, Jallandhar, Ludhiana, Fatehgarh Sahib, Nawanshahr. The highest value of 2520 mg/l of sulphate has been observed at Abohar in district Ferozepur. In majority of ground water samples (79%), the concentration of sulphate is below 200 mg/l.

Plate: 6.10



***Nitrate*:** Nitrate, an indicator of domestic, irrigation and industrial contamination, is found in significant number of samples. Its concentration in groundwater ranges from trace at a few places to 660 mg/l at Bhaliana, district Muktsar. In the State, nitrate in water samples varies from traces to 660 mg/l. BIS permits a maximum concentration of 45 mg/l nitrate in drinking water. Considering this limit, it is found that 65.4% of the samples, spread over the entire State, have nitrate below 45 and 34.6% more than 45 mg/l. Spatial distribution of nitrate indicates that ground water with permissible nitrate content generally occurs in the northern and central parts with a few isolated patches with nitrate above 45mg/l. A considerable area of the southern and southwestern part of the State have nitrate concentration exceeding 45 mg/l (Plate 6.11). Furthermore, quite a significant number of water samples from Bathinda, Ferozepur, Mansa, Faridkot and Muktsar districts are found to have nitrate above 100 mg/l.



A survey of groundwater samples from 21-38 meter-deep tubewells located in cultivated fields in various blocks of Punjab revealed that 78% water samples had less than 5 mg NO_3^--N l^{-1} and 22% samples had 5-10 mg NO_3^--N l^{-1} (Bajwa *et al*., 1993). Sixty percent of water samples from shallow-depth (9-18 m) hand-pumps had 5-10 mg NO_3^--N l^{-1} and 2% samples had more than 10 mg NO_3^--N l^{-1}. The amount of NO_3^--N content in the soil profile to a depth of 210 cm in June correlated significantly with the NO_3^--N concentration in well-water in September, confirming that nitrates tend to reach the groundwater during the rainy season (Bijay-Singh and Sekhon, 1976a).

Plate 6.11

***Fluoride*:** The fluoride (F) content in ground water of the State is generally less than 1.0 mg/l (78%). It ranges from 0.04 mg/l at Fatehgarh Sahib in district Fatehgarh Sahib to 13.8 mg/l at Lambi, district Muktsar. Fluoride in small amounts in drinking water is beneficial while in large amounts it is injurious. The fluoride content in ground water ranges from 0.04 to 13.8 mg/l. BIS recommends that fluoride concentration up to 1.0 mg/l in drinking water is desirable, up to 1.5 mg/l is permitted and above 1.5 mg/l is injurious. Classification of samples based on this recommendation, it is found that 78.4% samples have fluoride in desirable range, 10% in the permissible and the remaining 11.7% have fluoride above 1.5 mg/l. Map showing spatial distribution of fluoride contents in ground water (Fig. 6.12) indicates that ground water in most parts of the State has desirable concentration of fluoride. Ground waters with fluoride above 1.5 mg/l are found mainly in Bathinda, Ferozepur, Mansa and Patiala districts of the State.

As per investigations conducted by CGWB in the year 2009, the fluoride contents in ground water of the State ranged from traces to 10.9 mg/l (village Bhikhi, district Mansa). About 5% of water samples analysed have Fluoride in the permissible range of 1.0 to 1.5 mg/l (BIS) and 14% have fluoride above 1.5 mg/l. The districts from where large number of water samples contains high values of fluoride are located in the Malwa region. However, higher fluoride concentration has also been reported from isolated locations in other districts of Punjab. Singh et al. (1977) surveyed groundwater samples of five blocks of Ludhiana district and found that the F concentration varied from 0 to 10.09 mg/l. On the basis of maximum permissible limit, 3, 5, 9 and 38% of the total samples collected were high in F concentration in Sidhwan bet, Ludhiana-I, Pakhowal and Jagraon blocks, respectively (Singh et al., 1977). While all the water samples collected from Sudhar block of Ludhiana were below the maximum permissible limit, Fluoride concentration in irrigation water samples of 100 villages in five development blocks of Bathinda varied from nil to 9 mg/l. It is reported that about 9% samples from Ludhiana and 66 % samples from Bathinda had F concentration of more than 1 mg/ l.High concentration of Fluorides is also reported in the districts of Bathinda, Mansa & Muktsar

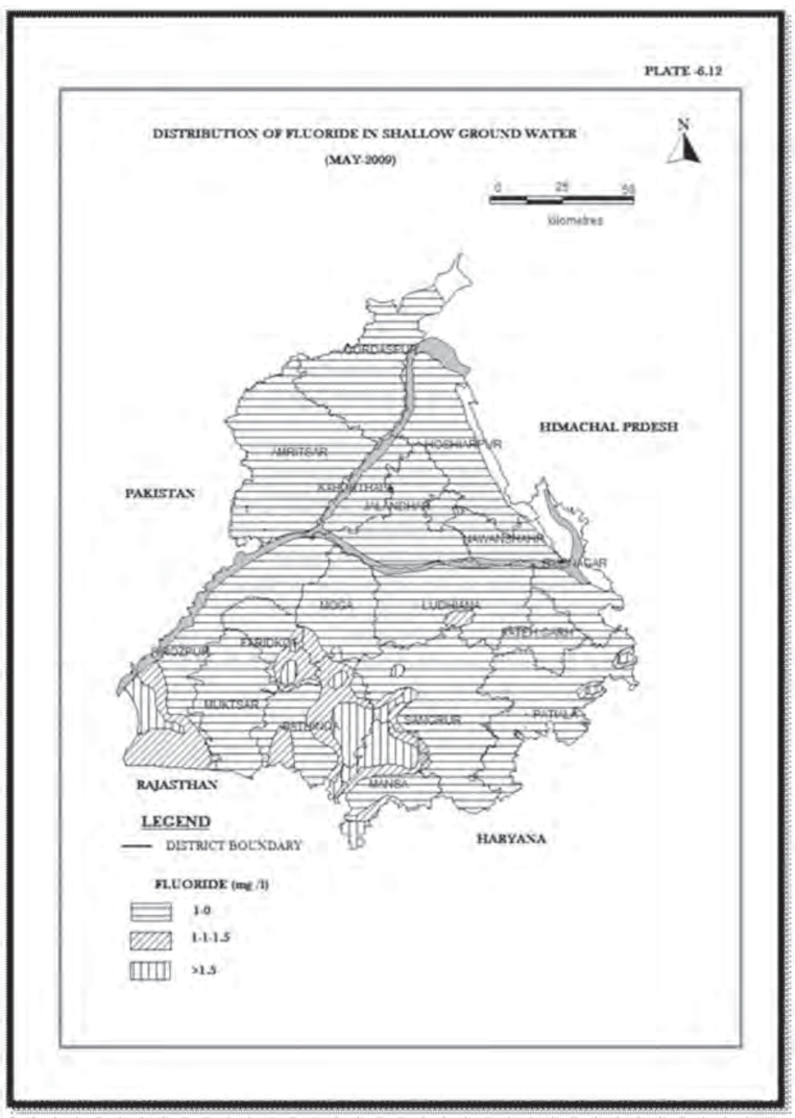


Plate 6.12

Types of Ground Water

Considering the predominance of the cation and anion in the chemical composition of ground water, its type is determined and its relation with its occurrence in an area as well as with its salinity is studied. It is found that no discernible relationship between type of water and its occurrence in any particular area could be established. Nearly all types of waters are available in each district of the State. However, study of relation of water type with salinity of the water clearly indicates that nearly 39 % ground waters of the State are fresh, have low salinity and predominance of calcium + magnesium cations and bicarbonate as anion. About 55 % ground waters having intermediate salinity and are of mixed type. In these waters, mostly HCO_3 as anion dominates but no individual cation predominates. At some places HCO_3-type of waters with sodium as dominant cation are also encountered in low to moderately saline ground waters. This can be attributed either to precipitation of $CaCO_3$ due to loss of CO_2 or dissolution of Na-salts from the topsoil layers or to ion exchange reaction during the downward percolation of water. At some isolated locations, sulphate is found to be dominant anion. In the remaining ground waters, where salinity is high; mostly Na is the dominant cation and Cl or Cl + SO_4+NO_3 (Mixed anion) are dominant. Nevertheless, a few exceptions have also been found in these simple and well-defined types of ground waters.

Potability of Ground Water

Salinity, chloride, fluoride and nitrate are the important parameters that are normally considered for evaluating the suitability of ground water for drinking uses. Based on recommendations made for these parameters by BIS, it is found that ground water at quite a few places is not suitable for drinking uses because of either EC/Cl/F/NO_3 or all of them. It is observed that unsuitable quality of ground water occurs in the southern and southwestern regions, while in the northern and central areas ground water is of suitable quality for drinking uses. Table-6.3 below shows district-wise distribution of ground waters in different classes of suitability based upon EC, Cl, F and NO_3 contents. District-wise availability of potable ground waters is also shown as bar diagram in Fig. 6.7.

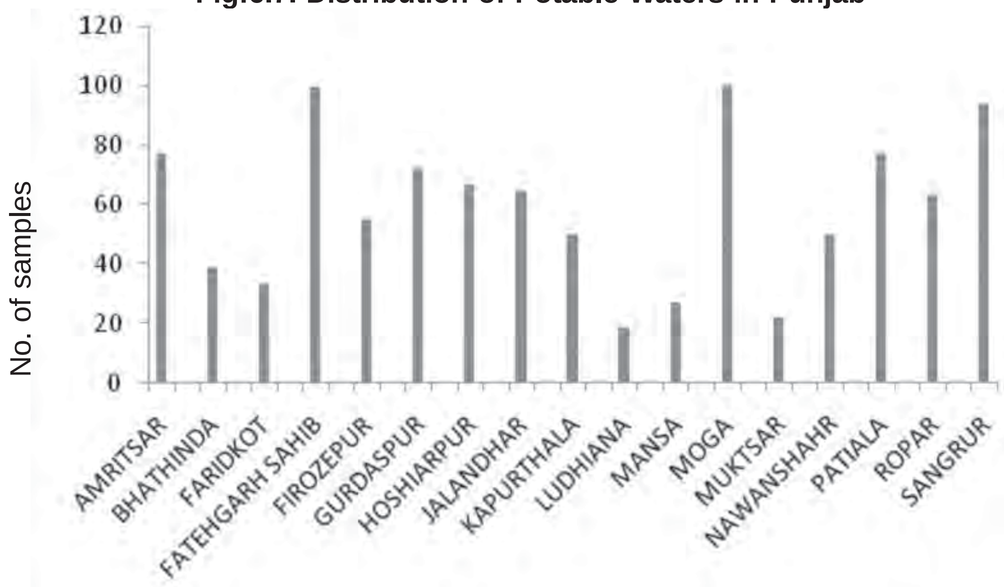
Table : 6.3 District-wise Distribution of Various Constituents in Different Classes (BIS) of Suitability

Sr. District	EC in 25^0C in µS/cm			Cl in mg/l			NO_3 in mg/l			F in mg/l		
	<750	750-3000	>3000	<250	250-1000	>1000	<45	45-100	>100	<1.0	1.0-1.5	>1.5
1 Amritsar	6	7	0	13	0	0	8	3	2	10	1	2
2 Bathinda	2	19	2	19	4	0	11	6	6	15	4	4
3 Faridkot	1	4	1	4	2	0	3	1	2	3	1	2
4 Fatehgarh Sahib	7	3	0	10	0	0	9	1	0	10	0	0
5 Ferozepur	2	13	5	15	4	1	15	0	5	10	5	5
6 Gurdaspur	17	7	1	24	1	0	18	3	4	24	1	0
7 Hoshiarpur	10	2	0	12	0	0	8	4	0	12	0	0
8 Jallandhar	9	5	0	13	1	0	10	4	0	12	1	1
9 Kapurthala	3	3	0	6	0	0	3	2	1	6	0	0
10 Ludhiana	12	4	0	16	0	0	3	13	0	14	1	1

11 Mansa	2	6	3	6	5	0	7	2	2	2	3	6
12 Moga	0	2	0	2	0	0	2	0	0	2	0	0
13 Muktsar	0	7	2	5	3	1	2	2	5	6	2	1
14 Nawanshahr	3	3	0	6	0	0	3	3	0	6	0	0
15 Patiala	5	17	0	3	19	0	19	3	0	18	1	3
16 Ropar	10	9	0	19	0	0	13	6	0	18	0	1
17 Sangrur	2	15	0	14	3	0	17	0	0	13	3	1
Total 231	91	126	14	187	42	2	151	53	27	181	23	27

* The numbers in each row represent the no. of samples in each category.

Fig:6.7. Distribution of Potable Waters in Punjab



Scope for Irrigation

It is observed that ground water occurring in the northern and central parts of the State falls under C_2S_1 and C_3S_1 classes of irrigation waters. It indicates that most of these waters are suitable for irrigating semi-salt tolerant crops on all soils. Ground water mostly from the southern and southwestern parts comprising of Bathinda, Faridkot, Ferozepur, Mansa, Moga, Muktsar, Patiala and Sangrur districts falls under C_3S_2,C_3S_3, C_3S_4, C_4S_1, C_4S_2, C_4S_3 and C_4S_4 classes of irrigation classification. Such waters when used continuously for irrigation, they are likely to cause salinity hazards and lead to reduction in crop yields. They may also cause sodium hazards and lead to hardening of soils when used for irrigation without the addition of adequate quantity of gypsum.

The computed RSC value of ground waters indicates that it varies from below zero to 20.67 meq/l. Waters with RSC value <1.25 meq/l are safe for irrigational uses, RSC between 1.25 and 2.5 are marginal and waters with RSC value >2.5 meq/l are unsafe. Based on RSC values of ground waters, it is found that 62.3% of the waters are safe, 12.6% marginal and the remaining 25.1% are unfit for irrigational uses.

The district wise distribution of ground waters in different categories of suitability for irrigational uses based on USSL and RSC considerations is given in Table-6.4.

Most of ground waters from Amritsar, Gurdaspur, Hoshiarpur, Jallandhar, Kapurthala, Ludhiana, and Ropar are suitable for irrigation for semi-salt tolerant crops on adequately drained soils. The waters from districts of Bathinda, Faridkot, Ferozepur, Mansa, Muktsar, Patiala and Sangrur show wide variability in irrigation rating.

Table No. 6.4 : Irrigation Rating of Well Waters of Punjab (Based on Eaton's index and USSL Classification)

S.No.	**District**	IRRIGATION SUITABILITY			
		EATON's INDEX (RSC in meq/L)			USSL Classification
		Safe <1.25	Marginal 1.25-2.5	Unsafe >2.5	
1	Amritsar	7	3	3	C_2S_1, C_3S_1
2	Bathinda	15	2	6	C_2S_1, C_3S_1, C_3S_2, C_4S_2
3	Faridkot	3	2	1	C_2S_1,C_3S_1, C_3S_2, C_4S_2, C_4S_4
4	Fatehgarh Sahib	6	3	1	C_2S_1, C_3S_1
5	Ferozepur	12	1	7	C_2S_1,C_3S_1, C_4S_1, C_4S_2, C_4S_4
6	Gurdaspur	21	2	2	C_2S_1, C_3S_1, C_4S_2
7	Hoshiarpur	10	1	1	C_2S_1,C_3S_1
8	Jallandhar	8	2	4	C_2S_1, C_3S_1
9	Kapurthala	5	1	0	C_2S_1, C_3S_1
10	Ludhiana	13	1	2	C_2S_1, C_3S_1
11	Mansa	4	1	6	C_2S_1, C_3S_1, C_3S_2, C_3S_4, C_4S_2, C_4S_4
12	Moga	0	1	1	C_3S_1, C_4S_4
13	Muktsar	7	0	1	C_3S_1, C_3S_3, C_3S_4, C_4S_1, C_4S_2,C_4S_4
14	**Nawanshahr**	4	2	0	C_2S_1, C_3S_1
15	Patiala	12	2	8	C_2S_1, C_3S_1, C_4S_1, C_4S_2
16	Ropar	13	2	4	C_2S_1, C_3S_1
17	Sangrur	4	3	10	C_2S_1, C_3S_1, C_4S_1 C_4S_2
	Total = 231	144	29	58	

Temporal Variation

The temporal changes in ground water quality are studied through percent of well water falling in different categories of suitability criteria based on concentration of important parameters such as salinity (EC), chloride, nitrate and fluoride contents. The percent well waters falling in desirable, permissible and unsuitable classes of BIS-1991 standards during 2010 are compared with percent well waters in same classes during 2006 to 2009. Table shows both positive and negative change in percent well waters in different suitability classes based on above parameters and overall variation in % wells from 2006 to 2010.

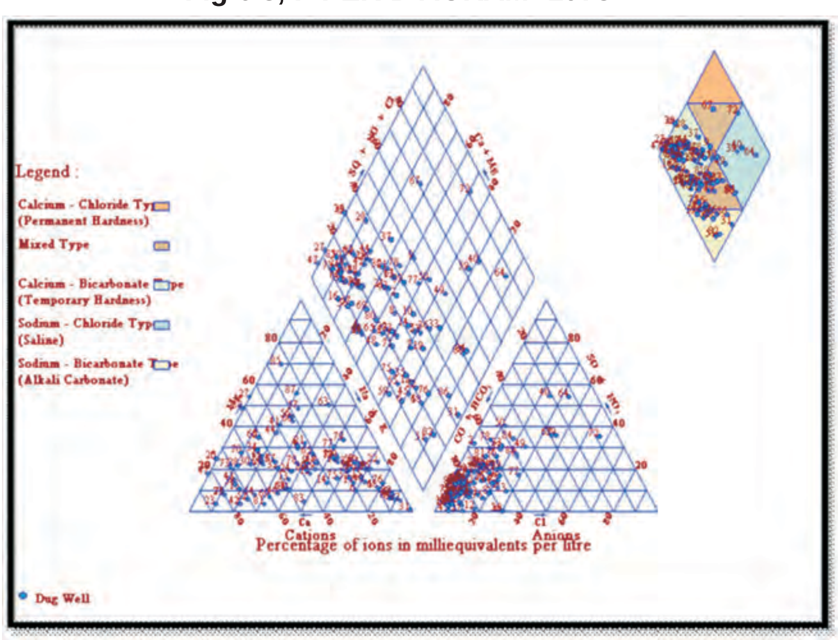
On perusal of the Table 6.5, it is evident that there is not much variation in the quality of ground water from 2009 to 2010 as indicated by no appreciable change in the percent samples falling under different suitability classes in these years. However, when percent samples are compared with those of 2006, it is found that there is a little change in salinity classes. There is no change in % samples having low salinity values in 2006, the % of moderately saline waters has increased by 5% while there has been a decrease in highly saline waters by 4%.

Table 6.5: Periodic Variation in Suitability Classes of Well Waters of Punjab

Parameter	**Class**	**% of Samples**					**Periodic Variation 2006-10**
		2006 (n=197)	2007 (n=259)	2008 (n=203)	2009 (n=204)	2010 (n=231)	
Salinity as EC	<750 µS/cm	39	41	26	37	39	0
	750—3000	50	50	63	53	55	+5
	>3000	11	9	11	10	6	-4
Chloride as Cl	<250 mg/l	85	86	84	85	81	-4
	250 - 1000	14	13	15	15	18	- 1
	>1000 mg/l	1	1	1	0	1	0
Nitrate as NO_3	< 45 mg/l	67	76	70	72	65	-2
	> 45 mg/l	33	24	30	28	35	-2
Fluoride as F	<1.0 mg/l	69	72	73	80	78	+9
	1.0 - 1.50	12	10	8	6	10	-2
	>1.50 mg/l	19	18	19	14	12	+5

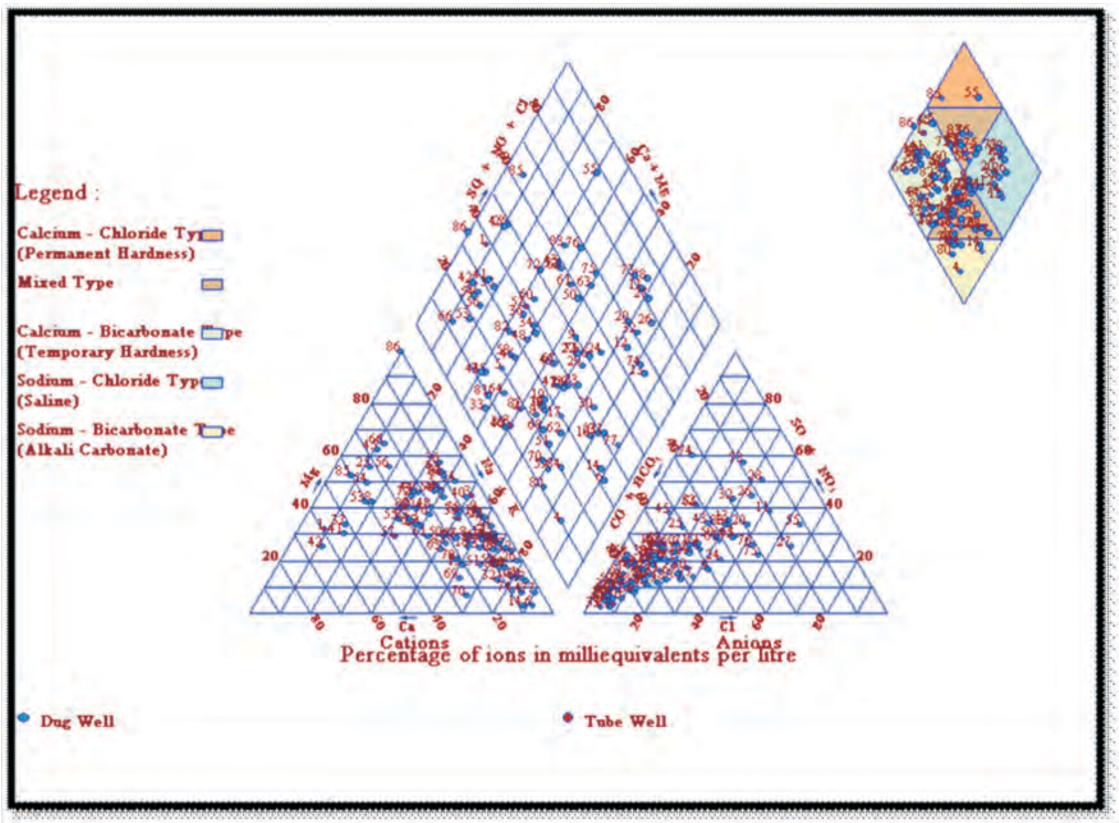
Considering the predominance of the cation and anion in the chemical composition of ground water, its type is determined and its relation with its occurrence in an area as well as with its salinity is studied. As per water quality data available for the water samples analysed during 1978, the type of water during that period is represented by Hill Piper diagram (Fig-6.8) which indicates that Calcium bicarbonate (temporary hardness) water was predominant in the State.

Fig 6.8, PIPER DIAGRAM -1978



The Hill Piper diagram (Fig-6.9) depicting the type of water for 2007 indicates that ground waters are having intermediate salinity and are of mixed type. In these waters, mostly HCO_3 as anion dominates but no individual cation predominates. At some places HCO_3-type of waters with sodium as dominant cation are also encountered in low to moderately saline ground waters. This can be attributed either to precipitation of $CaCO_3$ due to loss of CO_2 or dissolution of Na-salts from the topsoil layers or to ion exchange reaction during the downward percolation of water.

Fig 6.9, PIPER DIAGRAM -2007



PRESENT SCENARIO OF URANIUM IN GROUND WATERS OF PUNJAB

As per State government's survey, water samples of various water supply schemes of districts of Gurdaspur, Fatehgarh Sahib, SAS Nagar, Hoshiarpur, Bathinda, Mansa, Ludhiana, Moga, Ferozepur, Muktsar, Sangrur and Faridkot were got analysed from BARC, Mumbai. Out of total 2,462 water samples collected results of 1686 are available so far, 1156 samples have Uranium concentration above the WHO permissible limit for drinking water. The results indicate that Blocks covered in the Districts of Amritsar,Gurdaspur, Ropar, Fatehgarh Sahib, SBS Nagar, SAS Nagar, Jallandhar, Kapurthala, Muktsar and Hoshiarpur are free from Uranium as per AERB drinking water limits for Uranium.

As per data available, the highest Uranium concentration of 350.3±3.60µg/l has been reported from tube well water at depth of 470 ft at village Mangiana, block Budhlada of Mansa district. The numbers of samples having uranium concentration above the permissible limit of WHO & AERB are presented in Table 1.

Table 6.6, District Wise Details of Uranium Exceeding WHO & AERB Permissible Limit (DWSS-2012)

Sr. No.	District	Source	No. of samples sent to BARC for analysis	No. of reports received	No. of sources found safe as per report received	No. of samples failed	
						as per WHO (15µg/l)	as per AERB (60µg/l)
1	Amritsar	Tubewell	45	45	36	9	0
2	Barnala	Tubewell	106	106	4	102	71
3	Bathinda	Tubewell	49	49	13	36	14
4	Faridkot	Tubewell	11	11	6	5	3
5	Fatehgarh Sahib	Tubewell	26	26	12	14	0
6	Ferozepur	Tubewell	345	342	82	260	61
7	Gurdaspur	Tubewell	56	56	52	4	0
8	Hoshiarpur	Tubewell	51	51	45	6	0
9	Jalandhar	Tubewell	50	50	27	23	0
10	Kapurthala	Tubewell	25	25	16	9	0
11	Ludhiana	Tubewell	280	280	84	196	16
12	Mansa	Tubewell	26	26	10	16	1
13	Moga	Tubewell	232	232	10	222	77
14	SAS Nagar	Tubewell	22	22	13	9	0
15	Muktsar	Tubewell	8	8	8	0	0
16	SBS Nagar	Tubewell	25	25	14	11	0
17	Pathankot	Tubewell	25	24	24	0	0
18	Patiala	Tubewell	88	88	22	66	1
19	Ropar	Tubewell	24	24	23	1	0
20	Sangrur	Tubewell	140	140	8	132	14
21	Tarn Taran	Tubewell	56	56	21	35	3
		Total	**1690**	**1686**	**530**	**1156**	**261**

Note : (i) Failed samples as per WHO limit shown in yellow colour includes failed samples as per AERB limit also.

Green Within Safe Limit

Yellow Failed as per WHO limit

Red : Failed as per AERB limit

6.3 AGENCY WISE - SPECIAL STUDIES

The organisations involved in water quality have taken up water quality analysis, monitoring, assessment and management in the State with various objectives. The studies have been taken up by the organisations at their own and also in collaboration with other organisations and institutions. The results and findings of some of the studies are well documented and widely published.The status of water quality studies done in the State is given below.

(A) Central Ground Water Board

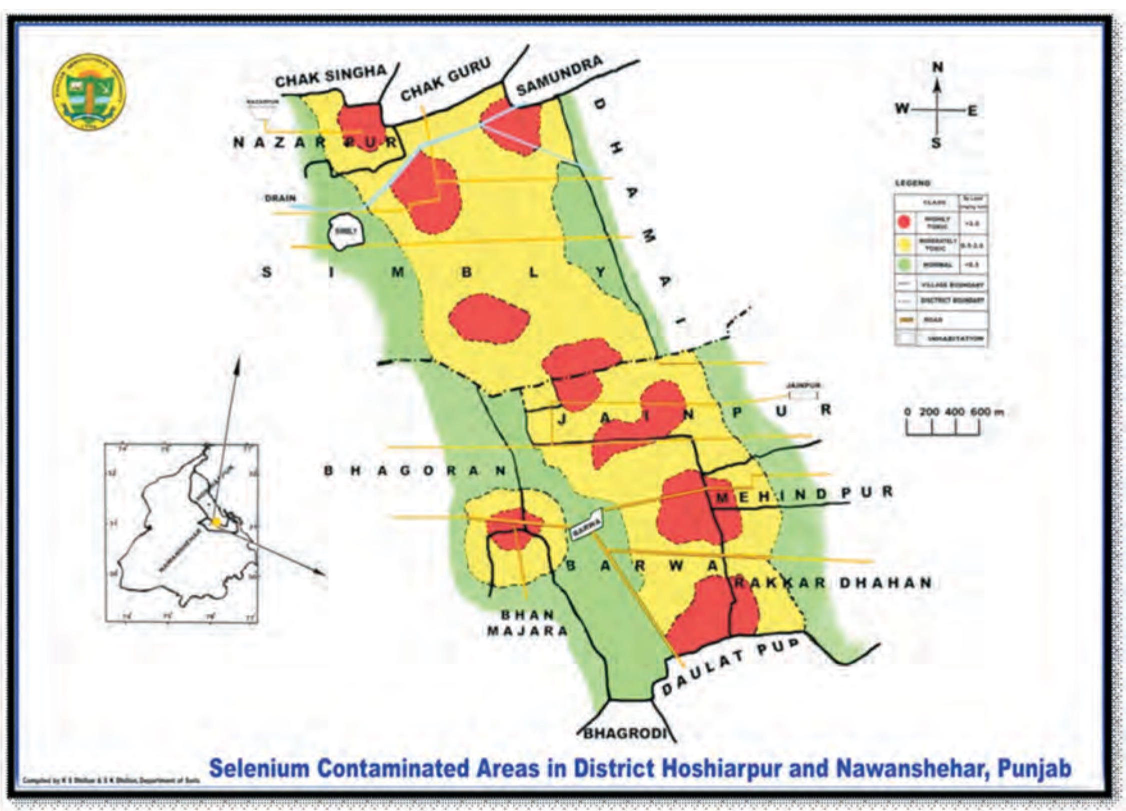
Besides the annual water quality monitoring of ground water monitoring stations, CGWB regularly takes up speific pollution studies.

1. Pollution due to Selenium

A survey undertaken in 1984-85 leads to identification of selenium toxic areas belonging to villages in the Nawanshahr and Hoshiarpur districts. The triangle shaped selenium contaminated area amounts to approximately 1000 ha. The toxic symptoms of Selenium are visible in plants, animals and humans. Dhillon and Dhillon (2003) determined the Selenium quality of groundwater drawn from 90 tubewells located in the seleniferous region of Punjab, which ranged between 0.25 and 69.5 µg/l. The maximum permissible limit of 10 µg/l for drinking purposes was exceeded in 11% of the tubewell water samples and 4.4% of water samples exceeded the maximum permissible level of 20 µg/l for irrigation purposes. They also observed that groundwater pumped from relatively shallow tubewells (24-36 m depth) contained 2-3 times more Selenium than that pumped from deep tubewells.

A preliminary study carried out by CGWB during 1998, in the affected area(Plate 6.13), revealed that Selenium was present above permissible levels (0.01mg/l) in soil and shallow groundwater. Out of 11 samples collected by Saini & Kumar (1996), 5 samples (4 from Nawanshahr & 1 from Hoshiarpur district) registered high Selenium. Highest value of Selenium was reported in a well water from Barwa village of Nawanshahr district. The maximum recommended concentration of Selenium in water used for drinking purposes is 0.01 mg/l (BIS 1991).

Plate 6.13

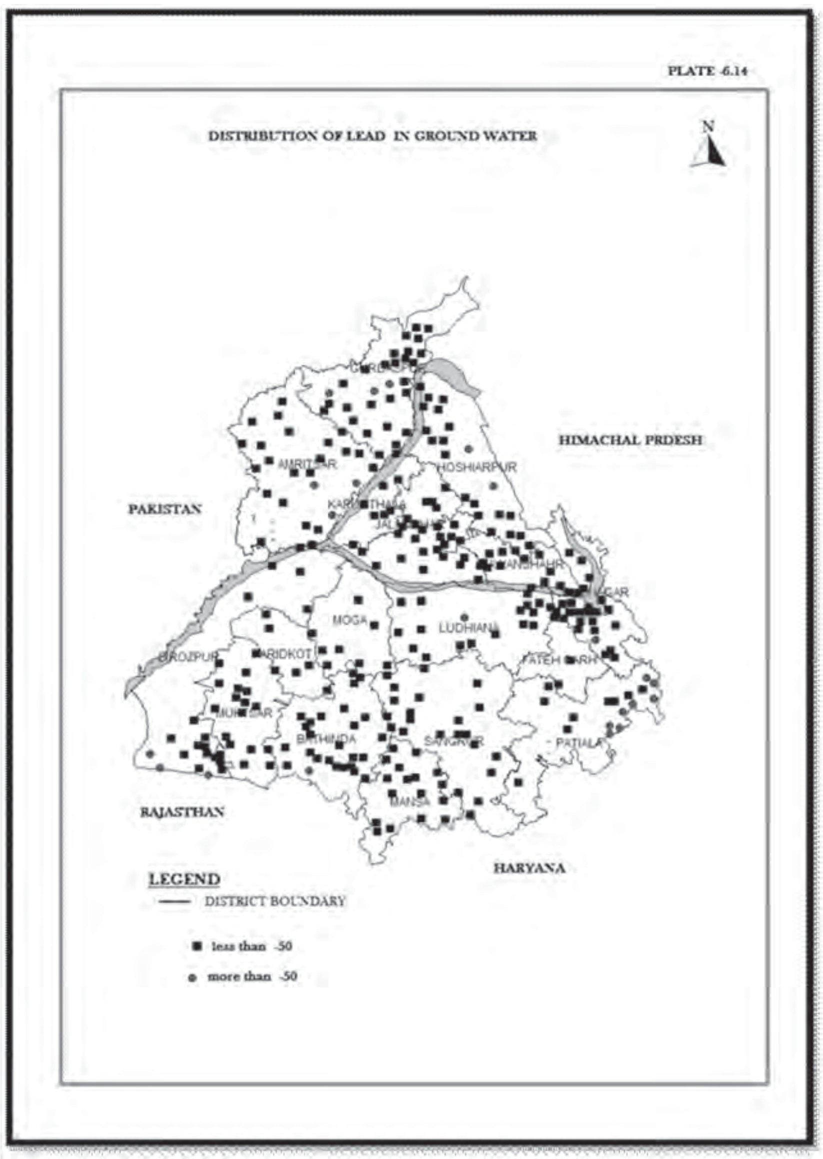


Selenium Contaminated Areas in District Hoshiarpur and Nawanshehar, Punjab

In continuation to the above, CGWB during 2001 again undertook an investigation to identify the source of Selenium. For this, micro groundwater sampling from shallow depth and soil samples from varying depths was carried out from the affected area. Water sample analysis and soil profiling revealed that groundwater contains much less concentration of Selenium as compared to soil. Further the maximum concentration of Selenium occurs upto a depth of 30 cm (Root zone) and concentration reduces upto a depth of 1 m. Below that Selenium was not detected in soil as per studies of CGWB.

2. Status of Heavy Metals in Ground Water of Punjab State

A preliminary study was carried out by CGWB in 2001 for determination of base line information on the presence of Heavy Metals in the ground water. Under this study, ground water samples from 355 dug wells and peizometers, uniformly distributed in Punjab State, were collected in May 2001 and analysed. Significance of the heavy metals has been determined with respect to suitability for drinking purposes.



Cadmium (Cd): In Punjab, the Cd concentration ranged from nil to 0.016 mg/l. About 2% of the wells have water with Cd more than the permissible level in the Ropar and Amritsar.

Chromium (Cr): Out of the 245 water samples tested for Cr, 32 wells recorded Cr exceeding the maximum permissible limit of 0.05 mg/l.

Copper (Cu): In Punjab, Copper ranged from nil to 1.067 mg/l and all the water samples have Cu concentrations below the maximum permissible level of 1.500 mg/l.

Lead (Pb):The concentration of lead ranged from nil to 0.407 mg/l and 8% of the wells in Punjab recorded Pb concentration more than the maximum permissible limit of 0.05 mg/l. The higher values of Lead are reported from Amritsar, Gurdaspur, Patiala, Hoshiarpur, Nawanshahr, Ludhiana and Muktsar districts (Plate 6.14).

Plate 6.14

Manganese (Mn): Perusal of the data shows that Mn ranged from nil to 2.024 mg/l in Punjab waters. 13% of samples collected in Amritsar, Jalandhar, Gurdaspur, Kapurthala, Patiala, Muktsar and Ropar district have higher Mn content. The maximum permissible limit formulated for Manganese in drinking water is 0.3 mg/l.

Nickel (Ni): In Punjab, the concentration of Nickel varied from nil to 0.086 mg/l.

Zinc (Zn): In Punjab the concentration of Zn varied from nil to 7.920 mg/l and the concentration of Zn does not exceed the maximum permissible limit of 15 mg/l.

3. Ground water Pollution in Amritsar City

Studies were taken up in 2002 which concluded that the shallow aquifers are more polluted in comparison to deeper aquifer (Plate 6.15). Nitrate was higher than the maximum permissible limit of 45 mg/l in six water samples of shallow aquifer with highest value of 126 mg/l while Fluoride was within permissible limit in all the samles collected. Highest Copper value reported in shallow aquifer is 0.068 mg/l. 51.8% of the samples collected had concentration of copper higher than the permissible limit of 0.05 mg/l. One sample from deeper aquifer had copper concentration up to 0.075 mg/l and effluent sample had copper upto 0.168 mg/l. Maximum Lead content was found upto 0.084 mg/l. 15.8% water samples of shallow aquifer had higher concentration of lead than permissible limit of 0.05 mg/l. Manganese has been detected in both shallow and deeper aquifers as well as in effluent samples collected. 89% of samples collected from shallow aquifer had manganese above the desirable limit with highest value being 0.762 mg/l. The manganese concentration was detected up to 0.0344 mg/l in deeper aquifer and 0.443 mg/l in effluent sample as against the permissible limit of 0.3 mg/l. Iron concentration was detected up to 23.17 mg/l in shallow aquifer and 17.70 mg/l in effluent samples. Iron was within permissible limit of 1.0 mg/l in the deeper aquifer. 92.6% of samples from shallow aquifer had Iron above the desirable limit of 0.3 mg/l.

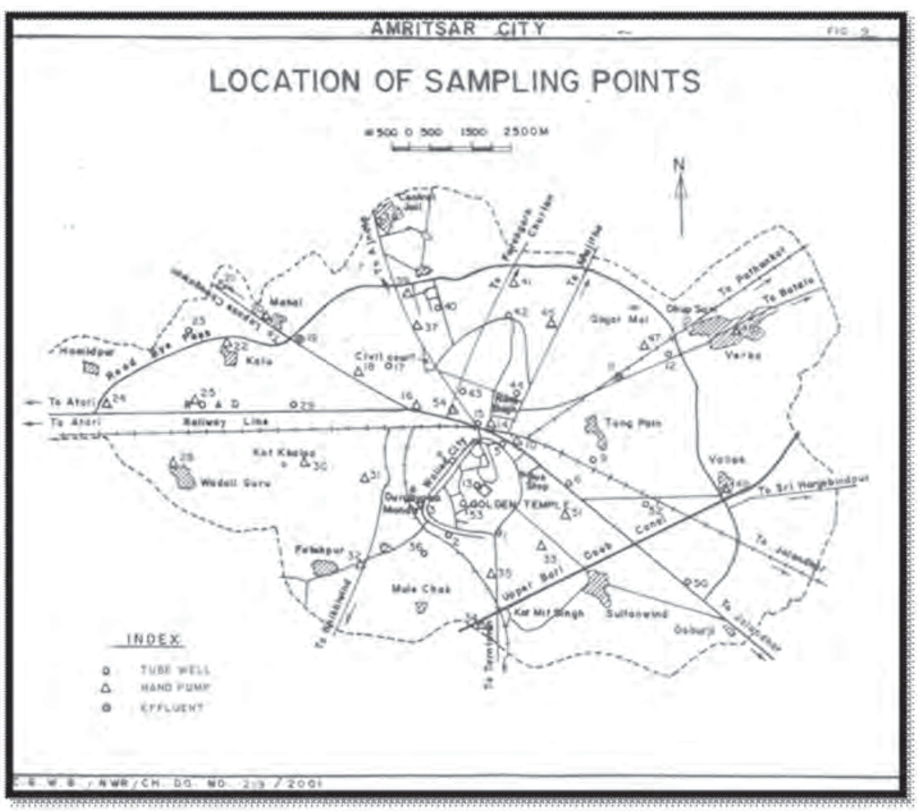
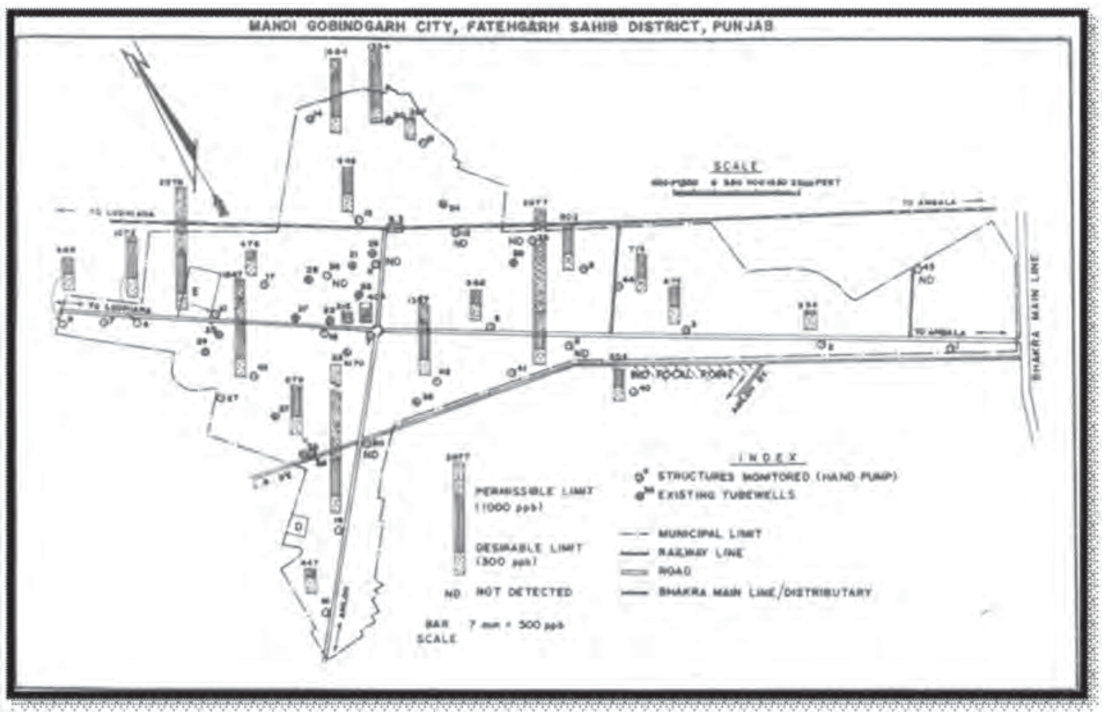


Plate 6.15

4. Groundwater Pollution in Mandi Gobindgarh

As per a preliminary study in 2002, Fe, Cu, Pb and Ni are found in the shallow groundwater of the area. Nitrate was observed in 3 samples of shallow aquifers with highest value of 125 mg/l at Amloh while Fluoride is within permissible limit in shallow aquifer. Deeper aquifer is uncontaminated by nitrate and fluoride. In shallow aquifer Chromium detected was upto 0 .101 mg/l and one water sample (1.884 mg/l) had copper above maximum permissible limit of 1.5 mg/l. Highest reported value of iron was 4.170 mg/l and 27 % of samples collected had iron above the permissible limit. Manganese was found to be upto 0.197 mg/l (Plates 6.16) while lead was found upto 0.317 mg/l. Deeper aquifer is comparatively clean with all the heavy metals within permissible limit.

Plate6.16

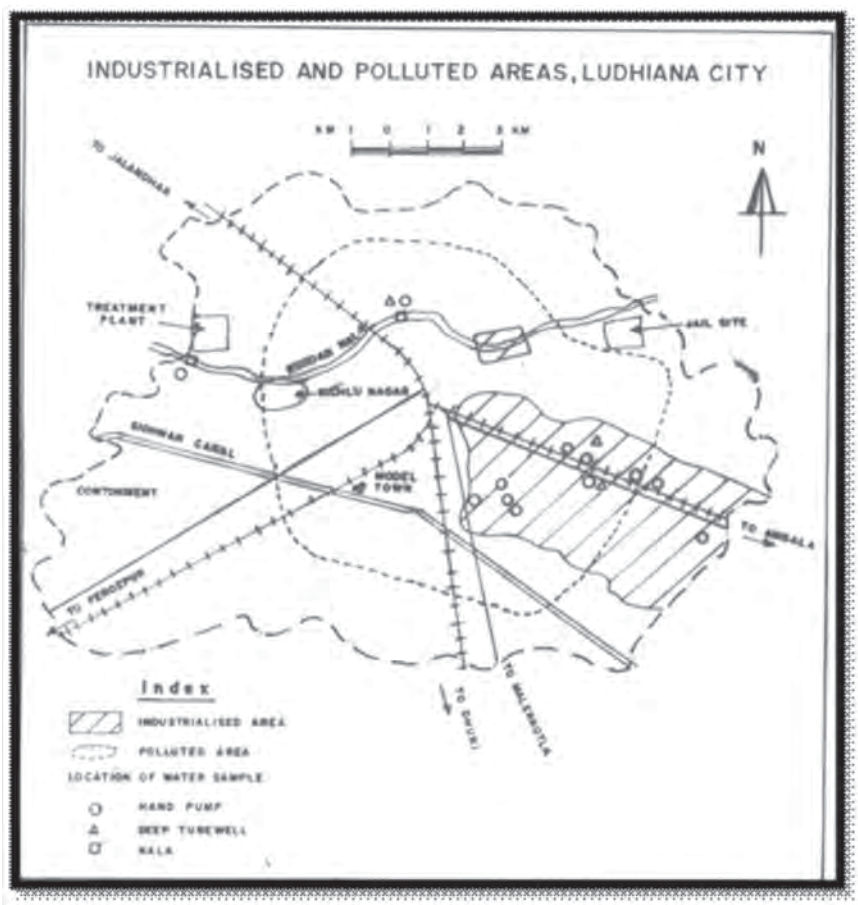


5. Groundwater Pollution of Ludhiana City

Studies were taken up in 1981, 1983, 1998 and 2004. Groundwater is contaminated due to presence of heavy metals and Cyanide The pollution has been observed in shallow groundwater close to industrial units (Plate 6.17). Nitrate concentration in ground water ranged upto 317 mg/l in shallow aquifer and was well within limits in the deeper aquifer. High fluoride value of 1.80 mg/l was reported from only one water sample from shallow aquifer. It has been observed that at some places near industrial area, Cadmium is twice the maximum permissible limit. Cadmium was higher than the maximum permissible limit of 0.01 mg/l in 12 water samples out of 129 samples analysed. Highest value was reported from water samples collected from E-109, focal point. Cyanide values were high in areas in immediate vicinity of Electroplating industries. Highest value of Cyanide reported is 0.51 mg/l from handpump water sample collected from Ranjit Dairy chilling centre (10 times higher than maximum permissible limit of 0.05 mg/l). Presence of Cyanide upto 0.029 mg/l is reported in a tubewell in Model town also. The chromium concentration ranged from nil to 0.021 mg/l, the highest value being reported from street No. 22, Janta Nagar (Gurmail Singh). Very high values of Chromium upto 1.60 mg/l at Satish Dhaba, GT road, Sherpur (30 times the BIS permissible limit of 0.05 mg/l)are found in the first aquifer. None of samples from second aquifer have reported Chromium occurrence. High values of Lead have been recorded from water samples collected from the first aquifer. Highest value reported is 0.52 mg/l in a handpump sample at the back of Concast. In some instances lead has been detected from deep tubewell at Rajgurual (0.03 mg/l).

Due to influent nature of Budha Nala, the industrial effluents return to ground water and pollute the shallow aquifer. In the Ludhiana City there are four well marked potential aquifers of 6-14 m thickness separated by thick clays. The first aquifer down to about 45m bgl is highly polluted due to industrial effluents. At times, the amount of toxic element has been found to be 10-100 times more than maximum permissible limit. Heavy elements have also been observed in deeper aquifers suggesting that pollutants are even migrating to deeper horizons. Budha Nala water samples have reported occurrence of toxic elements. It has been inferred that hydraulic loading of pollutants into the aquifer has exceeded the natural cleaning process of the aquifer.

Plate 6.**17**



6. Occurrence of Arsenic in Shallow groundwater of Punjab

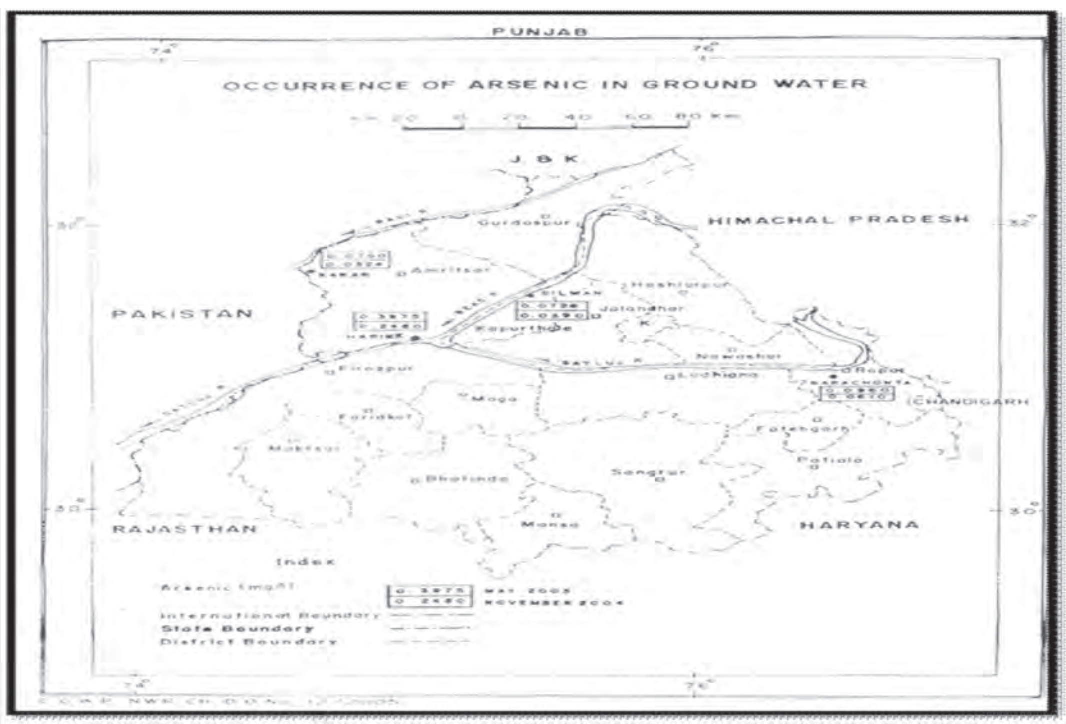
A preliminary study during 2004 was undertaken by CGWB, during which 261 no. shallow ground water samples of Punjab State (Plate 6.18), were analysed using hydride generation technique with the help of Atomic Absorption Spectrophotometer for determination of Arsenic. Wide spatial variation in arsenic concentration was observed. Arsenic concentration exceeding the limit of 0.01mg/l was encountered at 12 locations in districts of Amritsar, Gurdaspur, Hoshiarpur, Kapurthala and Ropar. Samples were again collected during post-monsoon from the locations where substantially higher Arsenic concentrations were recorded. It was observed that the magnitude of Arsenic values was in the similar higher ranges as noticed during Pre-monsoon period though impact of dilution due to rains is evident in the relatively lesser values.

Locations having arsenic above the safe limit of 10 ppb for drinking water (BIS) are presented in table 6.7 along with the results of samples collected in 2004

Table 6.7 Locations having high concentration of Arsenic (> 0.01 mg/l)

S. No.	District	Total No. of samples	Location	Arsenic, mg/l	
				May 2003	November 2004
1.	Amritsar	18	1. Harike 2. Kakar	0.3975 0.0790	0.2480 0.0324
2.	Gurdaspur	26	1. Behrampur 2. Naushera 3. Galri 4. Sahla	0.0113 0.0150 0.2010 0.0330	- - - -
3.	Hoshiarpur	17	1. Rehlan 2. Atowal 3. Sham Chaurasi	0.0121 0.122 0.015	- - -
4.	Kapurthala	7	1. Dabulian 2. Dhilwan	0.0184 0.072	- 0.0390
5.	Ropar	15	1.Bara Chounta	0.096	0.0610

Plate 6.18



A study of Arsenic Contamination of ground water in parts of Mansa district has been conducted by CGWB, NWR, Chandigarh during July 2010. A total of 105 samples from different location and different sources like Canal water, hand pumps and tubewells spread over all over the district were collected. It was observed that at 6 locations (Table 6.8), the Arsenic concentration above the permissible limit of 0.01 mg/l in drinking water has been found. The depth from where these water samples have been collected, ranged from 13 to 35m. The highest value of 0.2080 mg/l at village Bhame Kalan was obtained.

Table 6.8 Locations with High Concentration of Arsenic (> 0.01 mg/l), Mansa District

Sr. No.	Location	Type of Well	Depth (in Feet)	Owners Name	Arsenic (in mg/l)
1	Dhaipi	Tube Well (Submersible)	110	Shri Roop Ram	0.0287
2	Ghari Bhaggi	Hand Pump	80	Shri Sukhdev Singh (Panch)	0.0147
3	Meerpur Dhani	Hand Pump (Field)	90	Shri Harmesh Singh	0.0163
4	Bhame Kalan	Hand Pump	40	Bus Stand	0.2080
5	Nandgarh	Hand Pump	65	Shri Babu Singh	0.0102
6.	Kotra Kalan	Hand Pump	60	Shri Joginder Singh	0.0110

Re-sampling in the same area was carried out duirng August 2010 from 32 locations and high arsenic (above 0.01 mg/l) was reported in nine water samples of seven villages. Abnormally high value again has been reported in hand pump water sample collected from Bus stand of Bhame Kalan (0.270 mg/l). The Arsenic concentrations of the remaining 8 locations are in the range of 0.01 to 0.04 mg/l.

7. Study of Ground water around Jagjit Industries Ltd., Hamira, District Kapurthala

CGWB took up a study during 2004 to assess the impact of Jagjit Industries Ltd a distillery in Kapurthala district on groundwater. 32 samples were collected from nearby villages around the vicinity of the factory and it was found that ground water at shallow level upto depth of 70' to 80,' in villages Hamira, Dayalpur, Lakhnkhole, Lakhankhurd and Naharpur is unfit for human consumption as it is colored and constituents like sulphate, nitrate, calcium and total hardness present beyond permissible limit of BIS. Iron and Manganese were also reported to be higher than the permissible limit in water samples of these locations. Treated effluent discharge was observed to be colored but total hardness, iron and manganese concentration were within permissible limit.

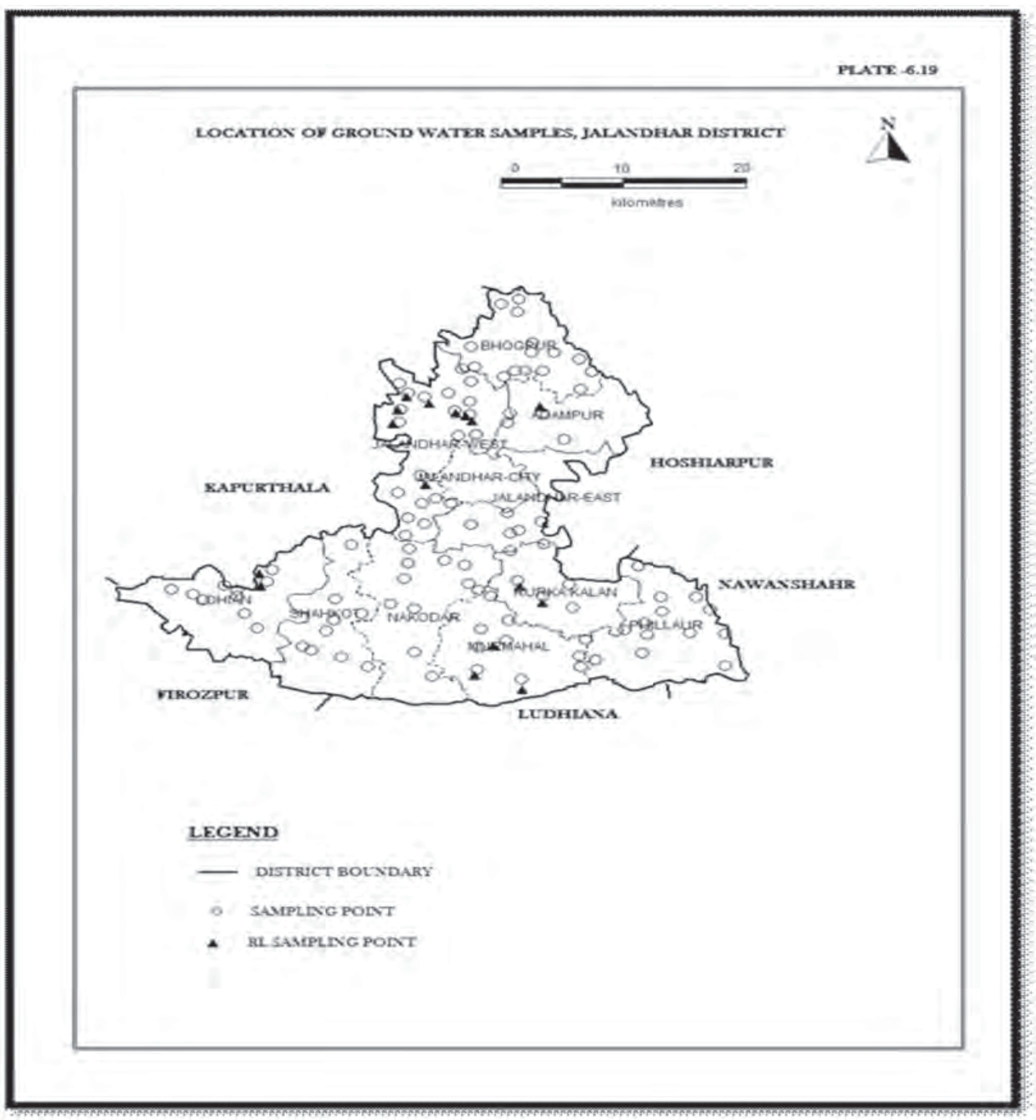
8. Effect of Fertilizer on Ground Water Quality in District Jallandhar (CGWB)

As many as 98 Nos water samples were collected from shallow aquifer and 15 from the deeper aquifer from entire Jallandhar district during June 2007. 26 No. samples were again collected during February 2008, from selected locations to study the impact of fertilizers applied for sowing Rabi crops during month of October (Plate 6.19)

Based upon the analysis and absence of geological sources for the nutrient ions and considering concentration of 20 mg/l of nitrate, 10 mg/l of potassium and 0.10 mg/l of phosphate as base value, it appears that use of excessive amount of fertilizers has started affecting the ground water quality at some places.

The nitrate level, in some cases, had gone up to 100 mg/l but it is not possible to prove conclusively what proportion of nitrate present in ground water owes its origin to fertilizers used in the area. In the study area, farmers are also keeping their livestock in the farms at most of the places, thus some proportion of nitrate may owe its origin to animal wastes. Further it is difficult to compute with certain degree of accuracy the rate of oxidation of soil nitrogen to nitrate and rate of reduction of nitrate to N_2O and N_2. Similarly for potassium and phosphate, it cannot be concluded that entire proportion of their concentration in ground water owes its origin to fertilizers because sources other than fertilizers may have put their share, though it may be in small proportion. These sources may be precipitation, inorganic content of canal water, waste disposal, etc. It is further confirmed by the analytical results of re-sampled sites, which show both positive and negative change in salinity, concentration of nitrate and potassium.

Plate 6.19



9. Pesticide Residues in Ground Waters of Chamkaour Sahib Block, Ropar District

A preliminary study carried out by CGWB during 2009 in Chamkour Sahib block of Ropar district reveals the presence of total HCH and total DDT in 50% of hand pump samples with high values at Roop nagar (0.001141 ppb HCH) and at Daudpur Badda (0.05987 ppb DDT). Total DDT, HCH has also been reported in tubewell samples located at Fasse and Bhoe Majra. Chloropyrifos (upto 0.01698 ppb at Rampur Bet) and Aldrin (up to 0.00117 ppb at Salarpur) has also been detected in few hand pump water samples. Chloropyrifos has been detected only in one tubewell sample located at Fasse (0.00022 ppb) and Aldrin has been found in tubewell waters of Khanpur (0.00002 ppb) and Bhoe Majra (0.00117 ppb). High values of total DDT (0.010940 ppb) have also been observed in Canal water in the area.

(A) Department Of Health And Family Welfare

1. District-wise status of Heavy Metals

On the direction of Director Health & family Welfare, Punjab, the Civil Surgeon, Faridkot formulated a 5 member team headed by an expert Head, Department of Forensic Medicine from Medical college, Faridkot. The team visited the centre on 07-04-2009 and also collected 5 water samples for Heavy Metal Testing. The samples from water, blood, soil and hair were also collected. The above samples were sent for analysis to the Department of Atomic Energy, Government of India, Mumbai but the results are still awaited**.**

The Department analyzed 411 water samples for presence of heavy metals in drinking water. The District-wise status and the results thereof upto 30th June, 2010 are detailed in Table 6.9**:-**

Table 6.9, The District-wise status of Heavy Metals (DH&FW)

Districts	No. of	No. of samples positive for Lead/ Arsenic/Copper/ Chromium/ Cyanide	No. of Samples showing excess than permissible limit
Amritsar	37	16 positive for Lead, 4 positive for Arsenic	3 showing lead, 1 sample Arsenic
Bathinda	50	9 positive for Arsenic & 7 positive for Lead.	Nil
Barnala	04	Nil	Nil
Faridkot	19	7 positive for Arsenic	Nil
Ferozepur	43	17 positive for Arsenic & 1positive for Lead.	4 positive for Arsenic
F.G Sahib	05	Nil	Nil
Gurdaspur	Nil	Nil	Nil
Hoshiarpur	26	1 Positive for Arsenic	Nil
Jalandhar	Nil	Nil	Nil
Kapurthala	05	Nil	Nil
Ludhiana	15	10 positive for Arsenic	Nil
Mansa	08	08 positive for Arsenic	Nil

Moga	62	2 positive for Lead 6 positive for Arsenic	3 positive for Arsenic
Muktsar	06	5 positive for Arsenic & 1 positive for Copper.	Nil
Patiala	01	Nil	Nil
Ropar	15	1 positive for Lead and Arsenic	Nil
Sangrur	46	13 positive for Arsenic & 6 positive for lead	Nil
S.A.S Nagar	25	7 positive for Arsenic.	Nil
Tarn Taran	05	Nil	Nil
Nawan Shahar	39	8 positive for Arsenic	Nil
Total	411		

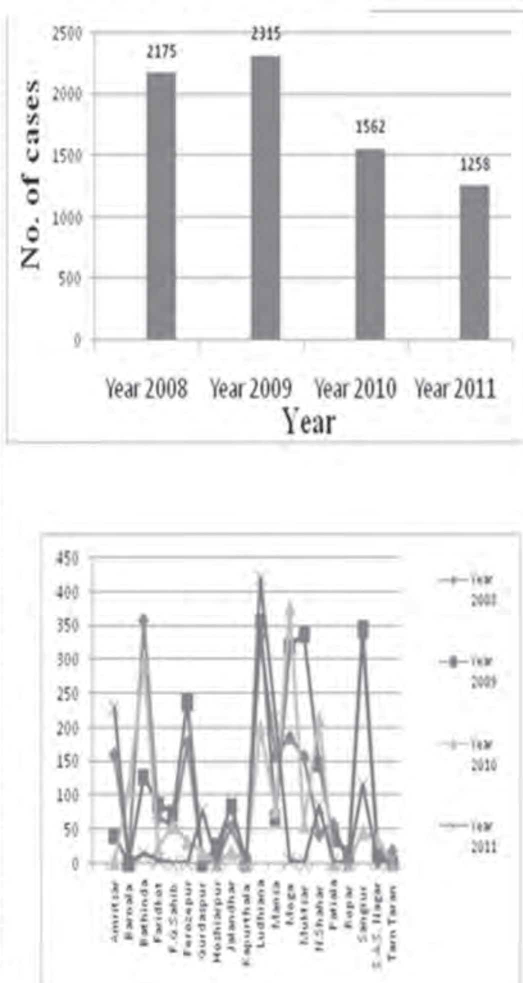
2. District wise persons affected by various water-borne diseases

The studies by Department of Health and Family Welfare, Govt. of Punjab of epidiomological investigations of various water borne diseases in various districts are depicted in Fig 6.10, 6.11 and 6.12.

Fig 6.10

Year Wise Distribution of Heatitis A & E cases

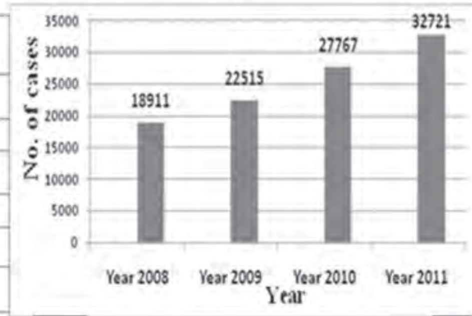
Name of the District	Year 2008	Year 2009	Year 2010	Year 2011
Amritsar	160	40	3	229
Barnala	8	0	109	0
Bathinda	358	127	293	14
Faridkot	67	87	24	5
F.G.Sahib	55	74	56	0
Ferozepur	177	237	32	0
Gurdaspur	0	0	16	78
Hoshiarpur	3	25	1	0
Jalandhar	54	84	17	90
Kapurthala	0	1	2	0
Ludhiana	335	356	200	420
Mansa	159	67	79	213
Moga	186	320	378	4
Muktsar	157	337	57	1
N.Shahar	43	146	213	85
Patiala	57	37	1	3
Ropar	0	14	1	0
Sangrur	335	346	46	115
S.A.S. Nagar	3	17	34	1
Tarn Taran	18	0	0	0
Total	2175	2315	1562	1258

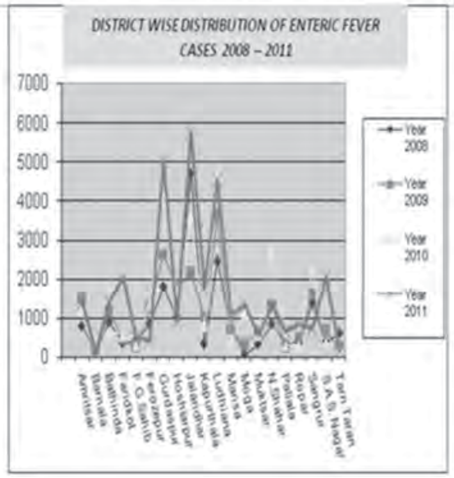


Year Wise Distribution of Enteric Fever Cases

Fig 6.11

Name of the District	Year 2008	Year 2009	Year 2010	Year 2011
Amritsar	792	1498	1197	1362
Barnala	163	225	411	170
Bathinda	888	1145	660	1444
Faridkot	356	456	549	2003
F.G.Sahib	435	272	307	523
Ferozepur	842	1301	1344	416
Gurdaspur	1801	2622	4158	4999
Hoshiarpur	1009	1802	1695	947
Jalandhar	4726	2167	3600	5755
Kapurthala	331	1043	817	1778
Ludhiana	2474	3633	4710	4545
Mansa	752	703	409	1067
Moga	67	325	1109	1359
Muktsar	333	673	569	575
N.Shahar	852	1328	2736	1294
Patiala	358	258	304	663
Ropar	328	493	316	842
Sangrur	1392	1622	2221	754
S.A.S. Nagar	394	687	382	2055
Tarn Taran	618	262	275	170
Total	18911	22515	27767	32721

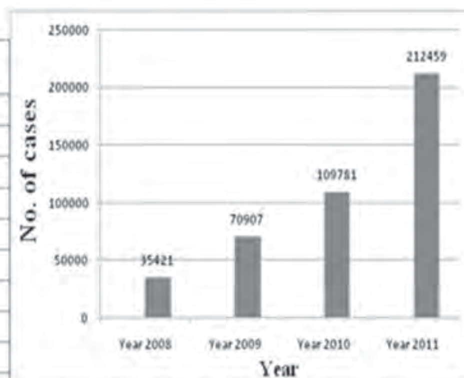


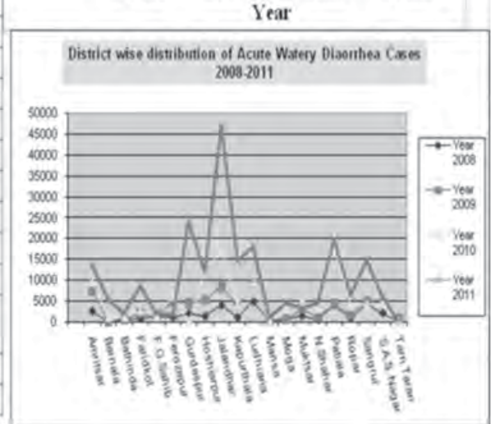


Year Wise Distribution of Acute Watery Diarrhea Cases

Fig 6.12

Name of the District	Year 2008	Year 2009	Year 2010	Year 2011
Amritsar	2669	7580	9618	13690
Barnala	14	0	1284	5394
Bathinda	613	745	1336	2242
Faridkot	780	2114	2846	8755
F.G.Sahib	1498	1523	1450	2307
Ferozepur	1191	4938	6249	1874
Gurdaspur	2103	4669	120	24012
Hoshiarpur	1398	5406	12497	12208
Jalandhar	4065	8582	16957	46936
Kapurthala	1084	4138	4366	14742
Ludhiana	4948	9498	9527	18258
Mansa	228	85	76	1213
Moga	983	559	3314	4669
Muktsar	1559	3244	4968	3719
N.Shahar	596	1069	3340	4620
Patiala	4168	4223	18608	19784
Ropar	861	1928	3860	6553
Sangrur	4406	5036	4415	14849
S.A.S. Nagar	2175	4777	4630	6456
Tarn Taran	172	793	320	178
Total	35421	70907	109781	212459





3. Districtwise Data on Water Borne Diseases in Punjab:

The Tables 6.10 & 6.11 show the district-wise data on Cases of water-borne diseases reported by IDSP in Punjab State during 2009 and 2010, respectively.

Table 6.10 IDSP data-2009

Name of the District	Cholera		Gastroenteritis		Hepatitis A & E	
	Cases	Death	Cases	Death	Cases	Death
Amritsar	0	0	7580	0	40	0
Bathinda	0	0	745	0	127	0
Barnala	0	0	0	0	0	0
Faridkot	0	0	2114	0	87	0
F.G.Sahib	0	0	1523	0	74	0
Ferozepur	0	0	4938	0	237	0
Gurdaspur	0	0	4669	3	0	0
Hoshiarpur	0	0	5406	0	25	0
Jalandhar	32	0	8582	0	84	0
Kapurthala	0	0	4138	0	1	0
Ludhiana	13	0	9498	0	356	0
Mansa	0	0	85	0	67	0
Moga	0	0	559	0	320	0
Muktasar	5	0	3244	0	337	0
N.Shahar	1	0	1069	0	146	0
Patiala	0	0	4223	0	37	0
Ropar	0	0	1928	0	14	0
Sangarur	0	0	5036	0	346	0
S.A.S Nagar	298	0	4777	0	17	0
Tarn Taran	0	0	793	0	0	0
Grand Total	349	0	70907	3	2315	0

Table 6.11 Disease Outbreaks, Compiled State Report for IDSP -2010

Sr. No.	Disease/ Illness responsible	Affected area- Dist/CHC/Vill	Date of start of outbreak	Date of reporting to DSU/CHC	No. of cases/	RRT Investigated/ Not Investigated	Epidemiological Factors
1.	Enteric Fever (Typhoid)	Village Loh Garh near Zirakpur Mohali	came to know on 10.5.2010		64 cases of fever		Almost all the village is affected by fever
2.	Diaorrhea	Village_dirba, PHC Kourian, DSU Sangrur	09-06-2010	09-06-2010	227 cases	Yes	Water supply leakage
3.	Hepatitis –E	Village Mashli Kalan (PHC Gharuan), SAS Nagar	23-06-2010	23-06-2010	7 cases	Yes	Contaminated water supply
4.	Hepatitis –E	JBCL, Factory, Lalru (Distt. Mohali)	28-06-2010	28-06-2010	36 cases/	Yes	Contaminated water supply
5.	Acute Diarrhoea /Dysentry	Block Bilga, Village Shamshabad, Jalandhar	14-07-2010	14-07-2010	81 Indoor Cases, 152 OPD	Yes	Contaminated Drinking Water.
6.	Jaundice (Hepatitis,Viral)	Village Khizrabad, PHC Boothgarh District Mohali)	15.7.2010	15.7.2010	13	Yes	H/O fever, Vomiting and Jaundice. Some pts had loose motion.
7.	Diarrhea	Village Dhakoli, PHC Dera Bassi, District Mohali	16.7.2010	16.7.2010	9	Yes	H/O loose motion. All of them belong to V. Dhakoli
8.	Diarrhea	Village Tiwana (Block Dera Bassi) Mohali	16.7.2010	18.7.2010	Cases: 100 / Deaths: 0	Yes	contamination of the water.
9.	Cholera	hutments in Badi Haveli Kalan Village (IIT Road Birla farm) Ropar	2/8/10 at 8.30 pm	02/08/10	01 admitted at PGI Chandigarh	Yes	Patient belongs to unhygienic hutments
10.	Gastroenteritis	Nawan Katra, Kalanour House of Hira Lal (Gurdaspur)	Reported by SMOI/C on 10-08-10	10-08-10	2 death, 3 cases of enteritis under observation	Yes	Localized cases
11.	Gastroenteritis	Ishwar Nagar Near M.C Dump, Amritsar	09/08/10	10/08/10	2 cases	Yes	
12.	Acute Diarrhoea	Slums of Chandan Nagar, Kartarpur, Jalandhar	17/8/2010	17/8/2010	14 cases	Yes	contaminated water.
13.	Diarrhoea	Bhumarshi Basti, PHC Chanarthal Kalan, F.G Sahib	18-08-10	19-08-10	50 (Total 480 patients examined)		
14.	Cholera	Dana Mandi, Moga	09-10-2010	09-10-2010	183 cases		
15.	Hepatitis-A, E	Ajit rd. Biwi Talla, Mehna Chowk Chowk, Bathinda	14/12/10	20/12/10 (Late reported)	126/0		Dirty water from taps
16	Diarrhea	Sekha road, Street No. 5, Barnala	20-07-10	20-07-10	Cases=21	Yes	Vomiting, Diahorrea

(C) Department Of Water Supply And Sanitation

Various water quality studies take-up by the department are as follows:

1. DWSS Schemes with unsuitable Drinking water Quality

A scientific digital data base for the water supply sources in Moga has been created by Punjab Remote Sensing Centre (PRSC) during 2006-07. The drinking water sources in Moga district were geo-referenced in terms of latitudes and longitudes using Garmin make Global Positioning System (GPS). Functional sources having unsuitable water quality are depicted in the Plate 6.20.

Plate 6.20

The drinking water sources in Patiala, Sangur and Barnala districts were geo referenced in terms of latitudes and longitudes using Garmin make Global Positioning System (GPS) by Punjab Remote sensing centre dueing 2006-07. Functional sources having unsuitable water quality are depicted in Plate 6.21 & 6.22.

Plate 6.21

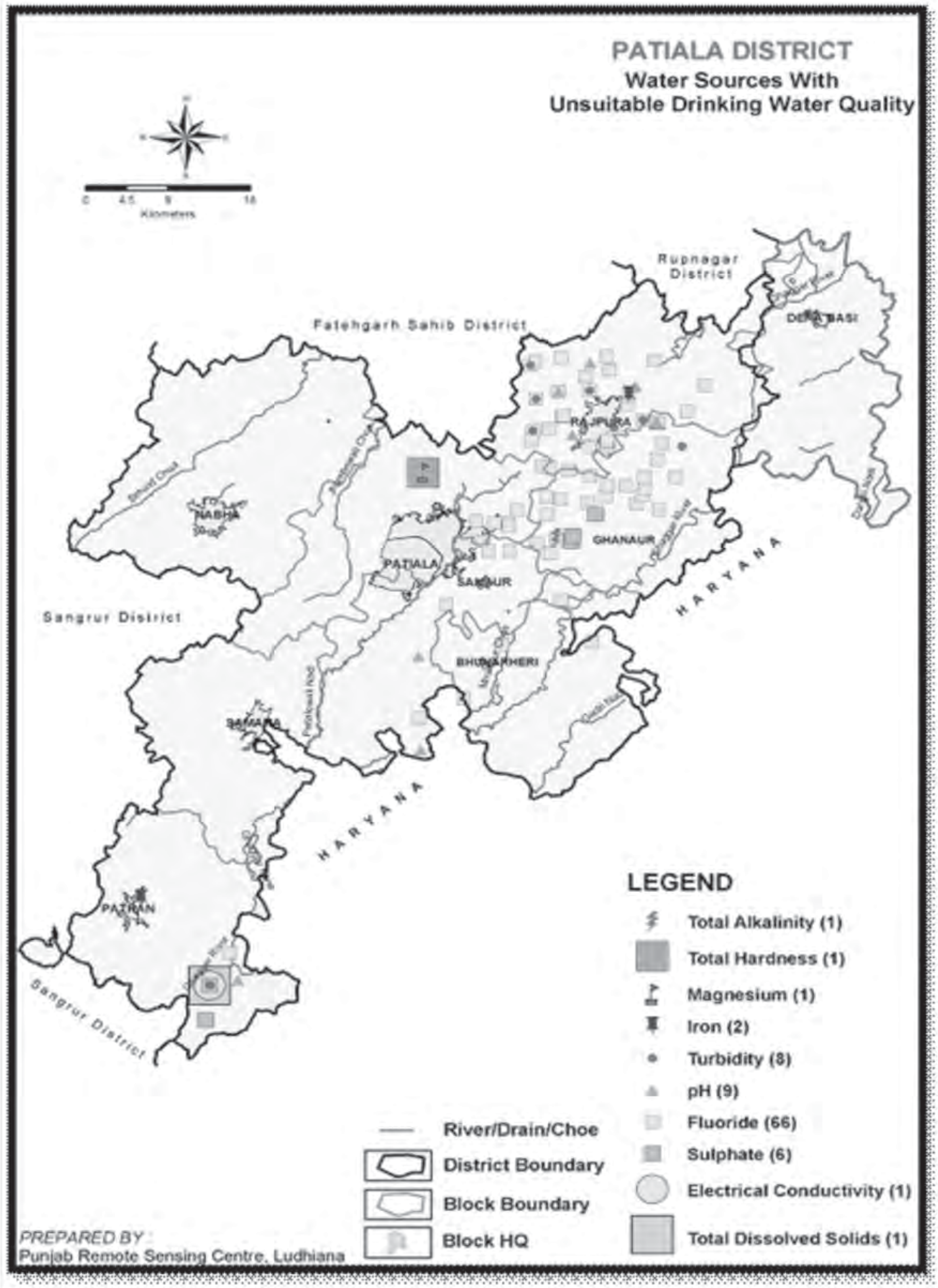
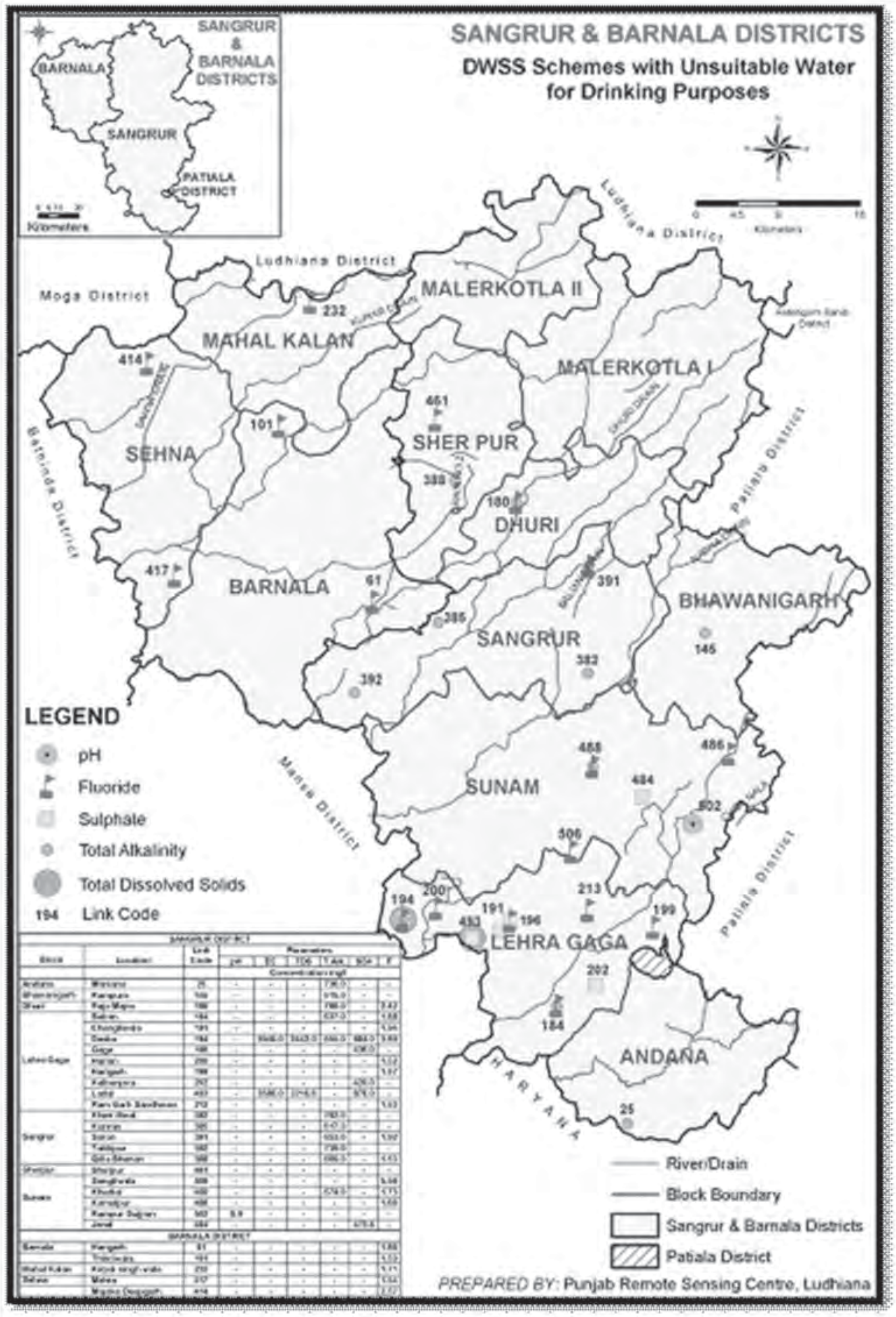

PATIALA DISTRICT
Water Sources With
Unsuitable Drinking Water Quality
Kilometers
Rupnagar District
Fatehgarh Sahib District
Sangrur District
Sangrur District
HARYANA
HARYANA
NABHA
RAJPURA
DERA BASI
PATIALA
SANOUR
GHANAUR
BHUNARHERI
SAMANA
PATRAN
LEGEND
Total Alkalinity (1)
Total Hardness (1)
Magnesium (1)
Iron (2)
Turbidity (8)
pH (9)
Fluoride (66)
Sulphate (6)
Electrical Conductivity (1)
Total Dissolved Solids (1)
River/Drain/Choe
District Boundary
Block Boundary
Block HQ
PREPARED BY :
Punjab Remote Sensing Centre, Ludhiana

Plate 6.22



2. Heavy Metals Districts in Bathinda, Mansa, Ferozepur, Faridkot, Muktsar & Moga Districts

The Department of Water Supply and Sanitation collected samples, during 2010, from the districts of Bathinda, Mansa, Ferozepur, Faridkot, Muktsar and Moga and got them tested for Heavy metals. The analysis report clearly shows that the trace elements are within permissible limit except Aluminium, which was found more than the desirable limit but well within the permissible limit i.e. 0.2 mg/l.

673 number samples were analyzed for determination of heavy metals and some of the samples have shown Aluminum beyond permissible limit and a few samples have shown Selenium and Arsenic beyond permissible limit in the areas of Nawanshahr, Hoshiarpur and Gurdaspur. District wise Details of Analysis for Heavy Metals (DWSS) is presented in table 6.12. Resampling and re-analysis in the area is being carried out for further confirmation.

Table 6.12 Districtwise Details of Analysis for Heavy Metals (DWSS)

Sr. No.	District	No. of Samples analyzed			No. of Samples failed		
		Tube-Well	Hand Pump	Canal	Tube-Well	Hand Pump	Canal
1	Amritsar	5					
2	Barnala	30			11		
3	Bathinda	17	4	1	3	4	
4	Faridkot	1	1	1			
5	Fatehgarh Sahib	25					
6	Ferozepur	148	6	1	9	4	
7	Gurdaspur	48			11		
8	Hoshiarpur	48			24		
11	Ludhiana	98	3		13	2	
12	Mansa	17	1	1	8		
13	Moga	15			5		
14	Muktsar		1	1			
15	NawanShahr	36	10		8	1	
16	Pathankot	21			1		
17	Patiala	35			7		
18	Roopnagar	16	10		1		
19	Sangrur	83			28		
20	SAS Nagar	13			11		
21	Tarn Taran	17			6		
Total		**673**	**36**	**5**	**146**	**11**	**0**

3. Selenium in Ground waters of district Roopnagar and Nawanshahr

The Deptt. Of Water Supply & Sanitation has carried out the determination of Selenium in Roopnagar and Nawanshahr districts during 2010. Selenium concentration was within permissible limits in all the 20 samples collected from Roopnagar district, whereas selenium more than 0.01 mg/l was reported in 3 No. samples out of 20 samples collected from various depths in Nawanshahr district. The failed samples were again analysed and the results were similar. The comparison of analysis report (Table 6.13) is as follows:

Table 6.13 Comparison of Analysis Report for Selenium (DWSS)

S.No.	Block	Village	Source	Depth (m)	Se in mg/l	
					Sample collected on 4.3.2010	Sample collected on 11.3.2010
1	Aur	Chak Dhana	DTW of W/S Scheme	120	Not detected	Not detected
			HP	27.5	0.036	0.037
2	Aur	Badwa	DTW of W/S Scheme	91.5	0.026	0.02
			HP	45.7	Not detected	Not detected
3	Aur	Jainpur	DTW of W/S Scheme	130	0.021	0.01
			HP	76	Not detected	Not detected

4. **Uranium in Ground water of Districts of Bathinda, Mansa, Ludhiana, Moga, Ferozepur, Muktsar, Faridkot, Gurdaspur, Fatehgarh Sahib, Hosiarpur, SAS Nagar and Sangrur.**

As per State government's survey, water samples of various water supply schemes of districts of Gurdaspur, Fatehgarh Sahib, SAS Nagar, Hoshiarpur, Bathinda, Mansa, Ludhiana, Moga, Ferozepur, Muktsar, Sangrur and Faridkot were got analysed from BARC, Mumbai. Out of total 2,462 water samples collected results of 1686 are available so far, 1156 samples have Uranium concentration above the WHO permissible limit for drinking water. The results indicate that Blocks covered in the Districts of Amritsar,Gurdaspur, Ropar, Fatehgarh Sahib, SBS Nagar, SAS Nagar, Jallandhar, Kapurthala, Muktsar and Hoshiarpur are free from Uranium as per AERB drinking water limits for Uranium.

As per data available, the highest Uranium concentration of 350.3±3.60µg/l has been reported from tube well water at depth of 470 ft at village Mangiana, block Budhlada of Mansa district. The numbers of samples having uranium concentration above the permissible limit of WHO & AERB are presented in Table 1.

Table 6.14 District Wise Details of Uranium Exceeding WHO & AERB Permissible Unit (DWSS-2012)

Sr. No.	District	Source	No. of samples sent to BARC for analysis	No. of reports received	No. of sources found safe as per report received	No. of samples failed	
						as per WHO (15µg/l)	as per AERB (60µg/l)
1	Amritsar	Tubewell	45	45	36	9	0
2	Barnala	Tubewell	106	106	4	102	71
3	Bathinda	Tubewell	49	49	13	36	14
4	Faridkot	Tubewell	11	11	6	5	3
5	Fatehgarh Sahib	Tubewell	26	26	12	14	0
6	Ferozepur	Tubewell	345	342	82	260	61
7	Gurdaspur	Tubewell	56	56	52	4	0
8	Hoshiarpur	Tubewell	51	51	45	6	0
9	Jalandhar	Tubewell	50	50	27	23	0

Table 6.14 District Wise Details of Uranium Exceeding WHO & AERB Permissible Unit (DWSS-2012)

Sr. No.	District	Source	No. of samples sent to BARC for analysis	No. of reports received	No. of sources found safe as per report received	No. of samples failed	
						as per WHO (15µg/l)	as per AERB (60µg/l)
10	Kapurthala	Tubewell	25	25	16	9	0
11	Ludhiana	Tubewell	280	280	84	196	16
12	Mansa	Tubewell	26	26	10	16	1
13	Moga	Tubewell	232	232	10	222	77
14	SAS Nagar	Tubewell	22	22	13	9	0
15	Muktsar	Tubewell	8	8	8	0	0
16	SBS Nagar	Tubewell	25	25	14	11	0
17	Pathankot	Tubewell	25	24	24	0	0
18	Patiala	Tubewell	88	88	22	66	1
19	Ropar	Tubewell	24	24	23	1	0
20	Sangrur	Tubewell	140	140	8	132	14
21	Tarn Taran	Tubewell	56	56	21	35	3
		Total	**1690**	**1686**	**530**	**1156**	**261**

Note : (i) Failed samples as per WHO limit shown in yellow colour includes failed samples as per AERB limit also.

Green Within Safe Limit

Yellow Failed as per WHO limit

Red : Failed as per AERB limit

As per findings of Physics Department, Punjab University, Southwest Punjab consists of Sutlej-Ghaggar plain, where the soil had largely developed by the material lead by rivers (alluvium) upto a depth of thousands feet. As expected, the region is deprived of Uranium deposits. The Uranium content in the soils is ~ 3 microgram/gram. Extensive irrigation of rich agricultural area and drinking water supply schemes in the region are mainly based on the available network of canals. Most of the region is water-logged and the soil is calcareous. Irrigation water percolating through soil dissolves carbon dioxide gas produced at high pressures from the plant root respiration and the microbial oxidation of the agricultural matter. The resulting carbonic acid reacts with the insoluble calcium carbonate to produce soluble bicarbonate, which is an efficient agent for leaching Uranium from soil. Percolating bicarbonate solution adds uranium to the ground water. Phosphate fertilizers (uranium content more than 50 microgram/gram) used in the cotton cultivation belt further add to the contamination. The concentration of chemicals produced due to decay of agricultural matter in calcareous soil and use of phosphate fertilizers, and dissolved salts in irrigation water are continuously increasing to threatening levels in the ground water due to the minimal use of the ground water. Similar high concentrations of bicarbonates do exist in ground water at many places, but the ground water level is low and there is continuous excessive use of ground water. These features prolong the period before the ground water quality deteriorates. Strong correlations have been reported between uranium and bicarbonate in the ground water in Central Valley, California.

The earlier contemplated sources in the form of fly ash from thermal power plants in Bathinda have been ruled out on the basis of systematic investigations. Basement granite core sample do not show any significant radioactivity. This rules out possibility of basement granite as a source of Uranium. Other sources such as weathering of exposed granite rocks at Tosham hills, Pesticides and depleted uranium used in wars have also been discarded. Agrochemical processes are possible reasons for Uranium contamination of ground water."

As per BARC findings, "It appears that Phosphatic fertilizers along with mineralogical control within the sediments is one of the possible causes of Uranium in ground water on the basis of their studies. These fertilizers are used extensively in the State and are known to contain uranium ranging from 20 to 300 mg/kg." However detailed systematic studies are required to confirm this.

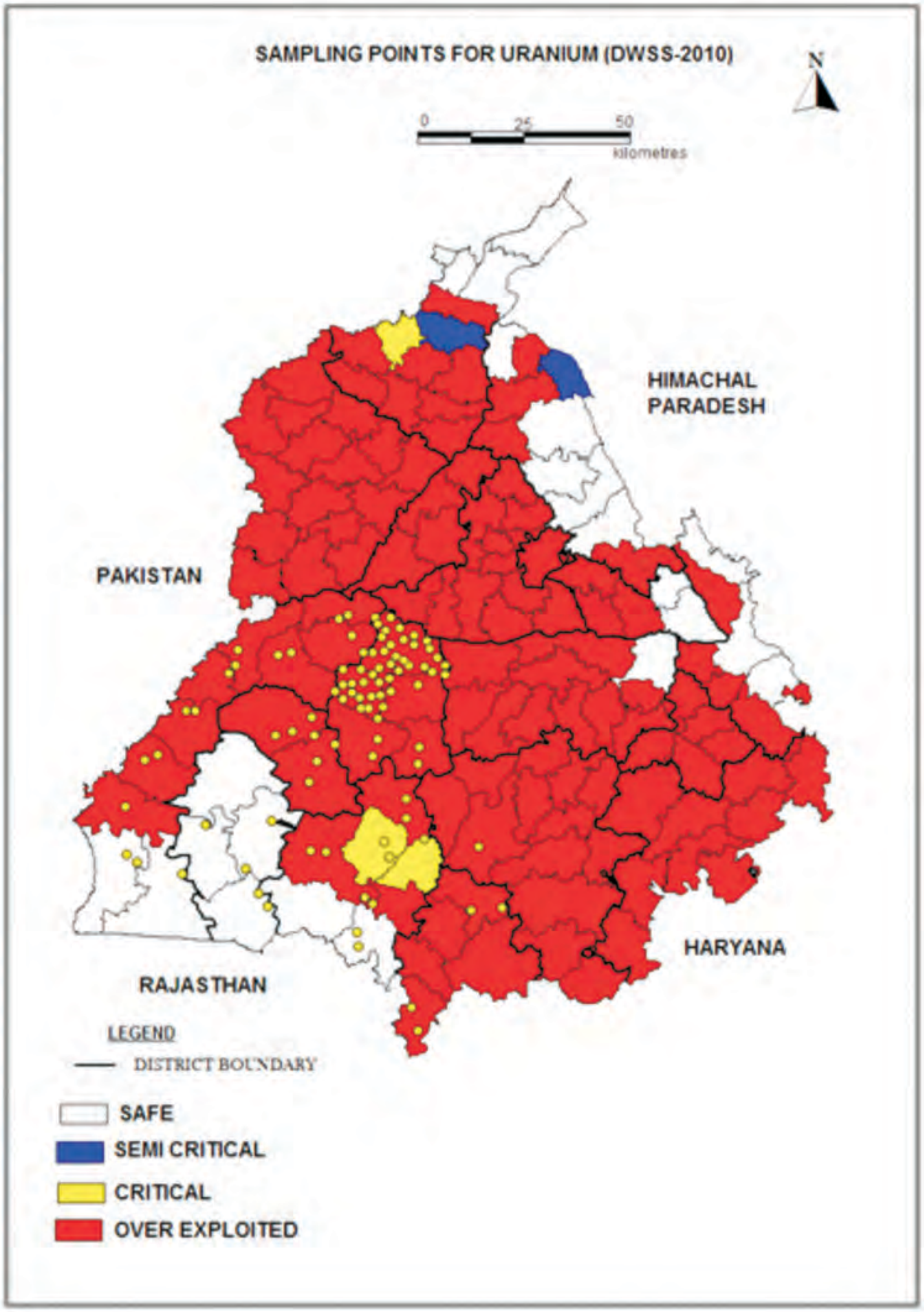
The levels of Uranium in drinking water for 4 districts, collected from different depths are depicted in Table 6.15 as comparable to the permissible limits of various agencies.

Table 6.15 Levels of Uranium in Drinking Water for 4 Districts (DWSS)

Sr. No.	Name of the District	of samples	Depth (ft.) Total No.	No of water	Remarks samples
	Bathinda	80	<100ft.	44	50% of total samples showed above AERB permissible limits (>60ppb)
			100-200ft	16	
			200-300ft	9	
			>300ft	7	
			Oft (canal water)	3	
			RO treated water	1	
	Mansa	80	<100ft.	42	42.5% of samples above limit
			100-200ft	16	
			200-300ft	6	
			>300ft	13	
			Oft (surface water)	2	
			RO treated water	1	
	Faridkot	30	<100ft.	20	36.7% of samples above >60ppb limits
			100-200ft	3	
			200-300ft	2	
			Oft (surface water)	5	
	Ferozepur	45	<100ft.	26	31.1% of samples above >60ppb limits
			100-300ft	9	
			>300ft	10	

On the perusal of above analysis reports, there has been no evidence of depleted Uranium till now. Water samples were collected from canal and tube wells during 2010 from 7 districts of Punjab by DWSS and are depicted on Plate 6.23.

Plate 6.23



5. Pesticide Studies in Faridkot, Bathinda, Mansa, Ferozepur, Muktsar & Moga districts

Department of Water Supply and Sanitation carried out analysis of water samples for determination of pesticide residues and organochlorine pesticides at selected locations in Faridkot, Bathinda, Mansa, Ferozepur, Muktsar & Moga districts (Table 6.16). No pesticidal residues were found in samples collected from these locations. Organophosphorous pesticides, Pyrethyroids, Fungicides, Weedicides and Poly nuclear Hydrocarbons were also determined in these samples and were not dectectable in any of the water samples.

Table 6.16, District wise Locations for Pesticidal Studies by DWSS (2010)

District Faridkot	District Bathinda	District Mansa Vill.Khiwa	Ferozepur	Muktsar	Moga
Vill. Kingra, Block Faridkot, Treated Canal Water	Vill.Rampura, Block Rampura, Treated Canal Water	Khurd Block Bhikhi,Treated Canal Water	Vill.Kandh wala Hazar Khan, Block Fazilka, Treated Canal Water	Vill.Lubanian Water,Block Muktsar,Treated Canal Water	Vill.Chand purana, Block Moga-2, Deep T/W
Vill.Deep singh Wala, Block Faridkot, Deep T/W	Vill.Dialpura bhai ka, Block Bhagta, Deep T/W	Vill.Mohar Singh Wala, Block Bhikhi, Deep T/W	Vill.Gumani wala, Block Jalalabad, Deep T/W	Vill.Bhange Wali, Block Muktsar, Shallow Handpump	
Vill. Kanian Wali, Block Faridkot, Shallow Handpump	Vill.Jajjal, Block Talwandi Sabo, Shallow Handpump	Vill.Kotra, Block Bhikhi,Shallow Handpump	Vill. Kandh wala Hazar Khan, Block Fazilka, Shallow Handpump		

6. Arsenic in Ground water of District Sangrur.

As per investigation, carried out by Deptt. of Water Supply & Sanitation in 2010, Arsenic is within permissible limits in water samples collected from deeper aquifer of Sangrur district (Table 6.17).

Table 6.17, Chemical Analysis Results for Arsenic determination (DWSS)

S No	District	Block	Village	Source	As in mg/l
1	Sangrur	Lehragaga	Shadihari	TW	0.004
2	Sangrur	Lehragaga	Raidharan	TW	0.002
3	Sangrur	Lehragaga	Badalgarh	TW	0.001

NGO/Farmers

A farmers perspective on Punjab ecological health is being represented by Kheti Virasat mission , an NGO actively involved in environmental issues in Punjab State. According to their Statement, highly toxic water is being used for irrigation where alternative source of clean water is not available. This water has grossly polluted the upper aquifer upto 200 feet and this has happened in just two decades.

Another aspect of crisis is fast deteriorating quality of ground water along with canal water. According to a survey done by Punjab Remote Sensing Centre at Punjab Agriculture University, Ludhiana and National Bureau of Soil Survey and Land use planning, Punjab has very high concentration of sodium carbonate and salinity in tube well water. Survey says that 57% of ground water is unfit for irrigation. Several farmers in Bathinda, Mansa, Muktsar, Faridkot and Moga districts lost their crop productivity and yield. The geo-physical analysis of ground water of Punjab shows that it contains high levels of Fluorine, Nitrates, Sulphate, Sodium, Selenium, cadmium, chromium and even nickel. The poor water quality also results in higher consumption of fertilizers and other nutrients to sustain the falling yields. Farmers are spending on gypsum and zinc every year to counter the effects of salinity. Salts in water also block percolation process that facilitate recharging of ground water. The south western Malwa region has been identified as facing the most severe environmental health crisis. Highly substandard ground water is also contributing high incidences of cancer in Malwa. There are several water borne diseases spreading in entire Punjab, but Malwa is worst victim. Graying of hairs, arthritis, and fluorosis both skeletal and dental are common health problems.

In earlier days, canal water is considered ideal for irrigation is no more so, due to industrial pollution and un-treated effluents released in rivers and rivulets. This has further deepens the water crisis and woes of common people. Malwa region faces unprecedented water crisis when black water flows through canals containing contaminators, pollutants, toxicants and whole lot of chemicals. Districts of Faridkot, Muktsar, Bathinda and Abohar-Fazilka were literally on water wars, as Municipal Committees were forced to stop supplying tap water to the people. This canal water is even unfit for irrigation also.

The ground water is contaminated more near the rivers and drains. The untreated industrial waste released into drains ,which is further seeping into the lands and thus polluting the ground water. The lives of people living along side of drains in Punjab are fast becoming vulnerable to even DNA damage. Dr J S Thakur of PGIMER who is working on this issue admits that water contaminated by untreated industrial waste might be leading to the DNA change and making people predisposed to cancer and congenital diseases. His views were supported by Dr. Gursatej Gandhi scientist at Genetics Department, Guru Nanak Dev University, Amritsar who had worked in Mahal village situated on the bank of a drain which carries industrial effluent. She says the ground water contamination due to industrial waste disposal in drains is causing very severe health challenge. The toxic waste after seeping into ground water brings several irreversible health damages. She cites examples of not only DNA damage, but also chromosome damage, Premature ageing and other adverse effects due to drinking of this contaminated ground water.

Pesticide consumption of cotton is 54% of total pesticide consumption in the country and a collaborative study carried out by GREENPEACE with Kheti Virasat Mission pesticide-exposed children had significantly impaired mental developmental abilities. The excessive use of pesticides has affected the ground water as well as drinking water resources. Another study conducted by the Centre for Science and Environment (CSE), New Delhi by Mathure *et al*., in 2005 on “Analysis of pesticide residues in blood samples from villages of Punjab” has found very high levels of pesticide residues in human blood samples which were taken from five Punjab villages (Mahi, Nangal, Jajjal and Balloh villages in Bathinda district and Dher village in Ropar district).

(D) Punjab Pollution Control Board

1. A Report on Groundwater of Quality of Ludhiana City

As per study taken up in 1993 the bacteriological, health related and aesthetic parameters indicate that quality of ground water from handpumps and few tubewells has been impaired in some areas. Cyanide and Chromium has been found in excess in some areas and ground water along GT Road is polluted with respect to Chromium. Leaching of pollutants has been reported because of untreated sewage discharge in Budhanala. Regular monitoring is being carried out, twice a year, at six locations in Ludhiana for bacteriological and chemical parameters in Ludhiana City since 2007.

2. Characterization Study of River Ghaggar and vegetables/crops grown along it

The study taken up in 2005 reveals that BOD, COD and TSS, heavy metals like Zinc and Iron were in excess of prescribed water quality criteria in the ground water samples. The concentration of Zn, Cu, Ni, Pb and Cr in soil samples irrigated with the river water is more than the soils irrigated with groundwater.

3. Status of Water Quality of Sirhind feeder Canal and Water Works of Faridkot

Water Sampling was carried out during 2006 and results of analysis indicate that water is fit for drinking purposes after disinfection.

4. Effect of Contaminants in Wastewater on Soil and Vegetables

Analysis of water samples collected from Lakhnaur drain and Patiali Ki Rao used for irrigation reveal that BOD, COD, TSS and TDS were higher than the prescribed standard limit.Pathogens were present in soil samples.Heavy metals were detected in the vegetables but were not detected in waste water and ground water.

5. Water Quality Studies of Drains/Nallahas/Choes

Based on the PPCB report (2007), large variations in the composition of sewage waters of industrial and non-industrial cities of Punjab have been reported. The concentration of potentially toxic elements was higher in sewage water of industrial towns of Ludhiana, Jalandhar and Amritsar, as compared with less or non-industrial towns of Sangrur and Abohar. The pollution load of municipal wastewater varies from drain to drain depending upon the nature of municipal discharge.

6. Uranium Content in water samples of Malwa Belt in Punjab

A compilation of various studies carried out by different agencies:

· In 2009 GNDU, Amritsar declared that Uranium content in groundwater of Bathinda was higher than the prescribed safe limits.A similar report was published by Ex Chief Engineer & Director Irrigation & Power, Amritsar.

- Hypothesis given by PAU, Ludhiana regarding presence of Heavy Metals including Uranium is attributed to underground saline strata.

- BARC, Mumbai Stated that concentration of Uranium in ground water were within permissible limit.

- Punjab University, Chandigarh has Stated that absence of systematic study has left sufficient room for probable causes of Cancer in Malwa belt of Punjab.

(E) School Of Public Heath And Community Medicine, PGIMER

Collaborative water quality related studies takenup by School of Public Heath and Community Medicine along with Punjab Pollution Control Board are as follows:

1. **Adverse reproductive and child health outcomes among people living near highly toxic waste water drains in Punjab, India**

This is the first evidence from north India to find an association between heavy metal and pesticide pollution of water and reproductive and child health morbidities. The study recommends regular monitoring of water quality of drains, industry and municipal bodies for organic and inorganic pollution with strict enforcement of standards for water pollution.

Collaborative Studies have been taken up by PGIMER, Chandigarh an apex Medical Research Institute of northern India and PPCB, Patiala in order to know the adverse reproductive and child health outcomes among people living near highly toxic waste water drains in Punjab, India. The study was conducted along five major waste water drains (namely Buddha drain, Hudiara drain, Kala Singha drain, East Bein drain and Tung Dhab drain) of Punjab, India from August 2005 to September 2007. The study determines the extent of the surface, ground and effluent water pollution due to industrial effluent and excessive use of pesticides in Punjab, India. Overall, results indicate a significantly higher association of environmental pollution due to heavy metals and pesticides with adverse reproductive effects and child health outcomes. This is the first evidence from north India to find an association between heavy metal and pesticide pollution of water and reproductive and child health morbidities. The study recommends regular monitoring of water quality of drains, industry and municipal bodies for organic and inorganic pollution with strict enforcement of standards for water pollution.

2. **Epidemiological Study of High Cancer among Rural Agricultural Community of Punjab in Northern India**

Based on a citizen's report, a house-to-house survey was conducted in 2007 at Talwandi Sabo and Chamkaur Sahib Community Development Blocks in Bathinda and Roop Nagar District respectively in Punjab State located in a northern part of India to identify the number of existing cancer cases, and the number of cancer deaths that occurred in the last 10 years

A study was conducted by PGI Chandigarh & PPCB, in the cotton belt of Malwa region of the State (2005), specially in Talwandi Sabo block, District Bathinda. The study compares cancer incidences in Talwandi Sabo block, District Bathinda (the study area) with that in Chamkaur Sahib block (selected as the control area) of Rupnagar district, Punjab. Since more than half of the pesticides manufactured in the country are estimated to be used on cotton crop, the study tried to find out if cotton cultivation, which is much more pesticide dependant than rice and wheat, could be linked to cancer. Water (tap and ground) and vegetable samples were analyzed between March to May 2004 from the study and control areas. Heptachlor levels, both in tap and ground water in Talwandi Sabo were reported to be higher than the permissible limit of 0.00003 mg/l. However, this pesticide was not found in Chamkaur Sahib. Similarly, malathion in tap water was higher than the permissible limit (0.0005 mg/l) in Talwandi Sabo, where as its level was within the permissible limit in Chamkaur Sahib. The levels of heptachlor endoepoxide, a - endosulfan, a - HCH/BHC, ethion and chloropyrifos

(0.027 µg/g), were more in vegetables grown in Talwandi Sabo as compared with vegetable samples from Chamkaur Sahib. Chloropyrifos and ethion pesticide levels were found to be above the permissible limits (0.01 µg/g and 1.0 µg/g) in fruit samples from Talwandi Sabo. Heptachor, aldrin and endosulfan were detected in blood samples taken from cancer patients from Talwandi Sabo and Chamkaur Sahib.

In conclusion, the cancer cases and deaths are higher in Talwandi Sabo block probably due to a cocktail of risk factors which were more common use of tobacco and alcohol, consumption of non-vegetarian and spicy food, high levels of heavy metals in water, and excessive pesticides use. It is difficult to pin point a single cause as cancer is caused by multiple factors.

(F) Water Resources & Environment Directorate

Depth wise studies of ground water quality conducted by Water Resources & Environment Directorate, Punjab, in south western parts of the State reveal that ground water quality generally deteriorates with depth. The ground water is saline / alkaline in nearly 50% of the area at depth of 35 meters as against 17% at the depth of 10-meters.The ground water quality is fresh in over 60% of area at 10-meter depth while it is nearly 30% at 35-meter depth. Ground water quality problem is more severe in the districts of Moga, Mansa, Bathinda & Muktsar. The total study area in S-W part of the State is 1.724 mha.The depth wise distribution of ground water quality in the region is given in Table 6.18 below:

Table 6.18 Distribution of Ground Water Quality in South-western Districts

Sr. No.	Quality of Ground water	% of Area at depth (m)				
		10	15	20	25	35
1.	Fresh	62.18	53.36	55.14	38.48	28.75
2.	Marginal	20.54	24.24	16.0	27.0	21.10
3.	Saline	17.28	22.40	27.86	34.52	50.15

Source: Takshi & Chopra, 2010 (Total Study Area in S-W part of the State = 1.724 mha)

Plate-6.24

CGWB / NWR (S.K. Singh) D.O.NO. 43 /2012

6.4 IMPACT OF WATER QUALITY VIS-A-VIS DEVELOPMENT

Since independence, there has been all-round development in agriculture, industrial, urban sectors. This has caused a huge stress on the water resources and resulted in environmental degradation especially in the sectors mentioned. This has led to deterioration in the surface and ground water quality to an extent that has now affected directly human race.

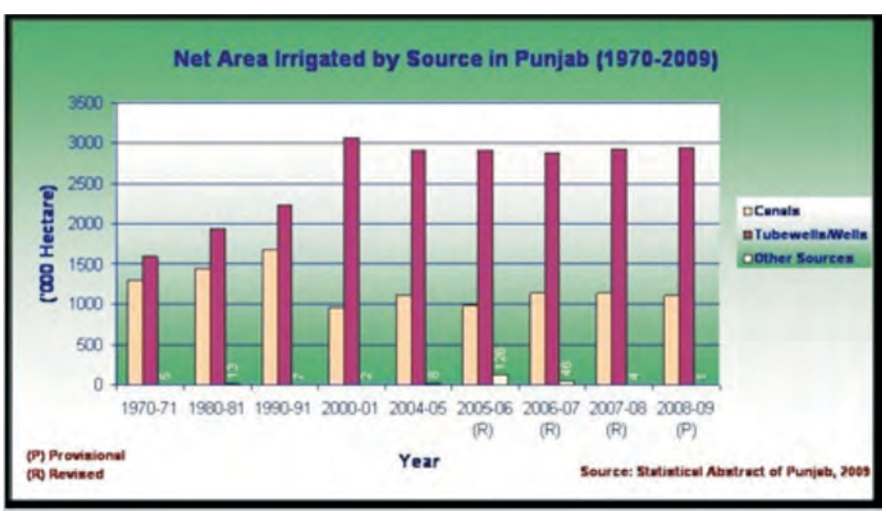
Agriculture Development

Agriculture in the State of Punjab was initially rain fed which was later supplemented by canals but due to unsure supply in the time of need the dependence shifted on Ground water due to its easy availability and control. Irrigation had been practiced in Punjab since pre-historic times. Bhakra Canal System was constructed from 1948 to 1963 and by 1966 net-sown area irrigated in Punjab had gone upto 54% against the national average of 19.5%. Out of this, 57.8% was canal irrigated, 41% was irrigated by wells/tubewells and remaining 2.7% by ponds, rivers and Persian wells.

Before 1960, about one-third of the total irrigation was done through wells and tubewells. At present, there are 12.32 lacs tubewells as compared to 1.92 lacs in 1970-71 and about 75% of total tubewells are electric-operated while the rest are operated with diesel engines. As such, the percentage of net area irrigated to net area sown has shown a tremendous increase from 71% to 97.4% during 1970-71 to 2006-09. Out of the total irrigated area, the area under irrigation by ground water through tubewells has increased from 55% to 73% during this period.

Punjab has an extensive network of canals in the State. But the area irrigated by government canals dwindled from 12860 sq. km to 11110 sq. km. Thus, presently surface water resources cover only 29 % of the total irrigated area of the State. On the other hand, net area irrigated by wells and tube wells has increased tremendously from 15910 sq. km to 28880 sq. km covering 71 % of the total irrigated area of the State since during the same period number of wells has increased from 1.92 lakhs to 12.76 lakhs. This phenomenal increase has been possible only because of extensive irrigation based on ground water sources. The histogram showing net irrigated area by different sources is given in Fig 6.13.

Fig. 6.13, Net Area Irrigated By Different Sources (1970-2009)



Substantial increase in the area under crops grown more than once has been primarily due to the availability of assured ground water for irrigation. The production of rice in the Punjab State has increased from 688 to 11000 thousand metric tons whereas yield has risen from 1765 to 4019 kg per hectare between the years 1970-71 to 2008-09. Similarly, production of wheat in the Punjab has increased from 5145 to 14596 thousand metric tons whereas yield per hectare has risen from 2238 to 4507 kg. between the years 1970-71 to 2008-09. In order to observe the impact of ground water development on water levels, data of six observations well for last 100 years were analysed (Fig- 6.14). The analysis of data shows that there is continuous rise in water levels in the canal command areas and it has become more significant after the introduction of new canal system especially after independence. Apart from this the long-term water level data observation wells being monitored by CGWB for pre-monsoon and post monsoon period were also analyzed using time series analysis. Pre-monsoon water level declining trend indicates that ground water development in the area is increasing while rising water level trend suggests that either the ground water development is reducing or there is additional recharge to ground water. The post-monsoon water level declining trend indicates that there is over exploitation of ground water. Thus the aquifer under stress does not gets fully recharged annually. Similarly a rising post-monsoon water level trend indicate that either the ground water development is reducing and/or there is an additional source of recharge to the groundwater. These principles have been taken fully care of while analyzing ground water trends of Punjab State for last three decades. Table 6.19 shows the area occupied by rising and declining trends of water levels in Punjab.

Fig. 6.14 - Historic water levels indicating rise in water level over a century

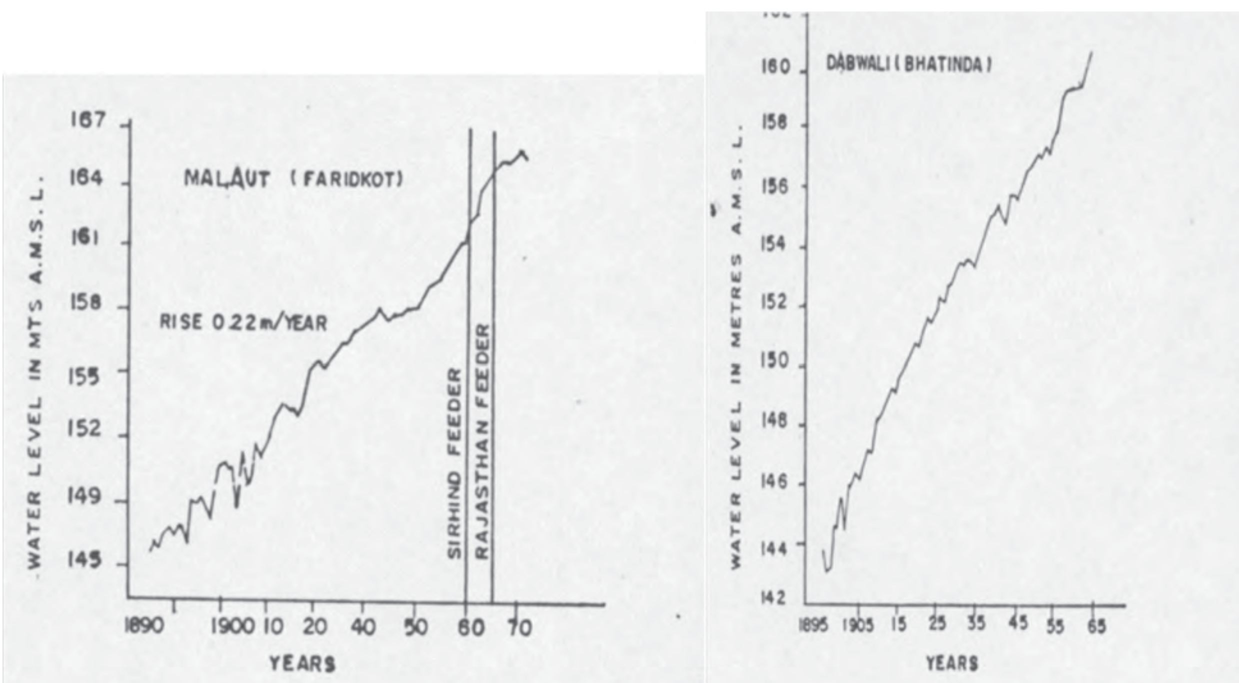
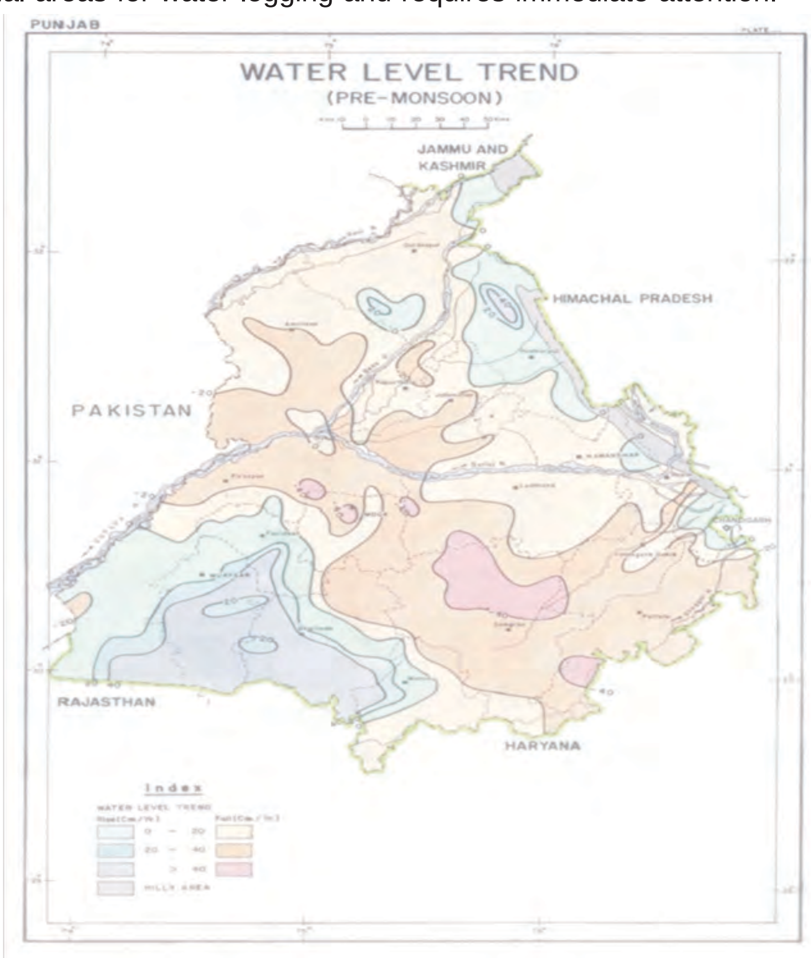


Table-6.19 : - Areal distribution of rising and declining water level areas (Sq.km) in Punjab.

Pre-Monsoon (%)	Post-Monsoon (%)	
RISE (cm/yr.)		
1. 0 –20	9601 (19)	14886 (30)
2. 20 – 40	3449 (7)	2307 (5)
3. >40	3833 (8)	3215 (6)
FALL (cm/yr.)		
1. 0 – 20	15345 (30)	17645 (35)
2. 20 – 40	16344 (32)	8670 (17)
3. >40	1790 (4)	3639 (7)

Areas showing rising water level trend both in pre & post-monsoon period are in the south western, north eastern and eastern parts of the State, covering parts of Faridkot, Muktsar, Ferozepur, Bathinda, Hoshiarpur, Gurdaspur and Ropar districts (Plate 6.25). 41% of the area has rising water levels during post-monsoon and 34% during pre-monsoon period. In the water logged areas, the magnitude of rising trend is very less since there is no space for additional storage and it is generally within 20 cm/yr. While in the areas where water levels are deep (5-10m) the alarming rate of rise even up to 70-80 cm/yr. has been observed mainly in parts of bathinda district and these are potential areas for water logging and requires immediate attention.

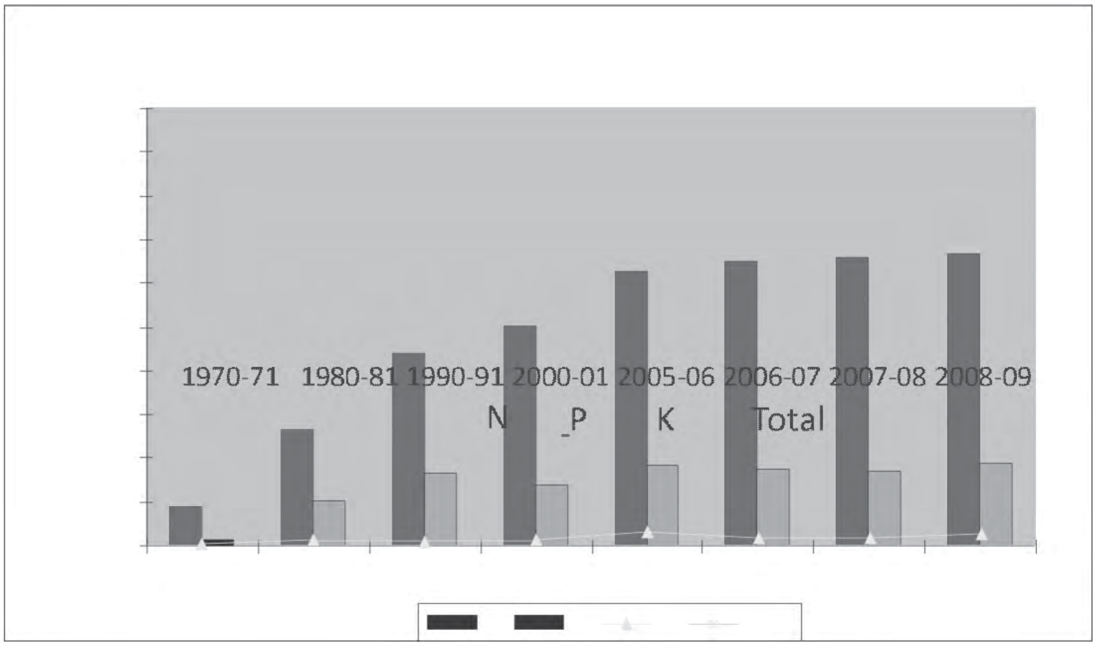
Plate 6.25



Areas experiencing declining water level trends both in Pre and Post-monsoon period are in the central and northwestern parts of the State. The districts falling in this area are Patiala, Sangrur, Mansa, Ludhiana, Jalandhar and Amritsar. Large parts of Punjab are reported to have declining water level trends. About 66% of area is having declining water level trends in pre-monsoon while 59% of the area is having declining water trends in post-monsoon.

Fertilizers have played an important role in the growth of agricultural technology. Where as initially organic fertilizers were mainly used in the fields, chemical fertilizers have now being used for enhancing the agricultural production in the State. In intensively cultivated semiarid subtropical region of Punjab, average fertilizer N consumption has increased by more than 300% from 1975 onwards, which has increased application more than 8 times in the past 35 years from 213 nutrients thousand tons in 1970-71 to 1768 nutrient thousand tons in2008-09 (Fig 6.15).

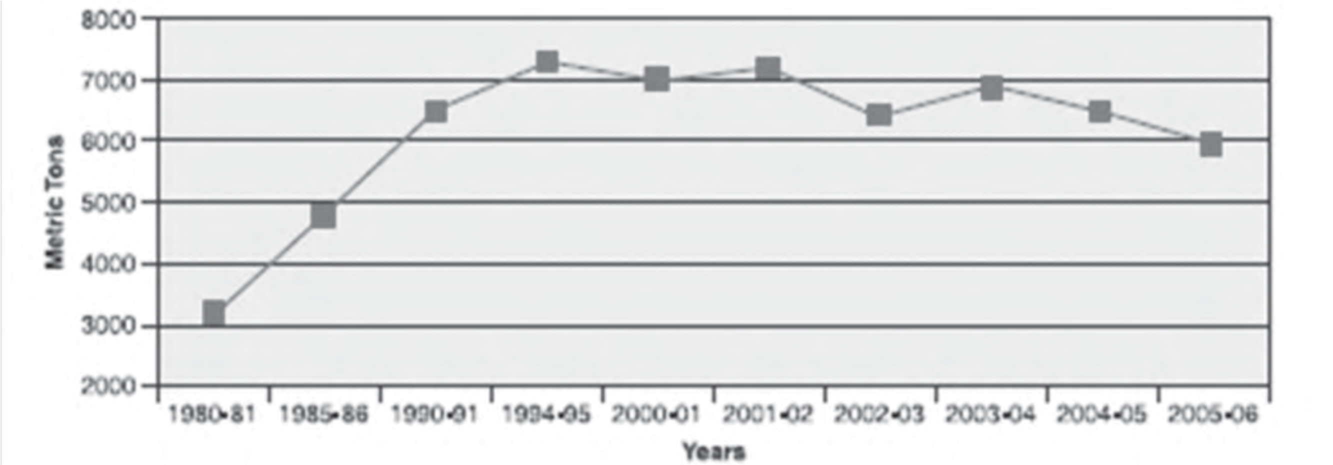
Fig. 6.15- Consumption Trend of Chemical Fertilizers in Punjab (1970-2009)



Due to higher inputs of fertilisers, pesticides etc for agriculture, ground water at numerous locations have reported higher concentrations of Nitrate and pesticides especially in the Malwa region which accounts for 75% of the pesticide consumption in the State.

Pesticides are being used for preventing, destroying, repelling, or mitigating any pest. Punjab State consumes about 17 percent of total pesticides used in India, which is one the highest in the country. Out of these, more than 90 percent of the pesticides were being used in the cultivation of cotton, rice and vegetables. It is estimated that often less than 0.1% of an applied pesticide reaches the target pest, leaving 99.9% as an unintended pollutant in the environment, including in soil, air, and water, or on nearby vegetation. Pesticides can also move from the site of application via drift, volatilization, leaching, and runoff. The Malwa region (cotton belt) accounts for nearly 75 percent of pesticides used in the State. A slight decrease in pesticide consumption since 2003-04 can be attributed to the better awareness among farmers as State government is now promoting bio-pesticides (Fig 6.16).

Fig 6.16.:- Consumption Trend of Technical Grade Pesticides (1980-2006)



Industrial Development

Due to the growth story of industry where a number of new hubs have mushroomed and is continuously discharging their untreated effluents in the natural drainage systems causing severe strain on the quality of the water courses. Punjab's industrial development can be broken up into five periods since independence. Pre-partition Punjab had very little industry and the industries that existed were a few woollen mills in Amritsar and Dhariwal, some old iron foundries in Batala and Mandi Gobindgarh and a couple of sugar mills. The economy of the State was totally dominated by agriculture and but processing of agricultural products was virtually unknown.

During the '50s and '60s, there was an explosion in the number of small scale units. Growth centred around Ludhiana, Jalandhar, Amritsar, Goraya. Most of these units produced bicycles, sewing machines, agricultural implements, medical instruments, hosiery, machine tools and sports goods or parts for these goods. This phase saw the emergence of a few units to process agricultural produce such as sugar mills at Batala and Bhogpur. Small scale industrial units number more than 0.2 million in Punjab today; they employ more than 0.9 million workers and constitute a vital and dynamic segment of industry.

Unavailability of major raw material such as Iron or Coal, was a definite hindrance for the establishment of large and medium scale units in Punjab. Punjab Government stepped into help make large & medium scale production profitable in Punjab. The establishment of the Punjab State Industrial Development Corporation in the '60s was intended to fill the gap in the development of the State. Acting as an entrepreneur, the PSIDC, on its own promoted projects and also set up larger units in the joint sector. These objects reached their fruition in the '70s and '80s and included Punjab Tractors Ltd (PTL), Punjab Alkalies ltd, Punjab Communication ltd. (PCL) are some of them.

The '70s witnessed the foundation of electronics production. The Punjab government set up an Electronics Township called ELTOP on a 290-acre site in Mohali, near Chandigarh. This township has emerged as one of the fastest growing centres for electronics production in the country. Projects set up in the township cover micro-electronic devices, computers, computer peripherals, communications, electronic typewriters, nickel cadmium batteries, uninterrupted power supply systems, colour picture TV tubes, medical electronics, X-ray equipment, EPABX systems. The only facility in the country for the design and fabrication of very large scale integrated circuits, the Semiconductor Complex (SCL) is also located in this township. Punjab Leads in manufacture of machines and hand tools, printing and paper machinery, auto parts and electrical switchgears. Punjab produces around 75% of bicycle and bicycle parts, sewing machines, Woollen and other Hosiery items, Shoddy blanket and jacket clothes and sports goods.

Application of sewage sludge to agricultural soils, and irrigation of field crops with sewage water and untreated industrial effluents alone, or in combination with ground/canal water, is a common practice in Punjab, especially in the vicinity of large cities, as these are considered reusable sources of essential plant nutrients and organic Carbon. More than 50% of the industries are in the red category of water polluting indicating large scope for untreated effluent to cause pollution.

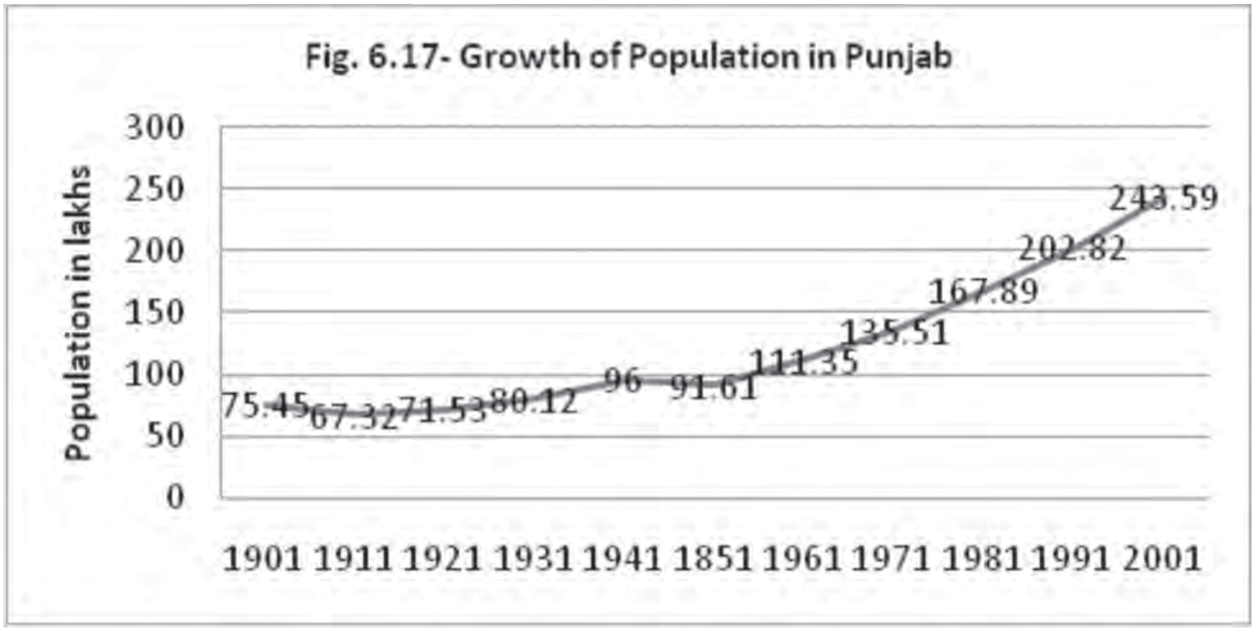
Urbanisation in Punjab

Punjab has experienced a fast growth of agriculture and industry in the recent past. It is widely recognized, by now, that the agriculture in Punjab has developed at a faster rate than the rate of growth of agriculture in other States of Indian Union. Although agricultural development has also been accompanied by growth of industrial sector, nevertheless the pace of growth of industry has been considerably slow. However, the rate of Urbanization has been considerably high. Initially the population was engaged in the farming activities. Landless labour was also attracted to Punjab from other States for better avenues. However with more opportunities in different sector than agriculture, population shifted to urban centres. The proportion of total population living in urban areas in the State has increased from 21.72 per cent in 1951 to 33.95 percent in 2001. There has been tremendous growth of population in the State wherein population has increased from 67.32 lakhs in year 1911 to 243.59 lakhs in year 2001 with percentage increase of around 20% during last 50 years (Table 6.20 & Fig. 6.17).

Table 6.20:-Population growth pattern in Punjab (1961-2001)

Year	Total Population	Urban Population	%age of Urban Population	Decadal growth ofurban population (%)/absolute	Total number of UAs/towns	Annual compound growth rate	
						Total	Urban
1961	11,135,069	2,567,306	23.06	29.06/578,039	106	—--	—--
1971	13,551,060	3,216,179	23.73	25.27/648,873	106	1.98	2.27
1981	16,788,915	4,647,757	27.68	44.51/1,431,578	134	2.16	3.75
1991	20,281,969	5,993,225	29.55	28.95/1,345,468	120	1.90	2.57
2001	24,289,296	8,245,566	33.95	37.58/2,252,341	157	1.82	3.24

Due to large scale **urbanisation** around the big cities in the State, there is huge pressure regarding municipal wastes being generated and being disposed of without any treatment. 73% of the total municipal solid waste is being generated in the 5 mega towns such as Ludhiana, Jalandhar, Amritsar, Bathinda, and Patiala. This type of disposal has caused water quality problems at number of places.



Cumulative effects of development

All the above mentioned activities have resulted in rise in water quality problems in the State which are as follows:-

- Industrial and Municipal wastes which are being disposed of in the nalas, drains etc have caused very high pollution levels in all the main rivers of the State. Water quality is very bad nearly at all locations in river Ghaggar followed by Satluj and Beas rivers.

- Due to unrestricted disposal of wastes, incidences of occurrence of pathogenic microorganisms have resulted in increase in cases of Gastroenteritis/water borne diseases as reported from large number of places like Moga, Jalandhar, Barnala, SAS Nagar.

- Drinking water at few places have been reported higher concentrations of heavy metals such as Lead, Chromium, Cadmium, Copper, Cyanide, Nickel etc. These problems are mainly observed around the industrial hubs like Ludhiana, Amritsar, Mandi Gobindgarh, Kapurthala etc.

- Due to higher inputs of fertilisers, pesticides etc for agriculture ground water at numerous locations have reported higher concentrations of Nitrate and pesticides especially in the Malwa region which accounts for 75% of the pesticide consumption in the State.

- Apart from these water quality problems due to anthropogenic sources, higher concentration of elements like Selenium, Arsenic, Fluoride, Uranium have been reported from Ground water samples. These values have been observed in Hoshiarpur, Nawanshahr districts in respect of Selenium; Amritsar, Gurdaspur, Hoshiarpur, Kapurthala and Ropar districts in respect of Arsenic contaminants. Concentrations of Uranium have been reported from several places in Bathinda, Mansa, Faridkot, Ferozepur, Moga districts and higher concentrations than permissible are reported from number of samples in these areas.

7. EMERGING ISSUES

Many organizations are involved in water-quality-monitoring programs and projects in the State. Numerous studies are being carried out and a lot of information regarding quality of water resources is being generated by these agencies that have helped in bringing out some of the emerging issues of the State to address water quality issues.

On the basis of studies carried out by **Central Ground Water Board** for quality evaluations of ground water as depicted in Plate 7.1, it is observed that:

- The State is characterized with two distinct topographical and hydro- geological settings: high yielding fresh groundwater regions in northern and central districts and the saline groundwater regions in south western districts.

- The ground water occurring in the southern and southwestern parts comprising of Muktsar, Bathinda, Mansa Ferozepur, Sangrur and Moga districts is saline to highly saline and is not suitable for drinking uses.

- 16% ground waters occurring in the southern and southwestern districts of the State have very high concentration of nitrate (above 100 mg/l).

- About 14% of the well water have fluoride above 1.5 mg/l. The districts from where large number of water samples contains high values of fluoride are located in the Malwa region.

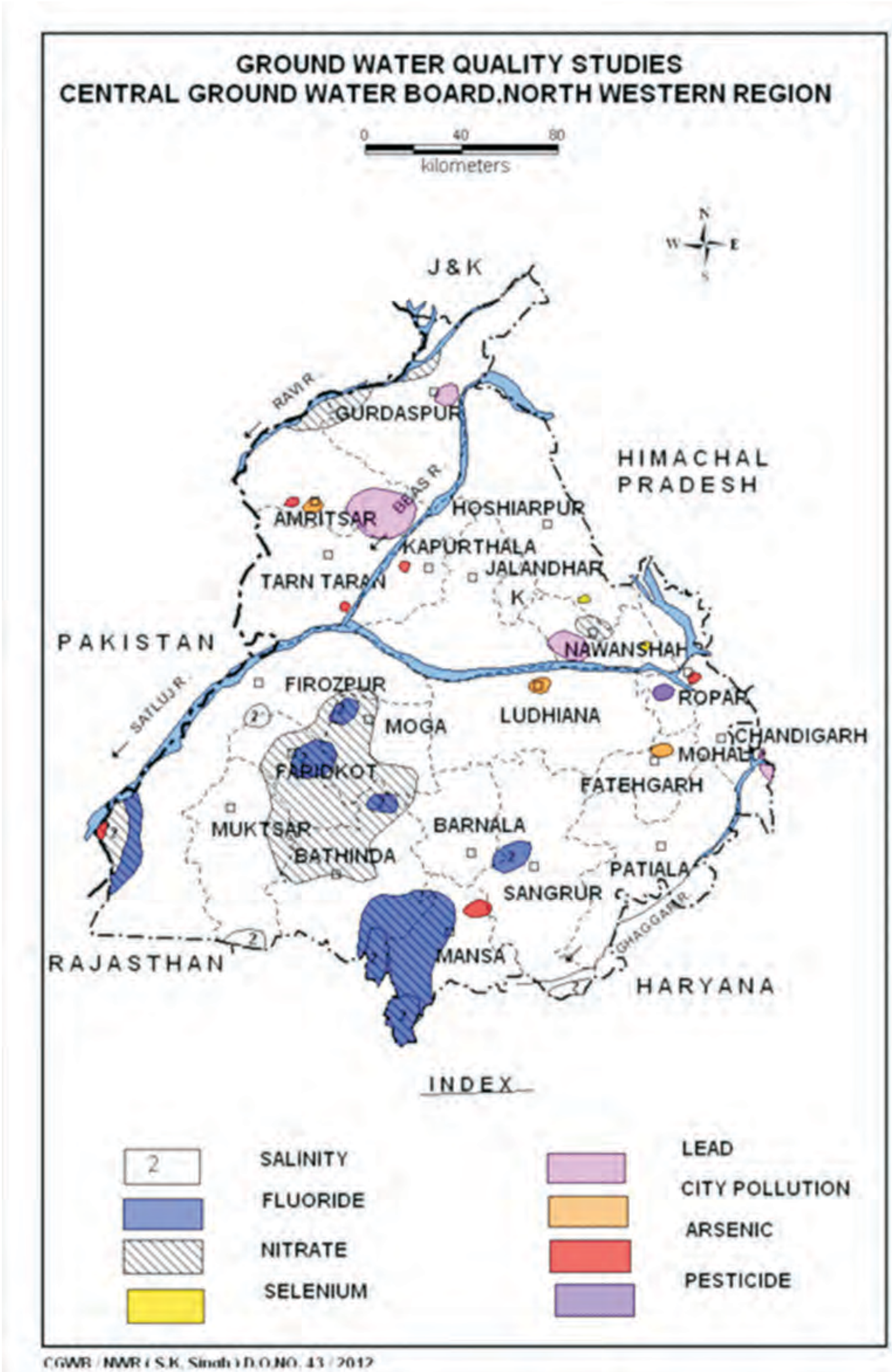
- Ground water is unsuitable for drinking uses at places in the southern and south western parts due to high EC or high fluoride or nitrate or combination of all.

- The areas mostly in southern and south western parts of the State where EC of ground water goes beyond 5000 µS/cm and SAR is more than 10, such waters are not suitable for customary irrigation.

- Selenium has been found above the permissible limit in in soil and shallow groundwater of Nawanshahr & Hoshiarpur district

- 15% of the wells in Amritsar, Jalandhar, Gurdaspur, Kapurthala, Ropar, Mansa and Bathinda districts have water with Fe above 1.0mg/l.

Plate 7.1



- Lead above the BIS permissible limit for drinking water has been reported in 8% of the wells from Amritsar, Gurdaspur, Patiala, Hoshiarpur, Nawanshahr , Ludhiana and Muktsar districts .

- Nitrate and heavy metal contamination has been observed in groundwaters of Amritsar City.

- Iron, Mangannese, chromium and lead contamination has been detected in ground water of Mandi Gobindgarh town.

- Very high concentration of Chromium, cadmium, cyanide and nitrate has been reported in ground water of Ludhiana City.

- Arsenic concentration exceeding the limit of 0.01mg/l was encountered in districts of Amritsar, Gurdaspur, Hoshiarpur, Kapurthala and Ropar. Very high values of Arsenic have been detected in Mansa district.

As per the available data the reported number of Cancer cases have been increasing in Muktsar, Moga, Faridkot, Amritsar, Tarn-Taran, Gurdaspur and Ferozepur districts. As per information provided by **Deptt. of Health & Family Welfare**,**IDSP, Punjab**, the State govt. has taken up various measures to mitigate further deterioration of water quality. and prevention of Cancer:

1. The testing of heavy metals in drinking water has been started in the State Public Health Lab.

2. The State Government has installed Reverse Osmosis Systems (RO) in affected villages.

3. Health Education activities are undertaken to make people aware about the causes signs and symptoms and prevention of cancer.

4. To control the use of pesticides, concerted efforts are being made by the Department of agriculture, Punjab.

   a) Pesticides consumption has declined drastically from 5975 Metric tons to 5690 Metric tons from 2006-07 to 2010-11. A major reason of this decline is the introduction of B.T Cotton in the State during the year 2006-07. The number of pesticide sprays has been reduced. Hence, use of pesticides has been controlled as compared to the earlier years.

   b) Manufacture, import and use of pesticides which are very injurious have been banned by the State Government.

   c) The registration of some pesticides which is not in the interest of human beings as well as animals has been withdrawn.

   d) The use of some dangerous pesticides has been restricted.

   e) Registration of some pesticides has already been refused.

   f) Farmers training camps are being conducted at village, block and district levels to educate the farmers about judicious use of pesticides.

As reported, the State govt. in collaboration with ICMR (Indian council of Medical Research), is aiming at mapping of areas with high incidence of cancer disease, especially in Malwa region, to prepare a Cancer Atlas of the Punjab State.. It is also observed that rate of cancer in the State is 30.5/lakh population where as the rate is as high as 75/lakh in Bathinda and Muktsar districts.

Plate 7.2

There is a lot of uproar about the rising level of some of the Heavy Metals and certain radioactive metals especially Uranium in Malwa belt of Punjab State. As per the media report and from some research data linked to this problem, the levels of the contaminants are also found to be very high in ground water as well as soil samples. Rapid urbanization and industrialization has resulted in pollution of the environment by toxic metals through agriculture by using pesticides and harmful chemicals and also through sewerage disposal.

Intially analysis for Uranium and Heavy Metals in 5 No. samples was per block by carried out **Department of Water Supply and Sanitation, Punjab.** Wherever, a single scheme / village was found contaminated with Heavy Metals or Uranium, all the water supply schemes of that particular block was tested for the presence of such contaminants.

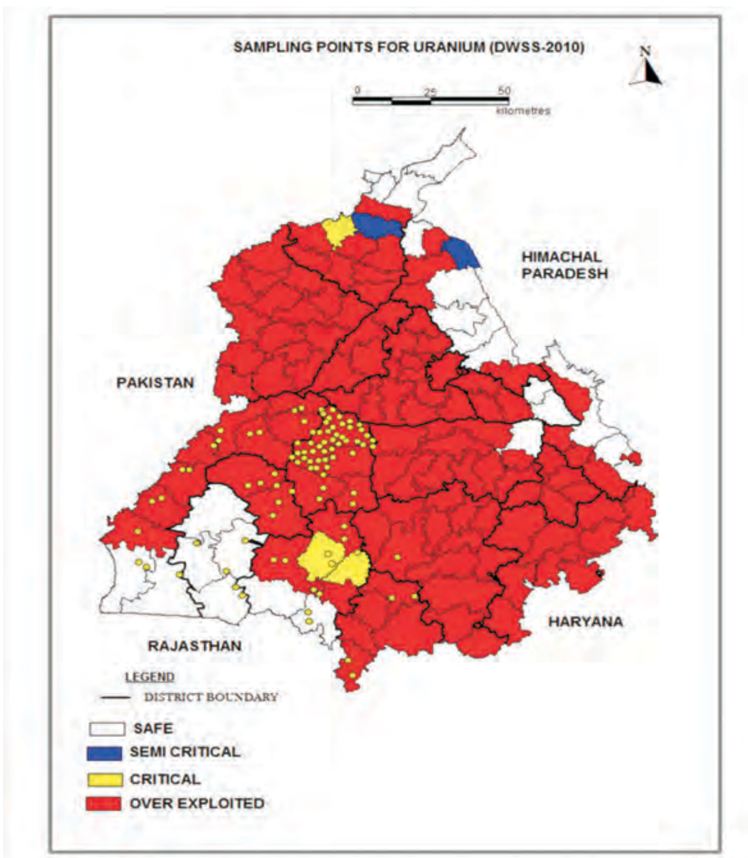
714 number samples were analyzed for determination of heavy metals and some of the samples have shown Aluminum beyond permissible limit and a few samples have shown Selenium and

Arsenic beyond permissible limit in the areas of Nawanshahr, Hoshiarpur and Gurdaspur. Districtwise.Resampling and re-analysis in the area is being carried out for further confirmation.

The vulnerable areas with respect to ground water quality studies carried out by DWSS are depicted in Plate 7.3 and based on the findings, it is observed that :

- High Selenium has been observed in Nawanshahr and Hoshiarpur districts.
- Arsenic above the permissible limit (BIS) has been found in Amritsar and Gurdaspur districts.
- Sangrur, Barnala and parts of Patiala district have high Fluoride in the groundwater.
- High concentration of Aluminium has been found in Gurdaspur, Nawanshahr Hoshiarpur, Patiala, Ropar and Moga districts.
- The entire south western belt of the State comprising of Ferozepur, Moga, Barnala, Bathinda and Sangrur have high incidence of Uranium in groundwater.

Plate 7.3



As per the studies carried out by **Directorate of Water Resource and Environment, Punjab** groundwater is declining alarmingly in fresh water regions and has risen steadily in saline groundwater regions in Muktsar, Bathinda and Faridkot districts. The studies carried out by the department reveal that watertable has risen by more than 10 m in 30 % and 10 % area of Muktsar and Bathinda districts, respectively in the past two decades. Based on findings depicted on Plate 7.4, it is observed that

- In south western districts 82.7% groundwater is of fresh and marginal quality at 10m depth, 77.6% at 15 m, 77.6% at 20m,72.14% at 25m, and 65.5% at 35m (Plate 7.4). 49.85% of ground water can be utilized for agricultural purposes and is brackish/ saline up to 15 m depth and unfit for irrigation in about one fourth of south western districts. The region is experiencing extreme instances of waterlogging and salinity problems and the issue is particularly severe in low lying areas which have inadequate or non- functional surface drains.

- Changing cropping patterns, aridity, rise in waters in old paleo- channels, use of poor quality irrigation waters and canal seepage have compounded the problem critically.

- Groundwater quality in the south western part of the State is a stumbling block in the exploitation of groundwater.

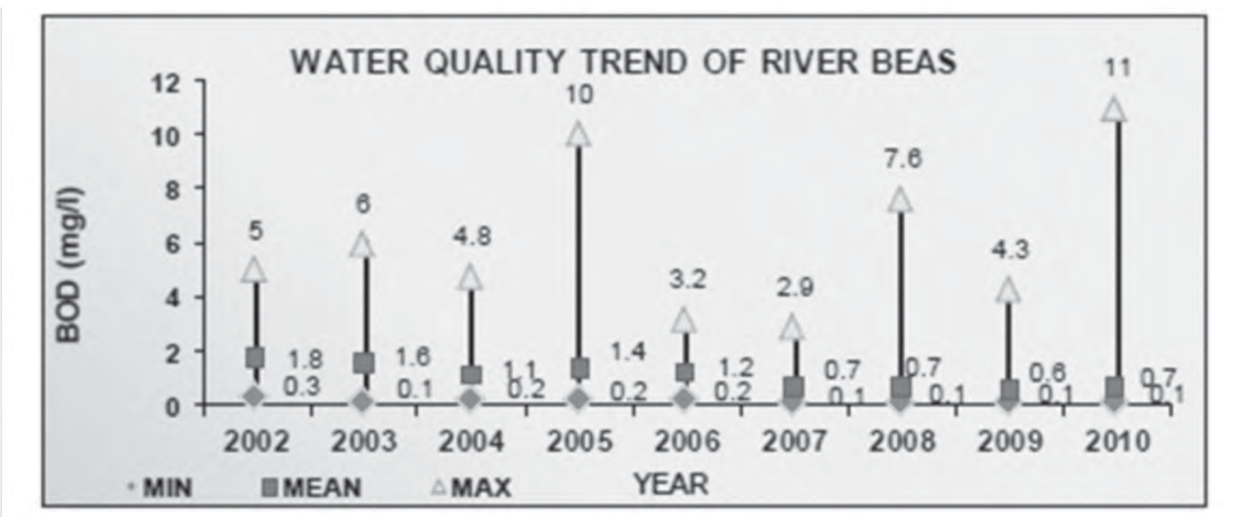
- The water table has been rising steadily over the last 3 decades reaching within 1 m or less from the surface over a large areas especially in blocks of Malout, Muktsar, Lambi and Giddarbaha of Muktsar district causing serious damage to standing crops.

Plate 7.4

Water quality in the aquatic ecosystems of Punjab is being monitored by the **Punjab Pollution Control Board** at several locations. The trend analysis of BOD of River Satluj and Beas,since 2002 to 2010 (Fig 7.1 & 7.2) shows that there is not much change in water quality with respect to BOD in River Satluj but the qualiy of River Beas has deteriorated since 2002.

Fig 7.1

Fig 7.2



As per studies carried out by Punjab Pollution Control Board, and based on the findings depicted in Plate 7.5, it is observed that:

- Ground water quality in Ludhiana city has been impaired in some areas. Cyanide and Chromium has been found in excess in some areas and ground water along GT Road is polluted with respect to Chromium. Leaching of pollutants has been reported because of untreated sewage discharge in Budhanala.

- Lakhnaur drain and Patiali Ki Rao used for irrigation reveal higher BOD, COD, TSS and TDS values than the prescribed standard limit.Pathogens were present in soil samples.Heavy metals were detected in the vegetables but were not detected in waste water and ground water.

- BOD, COD and TSS, heavy metals like Zinc and Iron are in excess of prescribed water quality criteria in the ground water samples along the river Ghaggar. The concentration of Zn, Cu, Ni, Pb and Cr in soil samples irrigated with the river water is more than the soils irrigated with groundwater.

- The water quality of drains like Tung Dhab, Hundiara Nallaha, East Bein and Budha nallaha is highly polluted. The surface water quality of of river Satluj, Beas and Ghaggar is also poor due to discharge of industrial effluents and sewage into the drain.

- The cancer cases and deaths are high in Talwandi Sabo block probably due to a cocktail of risk factors which were more common use of tobacco and alcohol, consumption of non-vegetarian and spicy food, high levels of heavy metals in water, and excessive use of pesticides.

Plate 7.5

CGWB / NWR (S.K. Singh) D.O.NO. 34/ 2012

8. WATER QUALITY MANAGEMENT STARTEGIES

The purpose of water quality management is to achieve sustainable use of our water resources by protecting and enhancing their quality while maintaining economic and social development. Water quality management involves the identification and assessment of point and non-point source pollutants and their sources, and then determining the best management practices to control those pollutants to meet water quality standards. Best Mangement practices to control nonpoint source pollution problems are a combination of structural (management or cultural) practices that a scientist, engineer, the Government, or a planning agency decides upon to be the most effective and economical way of controlling a specific water quality problem without disturbing the quality of the environment.

Since water quality situation of both surface water and ground water in the State is alarming, there is urgent need to formulate a detailed plan of action for water quality management by involving all the existing organizations and other stakeholders. The formulation of water quality management plan should take into consideration the following aspects.

- Inventory of all sources of pollution and water contamination affecting the surface and ground water quality.
- Nature and extent of pollution in both surface and ground water.
- Existing measures for protection of water resources and remediation of pollutants and their impact. Striating to protect the water resources from further deterioration and remediation.
- Details of cost effective clean remediation technologies and their adoption by various stakeholders.
- Plan of institutional strengthening convergence of activities, linkages with other central State, an institution and Non government and Voluntary organization.
- Plan for awareness and education of stakeholders involving Municipalities, Panchayats, schools, institutions, non government and voluntary and other social organizations.
- Action plan for effective implementation of environmental laws for protection, regulation and remediation with active involvement of stakeholders.

Inventory of the source of pollution

This should include-

- Inventory of outfalls in the surface water including their pollution load.
- Inventory of sources polluting the ground water and their pollution load.
- Activities affecting the quality of ground water in catchment area.
- Inventory of chemicals being used in agriculture etc and their pollution load.

It is necessary to identify the nature and magnitude of pollution to assess the requirement of protection and remediation measures. It may include-

- Compilation of base data of surface and ground water and their comparison with various use standards.

- Data analysis in time and space to assess the changes in water quality and identification of magnitude of problem.

Water Monitoring and Data Sharing Mechanism:

The monitoring of surface water quality is being done periodically by PPCB. CGWB is monitoring ground water quality through observation wells in the State in the month of May. Besides, Water Supply and Sanitation Department and IDSP are also monitoring the water quality of ground water sources being used for water supply in the State. It may be seen that number of observation points in the State for water quality monitoring are very less and doesn't provide true picture of water quality in space and time. It may also lead to non-focused approach and wasteful expenditure. The water quality monitoring should include-

- Strengthening of the monitoring network to acquire the data on existing water sources at micro scale. Water Quality Assessment Authority has notified a "Protocol for Water Quality Monitoring". This protocol need to be strictly adhered while monitoring the water quality.

- Intensive monitoring network be established for continuous surveillance in areas affected with various constituents posing health related problems.

- Surveillance of pollution sources to improve compliance with standards and regulation by PPCB needs to be strengthened.

- Since Punjab has intensive agricultural practices and there is apprehension that excessive use of fertilizer and pesticides is responsible for cancer etc., there is a need to establish specific protocol for water quality monitoring in this regard.

- Many organizations are involved in water-quality-monitoring programs and projects in the State. It is pertinent to synergize the efforts so as to achieve the best results and avoid wasteful expenditure from the government exchequer.

The data generated by various organizations is being maintained by themselves as per available facility. There is no established protocol for common storage and dissemination of the data for the users. It is also resulting in duplication of efforts leading to wastage of manpower and public funds. There is a need to bring all the data on a common platform to ensure its availability to all users. Area specific user friendly literature needs to be prepared to address the concerns of the stakeholders and implementation of water quality management program. There is need to increase the investment in the awareness campaign and education programs to protect the water quality.

The various options for water quality management may be grouped under two broad categories, the Non Structural and Structural Measures, in the present chapter, an attempt has been made to elaborate upon various management measures in reference to Punjab State.

8.1 MANAGEMENT OPTIONS

In the preceding paragraphs, it has been mentioned that the State is facing pollution and contamination due to excessive use of fertilizers and pesticides, industrial effluents and geogenic contamination. In order to initiate any management measure, it is pertinent to assess the gravity of the problem and hence a proper inventory of the situation is of utmost importance, similarly there is an urgent need to establish effective monitoring mechanism in place so as to monitor the dynamic nature of problems in time and space.

Non Structural Measures

The non structural measures broadly includes the various removal and treatment techniques, in situ remediation techniques and source control, the same is being discussed briefly in following paragraphs.

(a) Selection of Treatment Technologies :

Inorganic contaminants cannot be destroyed, and in most cases are not volatile. Treatment generally involves forming a bond between the inorganic ion and a solid surface, either a granular media (e.g., activated alumina, ion exchange resin) or a suspension that can be removed with conventional sedimentation and filtration. Some chemicals may become insoluble by changing the pH or adding an oxidant; they may then be removed by filtration. In some cases, biological treatment is known to catalyse the removal process. Tight membranes, such as those used in the reverse osmosis process, in principle can remove any organic or inorganic contaminant. However, because of the expense, tight membranes are rarely used for chemical removal, except for desalination of brackish or ocean water. Various technologies for removal of contaminants are tabulated (Table 8.1) below:

Table 8.1 Technologies for removing chemical contaminants

Contaminant (selected)	Oxidation	Ion Coagulation	Precipitation/ exchange	Adsorption softening	Membranes	Biological Treatment
Arsenic	+++<0.005	+++<0.005	+++<0.005	+++<0.005	+++<0.005	+++<0.005
Fluoride		++		+++<1	+++<1	
Iron	+++<0.1	+++<0.1			+++<0.01	+++<0.1
Manganese	+++<0.05	++			+++<0.05	+++<0.05
Nitrate			+++<5		+++<5	+++<5
Nitrate	+++<0.1					
Uranium		++	+++<0.001	++	+++<0.001	

++ > 50% removal +++ > 80% removal Source: After WHO (2006, Chapter 8)

Some chemical contaminants can be destroyed or converted to benign forms, in particular organic compounds such as pesticides or solvents. In general, organic compounds can be removed from water by air stripping, adsorption onto activated carbon, or biological or chemical transformation. However, partially transformed organic compounds may be as toxic as, or more toxic than, the parent compound.

(b) Removal of Priority Inorganic

Arsenic, fluoride and nitrate/nitrite are the primary inorganic compounds of health concern in drinking water. Arsenic presents a challenge because the treatment target is so low, of the order of 5 to 50 mg/l. In highly contaminated areas, these targets could require a reduction of > 99%, which is difficult to achieve easily and economically with any technology. The most common treatments are coagulation with alum or iron salts; adsorption onto activated alumina; and ion exchange. Most removal processes are more effective for As^{V} than As^{III}, so pre-oxidation is usually required. Biologically activated reactors can improve removal of AsIII. Target concentrations for removal of fluoride are much higher, of the order of 1 mg/l, but fluoride is not extensively removed in conventional coagulation. Alum/lime coagulation is more effective, but requires a lot of chemical addition and produces a large amount of waste sludge. Adsorption onto activated alumina or bone char is also an option. Nitrate is perhaps the most difficult to remove from drinking water, because of its chemical inertness. In municipal plants, biological removal (denitrification) is possible. At the community or household level, ion exchange is the most practical option. Nitrite is generally removed following oxidation to nitrate.

Some of the options available for treatment are as Source substitution, Coagulation, Precipitation, Oxidation, Ion exchange, Membrane filtration and Adsorption. Adsorption technology includes removal by Activated carbon/charcoal and Activated alumina

The two most important examples are arsenic and fluoride removal

Nirmal: combined household treatment of arsenic and iron

A filter candle is produced, using a process that combines fired clay and rice husks to produce a porous, easily cleaned, carbon-based “clay husk” filter. Following iron removal, arsenic is removed in an activated alumina sachet. The filter body is constructed of ferro-cement using. In addition, removing iron before removing arsenic makes the arsenic portion of the unit much more efficient, and results in longer use of the activated alumina adsorption media. Eventually, the media must be changed. The arsenic-rich regenerate Solution can be used by sanitary marts in the production of latrine squatting plates, effectively preventing any possible re-contamination of the environment.

The Nalgonda process

The Nalgonda process makes use of coagulation and precipitation to remove fluoride from water. Alum and lime are added to form polymeric aluminum hydroxide species at high pH. Fluoride reacts with these aluminum species, and is removed along with aluminum flocs that settle out of solution. Calcium fluoride precipitates may also form. If the raw water is very hard, or low in alkalinity, more lime must be added to allow efficient floc formation. This system is consistently able to produce water with < 1 mg/l fluoride, with raw waters containing up to 20 mg/l fluoride.

Management of residuals

All treatment technologies will result in some kind of waste product, which should be handled and disposed of safely. Many wastes are harmless and can simply be disposed of locally. Some residuals, though, may contain elevated levels of chemicals that require special management. Potentially hazardous wastes might leach toxic chemicals into the environment after disposal. The stability of a waste can be evaluated using chemical tests such as if testing shows that the waste is likely to leach, it may be stabilized by mixing with cement or blending with glass.

(c) Phyto-remediation Processes and Applications

Phyto-remediation is a remediation process that entails the use of plants to partially or substantially remediate selected substances in contaminated soil, sludge, sediment, groundwater, surface water and wastewater. It is also referred to as green remediation, botanoremediation, agro-remediation or vegetative remediation (Pivetz, 2001). Depending on the type of contaminant and underlying process, phytoremediation is broadly categorized into the following main areas (Lasat, 2000; UNEP, 2010):

- *Phytodegradation*
- *Phytoextraction*
- *Phytostimulation*
- *Rhizofiltration*
- *Phytovolatilization*
- *Phytostabilization*

(d) Microbial Remediation Processes and Applications

The cost effective and eco-friendly newer biotechnological processes viz. bioremediation and bio-beneficiation through microbial metal re-absorption have been widely accepted. There is however a need to search such metal tolerant, metal absorbent as well as moderate thermophilic acidophilic organisms for bio-geotechnological applications (Martin-Gonzalez et al., 2006; Umrania, 2006).

Depending on the type of contaminant and underlying process, microbiological quality can be improved by any of the following methods:

Sedimentation

Coagulation

Filtration

- *Rapid filtration*
- *Slow sand filtration*
- *Bank infiltration*
- *Cloth and membrane filtration*
- *Ceramic filtration*

Disinfection

- *Physical disinfection*

  Boiling

Pasteurization

Ultraviolet radiation

Solar Disinfection (SODIS)

· *Chemical disinfection*

Combined coagulation, precipitation and chlorination

(e) Aquifer Remediation

Once ground water is contaminated, it is difficult and typically very expensive to restore to natural or pre-contamination conditions. The broad range of chemical, physical, and biological characteristics of the thousands of potential ground water contaminants coupled with the complex heterogeneities of subsurface flow and contaminant transport make it very difficult to determine the exact nature and extent of ground water contamination in a given area or aquifer. If the value of the ground water that has been contaminated is great enough, it is very important to conduct an appropriate remedial investigation that is aimed at determining the nature and extent of the contaminant or contaminants. This remedial investigation is then used to conduct a feasibility study that will focus on evaluating potential remedial options. Strategies and technologies that are typically used to remediate contaminated ground water include the following general categories:

The objective of source removal is to reduce or eliminate the volume of waste (solid or liquid) or non-waste that is the source of the ground water contaminant(s). Removal should stop or minimize ongoing contamination; however, it is important not to transfer the problem from one location to another.

(f) Source Control

To determine if source removal is a viable option, it is necessary to consider the following items: (1) problems associated with excavation and transport of the source material; (2) accessibility, distance, and road conditions between the origin and disposal sites; (3) cost; and (4) political, social, and legal factors. Over the last couple of decades, a multitude of measures have been developed to control contaminant sources; two commonly utilized methods are source control measures, surface runoff control and ground water barriers. Both of these options are aimed at preventing water from moving into and through the contaminant source, thus minimizing or stopping the leaching and subsequent transport of contaminants.

Surface-runoff controls. Surface-runoff control measures are used to minimize or prevent infiltration of precipitation and overland flow. Overland flow over an area of concern can be prevented by contouring the land using dikes, berms, ditches, terraces, benches, levees, and sedimentation basins. These features can be used to divert or collect the overland flow to prevent infiltration.

Hydrodynamic control

A properly located array of recharge and discharge wells can be used to prevent a ground water contamination plume from (1) moving into the zone of influence of a water supply well or well field

(g) In Situ Remediation

If it is required or desirable to treat contaminated ground water, and it cannot be achieved by in situ treatment, it will be necessary to collect the contaminated water, treat it by methods appropriate for the contaminant(s), and return it to the subsurface. The pump-and-treat system is the most common and the most successful collection and treatment technique. Depending on the site hydrogeology, the nature of the ground water contaminant(s), and the extent of the plume, an array of extraction wells is installed to remove contaminated ground water for treatment. Once treatment has been completed, the "clean" ground water is returned to the subsurface through infiltration ponds/trenches, spreading basins, or injection wells or is discharged to the surface. The location and operation of extraction wells is highly dependent on subsurface hydrogeological conditions.

In situ treatment techniques can be grouped into two categories: (1) physical/chemical treatment processes and (2) biological treatment processes. In situ treatment processes include the injection of a treatment medium into an aquifer. As contaminated ground water comes in contact with this medium, specific chemical/biological reactions are catalyzed, causing the contaminant to participate in reaction(s) that reduce its concentration and/or toxicity or break it down into nontoxic constituents.

A performance monitoring program must be developed and implemented at contamination sites that are being, or have been, remediated. The performance monitoring plan should be designed to provide data that can be used to determine whether the remedies that were utilized have achieved the established water, particularly ground water contamination sites are established based on legal and political requirements, use requirements, and/or the constraints of remediation technology.

(h) Regulated Application of Fertilizer & Pesticides

The regulation of fertilizers must be based on sound scientific and agronomic principles. Just as soil, water and air are essential for growing food, so too are nutrients provided by fertilizers. Balanced nutrition, soil testing, nutrient use efficiency measures, and other tools are essential considerations for appropriate fertilizer use.

There should be comprehensive use of Nutrient Management Planning (NMP) when using fertilizer products.

- This will help choose the right nutrient source, at the right time, rate, and place. Best Management Practices (BMPs) match fertilizer type to crop needs, and fertilizer amounts to crop needs, making nutrients available when crops need them, and keeping nutrients where crops can use them. BMPs are designed to provide adequate nutrition for crops, while minimizing nutrient losses to the environment.

- Policies that assure regional and farm-specific conditions are considered as farmers develop and implement Best Management Practices. This flexibility is critical in order for farmers to maximize the economic and environmental benefits of adopting BMPs.

Appropriate fertilizer application can improve the quality of the environment. However, the regulation of fertilizers must be consistent with and based upon sound scientific principles.

- Fertilizers should not be regulated by subdivisions below the level of the State.

- State should develop legislation that prohibits the regulation of fertilizers below the level of the State in order to insure that these materials are regulated based on sound scientific principles needed to protect the environment.

Pesticides are an important component of agriculture/horticultural production systems. Pesticides are utilized in integrated pest management programs and result in the production of abundant and safe food, fibre and crops which sustain the quality of life we enjoy.

STRUCTURAL MEASURES

(a) Institutional strengthening

There are several organizations in the State which are actively working in the field of water quality monitoring and management. The strength of these organizations is inadequate in terms of manpower, technical capabilities, and infrastructure to meet the goal of water quality monitoring. Since the data needs to be collected at micro level and adopt management measures at village/ block level, these organizations need to be suitably strengthened by recruiting technical manpower, up gradation of laboratories and training and re-training of existing staff. Other stakeholders like Panchayats, schools, colleges, NGOs, VOs etc. be associated with the projects by providing necessary training in water quality monitoring and evaluation and also capacity building at grass root level. Periodic workshops/seminars and training will lead to positive interaction, data dissemination and avoiding duplication of effort.

8.2 REGULATIONS AND POLICY FRAMEWORK

In India, water law is made of different components. It includes international treaties, federal and State acts. It also includes a number of less formal arrangements, including water and water-related policies as well as customary rules and regulations.

National Framework

Water supply is a State subject under the Constitution of India. However, States are guided by policies and regulations enunciated by the Government of India. These include:

- 73rd Constitutional Amendment
- The National Water Policy of 2002
- The Environment (Protection) Act, No.29 of 1986
- Water (Prevention and Control of Pollution) Act, 1974 (Central Act 6 of 1974) as amended in 1988
- Water (Prevention and Control of Pollution) Cess Act No 36 of 1977
- Forest (Conservation) Act No. 69 of 1980 as amended in1988
- The Wildlife (Protection) Act 1972 as Amended in 1991
- EIA Notification of 1994 with amendments

The 73rd Constitutional Amendment designates Panchayati Raj Institutions as providers of basic services to rural communities which include drinking water and sanitation.

National Water Policy aspects impacting Water Supply Schemes

- Water is a scarce and precious national resource to be planned, developed and conserved as such, and on an integrated and environmentally sound basis, keeping in view the needs of the States concerned.

- Water should be made available to water scarce areas by transfer from other areas including transfers from one river basin to another, based on a national perspective, after taking into account the requirements of the areas/ basins.

- Water resource development projects should, as far as possible, be planned and developed as multipurpose projects. Provision for drinking water should be a primary consideration. The projects should provide for irrigation, flood mitigation, hydro-electric power generation, navigation, pisiculture and recreation wherever possible.

- The study of the impact of a project, during construction and later, on human lives; settlements, occupations, economic and other aspects should be an essential component of project planning.

- In the planning, implementation and operation of projects, the preservation of the quality of environment and the ecological balance should be a primary consideration. The adverse impact, if any, on the environment should be minimized and should be off-set by adequate compensatory measures.

- There should be an integrated and multi-disciplinary approach to the planning, formulation, clearance and implementation of projects, including catchment treatment and management, environmental and ecological aspects, the rehabilitation of affected people and command area development.

- Special efforts should be made to investigate and formulate projects for the benefit of areas inhabited by tribal or other specially disadvantaged groups such as Scheduled Castes and Scheduled Tribes. In other areas also, project planning should pay special attention to the needs of Scheduled Castes and Scheduled Tribes and other weaker sections of society.

- In the planning and operation of systems, water allocation priorities should be broadly as follows: (i) Drinking water, (ii) Irrigation, (iii) Hydro-power, (iv) Navigation and (v) Industrial and other uses.

However, these priorities might be modified, if necessary, in particular regions with reference to area specific considerations.

- There should be a close integration of water-use and land-use policies.

Scope of relevant national environment regulations listed above is presented in Table 8.2:

Table 8.2 Scope of Relevant Environment Regulations

S.No.	Relevant Act	Scope of the Act
1	The Environment (Protection) Act. No 29 of 1986	Under the Act the central government is empowered to take measures necessary to protect and improve the quality of the environment by setting standards for emission and discharges, regulating the location of industries, management of hazardous wastes, and protection of public health and welfare.
2	Water (prevention and control of pollution) Act 1974 (Central Act 6 of 1974) as amended in 1988	The Act prohibits the discharge of pollutants into the water bodies beyond a given standard and lays penalties for non-compliance.
3	Water (prevention and control of pollution) Cess Act No 36 of 1977	This Act provides for a levy and collection of a cess on water consumed by industries and authorities. It aims at augmenting the resources of the central and State boards for prevention and control of water pollution.
4	Forest Conservation) Act (No 69 of 1980 and amendment in 1988	This Act restricts the powers of the State in respect of de-reservation of forests and use of forestland for non-forest purposes.
5	The Wildlife (protection Act 1972) Amendment 1991	This Act provides the protection to listed species of flora and Fauna in the declared network of ecologically important protected area such as wild life sanctuaries and national parks.
6	ELA Notification of	All projects listed under schedule-I of the notification require environmental clearance from the MOEF. Water supply and sanitation projects. However, are not covered in the schedule(The list of project categories under schedule-I of the environmental Impact assessment Notification is given in Annexure 8) Amendment to the notification dated 7thJuly 2004, brings large housing projects, Which will house more than 1000 residents or discharge more than 50 KLD of sewage or having in investment of Rs 50 crore, under its ambit.

Ministry of Environment and Forests

WHEREAS the Water Quality Assessment Authority (WQAA) was constituted by the Central Government vide Order No. S.O. 583 (E) dated the 29th May, 2001 and No. S.O. 635 (E) dated the 27th October, 2004 to exercise powers under section 5 of the Environment (Protection) Act, 1986 (29 of 1986) for issuing directions and for taking measures with respect to matters referred to in clauses (ix), (xi), (xii) and (xiii) of sub-section (2) of section 3 of the said Act and to standardize method(s) for water quality monitoring and to ensure quality of data generation for utilization thereof and certain other purposes;

AND WHEREAS it is necessary and expedient to evolve water quality assessment and monitoring protocol as directed by the Water Quality Assessment Authority in order to maintain uniformity in the procedure for water quality monitoring mechanism by all monitoring agencies, departments, Pollution Control Boards and such other agencies so that water related action plans may be drawn up on the basis of reliable data;

AND WHEREAS the uniform process on water quality monitoring shall provide frequency of monitoring, procedure for sampling, parameters for analysis, analytical techniques, quality assurance and quality control system, infrastructure requirement for laboratories, procedure for data processing, reporting and dissemination and such other matters as the Central Government deems necessary for the said purpose, both for surface and ground water;

AND WHEREAS due to the deterioration of the river water quality, health and livelihood of the downstream people are being severely affected and concerns are raised time and again;

AND WHEREAS the immediate maintenance and restoration of 'wholesomeness' of the river water quality is the mandate under the Water (Prevention and Control of Pollution) Act, 1974 (6 of 1974) and that of maintenance of the ground water quality by the Central Ground Water Authority constituted under the provisions of the Environment (Protection) Act, 1986;

AND WHEREAS sub-rule (4) of rule 5 of the Environment (Protection) Rules, 1986, provides that whenever it appears to the Central Government that it is in public interest to do so, it may dispense with the requirement of notice under clause(a) of sub-rule(3) of the said rule";

AND WHEREAS the Central Government is of the opinion that it is in public interest to dispense with the requirement of notice under clause (a) of sub-rule (3) of rule 5 of the said rules to issue the Order.

State Framework

Water supply and sanitation in Punjab is guided by the following State and National laws:

• **State Water Policy – drafted in 1997**

Punjab is one of the States to have formulated a draft framework of Water Policy within the overall framework of the National Water Policy (1987). The policy was approved for enactment. However, the National Water Policy has since been revised in keeping with the developments on the subject, and the new policy approved by the Parliament came into force in 2002. To keep pace with the National Water policy, GoP made few amendments in the State water policy, which is under consideration for approval and enactment.

The broad objectives of the Punjab State Water Policy are:

- To allocate available water resources judiciously to different sectors.
- To preserve sweet ground water resources in the area where the static ground water resources are limited.

- Transfer the O&M of existing rural water supply, sanitation and environmental facilities to local bodies or beneficiary associations.
- Promote beneficiary participation to capital cost of public investments in irrigation, water supply, sanitation and environment control works.
- Promote the recovery of O&M costs in existing and new facilities by bringing rational approach for fixing the rate of water for various uses.
- Promote beneficiary participation in all aspects of water planning and management.
- Prepare, approve and initiate the implementation of State water and water related environmental plans.
- Proceed with institutional reform to strengthen and centralize the collection, storage and processing of water and monitoring of all water related activities.
- Strengthen the research, development and dissemination of efficient and cost effective uses of water.
- Initiate mitigating measures to safeguard the environment and ecological balance from all water related activities and promote safe use and disposal of water.
- Provision of flood protection, drainage facilities and solving water logging and salinity problems.
- Regulation of land use in flood prone areas.
- Provide social justice and adequate rehabilitation measure for persons displaced or adversely affected by project construction.
- Optimize economic benefits by multipurpose use of water for hydropower generation, preservation and enhancement of fisheries, preservation and stoppage of encroachments of wetlands for wild life.
- Initiate adequate measures for artificial recharge of ground water.
- Promote remote sensing techniques for water resource development in the State. The Policy, which will apply to all the water resources in the State, has also outlined an Action Plan and identified the institutional framework for implementation. Some of the important components of the Action Plan are given below:
- Planning, Designing and Management of water resources will be done on an integrated basis with active coordination of all water user bodies whether public or private.
- Review of various issues identified and proposed management action plan at the State and regional levels,
- The plan would be structured on a five-year operation to fully implement the State water policy. The Policy recognizes that water is a prime natural resource and a basic human need. The policy emphasizes the need to estimate water resources and plan their allocation and utilisation so that human consumption gets the first priority over agriculture, industry and power generation. Water quality is an important component of the Policy and improvements in strategy and innovation in techniques are recognized as the vehicles to eliminate pollution of surface and ground water resources. The environmental aspects

related to water are to be given due considerations to ensure sustainability of source and protect it for future generations. All the above aspects have been adequately captured in the draft framework of the State Water Policy of Punjab. However it is recommended that the State Water Policy is enacted at the earliest to ensure speedy implementation of the schemes under this project.

• **The Punjab State Tube well Act, 1954:** The Government of Punjab has drafted an act to provide for the construction improvement and maintenance of State Tube well irrigation works in Punjab. This Act, called the Punjab State Tube well Act, 1954 extends to the whole of the State.

• **The Inter-State River Water Dispute Act-1956:** In order to promote integrated and optimum development of waters of inter-State rivers and river valleys, under Entry 56 of List-I of the Constitution, Parliament has enacted the River Boards Act, 1956. This act contemplated the appointment of river boards by the central government in consultation with the State governments. It is expected that these

boards would help in coordinated and optimum utilization of river waters and promote development of irrigation, drainage, water supply, flood control and hydroelectric power. The State cannot legislate on use of waters of inter-State rivers and river valley beyond their State boundaries. In the constitution, water is a matter comprised in Entry 17 of List-II. This entry is subject to the provisions of Entry 56 of List-I. The result is that no State can effectively legislate inter-State river water for its own benefits. Only Parliament can effectively regulate by law the beneficial use and distribution of such waters among the States. Secondly, the quantity of water available to each of the States depends upon the equitable share of the other States. Thirdly a dispute about the waters of an inter-State river can arise from any actual and proposed legislation of a State.

• **Punjab Panchayat Raj Act, 1994:** This Act prescribes the purpose and manner of organizing Village and Town Panchayats. It authorizes the Panchayats to construct, repair and maintain any community asset including water related structures like ponds, water supply and sanitation schemes. This Act allows the Government to transfer to Panchayats the duty of protecting and maintaining any irrigation works or regulate distribution of water.

• **The Punjab Preservation of Sub-Soil Water Act, 2009:** The Punjab State has enacted an Act namely “The Punjab Preservation of Sub-Soil Water Act, 2009” for regulating the use of ground water for growing paddy to avoid excessive exploitation, use and wastage of ground water resources. The Act provides for the prohibition of sowing nursery of paddy before 10th May and transplanting paddy as notified by State Government, i.e. before 10th June.

WAY FORWARD

This report has brought out an extensive profile on agriculture, industrial growth, and uncontrolled urbanization which has put tremendous pressure on the water resources of the State both in terms of quantity and quality. Further long dry spells and low precipitations aggravated the problem in the semi-arid region of the State. Over-exploitation of the resource and discharge of untreated municipal and industrial effluents in rivers, canals and drainage system have created multiple environmental problems and social challenges. It has posed a threat to degrade the quality of soil and reduce crop yields along with deteriorating the quality of both surface and ground water. The various organizations engaged in water quality issues in the State have taken appreciable initiatives in it's monitoring, protection and remediation. The studies taken up by the various departments have brought out a few emerging issues which need to be addressed through preventive and remedial measures. The approach towards tackling the water pollution in Punjab has to include identification of vulnerable areas and adopting remedial measures thereto. It should also be sector wise viz **Problem Specific Programme** to include heavy metals and pesticides, industrial pollution and waste water and effluents; **Area Specific Programme** to include sensitive zones like heavy metals including Uranium contamination in Malwa belt and pesticides in cotton growing belt; identifying and prioritizing of problematic areas like selenium toxicity in Nawanshahr and Hoshiarpur districts of Punjab. **Sector Specific programme** are also required to be taken up as industrial hubs and specific polluting industries discharge their effluents haphazardly which causes environmental problems; even leading to both surface and groundwater pollution in the State. Some of the vital issues which need immediate attention are summarized as follows:

1. The studies conducted so far with regard to the presence of Heavy metals and Uranium in ground water are limited. A thorough and comprehensive investigation is required to be undertaken involving concerned agencies like Department of Water Supply and Sanitation (DWSS), Punjab Pollution Control Board (PPCB), Bhabha Atomic Research Centre (BARC), Central Ground Water Board (CGWB) and various Universities. A comprehensive aquifer wise water sampling should be taken up in the first phase to assess the intensity of contamination. Based on the results, contaminated areas should be precisely demarcated and micro-level studies should be initiated in those pockets. Water pollution caused by heavy metals due to urban and industrial activity also needs to be ascertained. Monitoring mechanism needs to be strengthened and water samples should regularly be collected and further analyzed at an accredited lab.

2. Rainwater drains carry contaminated effluents which ultimately discharge to Nallas or rivers causing pollution to surface as well as ground water resources. Lining of drains carrying potentially dangerous effluents will also help in arresting seepage of contaminants to ground water; thus controlling the ground water pollution. In order to contain the polluted ground water, one of the viable solution is dilution through augmenting the ground water recharge by adopting suitable artificial recharge measures also in those areas.

3. There is no fix pattern of distribution of Arsenic in the ground water of Punjab. Comprehensive action plan should be drawn to take up extensive water sampling through out the State from various sources such as ground water, river and canal water. Locations having higher Arsenic should be clearly demarcated. Ground water pumpage from these small zones/locations should be banned altogether and fresh water be supplied in these areas. A number of techniques are in use for removal of Arsenic from ground water and affordable techniques be popularized by providing subsidies/incentives.

4. Currently, the State consumes about 17 percent of total pesticides used in India. Out of these, more than 90 per cent of the pesticides are being used in the cultivation of cotton, rice and vegetables. The Malwa region (cotton belt) accounts for nearly 75 percent of pesticides used in the State. Detection and quantification of pesticides and heavy metal residues in groundwater in all the districts falling in Malwa region of Punjab should be taken up. Agencies like PGI, PPCB, CGWB, PU and State Agriculture Department should be involved in the action plan. Agriculture Department should educate people involved in Agriculture about proper pesticide storage, use and disposal of the empty pesticide containers. Steps should be taken so that pesticides are used judiciously and safely. Department of Public Health & Family Welfare should monitor the level of pesticides and heavy metals in drinking water periodically. A comprehensive study should be undertaken to bring out the status of environmental health in other cotton growing areas of Punjab.

5. The contamination of ground water by pesticides needs thorough investigation and study. Ground water is vulnerable to contamination due to excessive use of pesticides in many parts of the State. Now it has become imperative that ground water vulnerable zones may be maped for resource management and land use planning.

6. High concentrations of fluoride, often significantly above the safe limit of 1 mg/l, constitute a severe problem in some semi-arid areas of Punjab. Extensive sampling be taken up to demarcate the affected areas as well as marginal area. Advanced removal techniques like reverse osmosis, electro dialysis and distillation be popularized. Nalgonda and activated alumina techniques are the most common small scale techniques and the same may be promoted.

7. Preventive as well as corrective measures are required to tackle Selenium toxicity in about 1000 ha area of Nawanshahr and Hoshiarpur districts which should be completed in well defined phases. Extensive ground water sampling should be undertaken in the fringe areas of these pockets to clearly establish the nature and extent of the selenium rich soils and ground water in order to identify such vulnerable areas having higher concentration of Selenium. It is anticipated that aquifers below 70m are not affected by Selenium toxicity. It needs to be confirmed by drilling exploratory tubewells to identify the selenium free aquifers in the identified pockets to tap water only from these aquifers. The zones should be sealed properly so that there is no mixing of contaminated waters from a single well. Corrective treatment measures in all of the identified pockets are to be initiated for removal of selenium such as Activated Alumina, Coagulation/filtration, Lime softening, Reverse Osmosis, Iron Hydroxide etc. Pilot studies be conducted to assess the effectiveness of these techniques. District wise comprehensive study for heavy metals contamination due to urban and industrial activities should be undertaken urgently.

8. Groundwater is saline in southwerstern region of Punjab and districts which are mainly affected are Muktsar, Bathinda and Faridkot. State Govt. Departments have taken up several measures like surface drains etc. The effectiveness of existing surface drains should be studied. Projects on integrated farming systems for management of waterlogged saline groundwater regions be implemented. Introduction of salt resistant crops may be promoted in the waterlogged saline groundwater areas of Punjab. Comprehensive studies to identify location specific measures based on drainage, integrated farming systems, micro- irrigation systems and agronomic/ varietal interventions, needs to be taken up.

9. The monitoring mechanism for water quality needs to be strengthened in view of increasing contamination of water resources. Though various departments are carrying out studies at their own level on need basis. The responsibility of each department should be well defined, monitoring be done on scientifically proved principles and with an aim to provide comprehensive information which will help to draw a suitable action plan for the concerned Department. Water Quality Assessment Authority constituted by MOEF emphasizes on uniformity in the procedure for water quality monitoring mechanism by all monitoring agencies, departments, pollution Control Board and such other agencies so that water related action plan may be drawn up on the basis of reliable data. There is an urgent need to streamline the frequency of monitoring, procedure of sampling, data processing, reporting and dissemination at appropriate forum so that the data could be shared by concerned State/Central agencies for public causes.

10. Areas affected with water borne diseases like fluorosis, cancer etc. should be earmarked by concerned State Departments and suitable action plan be devised for its remediation. Community participation in various water quality restoration programme should be encouraged. Creating appropriate environmental awareness and providing scientifically based information to citizen is also equally important to motivate and sensitize them to protect the environment and spur them towards positive action. The users should be made aware of the importance of preventing contamination of water and also of the importance of clean and healthy surroundings near water sources.

11. In the light of the emerging trend of cancer incidence which is 30.54 per lakh population in the State, there is an urgent need to identify such vulnerable areas especially in Malwa region. The hotspots of cancer prevalence are to be identified based on scientific studies and to correlate these findings if at all they owe their origin due to contaminated water.

12. R&D studies need to be taken up by the premier Institutes of the State like PU, PAU with other research organizations to establish the cause and effects due to presence of heavy metals, uranium, arsenic and pesticides in water which poses serious health hazards to human being.

13. Advanced collaborative studies including foreign Institute participation are required to identify the sources of contamination, extent of pollution and cost effective remedial measures for protection and preservation of this precious resource.

14. Since quality of water is extremely important, there is a need for strengthening the infrastructure and dedicated manpower of the concerned organizations. The existing staff need to be trained in advanced technologies. There should also be strengthening of the organizations with adequate qualified manpower. These organizations be provided adequate funds to modernize the laboratories with advanced water quality analysis instruments. There should be adequate number of mobile labs in all districts to enable regular on the spot monitoring of the water quality. Water Quality Labs at districts level need to be strengthened with adequate facilities for water analysis.

Drinking water Standards - BIS (IS-10500, 1991) Annexure I

S. No.	Parameters	Desirable limits (mg/l)	Permissible limits (mg/l)
Essential Characteristics			
1	Colour Hazen unit	5	25
2	Odour	Unobjectionable	-
3	Taste	Agreeable	-
4	Turbidity (NTU)	5	10
5	pH	6.5 - 8.5	No relaxation
6	Total Hardness, $CaCO_3$	300	600
7	Iron (Fe)	0.3	1
8	Chloride (Cl)	250	1000
9	Residual Free Chlorine	0.2	-
10	Fluoride (F)	1	1.5
Desirable Characteristics			
11	Dissolved Solids	500	2000
12	Calcium (Ca)	75	200
13	Magnesium (Mg)	30	100
14	Copper (Cu)	0.05	1.5
15	Manganese (Mn)	0.1	0.3
16	Sulphate (SO_4)	200	400
17	Nitrate (NO_3)	45	100
18	Phenolic Compounds	0.001	0.002
19	Mercury (Hg)	0.001	No relaxation
20	Cadmium (Cd)	0.01	No relaxation
21	Selenium (Se)	0.01	No relaxation
22	Arsenic (As)	0.01	No relaxation
23	Cyanide (CN)	0.05	No relaxation
24	Lead (Pb)	0.05	No relaxation
25	Zinc (Zn)	5	15
26	Anionic Detergents (as MBAS)	0.2	1
27	Hexavelant Chromium	0.05	no relaxation
28	Poly Nuclear Hydrocarbons (as PAH)	-	-
29	Alkalinity	200	600
30	Aluminium (Al)	0.03	0.2
31	Boron (B)	1	5
32	Pesticides	Absent	0.001
33	Mineral Oil	0.01	0.03
34	Radioactive Material		
	Alpha Emmiters, Bq/l	-	.0.1
	Beta Emmiters, pci/l	-	1

NTU = Nephelometric Turbidity Unit

Water Quality Parameters For Drinking Purposes And Their Effects Annexure II

S. No.	Parameters	Prescribed limits IS:10500, 1991		Probable effects
		Desirable limit	Permissible limit	
1.	Colour (Hazen unit)	5	25	Makes water aesthetically undesirable.
2.	Odour	Essentially free from objectionable odour		Makes water aesthetically undesirable.
3.	Taste	Agreeable		Makes water aesthetically undesirable.
4.	Turbidity (NTU)	5	10	High turbidity indicates contamination/Pollution.
5.	pH	6.5	8.5	Indicative of acidic or alkaline waters, affects taste, corrosivity and the water supply system.
6.	Hardness as $CaCO_3$ (mg/l)	300	600	Affects water supply system (Scaling), Excessive soap consumption, calcification of arteries. There is no conclusive proof but it may cause urinary concretions, diseases of kidney or bladder and stomach disorder.
7.	Iron (mg/l)	0.30	1.00	Gives bitter sweet astringent taste, causes staining of laundry and porcelain. In traces it is essential for nutrition.
8.	Chloride (mg/l)	250	1000	May be injurious to some people suffering from diseases of heart or kidneys. Taste, indigestion, corrosion and palatability are affected.
9.	Residual Chlorine (mg/l) Only when water is Chlorinated	0.20	-	Excessive chlorination of drinking water may cause asthma, colitis and eczema.
10.	Total Dissolved Solids (mg/l) (TDS)	500	2000	Palatability decreases and may cause gastro-intestinal irritation in human, may have laxative effect particularly upon transits and corrosion, may damage water system.
11.	Calcium (Ca) (mg/l)	75	200	Causes encrustation in water supply system. While insufficiency causes a severe type of rickets, excess causes concretions in the body such as kidney or bladder stones and irritation in urinary passages. (Essential for nervous and muscular system, cardiac functions and in coagulation of blood.)
12.	Magnesium (Mg) mg/l	30	100	Its salts are cathartics and diuretic. High conc. may have laxative effect particularly on new users. Magnesium deficiency is associated with structural and functional changes. It is essential as an activator of many enzyme systems.
13.	Copper (Cu) mg/l	0.05	1.50	Astringent taste but essential and beneficial element in human metabolism. Deficiency results in nutritional anaemia in infants. Large amount may result in liver damage, cause central nervous system irritation and depression. In water supply it enhance corrosion of aluminium in particular.
14.	Sulphate (SO_4) mg/l	200	400	Causes gastro intestinal irritation Along with Mg or Na, can have a cathartic effect on users, concentration more than 750 mg/l may have laxative effect alongwith Magnesium.
15.	Nitrate (NO_3) mg/l)	45	100	Cause infant methaemoglobinaemia (blue babies) at very high concentration, causes gastric cancer and affects adversely central nervous system and cardiovascular system.
16.	Fluoride (F) mg/l	1.0	1.50	Reduces dental carries, very high concentration may cause crippling skeletal fluorosis.

17.	Cadmium (Cd) mg/l	0.01	-	Acute toxicity may be associated with renal, arterial hypertension, itai itai disease, (a bone disease). Cadmium salt causes cramps, nausea, vomiting and diarrhoea.
18.	Lead (Pb) mg/l	0.05	-	Toxic in both acute and chronic exposures. Burning in the mouth, severe inflammation of the gastro-intestinal tract with vomiting and diarrhoea, chronic toxicity produces nausea, severe abdominal pain, paralysis, mental confusion, visual disturbances, anaemia etc.
19.	Zinc (Zn) mg/l	5	15	An essential and beneficial element in human metabolism. Taste threshold for Zn occurs at about 5 mg/l, imparts astringent taste to water.
20.	Chromium (Cr^{+6}) mg/l	0.05	-	Hexavelant State of Chromium produces lung tumours can produce cutaneous and nasal mucous membrane ulcers and dermatitis.
21.	Boron (B) mg/l	1.00	5.00	Affects central nervous system its salt may cause nausea, cramps, convulsions, coma etc.
22.	Alkalinity mg/l $CaCO_3$	200	600	Impart distinctly unpleasant taste may be deleterious to human being in presence of high pH, hardness and total dissolved solids.
23.	Pesticides ìg/l	Absent	0.001	Imparts toxicity and accumulated in different organs of human body affecting immune and nervous systems may be carcinogenic.

Effects of water quality parameters in water on Livestock   Annexure III

S. No.	Parameters	Prescribed limits IS:10500, 1991		Probable effects
		Desirable limit	Permissible limit	
1.	Salinity (Total soluble salts mg/l)	1000	3000	High salinity may cause diarrhoea, is a risk to pregnant/lactating animals and increases mortality.
2.	pH	6.5	8.2	-
3.	Boron mg/l	1.0	5.0	No definite effect
4.	Cadmium mg/l	0.01	0.05	Cause permanent sterility, reduced longevity and malformation in foetus.
5.	Chromium mg/l	0.00	0.01	Not readily absorbed in animal tissue.
6.	Copper mg/l	0.1	0.5	Most livestock (except sheep) tolerate rather high levels.
7.	Iron mg/l	No limit recommended		-
8.	Lead mg/l	0.05	0.1	High levels may cause poisoning.
9.	Zinc mg/l	-	25	Relatively non toxic to animals. Very high levels may cause reduced water consumption, egg production and body weight.
10.	Nitrates mg/l	10	100	Leads to methaemoglobinaemia, erosion and haemorrhage of gastric mucosa leading to death. Cause reduction in plasma and vitamin A in liver.
11.	Pesticides	Absent	0.001	Non-lethal doses may affect growth rate, egg production and viability of the young.
12.	Pathogens	-	-	Water contaminated with parasitic organisms cause infection, serious livestock losses. Infected water may be a source for listeriosis, cause urinary disease abscesses and mastitis in livestock.
13.	Fluorides mg/l	1.0	2.0	High levels lead to tooth mottling and transferred into milk and eggs.

Surface Water Quality Standards-BIS   Annexure-III

Surface Water Quality Standards-BIS Annexure-III

Characteristic	Tolerance Limit				
	Class A	Class B	Class C	Class D	Class E
pH value	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5
Dissolved Oxygen (mg/l), min.	6	5	4	4	—
BOD (5-days at 20° C, mg/l, min.	2	3	3	—	—
Total Coliform Organism, MPN/100ml, max	50	500	5000	—	—
Colour, Hazen units, max.	10	300	300	—	—
Odour	10	300	300	—	—
Taste	Tasteless	—	—	—	—
Total dissolved solids, mg/l, max.	500	—	1500	—	2100
Total hardness(as $CaCo_3$), mg/l, max.	300	—	—	—	—
Calcium hardness (as $CaCO_3$), mg/l, max.	200	—	—	—	—
Magnesium hardness (as $CaCO_3$), mg/l, max.	100	—	—	—	—
Copper (as Cu), mg/l, max.	1.5	—	1.5	—	—
Iron (as Fe), Mg/l, max.	0.3	—	0.5	—	—
Manganese (as Mn), mg/l, max.	0.5	—	—	—	—
Chlorides (as Cl), mg/l, max.	250	—	600	—	600
Sulphates (as SO_4), mg/l, max.	400	—	400	—	1000
Nitrates (as NO_3), mg/l, max.	20	—	50	—	—
Fluorides (as F), mg/l, max.	1.5	1.5	1.5	—	—
Phenolic compounds (as C_6H_5 OH), mg/l, max.	0.002	0.005	0.005	—	—
Mercury (as Hg), mg/l, max.	0.001	—	—	—	—
Cadmium (as Cd), mg/l, max.	0.01	—	0.01	—	—
Salenium (as Se), mg/l, max.	0.01	—	0.05	—	—
Arsenic (as As), mg/l, max.	0.05	0.2	0.2	—	—
Cyanide (as CN), mg/l, max.	0.05	0.05	0.05	—	—
Lead (as Pb), mg/l, max.	0.1	—	0.1	—	—
Zinc (as Zn), mg/l, max.	15	—	15	—	—
Chromium (as Cr^{6+}), mg/l, max.	0.05	—	0.05	—	—
Anionic detergents (as MBAS) mg/l, max.	0.2	1	1	—	—
Polynuclear aromatic hydrocarbons, (as PAH)	0.2	—	—	—	—
Mineral oil, mg/l, max.	0.01	—	0.1	0.1	—
Barium (as Ba), mg/l, max.	1	—	—	—	—
Silver (as Ag), mg/l, max.	0.05	—	—	—	—

Pesticides	Absent	—	Absent	—	—
Alpha emitters, uC/ml, max.	10^{-9}	10^{-9}	10^{-9}		
Beta emitters, uC/ml, max.	10^{-8}	10^{-8}	10^{-8}	10^{-8}	10^{-8}
Free ammonia (as N), mg/l, max.	—	—	—	1.2	—
Electrical conductance at 25° C, mhos, max.	—	—	—	1000×10^{-6}	2250×10^{-6}
Free carbon dioxide (as CO), mg/l, max.	—	—	—	61	—
Sodium absorption ratio	—	—	—	—	26
Boron (as B), mg/l, max.	—	—	—	—	—
Percent sodium, max.	—	—	—	—	—

*Explanation for Symbols:

A: Drinking water sources without conventional treatment but after disinfection.

B: Organized outdoor Bathing.

C: Drinking water sources with conventional treatment followed by disinfection.

D: Propogation of wild life and Fisheries.

E: Irrigation, industrial cooling and controlled water disposal.

Effects of water quality parameters in Irrigation water (IS:10500, 1991) Annexure IV

S. No.	Parameters	Prescribed limits IS:10500, 1991		Probable effects
		DL	PL	
1.	Salinity/EC in ìmhos/cm at 25[0]	Sensitive Crops < 1500 Semitolerant 1500-3000 Tolerant crop > 3000		Plant growth is retarded with stunted fruits, leaves and stem in high salinity.
2.	Sodicity/SAR	SAR < 10 10 - 18 18 - 26 > 26	Excellent Good Medium Bad	Causes defloculation of soil, restricting free movement of water.
3.	R.S.C. meq/l	< 1.25 1.25 - 2.5 > 2.5	Excellent Good Bad	Result in increase of sodium causing adverse effect.
4.	Sodium (Na) %	No guideline		Increase total salinity, has adverse effect on sodium sensitive species such as stone fruit trees and avocados. Effects soil structure & permeability.
5.	Chloride (Cl) mg/l	No guideline		May have direct toxic effects alongwith sodium.
6.	Nitrate (NO_3) mg/l	No guideline		An essential plant nutrient but its excess may delay maturity and seed growth in some plants.
7.	Boron (B) mg/l	Sensitive crops < 1.0 Semi tolerant crops 1.0-2.0 Tolerant crops 2.0 - 4.0 Unsatisfactory for most crops > 4.0		An essential plant nutrient at low concentration but high conc. are toxic to plant.
8.	Copper (Cu) mg/l	0.20[a]	5.00[b]	Essential for plants as a micro nutrient. Deficiency may cause crop damages, chlorosis also leading to dieback of plant.
9.	Lead (Pb) mg/l	5.20[a]	10.00[b]	Some plants accumulate it which may have harmful effects on human health. Very high concentration may reduce root growth.
10.	Zinc (Zn) mg/l	2.00[a]	10.00[b]	An essential plant nutrient as activator of enzymes. Deficiency leads to several diseases such as by ionising, rosette or little leaf. High concentration produces toxic effects.
11.	Chromium (Cr) mg/l	0.10[a]	1.00[b]	Toxic to plants. Very high conc. may reduce growth, produce iron deficiency in plants and reduce the yields.
12.	Cadmium (Cd) mg/l	0.01[a]	0.5[b]	Reduces plant growth, bio-accumulates in plants, cause adverse effects (ilai-ilai) on human consumption, reduces yields.
13.	Iron (Fe) mg/l	5.0[a]	20.0[b]	An important and essential element. Deficiency caused by excess of lime in soils, results in chlorosis. Excess iron contribute to soil acidification.
14.	Nickel (Ni) mg/l	0.20[a]	2.0[b]	Cause stunded growth of plant in the concentration 0.5 mg/l. Toxic to barley, beans, Oats, when more than 2.0 mg/l.

a= Continuous use; b =Short term use on fine texture soils.

Water quality parameters for Industries and their Probable Effects   Annexure V

S. No.	Parameters	Prescribed limits IS:10500, 1991		Probable effects
		Desirable	Permissible	
1	pH	6.5	8.2	Low pH increases corrosion of concrete; pH 7 is required for most industries, pH 6.7-7.2 is advised for carbonated beverage industry.
2	Total dissolved solids, mg/l	500	3000	Causes foaming in boilers and solids interfere with clearness, colour or taste of finished products. Low TDS values are required in most industries, high TDS leads to corrosion.
3	Iron, mg/l	0.1	2.0	Recommended value for food processing units is 0.2mg/l, for paper and photographic industry iron of 0.1 mg/l is recommended, iron less than 0.1 mg/l is recommended in cooling waters.
4	Chloride, mg/l	25	200	Significantly effect the rate of corrosion of steel and aluminium.
5	Fluoride, mg/l	0.2	1.0	Harmful in industries involved in production of food, beverages, pharmaceuticals and medical items.
6	Calcium, mg/l	20	500	High calcium leads to spots on films. Have undesirable effects like forming scale, precipitates and curds in industry. It may interfere in formation of emulsions and processing of colloids upsetting fermentation process and electroplating rinsing operations.
7	Magnesium, mg/l	5	30	No definite effect
8	Sulphate, mg/l	25	250	Increases corrosiveness of water towards concrete, low sulphate (20mg/l) is recommended for sugar industries.
9	Nitrate, mg/l	15	30	Injurious to dyeing of wool and silk fabrics and harmful in fermentation process for brewing. Nitrate in some water protects metals in boilers from inter-crystalline cracking.
10	Copper, mg/l	0.01	0.5	Copper is undesirable in food industry as it has colour reactions and imparts fishy taste to finished products. Affects smoothness and brightness of metal deposits in metal plating, baths.
11	Chromium, mg/l	N.A.	N.A.	It is corrosion inhibitor.
12	Zinc, mg/l	N.A.	N.A.	Zinc bearing water should not be used in acid drinks like lemonade
13	Lead, mg/l	N.A.	N.A.	Trace of lead in metal plating baths will affect smoothness and brightness of deposits.

N.A.= Not Available

Annexure VI

Pesticides, Organic constituents of health significance (WHO-2008)

S.No.	Substance	Formula	Health based guideline by the WHO
1	Alachlor	$C_{14} H_{20} Cl N O_2$	20 µg/l
2	Aldicarb	$C_7 H_{14} N_2 O_4 S$	10 µg/l
3	Aldrin and dieldrin	$C_{12} H_8 C_{l6}$//$C_{12} H_8 Cl_6 O$	0.03 µg/l
4	Atrazine	$C_8 H_{14} Cl N_5$	2 µg/l
5	Bentazone	$C_{10} H_{12} N_2 O_3 S$	30 µg/l
6	Carbofuran	$C_{12} H_{15} N O_3$	5 µg/l
7	Chlordane	$C_{10} H_6 Cl_8$	0.2 µg/l
8	Chlorotoluron	$C_{10} H_{13} Cl N_2 O$	30 µg/l
9	DDT	$C_{14} H_9 Cl_5$	2 µg/l
10	1,2-Dibromo-3-chloropropane	$C_3 H_5 Br_2 Cl$	1 µg/l
11	2,4-Dichlorophenoxyacetic acid (2,4-D)	$C_8 H_6 Cl_2 O_3$	30 µg/l
12	1,2-Dichloropropane	$C_3 H_6 Cl_2$	No guideline
13	1,3-Dichloropropane	$C_3 H_6 Cl_2$	20 µg/l
14	1,3-Dichloropropene	$CH_3 CHClCH_2 Cl$	No guideline
15	Ethylene dibromide (EDB)	$Br CH_2 CH_2 Br$	No guideline
16	Heptachlor and heptachlor epoxide	$C_{10} H_5 Cl_7$	0.03 µg/l
17	Hexachlorobenzene (HCB)	$C_{10} H_5 Cl_7 O$	1 µg/l
18	Isoproturon	$C_{12} H_{18} N_2 O$	9 µg/l
19	Lindane	$C_6 H_6 Cl_6$	2 µg/l
20	MCPA	$C_9 H_9 Cl O_3$	2 µg/l
21	Methoxychlor	$(C_6H_4OCH_3)_2CHCCl_3$	20 µg/l
22	Metolachlor	$C_{15} H_{22} Cl N O_2$	10 µg/l
23	Molinate	$C_9 H_{17} N O S$	6 µg/l
24	Pendimethalin	$C_{13} H_{19} O_4 N_3$	20 µg/l
25	Pentachlorophenol (PCP)	$C_6 H Cl_5 O$	9 µg/l
26	Permethrin	$C_{21} H_{20} Cl_2 O_3$	20 µg/l
27	Propanil	$C_9 H_9 Cl_2 N O$	20 µg/l
28	Pyridate	$C_{19}H_{23}ClN_2O_2S$	100 µg/l
29	Simazine	$C_7 H_{12} Cl N_5$	2 µg/l
30	Trifluralin	$C_{13} H_{16} F_3 N_3 O_4$	20 µg/l
31	Chlorophenoxy herbicides (excluding 2,4-D and MCPA)	2,4-DB $C_{10} H_{10} Cl_2 O_3$	90 µg/l
	Dichlorprop	$C_9 H_8 Cl_2 0_3$	100 µg/l
	Fenoprop	$C_9H_7Cl_3O_3$	9 µg/l
	MCPB	$C_{11} H_{13} Cl O_3$	No guideline
	Mecoprop	$C_{10}H_{11}ClO_3$	10 µg/l
	2,4,5-T	$C_8 H_5 Cl_3 O_3$	9 µg/l

Annexure VII

Organic Compounds of health significance (WHO-2008)

Group	Substance		Formula	Health based guideline by the WHO
Chlorinated alkanes	Carbon tetrachloride		$C\ Cl_4$	2 µg/l
	Dichloromethane		$C\ H_2\ Cl_2$	20 µg/l
	1,1-Dichloroethane		$C_2\ H_4\ Cl_2$	No guideline
	1,2-Dichloroethane		$Cl\ CH_2\ CH_2\ Cl$	30 µg/l
	1,1,1-Trichloroethane		$CH_3\ C\ Cl_3$	2000 µg/l
Chlorinated ethenes	1,1-Dichloroethene		$C_2\ H_2\ Cl_2$	30 µg/l
	1,2-Dichloroethene		$C_2\ H_2\ Cl_2$	50 µg/l
	Trichloroethene		$C_2\ H\ Cl_3$	70 µg/l
	Tetrachloroethene		$C_2\ Cl_4$	40 µg/l
Aromatic hydrocarbons	Benzene		$C_6\ H_6$	10 µg/l
	Toluene		$C_7\ H_8$	700 µg/l
	Xylenes		$C_8\ H_{10}$	500 µg/l
	Ethylbenzene		$C_8\ H_{10}$	300 µg/l
	Polynuclear Aromatic		$C_2\ H_3\ N_1\ O_5\ P_{13}$	0.7 µg/l
	Hydrocarbons (PAHs)			
Chlorinated benzenes	Monochlorobenzene (MCB)		$C_6\ H_5\ Cl$	300 µg/l
	Dichlorobenzenes (DCBs)	1,2-Dichlorobenzene (1,2-DCB)	$C_6\ H_4\ Cl_2$	1000 µg/l
		1,3-Dichlorobenzene (1,3-DCB)	$C_6\ H_4\ Cl_2$	No guideline
		1,4-Dichlorobenzene (1,4-DCB)	$C_6\ H_4\ Cl_2$	300 µg/l
	Trichlorobenzenes (TCBs)		$C_6\ H_3\ Cl_3$	20 µg/l
Miscellaneous organic constituents	Di(2-ethylhexyl) adipate (DEHA)		$C_{22}\ H_{42}\ O_4$	80 µg/l
	Di(2-ethylhexyl)phthalate (DEHP)		$C_{24}\ H_{38}\ O_4$	8 µg/l
	Acrylamide		$C_3\ H_5\ N\ O$	0.5 µg/l
	Epichlorohydrin (ECH)		$C_3\ H_5\ Cl\ O$	0.4 µg/l
	Hexachlorobutadiene (HCBD)		$C_4\ Cl_6$	0.6 µg/l
	Ethylenediaminetetraacetic acid (EDTA)		$C_{10}\ H_{12}\ N_2\ O_8$	200 µg/l
	Nitrilotriacetic acid (NTA)		$N(CH_2COOH)_3$	200 µg/l
	Organotins	Dialkyltins	$R_2\ Sn\ X_2$	No guideline
		Tributil oxide (TBTO)	$C_{24}\ H_{54}\ O\ Sn_2$	2 µg/l

Disinfectants and disinfectant by-products (WHO-2008)

Group	Substance		Formula	Health based guideline by the WHO
Disinfectants	Chloramines		$NHnCl^{(3-n)}$, where n = 0, 1 or 2	3 mg/l
	Chlorine		Cl_2	5 mg/l
	Chlorine dioxide		ClO_2	No guideline
	Iodine		I_2	No guideline
Disinfectant b5y-products6	Bromate		$Br\ O_3$-	25 µg/l
	Chlorate		$Cl\ O_3$-	No guideline
	Chlorite		$Cl\ O_2$-	200 µg/l
	Chlorophenols	2-Chlorophenol (2-CP)	$C_6\ H_5\ Cl\ O$	No guideline
		2,4-Dichlorophenol (2,4-DCP)	$C_6\ H_4\ Cl_2\ O$	No guideline
		2,4,6-Trichlorophenol (2,4,6-TCP)	$C_6\ H_3\ Cl_3\ O$	200 µg/l
	Formaldehyde		HCHO	900 µg/l
	MX (3-Chloro-4-dichloromethyl-5-hydroxy-2(5H)-furanone)		$C_5\ H_3\ Cl_3\ O_3$	No guideline
	Trihalomethanes	Bromoform	$C\ H\ Br_3$	100 µg/l
		Dibromochloromethane	$CH\ Br_2\ Cl$	100 µg/l
		Bromodichloromethane	$CH\ Br\ Cl_2$	60 µg/l
		Chloroform	$CH\ Cl_3$	200 µg/l
	Chlorinated acetic acids	Monochloroacetic acid	$C_2\ H_3\ Cl\ O_2$	No guideline
		Dichloroacetic acid	$C_2\ H_2\ Cl_2\ O_2$	50 µg/l
		Trichloroacetic acid	$C_2\ H\ Cl_3\ O_2$	100 µg/l
	Chloral hydrate (trichloroacetaldehyde)		$C\ Cl_3\ CH(OH)_2$	10 µg/l
	Chloroacetones		$C_3\ H_5\ O\ Cl$	No guideline
	Halogenated acetonitriles	Dichloroacetonitrile	$C_2\ H\ Cl_2\ N$	90 µg/l
		Dibromoacetonitrile	$C_2\ H\ Br_2\ N$	100 µg/l
		Bromochloroacetonitrile	$CH\ Cl_2\ CN$	No guideline
		Trichloroacetonitrile	$C_2\ Cl_3\ N$	1 µg/l
	Cyanogen chloride		Cl CN	70 µg/l
	Chloropicrin		$C\ Cl_3\ NO_2$	No guideline

Annexure IX

Tolerance Limit for Industrial Effulent Water Discharge (BIS)

Sr.	Characteristic	Maximum tolerance limits for industrial effluents discharged (mg/l)			
		Into inland surface water	**Into public sewers**	**On land for irrigation**	**Marine/ Coastal Area**
1	Colour and Odour	Absent	-	Absent	Absent
2	Suspended solids	100	600	200	a) For Process waste water 100 b) For cooling water effluent 10 percent above total suspended matter of effluent
3	Particle size of suspended solids	Shall pass 850 micron IS Sieve	-	-	a) Floatable solids, solids max. 3 mm b) Settleable solids max 856 microns
4	Dissolved solids (inorganic)	2100	2100	2100	
5	pH value	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0
6	Temperature ?C	Shall not exceed 40 in any section of the stream within 15 meters down stream from the effluent outlet	45 at the point of discharge	-	-
7	Oil and grease	10	20	10	20
8	Total residual chlorine	1	-	-	1
9	Ammonical nitrogen (as N)	50	50	-	50
10	Total kjeldahl nitrogen (as N)	100	-	-	100
11	Free ammonia (as NH3)	5	-	-	5
12	Biochemical Oxygen Demand (5 days at 20^0C)	30	350	100	100
13	Chemical Oxygen Demand	250	-	-	250
14	Arsenic (as As)	0.2	0.2	0.2	0.2
15	Mercury (as Hg)	0.01	0.01	-	0.01
16	Lead (as Pb)	0.1	1	-	2
17	Cadmium (as Cd)	2	1	-	2
18	Hexavelant Chromium (as Cr+6)	0.1	2	-	1
19	Total Chromium (as Cr)	2	2	-	2
20	Copper (as Cu)	3	3	-	30
21	Zinc (as Zn)	5	15	-	15
22	Selenium (as Se)	0.05	0.05	-	0.05
23	Nickel (as Ni)	3	3	-	-
24	Boron (as B)	2	2	2	-
25	Percent sodium	-	60	60	-

O/o Chief Engineer (South), Punjab
Water Supply and Sanitation Department, Patiala

To,

The Chairman
Central Ground Water Board
Bhujal Bhawan, NH-IV
Faridabad, Haryana

Dear Shri Sushil Gupta,

Water is the foundation of human society and will become even more critical as population growth and development of stakeholders /sectors put pressure on water resources in years ahead. Water resources of Punjab are affected by anthropogenic activities such as agricultural practices, urbanization and industrialization along with geogenic changes. This has resulted in both ground water and surface water pollution over space and time. Of late, serious concern has been expressed about deterioration of water quality in different parts of the state by many Organizations and people at large. Water quality problem has posed serious health hazards and inhabitants are affected by various water borne diseases. To mitigate this problem, various central and state departments, R&D institutions are actively engaged in water quality assessment and monitoring. Present report has successfully captured geo-chemical scenario of water resources in the State by integrating large volume of data generated by various organizations. I appreciate the effort of providing a wealth of information on surface and ground water quality, present status and its bearing on health hazards by Central Ground Water Board. This compendium will form a base for formulating the road map for pollution mitigation by various Central/State departments, academic Institutions, researchers and other stakeholders in Punjab State. I congratulate you for releasing this report for the use of people and planners.

Chief Engineer (South)

ਅ.ਸ.ਪੱ.ਨੰ: 136/PA/ASDO/R.

K.S.Takshi,

ਮੁੱਖ ਇੰਜੀਨੀਅਰ, ਰਾਵੀ

ਸਿੰਚਾਈ ਵਿਭਾਗ ਪੰਜਾਬ

ਚੰਡੀਗੜ੍ਹ

ਮਿਤੀ : 20-05-2013

Dear Sh. Sushil Gupta Ji,

I, take this opportunity to congratulate you on bringing out volume on **"Punjab Water Quality Issues and Challenges".** The volume has been nicely complied containing immense information on Hydro-chemical and hydrogeological conditions of the water resources in Punjab State. Any chemical imbalance in surface-ground water dynamics affects the ground water resource in terms of quality and quantity and the complete understanding of the hydro-chemical scenario and behaviour of ground water level are key components in understanding water quality issues and suitable management plan to safeguard the precious water resources of the State. The compiled volume would be useful in delineating vulnerable areas and planning road map to prevent pollution of water resources.

I congratulate Central Ground Water Board with special mention to you for offering such a valuable publication to Scientists, Planners and policy makers who are dealing with water resources.

With regards,

Sincerely your's,

20/5/13

(K.S.Takshi)

To,

Mr. Sushil Gupta,
Chairman,
Central Ground Water Board,
Bhujal Bhawan, NH-IV,
Faridabad, Haryana

PANJAB UNIVERSITY

Professor. R. Jindal
Chairman

Department of Environment Studies
Chandigarh.160 014 (India)

The Chairman
Central Ground Water Board
Bhujal Bhawan, NH-IV
Faridabad, Haryana

Respected Shri Sushil Gupta,

It is my pleasure to have an opportunity to look into the Volume "**Punjab Water Quality Issues and Challenges** ", proposed to be published by Central Ground Water Board. I congratulate that the volume has come up extremely well incorporating various information derived through hydro chemical analysis. Both the urban and rural areas are dependent on the ground water resources of the State and are under threat due to over exploitation and contamination due to geo-genic and anthro-pogenic reasons. The volume includes a well organized compilation incorporating figures & maps clearly elucidating hydro chemical and hydro-geological conditions and changing scenario of the water resources in Punjab making it interesting to readers. Awareness among the masses will be generated on the potential health hazards due to use of contaminated. I appreciate your efforts that the report provides comprehensive information on Water Quality Management strategies and overview all aspects of aquifer system of Punjab State. It will definitely serve as an indispensable reference book and tool for understanding and management of water resources in the State.

RJindal
23/5/2013
(R . Jindal)

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जल संरक्षण वर्ष 2013 Water Conservation Year

जल बचायें - जीवन बचायें Save Water - Save Life

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