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Efficiency Study of Damodar Left Bank Irrigation System and Strategies for Integrated Command Area Water Management

Final Report

Report submitted to the
Ministry of Water Resources, River Development & Ganga Rejuvenation
by

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Anirban Dhar

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Introduction

1.1 Overview

Cultivation of paddy is practiced extensively in many parts of India, and in fact is the staple food for almost entire south-east Asia (Calpe 2003). As commonly recognised (Brouwer et al. 1989), the basin irrigation technique is most suitable for paddy cultivation where the almost level land is divided into smaller “basins” by raising very low-height “bunds” or dykes along the basin peripheries. This helps holding the water within the basin for a longer time, an almost certain requirement for paddy cultivation. Basin irrigation is also suitable for cereal crops, which may also be grown in these basins during other times of the year as a part of crop rotation. Of course, the suitability of the crop grown depends upon the predominant type of soil in the region and availability of water. For paddy cultivation, generally grown in low-permeability soils like clay, these bunds help in keeping the basins inundated for longer periods of time. Inflow into each basin is from openings in the bunds bordering the watercourse through unregulated outlets (Figure 1.1). The source of water for irrigation in these basins may be from a surface water body or from groundwater (Figure 1.2).

Apart from irrigation of fields by individual sources of water, large irrigated areas, especially irrigated canal command areas often face the necessity of using multiple sources like that from the canal system supplemented by groundwater. This method of combined use of both surface and groundwater, commonly termed as “conjunctive water use”, is also considered important for reducing water logging in the fields, prevent salinisation, and reduce excessive depletion of the groundwater table. FAO (1995) describes "conjunctive use" as the harmonious combination of both sources of water in order to minimise undesirable physical, environmental and economical effects of each solution and to optimise the water demand/supply balance'. In fact, the Government of India is also actively emphasising the use of conjunctive water use for increasing water use efficiency in irrigated canal command areas (CWC 2014).

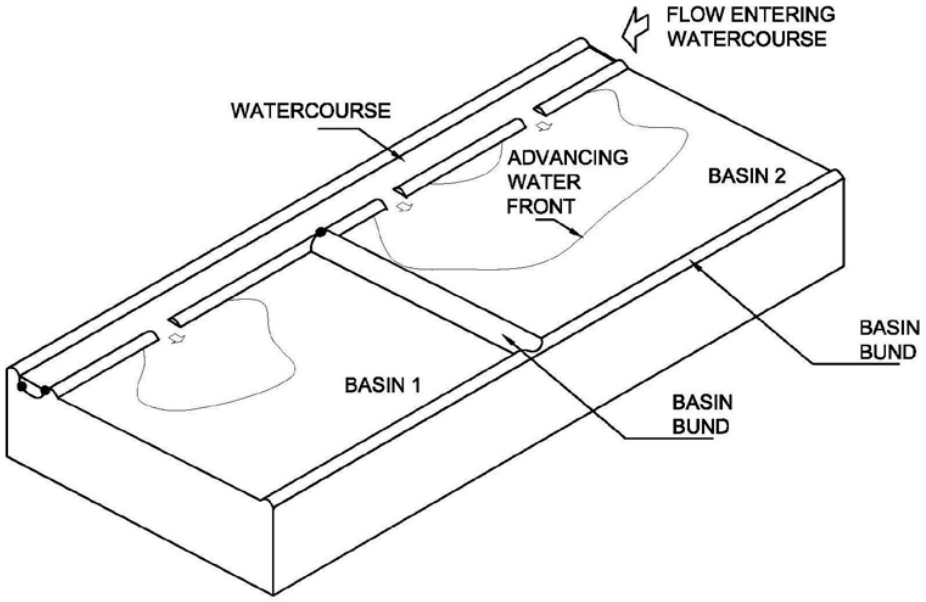


Figure 1.1: Basin irrigation by application of water in "basins" from a watercourse.

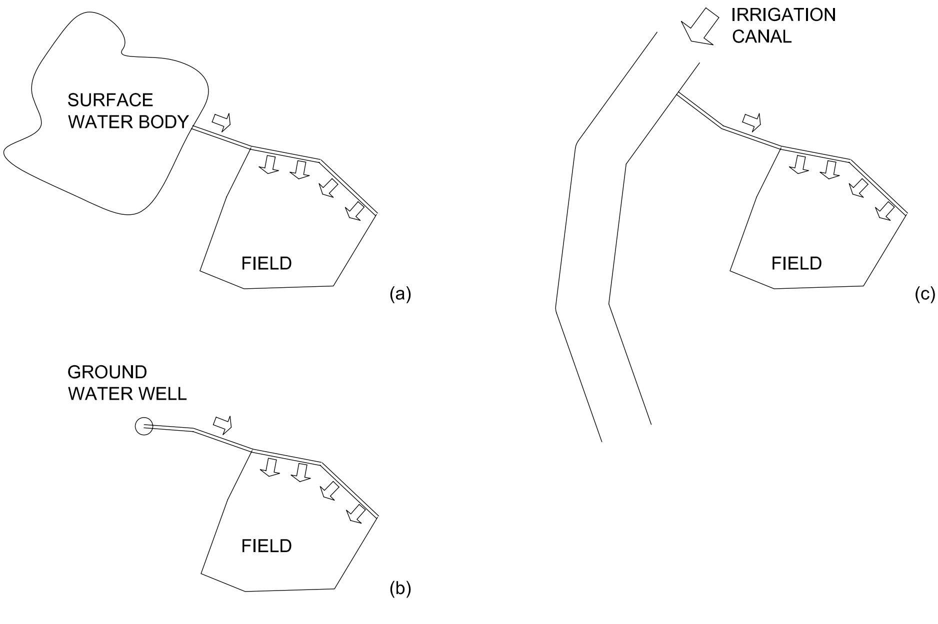


Figure 1.2: Possible sources of water for basin irrigation: (a) Surface water body, like a lake or pond; (b) Groundwater; and (c) Irrigation canal.

The project work presented in this report focuses on quantifying the water balance in a system of conjunctively irrigated area (or district, as it is called in some countries) where the predominant cultivated crop is paddy, requiring basin irrigation through canal water application. It is also considered that if the supplied irrigation water is not enough to meet the crop evapotranspiration demand, the water to the fields is to be supplemented by water pumped from the underlying unconfined aquifer. It may be kept in mind that this aquifer is hydraulically connected to the basins as it receives the infiltrated water for replenishment. The overall philosophy of the work is to represent the concerned processes of irrigation in such a system by physically based governing equations and solving these using suitable numerical techniques in an integrated setup. The attempt is to create a deterministic model of a basin irrigation system where, with a given quantity of canal inflow and a known amount of rainfall, it is possible to predict the position of the groundwater table for a specified crop type. As is recognised, excessive depletion of groundwater table is considered harmful to the environment and thus its prediction under different conditions is of utmost importance to the society in general and to planners in particular. This research work, therefore, attempts to contribute in this direction by providing a scientific tool to the decision makers in obtaining rational inferences under specified conditions as experienced in basin irrigated canal command areas.

1.2 Basin irrigation for Paddy cultivation

The application of water in basin irrigated plots is either by direct conveyance of water to the field or by the cascade method where the excess water from one field is conveyed to the next, lower in elevation, by gravity (Brouwer et al. 1989). These two processes may work together as shown in Figure 1.3.

As the water enters the basin from the opening(s) in the bunds, a front of water spreads over the soil surface as it progresses towards the far end of the basin. Simultaneously, water infiltrates into the soil from the wetted area behind the moving front. The flow within each basin is largely two-dimensional as the depth of water is much smaller compared to the horizontal extent of the basins. As the water completely fills up a basin, it starts accumulating, or inundating the basin, a phenomenon commonly termed as "ponding". It may be appreciated that as the slope of the basins is generally low, the dynamic nature of the flow assumes importance only during the advancement of the water front (Figure

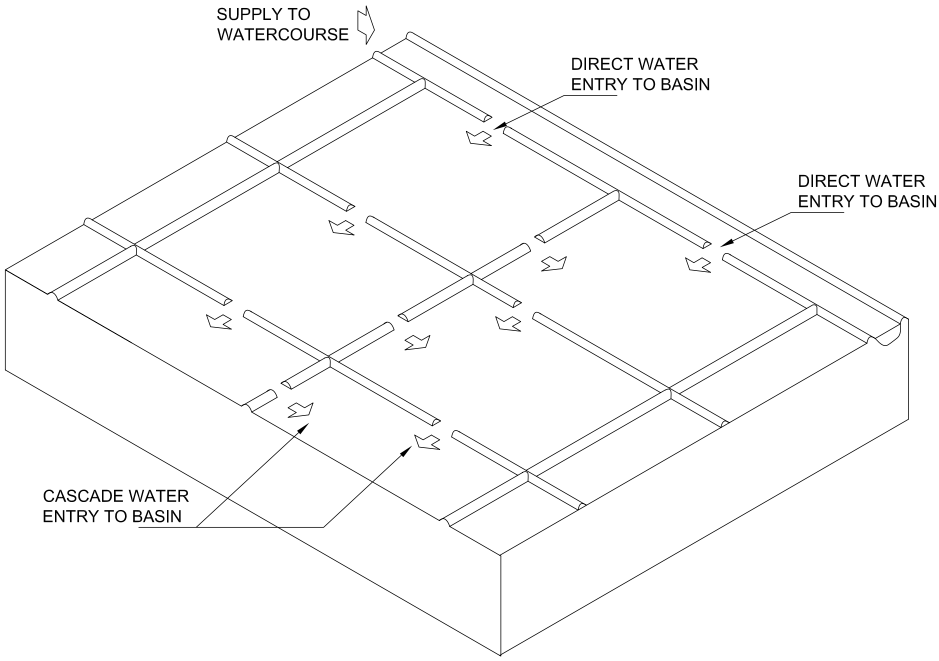


Figure 1.3: Basin irrigation by a combination of the “direct” and the “cascade” methods.

1.4a). During ponding, which occurs over a longer time, only a mass conservation takes place between the inflowing sources and losses due to infiltration and evapotranspiration, if any (Figure 1.4b).

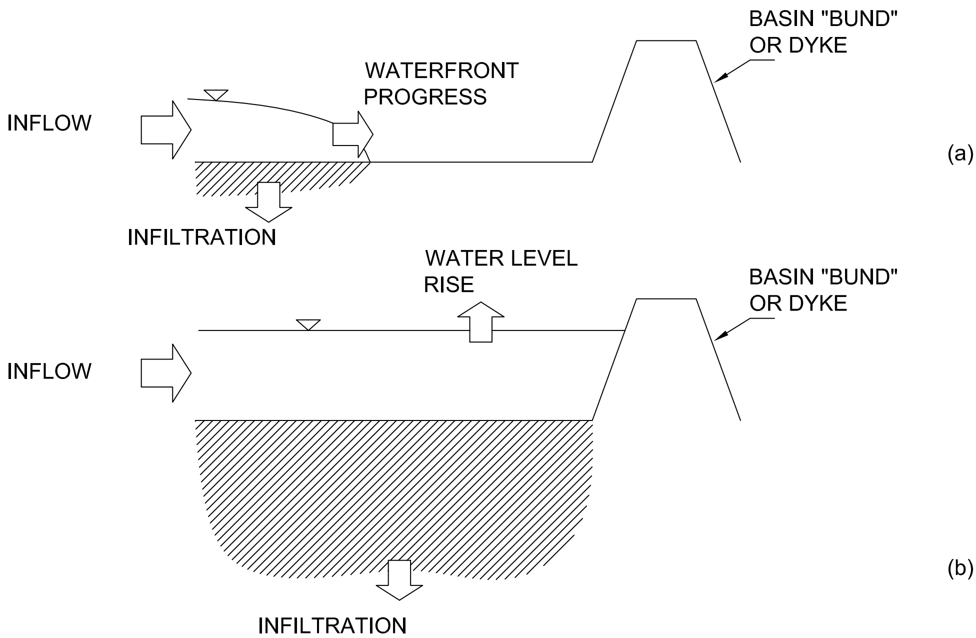


Figure 1.4: Basin water movements (a) Waterfront advance in a basin during initial “wetting” stages; (b) Water accumulation during “ponding”.

According to Brouwer et al. (1989) for good crop growth the root zone has to be saturated uniformly and the right amount of water has to be applied to the fields for a designed period of time in order to maintain the near-uniform saturation level of the soil. Under- or over-irrigation is considered harmful to crop growth. This is generally true for all crops, except paddy, where the water in the basin is allowed to pond up as it is considered favourable for its cultivation and also helpful in discouraging weed growth. Thus, for other crops, the advancement of water from the inlet to the far end needs to be carefully estimated, with the water source shut off once the soil has achieved the requisite moisture level. For paddy cultivation, however, the cultivator has to wait not only for the water front to cover the entire basin, which takes a relatively shorter time, but also for the water to head up in the basin up to a certain depth. This depth of ponding varies according the practice followed in a region or the type of paddy grown but is generally seen to vary between 50 *mm* to 150 *mm*. Once the desired ponding depth is reached, the water overflows to the next basin usually through a cut in the basin bund. In this way, the water migrates from one basin to the next till there is no more excess water to cross the bunds. The basins beyond those partially filled thus remain deprived of sufficient water, unless irrigated by an alternate source. The present work focuses on the paddy cultivation in canal irrigated areas, where this practice of cascade basin flooding is dominant.

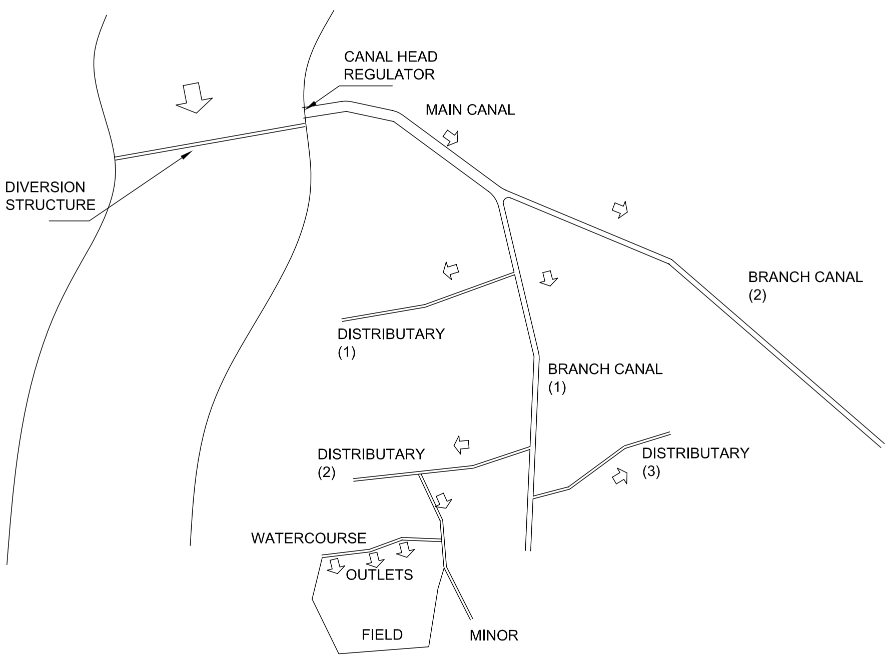


Figure 1.5: Canal network system showing the hierarchy of branches.

1.3 Water distribution in the canal command areas

Although the paddy fields are largely irrigated by the cultivators' individual water sources, quite a few irrigation schemes have been implemented in India for utilising river water with the help of a diversion structure (weir or barrage) and distributing the diverted water through a suitable canal network to a designated command area. In such schemes, the diverted flow is typically routed through a network of canal branch hierarchy (CBIP 1991), as shown in Figure 1.5.

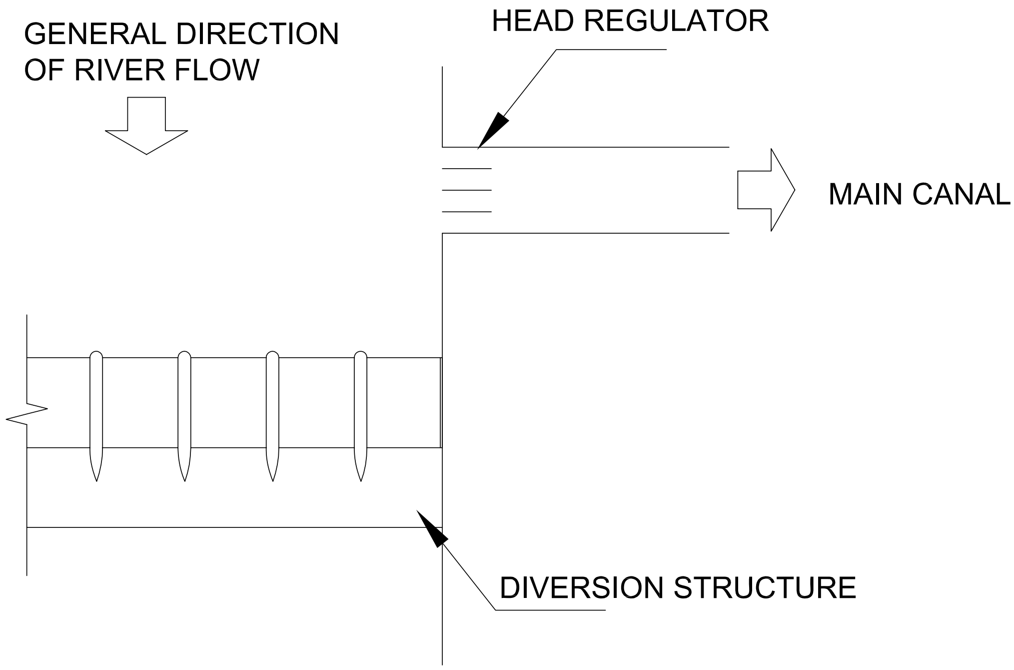


Figure 1.6: Diversion structure and main canal head-regulator.

The main canal takes off from the diversion structure through what is known as the "head regulator" (Figure 1.6). Within the canal network, the flows from the main canal to the branches and from there on to the distributaries and subsequently to the minors pass through controlling regulators, as shown in Figure 1.7 for a typical distribution junction. The regulators are named, according to their function, such as the "cross regulator" (located across the main channel for heading up the flow) or the "head regulator" (located at the head of the off-taking branch). The distribution of flow through the network of canals by operating the regulators is generally administered by a State controlled irrigation command area management authority.

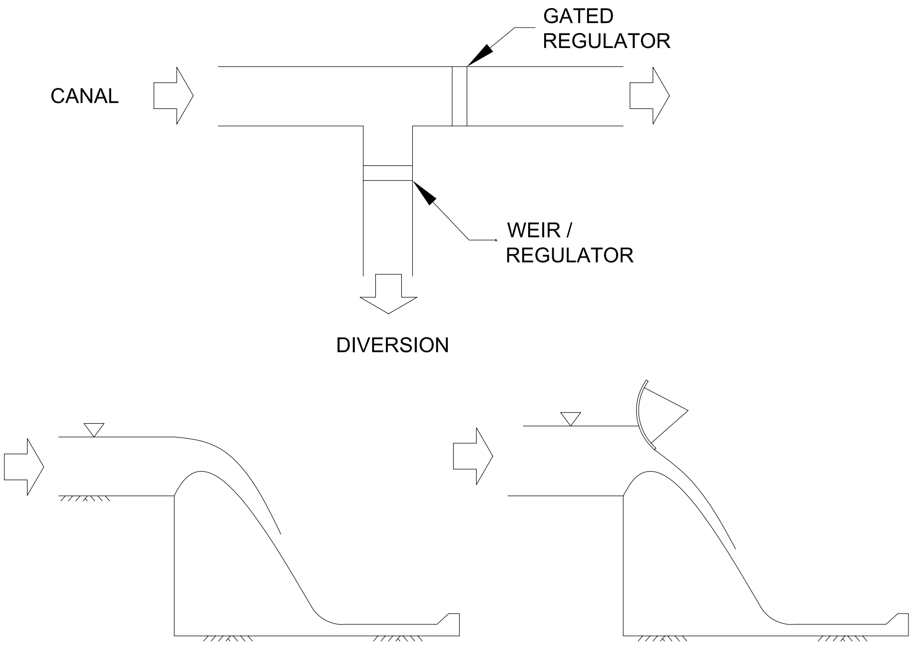


Figure 1.7: Regulators for control of flow into off-taking branches of a canal.

1.4 Water management in the fields and its problems

Once the flow reaches the water course from the State administered canal system, it is generally left to the water users (the cultivators) for mutual sharing. At this stage, cultivators' collectives, commonly known as the Water Users' Associations (WUA-s), play a role in deciding the distribution of water amongst the plots belonging to the different cultivators. These cooperative organisations of the water users usually decide on sharing the water on a rotational basis. Broadly, four such rotational distribution systems have been practiced in the Indian subcontinent. These are (CBIP 1991): (a) the "Warabandi system", followed in Northwest India (and Pakistan), (b) the "Shejpali system", practiced in Western India (mainly in the States of Gujarat and Maharashtra), (c) the "Localized system" followed in the Southern States of Andhra/Telengana, Karnataka, and parts of Odisha, and (d) the "Zonal system" practiced mostly in the State of Tamil Nadu. Details about these rotational systems of water distribution amongst the stakeholders, some of which date back to more than a century or more, may be found in CBIP (1991) and Narain (2003).

In some parts of India, however, like in the East and Northeast of the country, where large irrigation projects have come up relatively recently over the past few decades, there appears to be a lack of such organised Water User's Associations leading to over-irrigation by the cultivators in the head-reaches of the water distribution system as compared to those at the tail-ends. One such relatively large storage and irrigation project that came up during the 1960-s is the Damodar Valley Corporation (DVC) project, set up in the lines of the Tennessee Valley Authority of the USA (Chaudhuri 2000). The project includes several dams in the upper catchment of the river Damodar and its tributaries and an irrigation project in the middle reach of the river. The administration of the irrigation project was eventually handed over from the control of the Corporation to the Irrigation and Waterways Directorate (IWD) of the Government of the State of West Bengal. The IWD, depending upon the availability of water each season, distributes fixed quantity of water in the branches of the canal system for given periods of time. However, though the distribution of water in the canals is decided by the administrators of the IWD, there is practically no systematic water sharing agreement among the cultivators. The lack of a Water User's Association on the lines of what has been prevalent in the rest of the country and mentioned previously results in a strong imbalance in equitable water use, with the cultivators at the head reach enjoying a disproportionately larger share of water than those at the tail end. The tail-end cultivators of the command area, therefore, invariably resort to groundwater pumping for meeting the water requirement of paddy, a rather water-intensive crop. This discrepancy in water distribution becomes even more glaring during the cultivation of the "Boro" or summer paddy. During this time, coinciding with the direst period of the year, the allocable water into the canals is low and the IWD has to resort to water rationing depending upon the available water in the storage dams as communicated to them by the DVC authorities. The supply of water to the canal branches is restricted by closing the cross regulators at different locations of the canal system. This system allows the canal water to travel only up to certain lengths along the canal and its branches from the head-works. Thus for a large portion of the tail-end reaches of this irrigation system, groundwater remains the only source to raise Boro paddy.

The deprivation of the tail-enders, and consequent over extraction of groundwater in those stretches, has been recognised as a prime issue of concern in many canal command areas (DSC 2004). One reason for this mismanagement of water at the field level is the absence of a rational water distribution "Decision Support System (DSS)". Looking deeper, it may be conjectured that the lack of a quantitative water balance scheme for such an irrigation system may be blamed at least partially on the lack of a scientific evaluation tool for water distribution in the fields.

As mentioned above, the over-utilisation of the canal water in the upper reaches requires the tail-end cultivators of the command area to irrigate their fields with water from extracted from the shallow (unconfined) groundwater reservoir. This source of water is primarily recharged in two ways: (a) with the precipitation falling directly over the surface and infiltrating below, and (b) by the infiltrated water from the basins fed by the surface irrigation system of the canal command areas.

1.5 Objectives of the Project

It is apparent from the observation in the preceding section that the decision on water distribution in the fields in at least some canal irrigation command areas requires an appropriate rational and scientific tool for evaluating the possible scenarios scientifically. The objective of this present study is to fill in this gap with a mathematical basis for the problem by attempting to numerically model the various processes of the irrigation system in a canal irrigated basin-flooded command area as closely as possible. It is hoped that the decision makers and planners involved in water management may benefit by this tool in arriving at rational solutions of water distribution in their respective irrigation districts. The specific objectives are as given below

- Assessment of the present water resource scenario of left bank irrigation system.
- Modelling of irrigation water requirement and evaluation of application efficiency.
- Modelling of ground water flow and conjunctive use with surface water.
- Development and implementation of a computer program for canal network flow simulation and comparison with an established commercially available program.
- Modelling of canal flow and evaluation of its efficiency.

- Integration of the canal network flow and ground water flow models for conjunctive water use.

- Investigation of possibility of the storage of spilled water from upstream dam(s).

1.6 Assessment of the present water resource scenario of DVC irrigation system

DVC irrigation system originally envisaged an irrigation potential of 393927 ha for Kharif and 40486 ha for Rabi Irrigation. In addition to Kharif and Rabi irrigation, Boro rice cultivation which was not a part of outflow from original proposal, has also been extended depending upon the availability of surplus water after taking into account all the committed requirements.Boro rice has been cultivated during mid-January to mid-April which is the most water scarcity period as rainfall during this period is very scanty. As a result, a large volume of water is distributed during this time, leading to massive water scarcity in some portions of the command area. In fact, since the cultivation of this rice form is prevalent not only in the head reaches of the canal network, but almost throughout the command area, the farmers in the middle and lower reaches are entirely dependent upon ground water. As a result, the ground water has seen a significant decrease over the past few decades. Hence a long term analysis of spatio-temporal change in Boro rice cropping pattern in DVC command area was carried out for assessment of present water scenario of DVC irrigation system. GIS and remote sensing platforms were used for georeferencing and delineation of the study area. The boundary of study area was digitized and was used to clip satellite images of different years. In this study Boro rice cropping pattern were identified from Landsat imageries. Landsat has a spatial resolution of 30 m with temporal resolution of 16 days. Landsat-5 TM, Landsat-7 ETM+ and Landsat-8 OLI images during Boro rice season (Jan- April) were acquired for a period of thirty years i.e. from 1988 to 2018 from USGS Global Visualization Viewer (GloVis) (http://glovis.usgs.gov). Cubic Convolution (CC) method was used to resample the satellite images which were in GeoTiff format and projected in Universal Transverse Mercator (UTM) with datum World Geodetic System (WGS) 84. The pre-processed images were then classified by unsupervised classification methods using ISODATA clustering algorithm which classify according to required number of classes and digital number of the pixels available. Two land cover classes namely Boro rice and other land use cover were identified in the study area. Built up area, barren land and water bodies were considered in other land use category. Based on this classification areal expansion of Boro rice and other land use cover during the last 30 years in DVC area was calculated and rice map were generated. Accuracy assessment of resultant rice maps was done using the high resolution images extracted from Google earth along with ground control points and field photos taken during field survey. It was observed that in 1988, 5057.39 km^2 areas were under other land use category while 1935.64 km^2 areas were under Boro rice cultivation which accounts 28% of study area. In 1989, 1942.709 Km^2 areas was under Boro rice cultivation while 5050.324 km^2 areas were under other land use categories. The Boro rice map of year 1988, 1989 are shown in Figure 1.8 and 1.9. A decreasing trend of rice cropping areas were seen in the year 1990, 1991 and 1992 with 1739.05 Km^2, 1839.89 Km^2, 1757.89 Km^2 area under Boro rice cropping system whereas in the year 1993 and 1994, there was sharp increase in area under Boro rice cultivation. Rice map of 1990, 1991, 1992, 1993 are shown in Figure 1.10, 1.11,1.12 & 1.13.

In the year 1993, 2471.95 Km^2 areas were under Boro cultivation which increased to 3157.825 Km^2 in year 1994. In 1995, 1855.15 Km^2 areas were under Boro rice cultivation while 5137.887 Km^2 areas were under other land use categories.In year 1996, 1997 the areas under Boro rice cultivation again increased to 2248.16 Km^2 and 3682.403 Km^2 where 4744.88 Km^2 and 3310.63 Km^2 areas were under other land use categories respectively. Rice map of year 1994, 1995, 1996 and 1997 are shown in Figure 1.14, 1.15, 1.16 & 1.17.

In the year 1998, 40% of area was under Boro rice cultivation which increased to 47% in the year 1999 and 60% of area was under other land use categories which decreased to 53% in the year 1999 as shown in Figure 1.18 & 1.19. In year 2000, 4277.61 km^2 areas was under Boro cultivation which comprised 61% of total area whereas area under other land use decreased to 2715.42 km^2 which was about 39% of study area. In 2001, the percentage of area under Boro rice cultivation again decreased to 42% while area under other land use cover increased to 58%. Boro rice map of study area in the year 2000 and 2001 are shown in Figure 1.20 & 1.21.

In year 2002, 3449.88 km^2 areas were found under Boro rice cultivation which

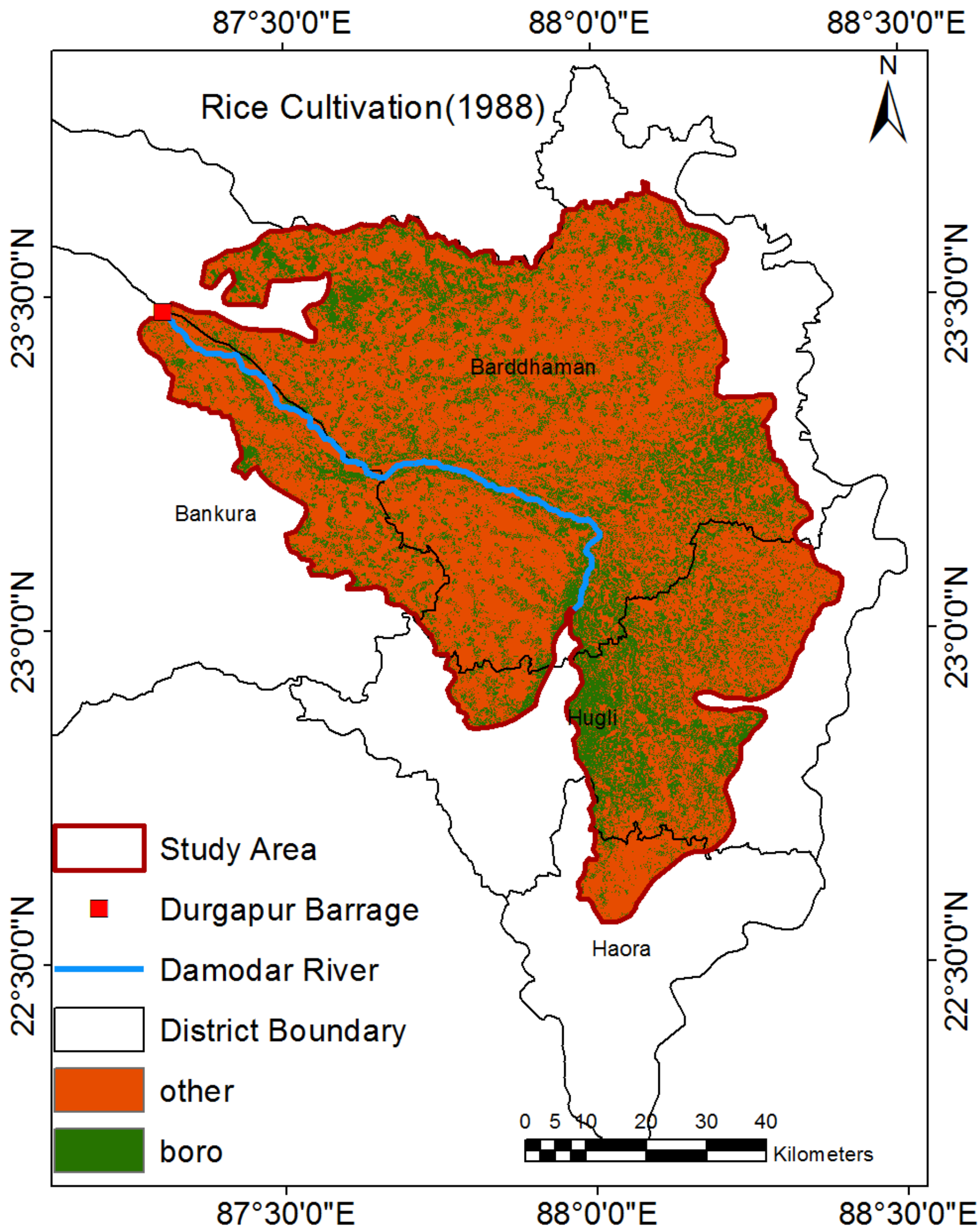


Figure 1.8: Boro rice map of DVC irrigation system in year 1988

comprised 49% of total study area and 3543.16 km^2 areas were under other land use categories. Similar percentage of area under Boro rice was also found in the

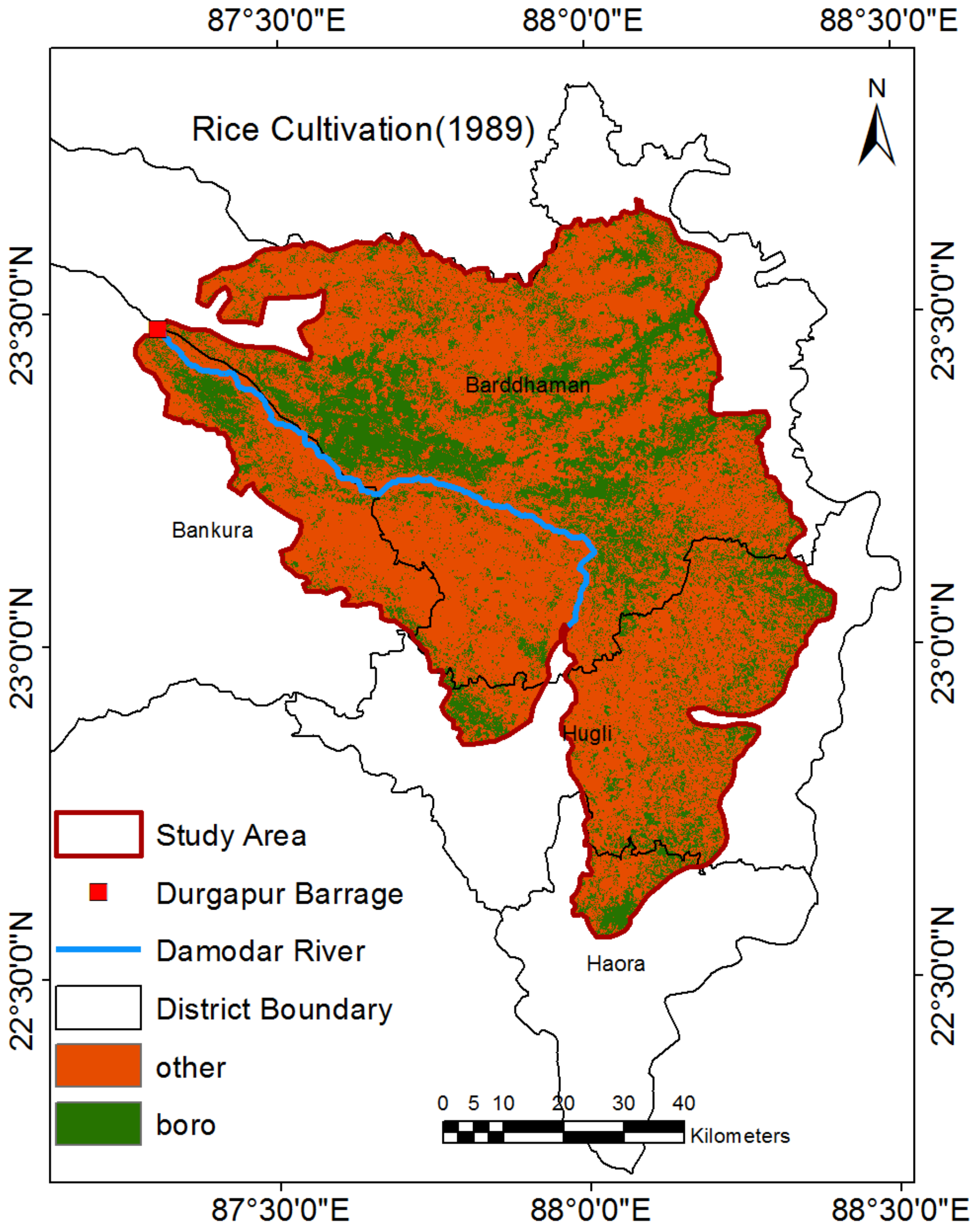


Figure 1.9: Boro rice map of DVC irrigation system in year 1989

year 2003, 2004 and 2005 which covered 3430.45 km^2, 3386.48 km^2 and 3343.52 km^2 respectively. Figure 1.22 to 1.25 show the Boro rice map of year 2002, 2003,

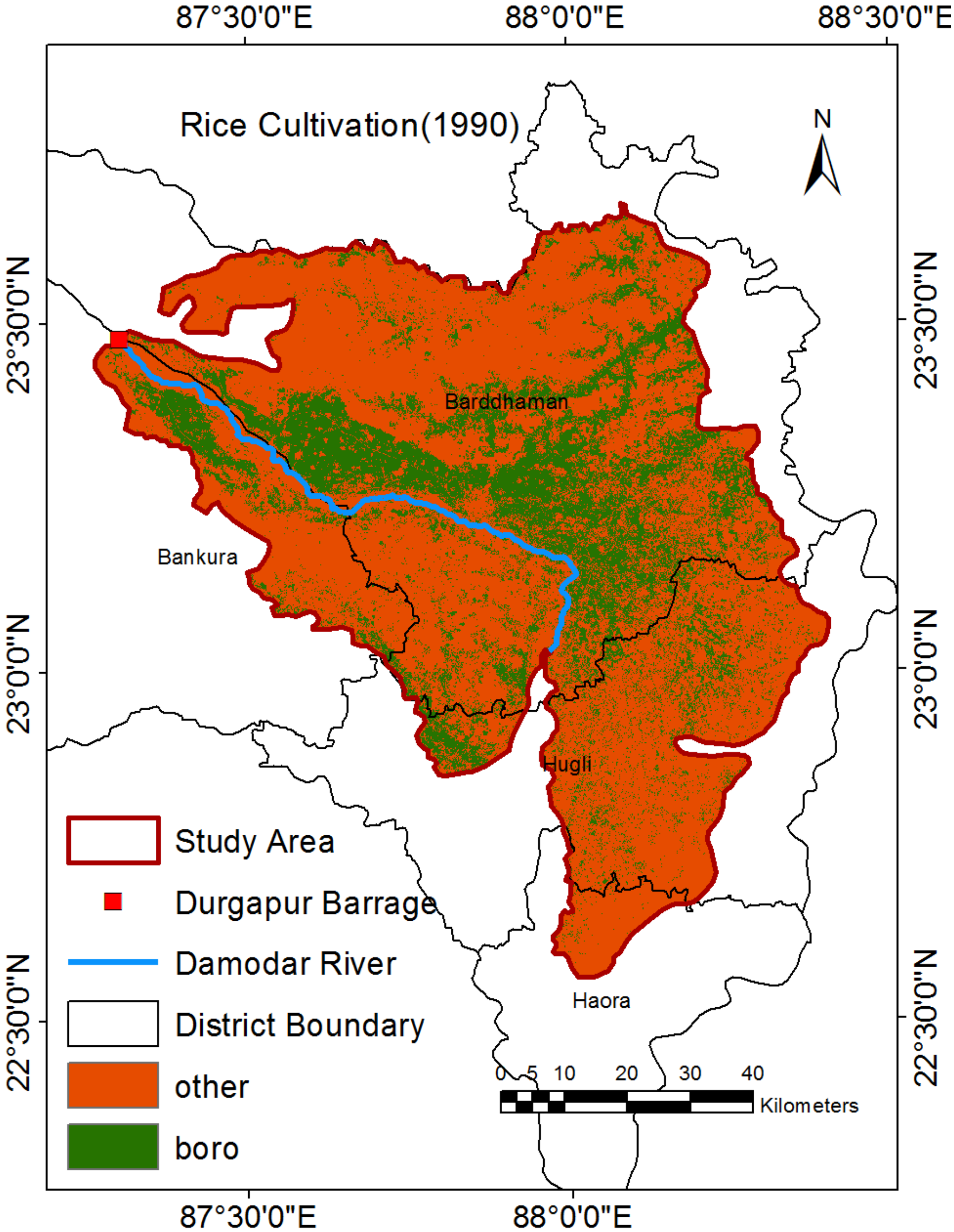


Figure 1.10: Boro rice map of DVC irrigation system in year 1990

2004 and 2005. In year 2006, 55% of study areas were under Boro rice cultivation consisting 3861.554 km^2. Areas under other land use categories were decreased

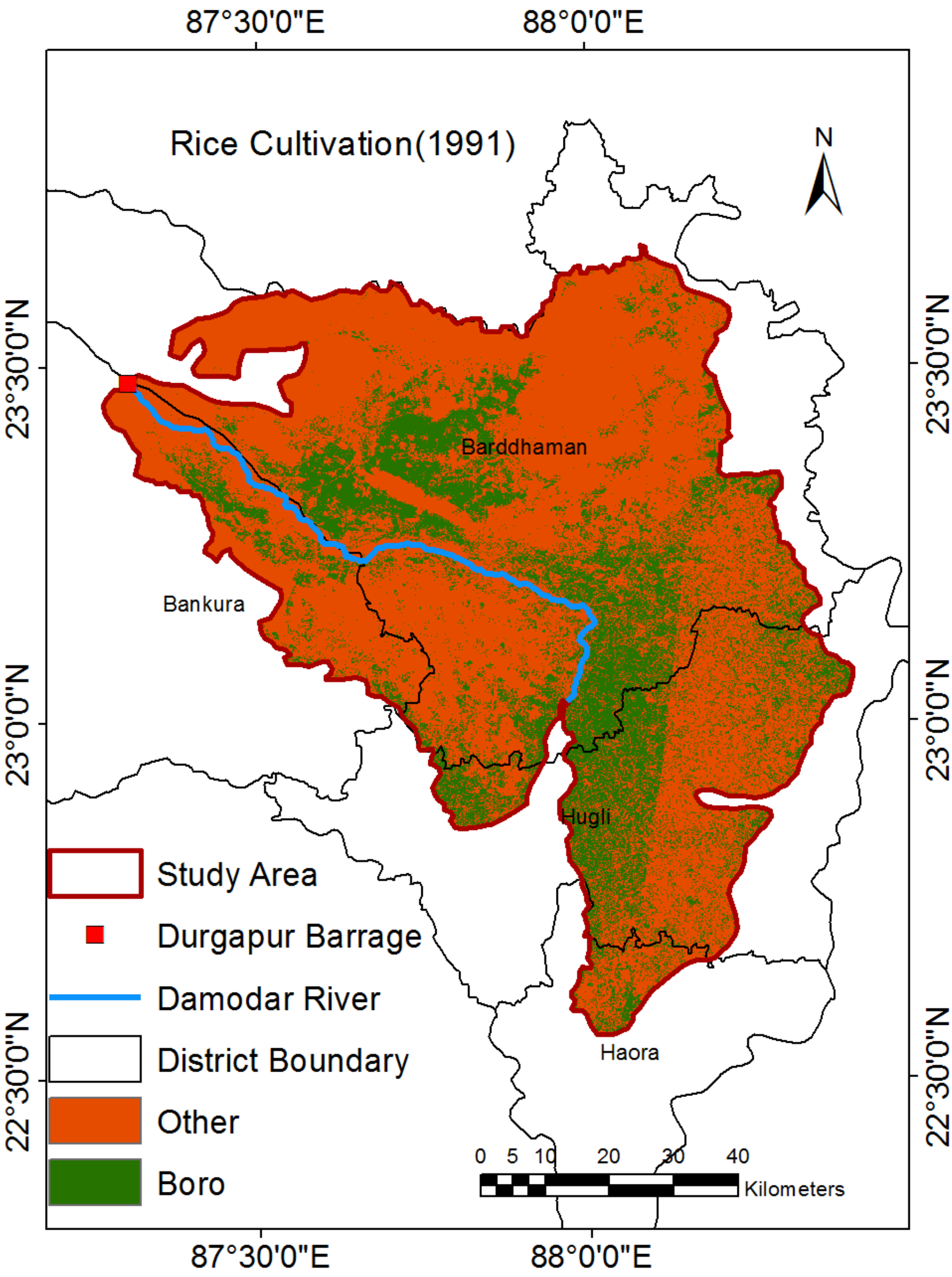


Figure 1.11: Boro rice map of DVC irrigation system in year 1991

to 45% covering 3131.48 km^2 of study area.

In 2007, around 50% of study area was under Boro cultivation while in 2008

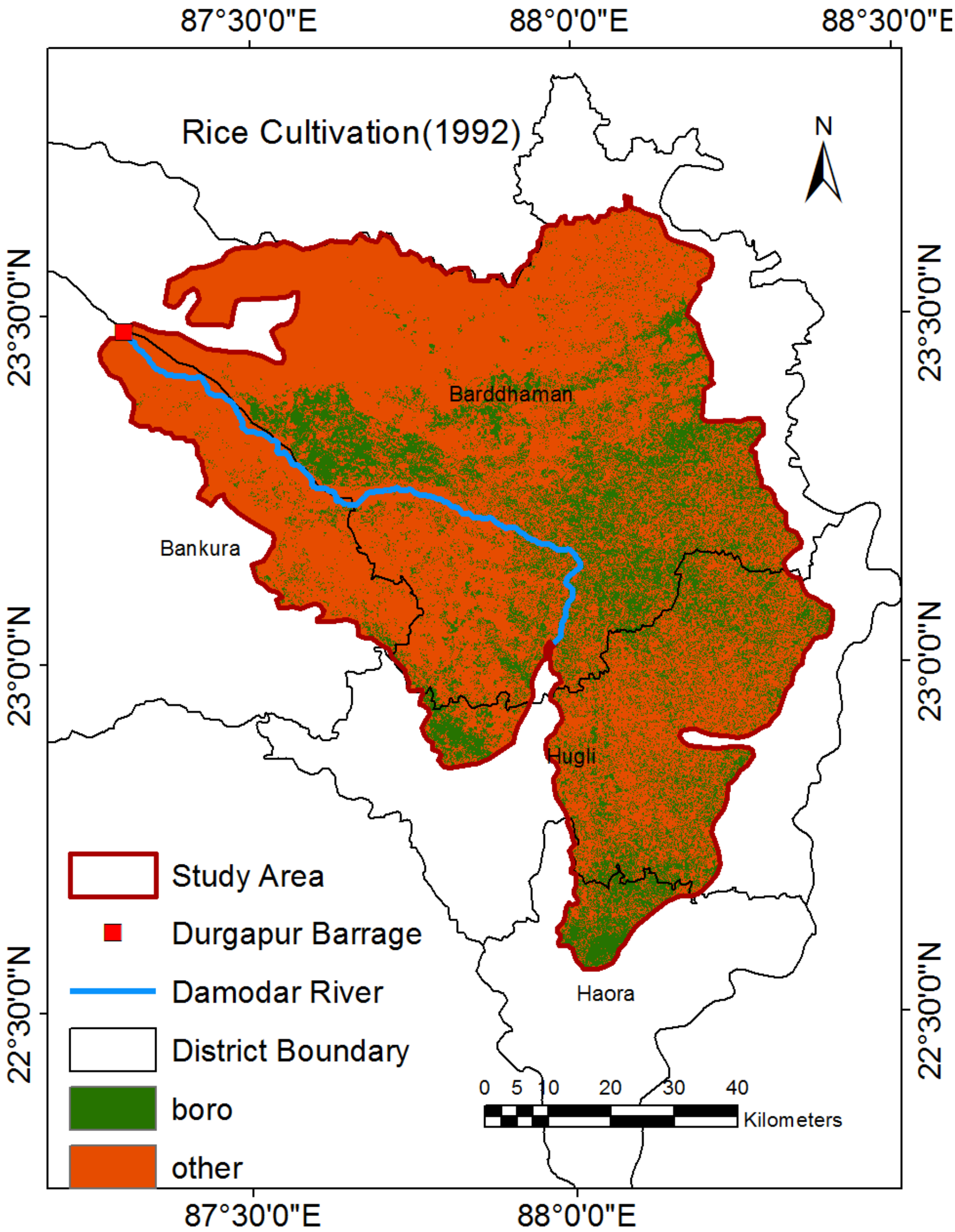


Figure 1.12: Boro rice map of DVC irrigation system in year 1992

it increased to 69% covering 4806.98 km^2 areas. Areal extent of Boro rice in 2009 was found in 4306.52 Km^2 areas covering 62% of study area where as 2686.514

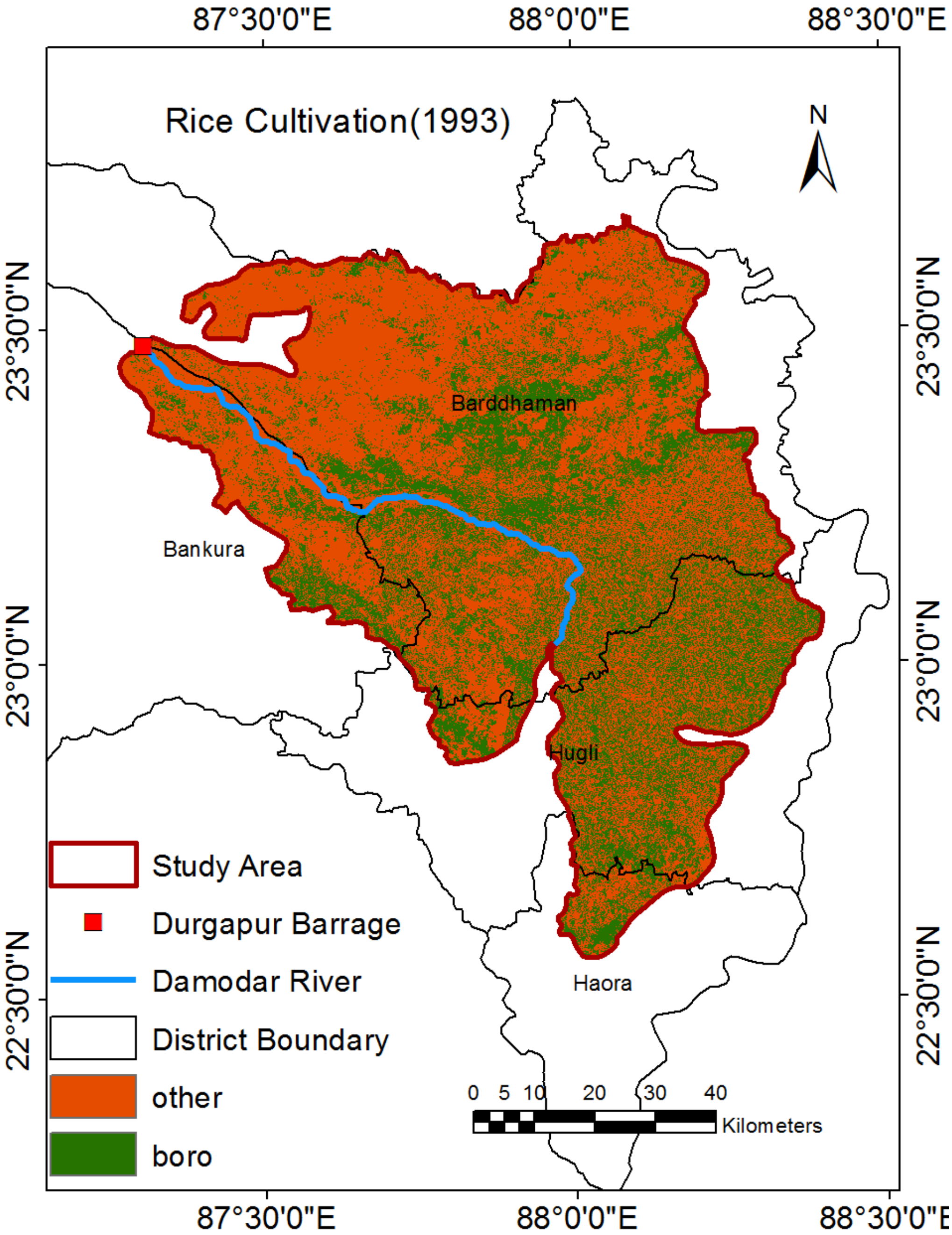


Figure 1.13: Boro rice map of DVC irrigation system in year 1993

Km^2 area was under other land use. Figure 1.26 to 1.29 represent the areal extent of Boro rice and other land use in year 2006, 2007, 2008 and 2009.

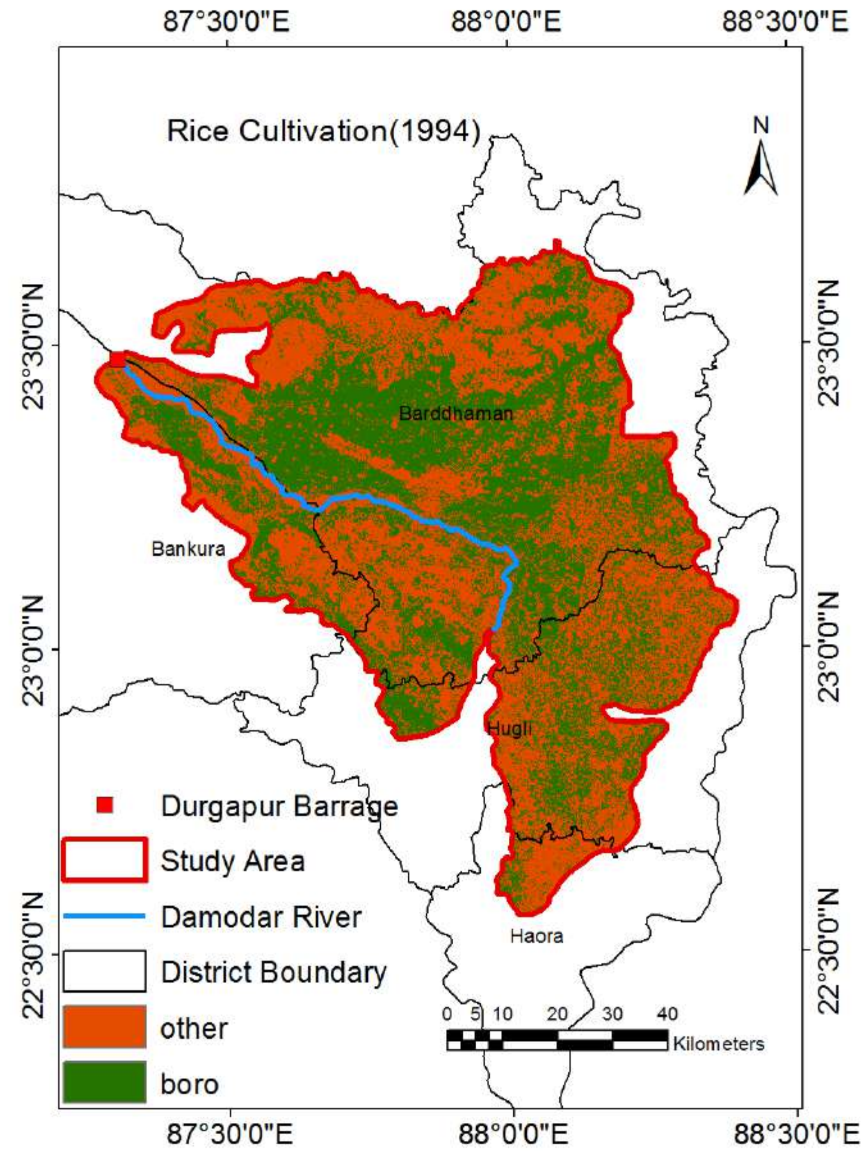


Figure 1.14: Boro rice map of DVC irrigation system in year 1994

Similar trends were found in the year 2010, 2011 2012 and 2013. In 2010, the area under Boro rice was about 60% comprising 4194.069 Km^2 whereas area under other land use categories was consisting 40% covering 2798.96 Km^2 areas. Increasing trend of Boro rice cultivation was found after 2011 in DVC command area which covered 4380.855 Km^2 in 2012, 4790.253 Km^2 in 2013, 4091.42 Km^2 in 2014, 3630.01 Km^2 in 2015 and 3799.041 Km^2 in 2016. Map of Boro rice cultivation in 2010, 2011, 2012 and 2013 were shown in Figure 1.30 to 1.33.

In 2017, 3372.24 Km^2 areas were under Boro rice cultivation while 3620.79 Km^2 areas were under other land use categories. Figure 1.34 to 1.37 show the areal extent of Boro rice cultivation along with other land use categories in the

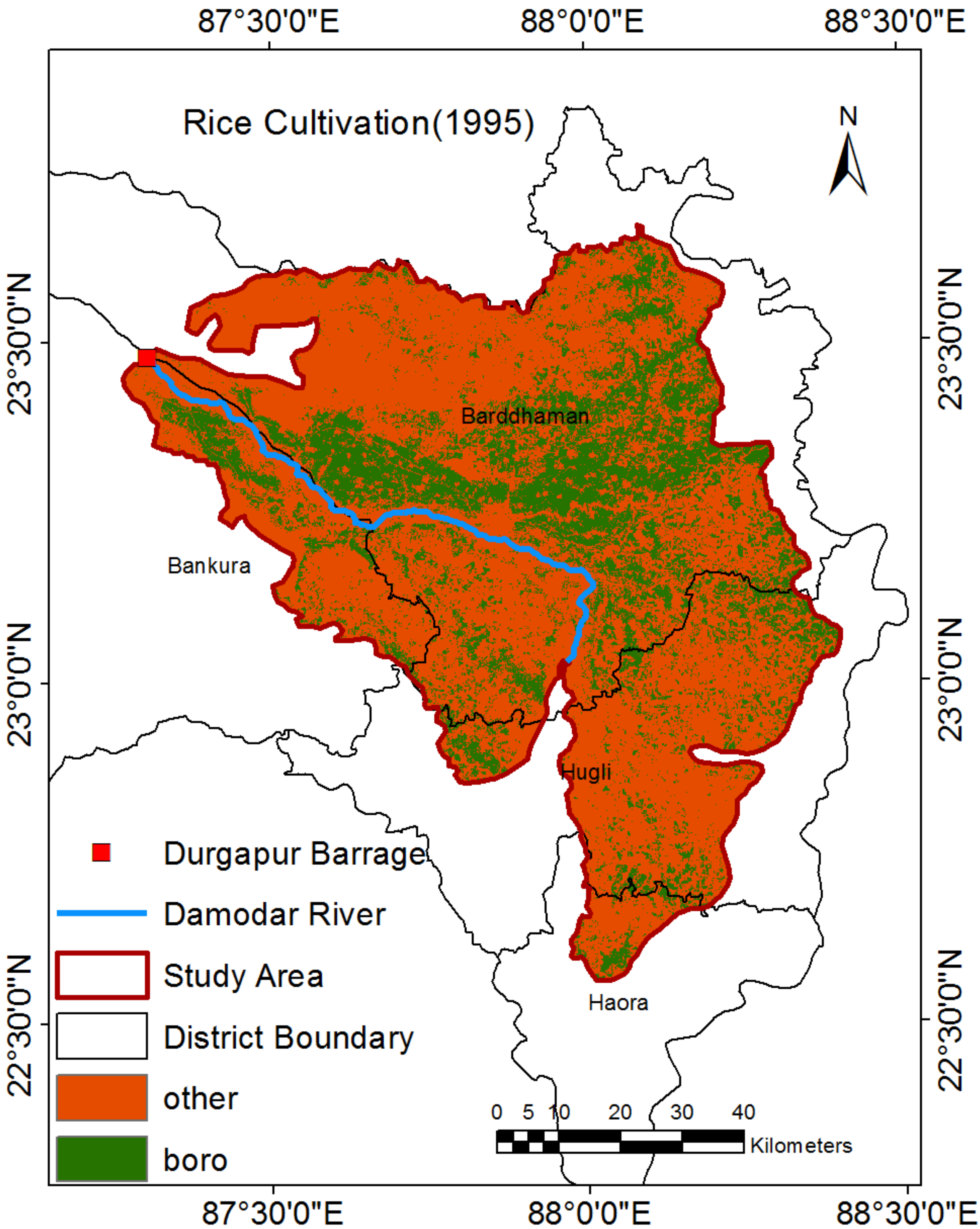


Figure 1.15: Boro rice map of DVC irrigation system in year 1995

year 2014, 2015, 2016 and 2017.

Based on the results obtained by employment of GIS and RS applications it

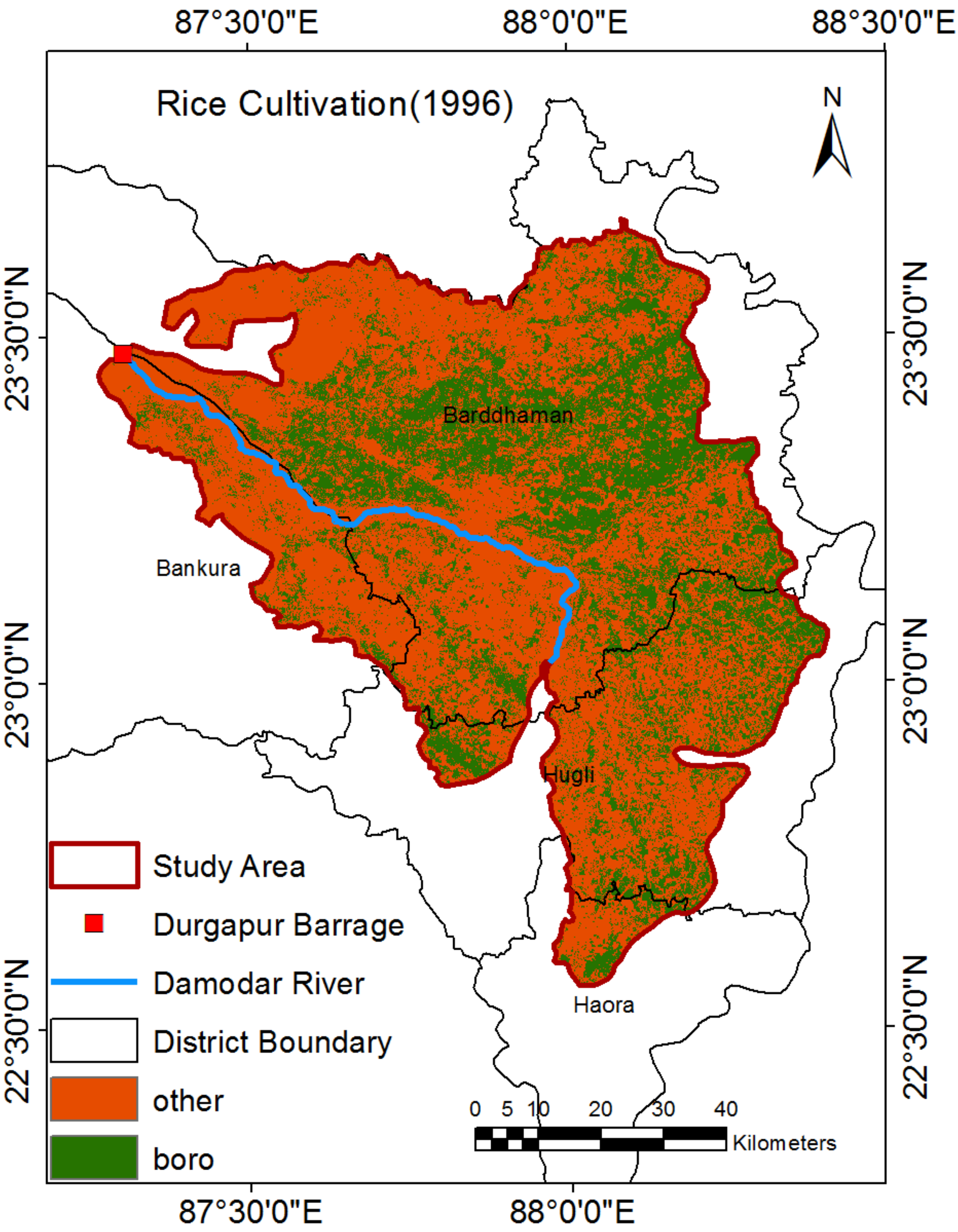


Figure 1.16: Boro rice map of DVC irrigation system in year 1996

was found that the land cover/land use practices in the study area have altered significantly in 30 years. During the study period the LULC shift in the study

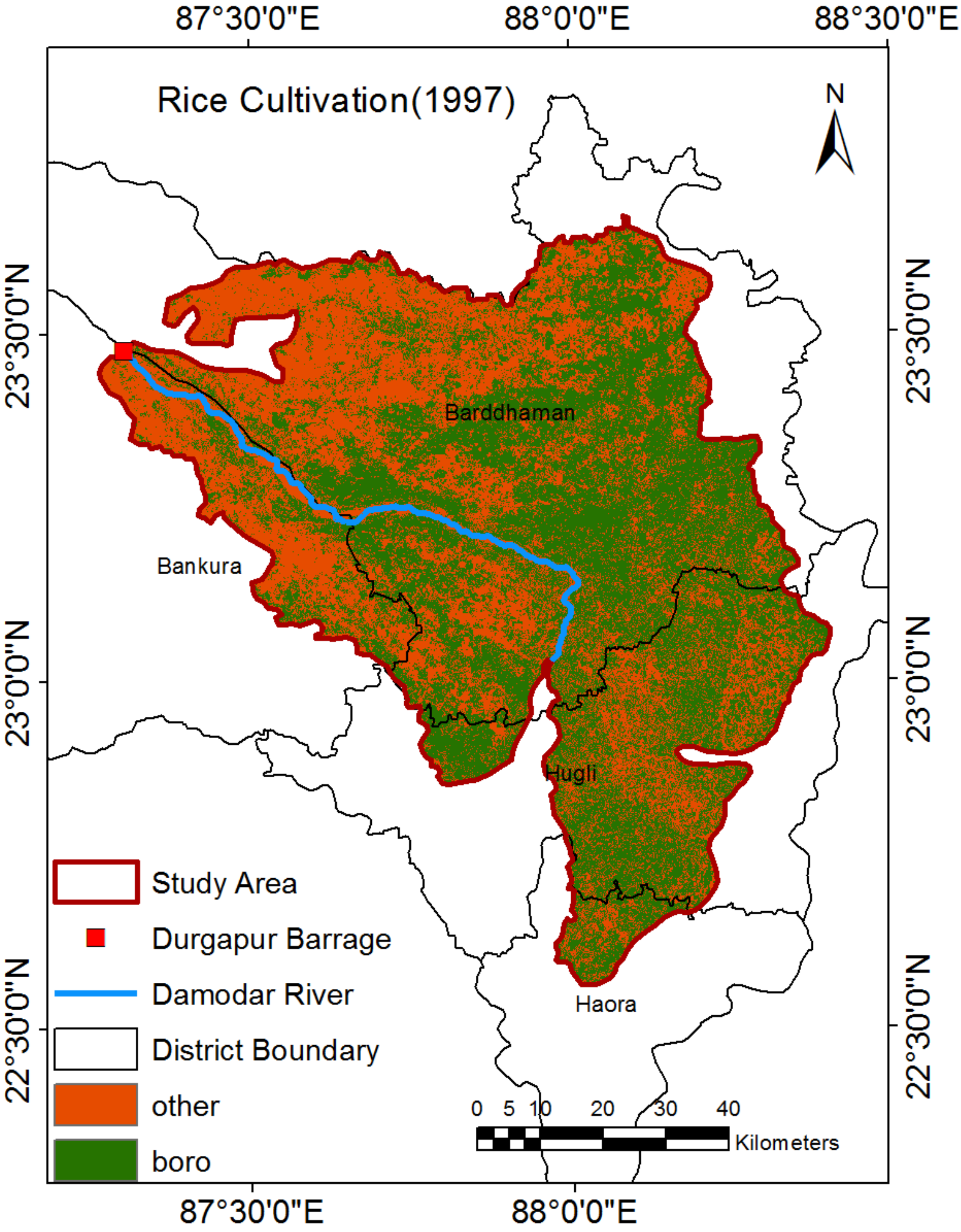


Figure 1.17: Boro rice map of DVC irrigation system in year 1997

area was evident by the increase in the area under Boro rice cultivation (29% to 47%) and decline in the area under other land use classes (71% to 53%).The

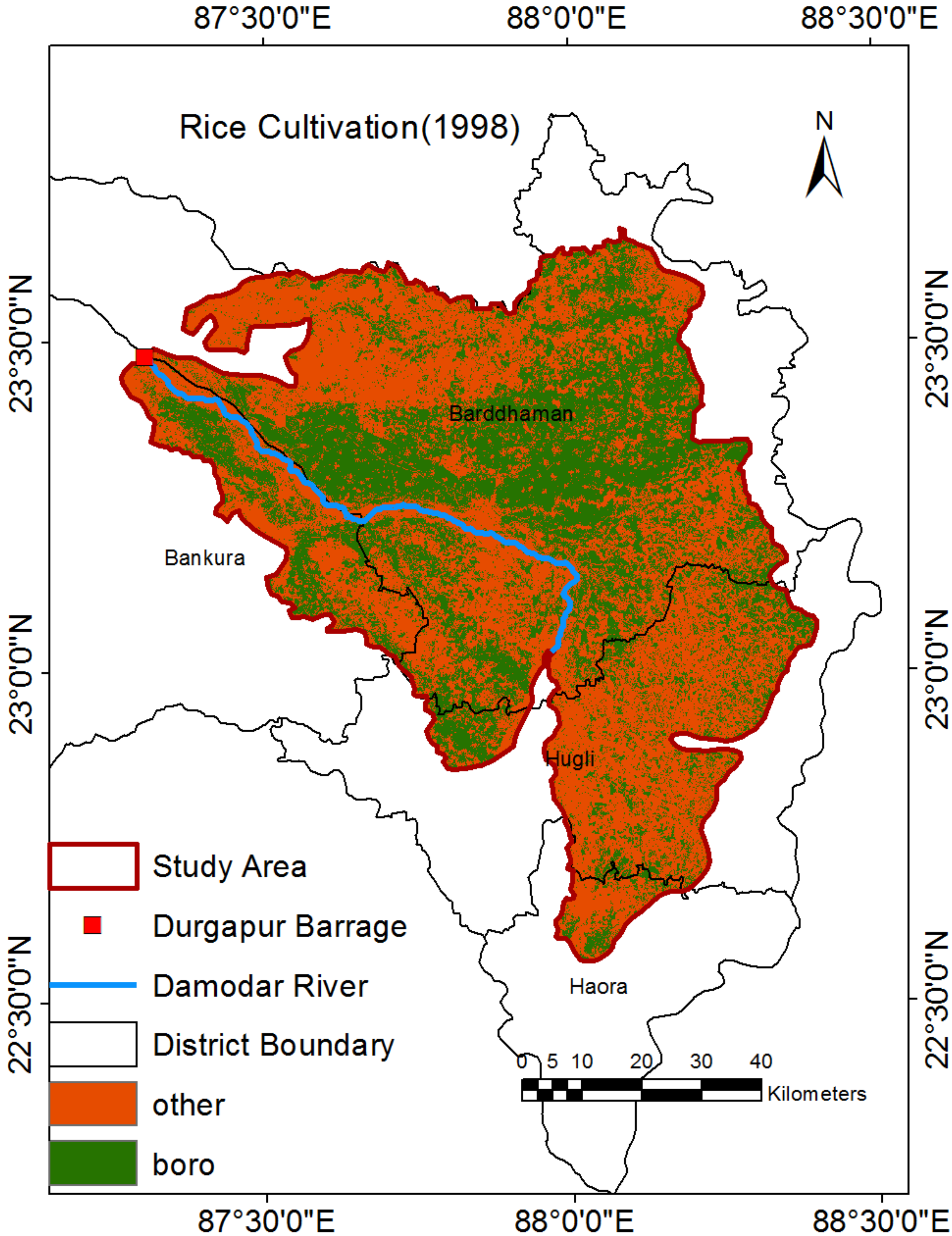


Figure 1.18: Boro rice map of DVC irrigation system in year 1998

area under Boro rice and other land use cover during the study period of 30 years are shown diagrammatically in Figure 1.38.As the study area is large, in

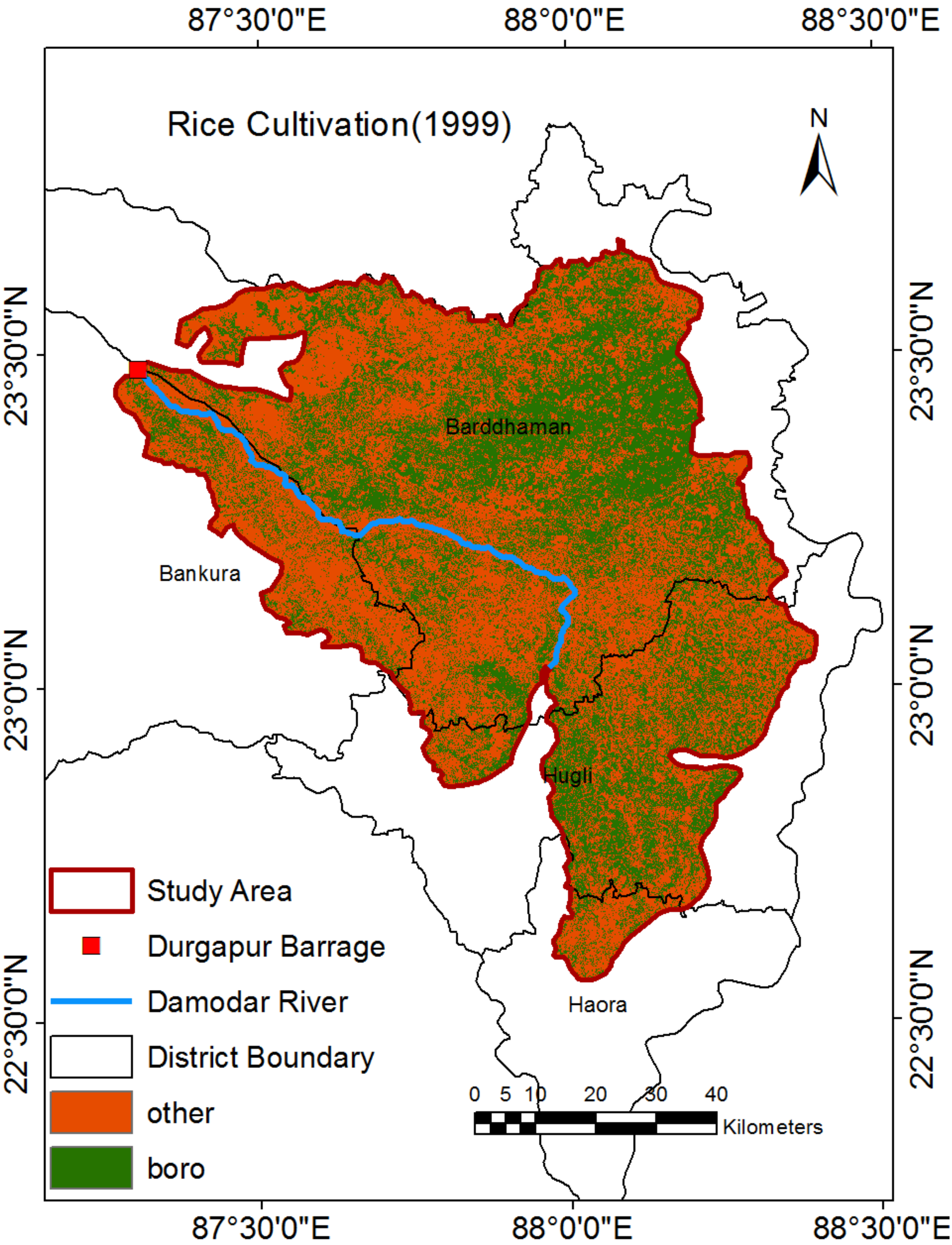


Figure 1.19: Boro rice map of DVC irrigation system in year 1999

order to realize a reasonable coverage of the validation samples, the reference data were extracted from high resolution (HR) images from the Google Earth for

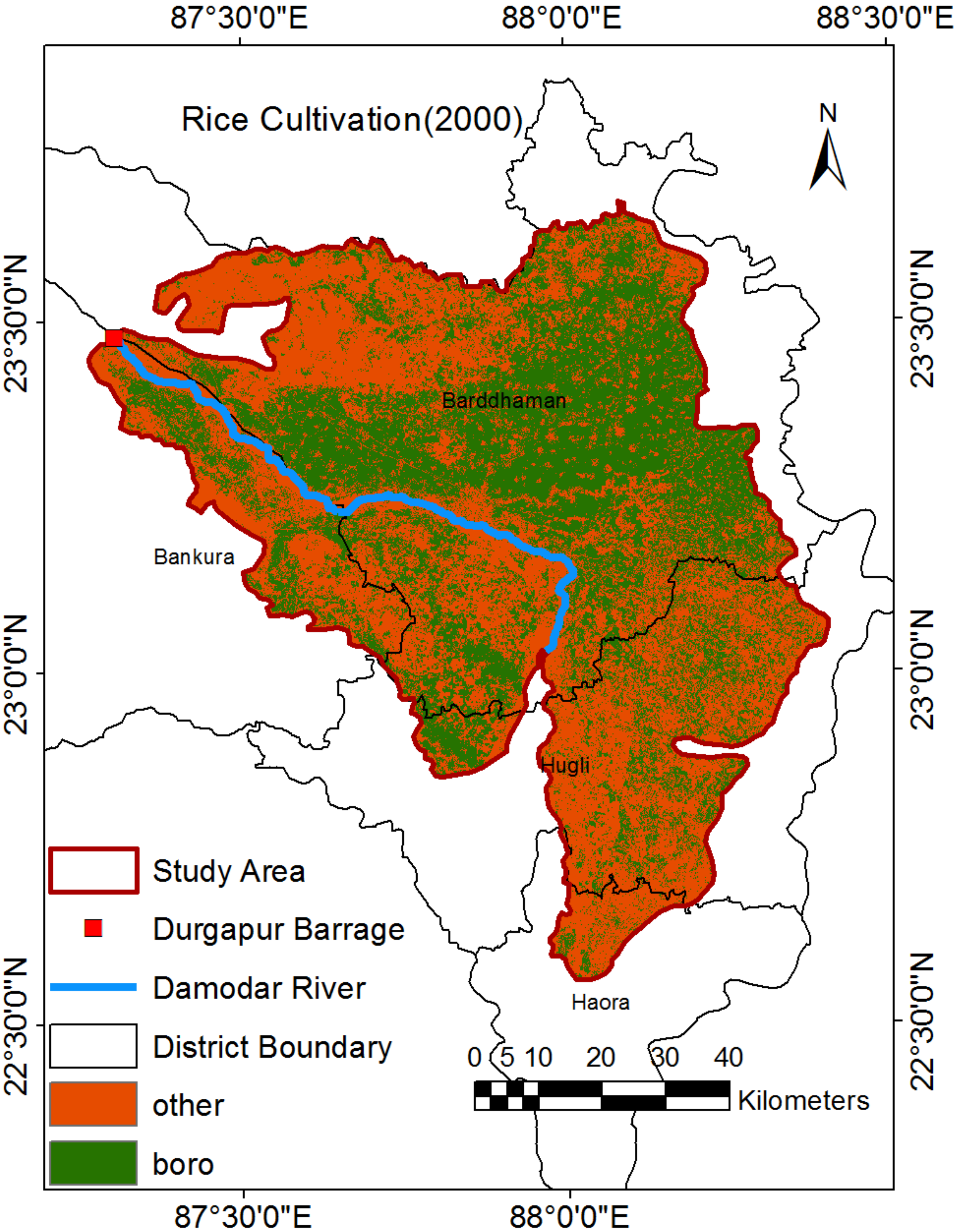


Figure 1.20: Boro rice map of DVC irrigation system in year 2000

different years using historical imagery function. Extracted images from Google Earth for year 2017 were shown in Figure 1.39.Extensive cultivation of Boro rice

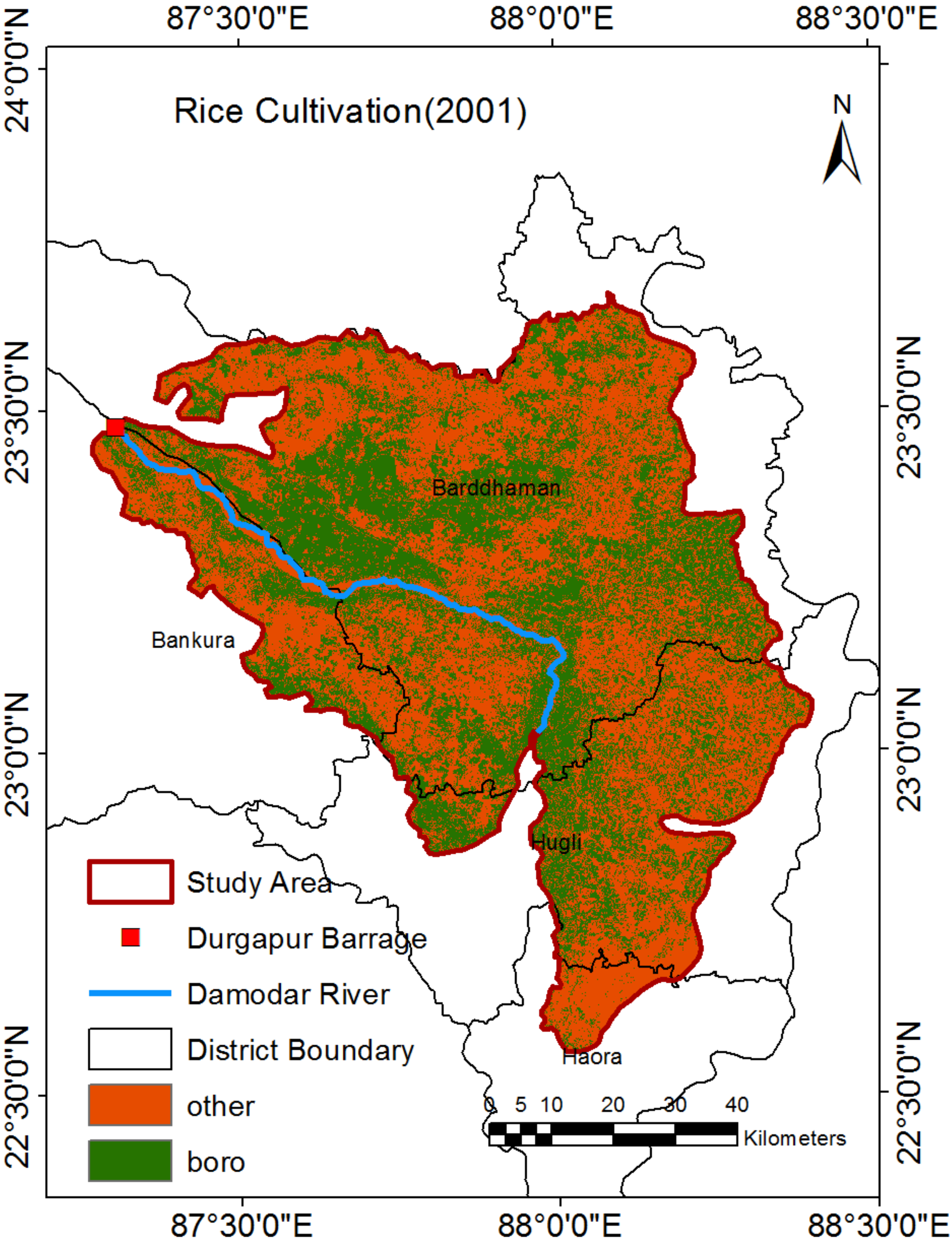


Figure 1.21: Boro rice map of DVC irrigation system in year 2001

during mid-January to mid-april can be observed from landscapes of rice fields in Figure 1.39.Accuracy assessment of prepared Boro rice maps were also carried

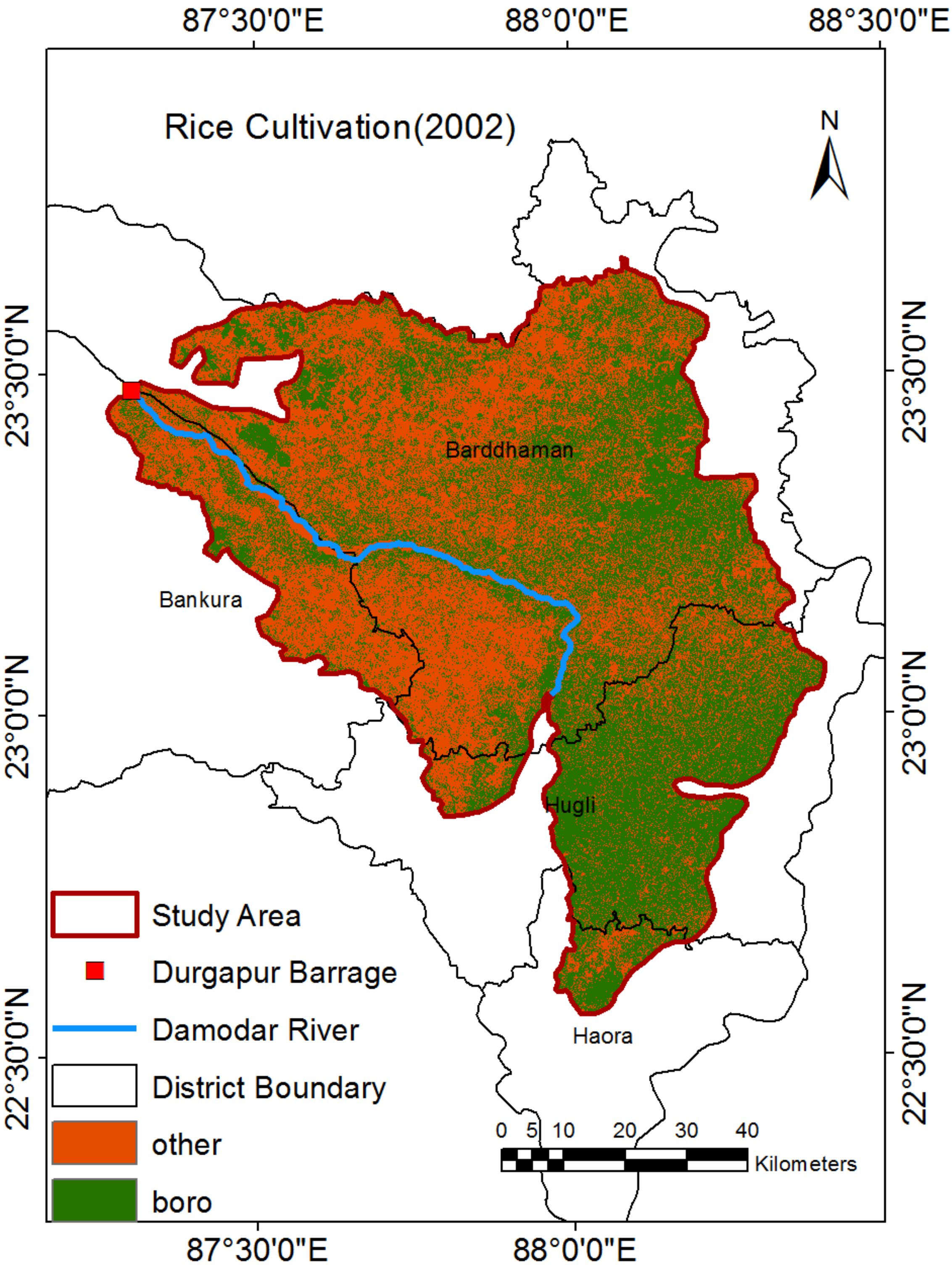


Figure 1.22: Boro rice map of DVC irrigation system in year 2002

out by taking ground control points (GCPs) over the study area. Nineteen GCPs were collected and field photos were taken (Figure 1.40, 1.41 & 1.42) during field

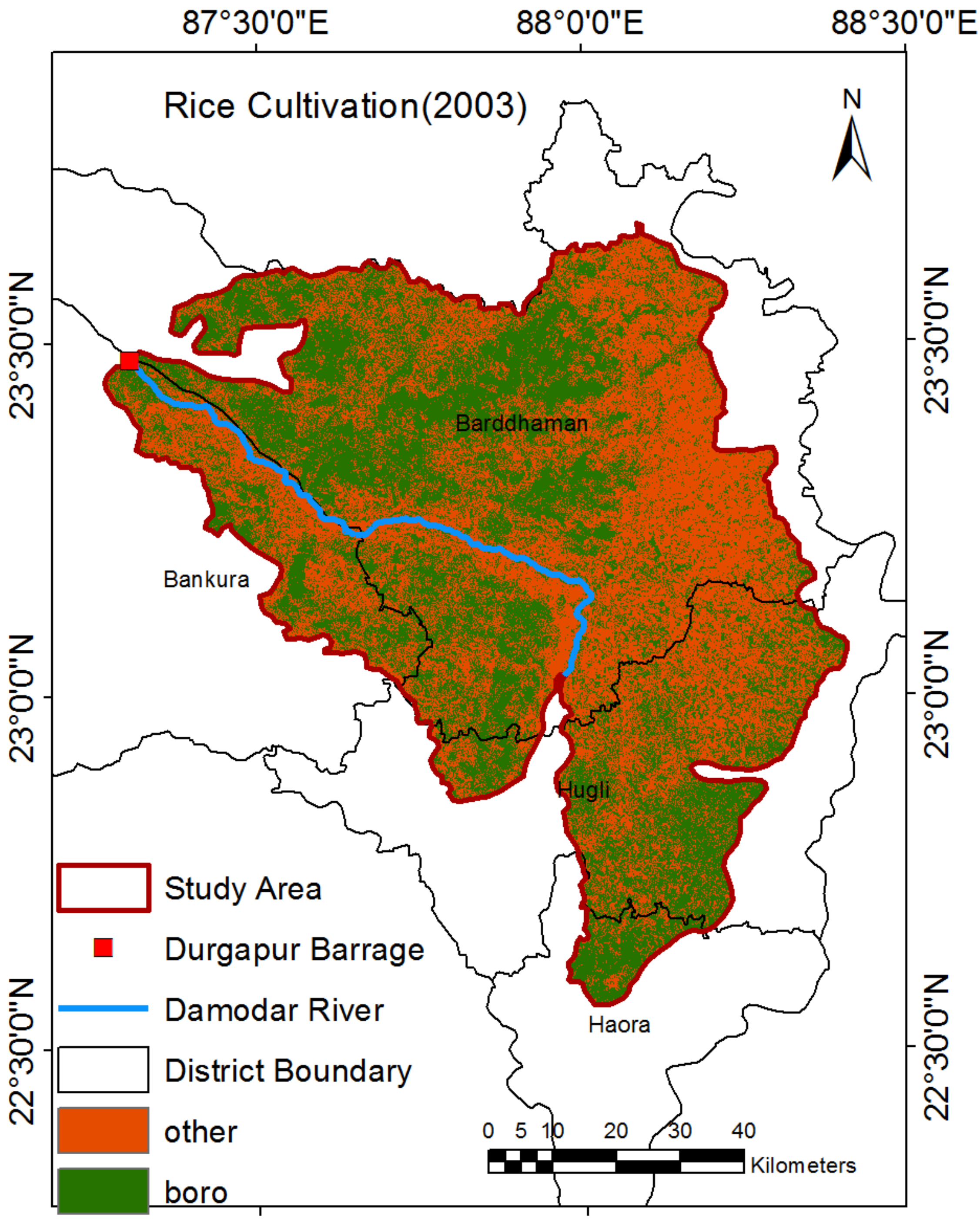


Figure 1.23: Boro rice map of DVC irrigation system in year 2003

survey conducted on 25th march 2017 which was the peak period of Boro rice cultivation.Based on the validation results overall accuracy of rice mapping was

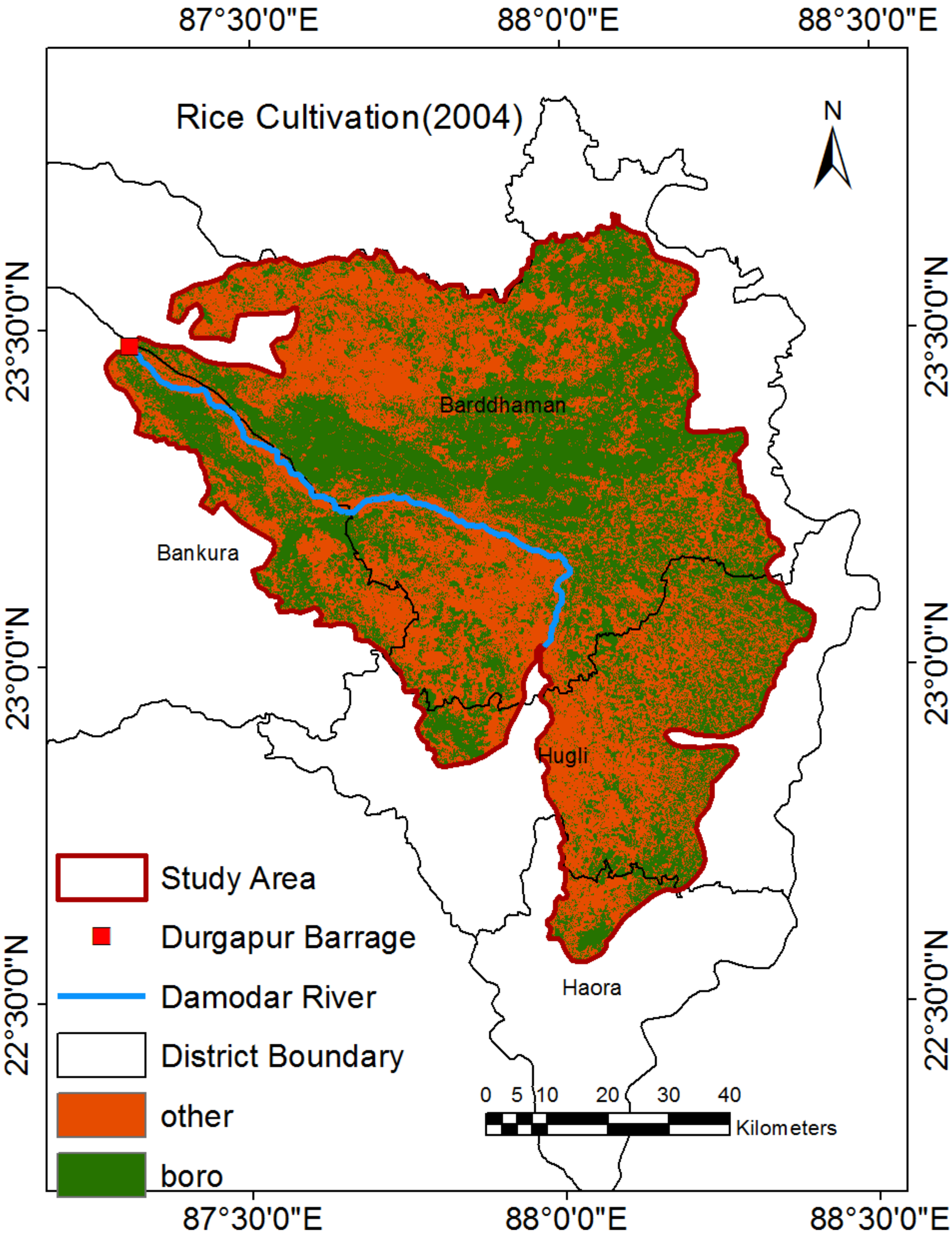


Figure 1.24: Boro rice map of DVC irrigation system in year 2004

found 93.75%. It was also observed that time series imageries of Landsat 5, 7 and 8 have higher capabilities of mapping large scale rice cultivating area in data

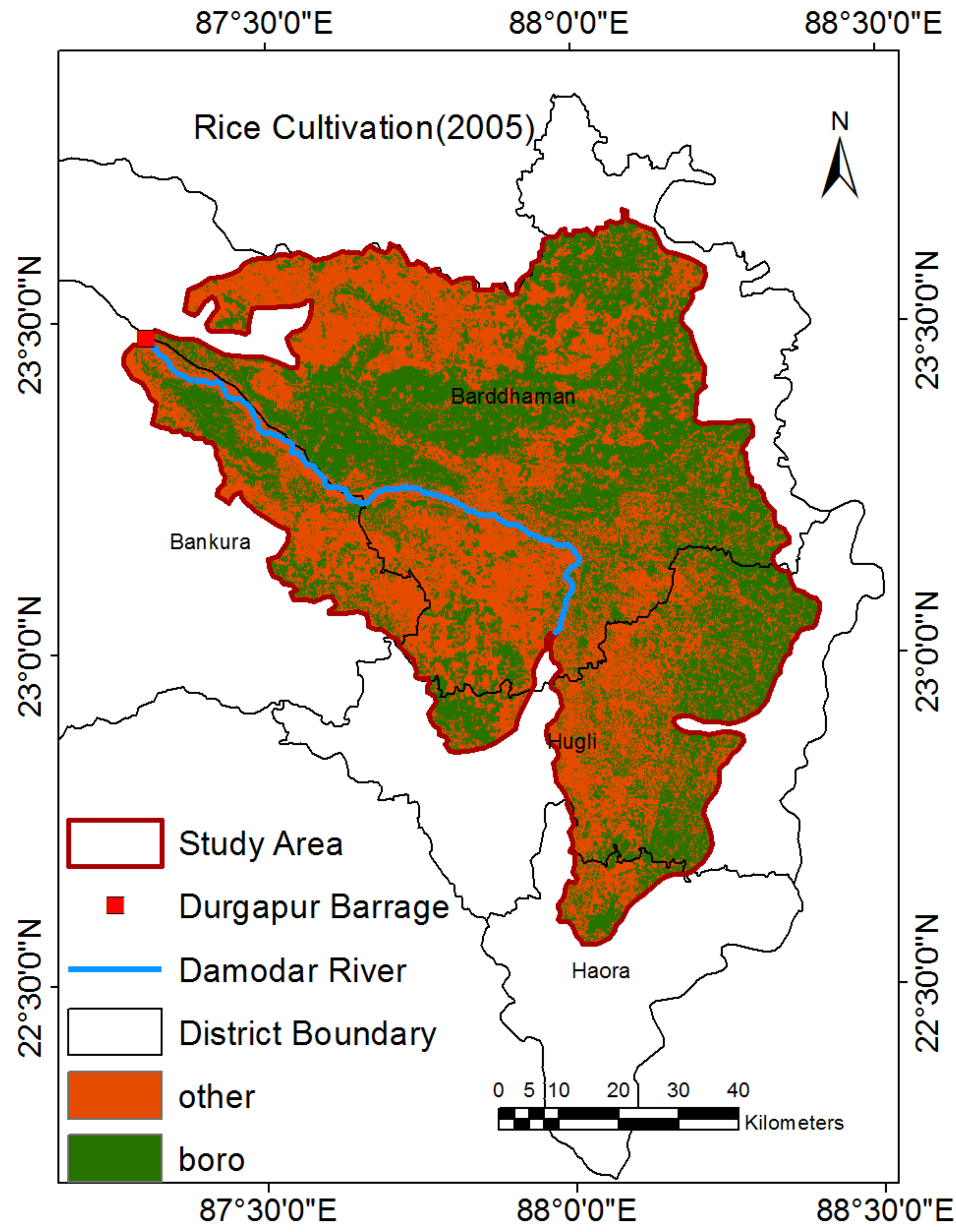


Figure 1.25: Boro rice map of DVC irrigation system in year 2005

scarcity region.

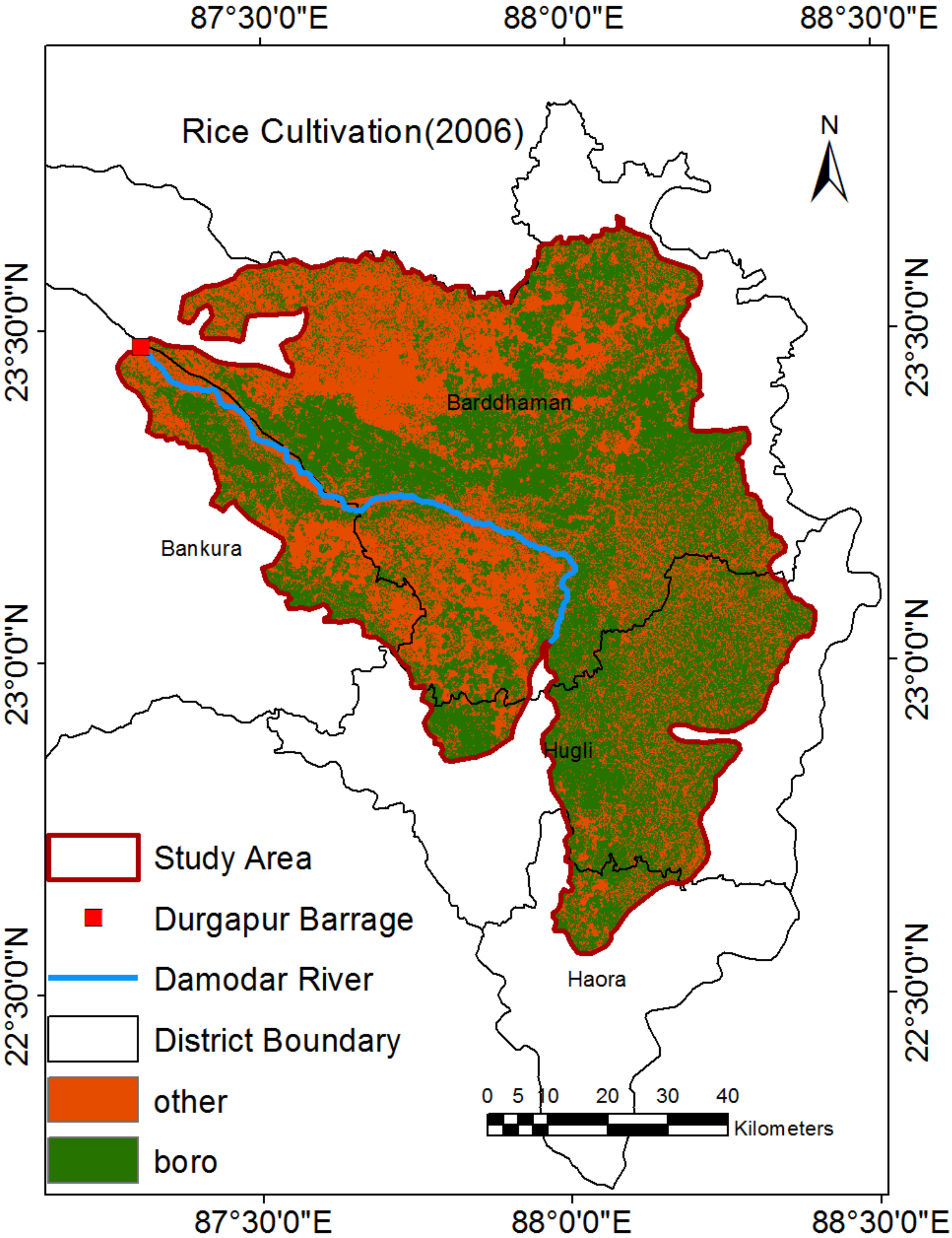


Figure 1.26: Boro rice map of DVC irrigation system in year 2006

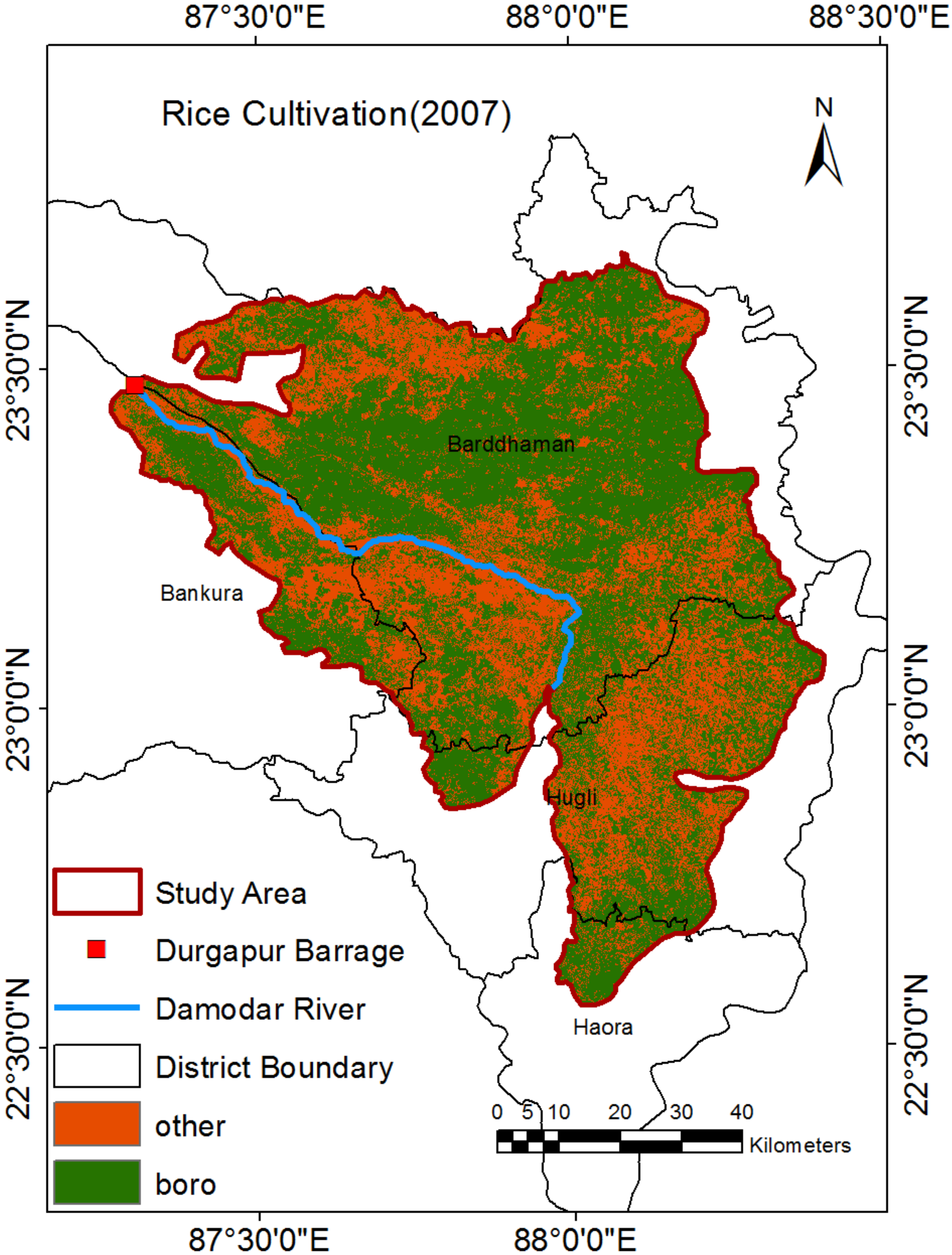


Figure 1.27: Boro rice map of DVC irrigation system in year 2007

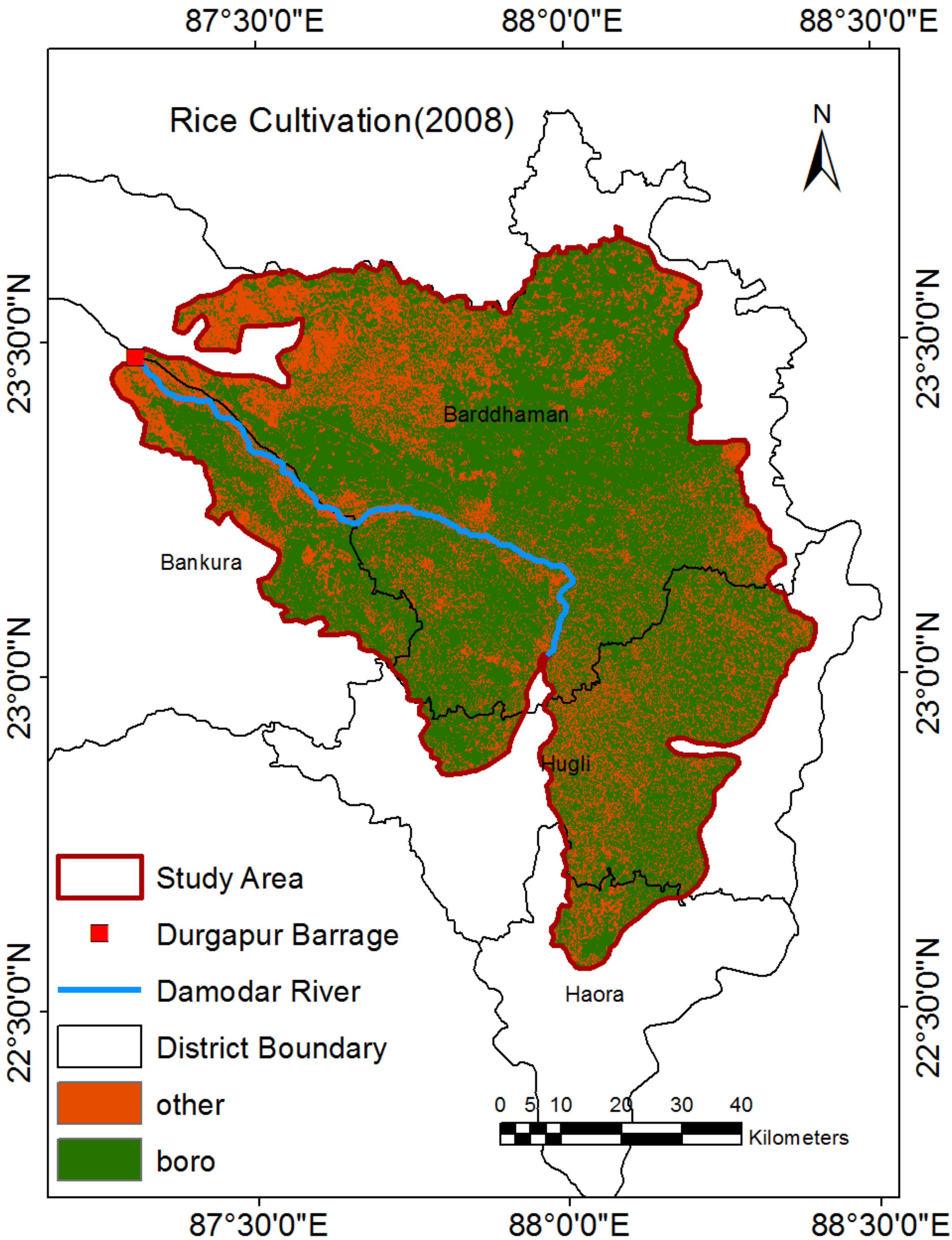


Figure 1.28: Boro rice map of DVC irrigation system in year 2008

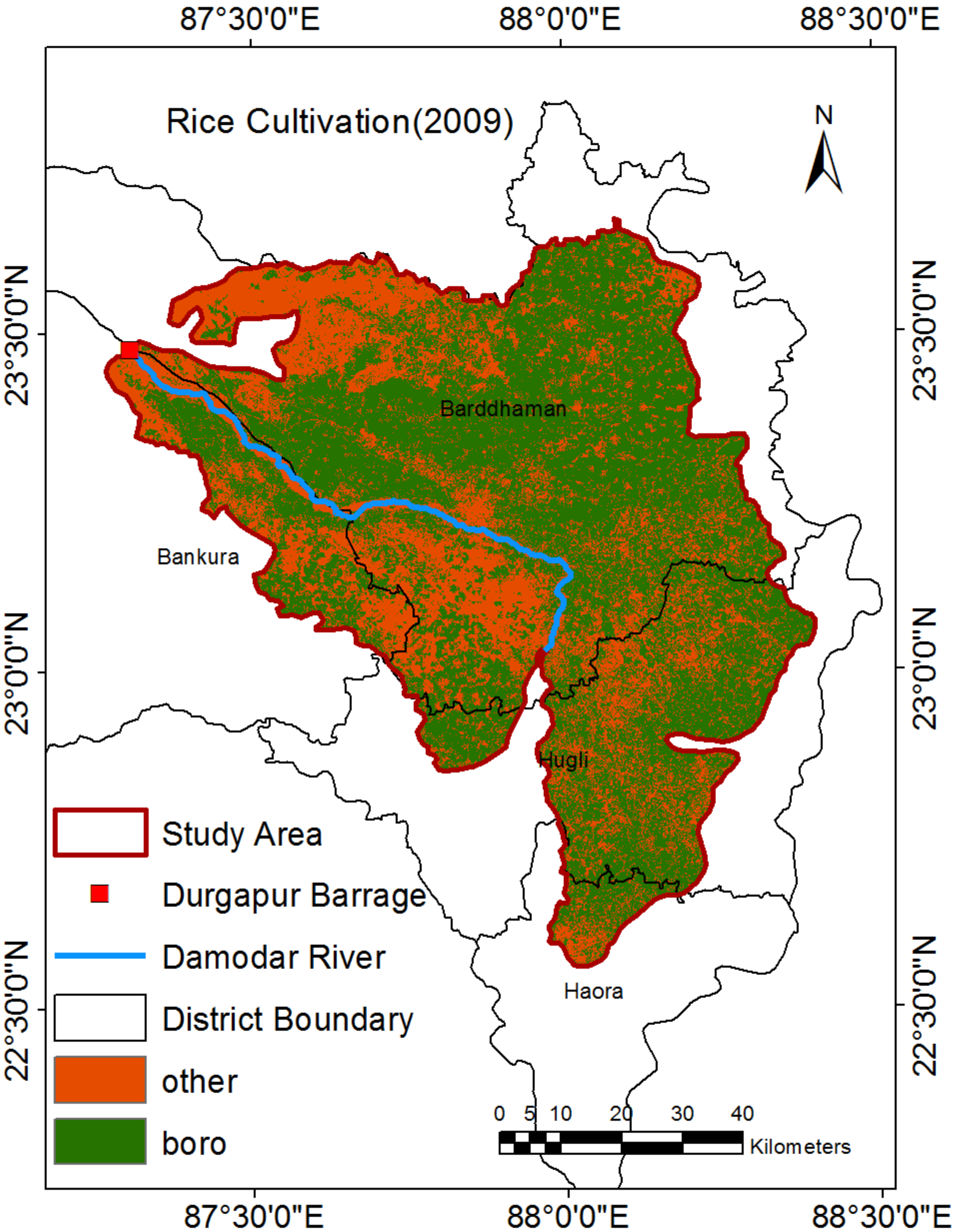


Figure 1.29: Boro rice map of DVC irrigation system in year 2009

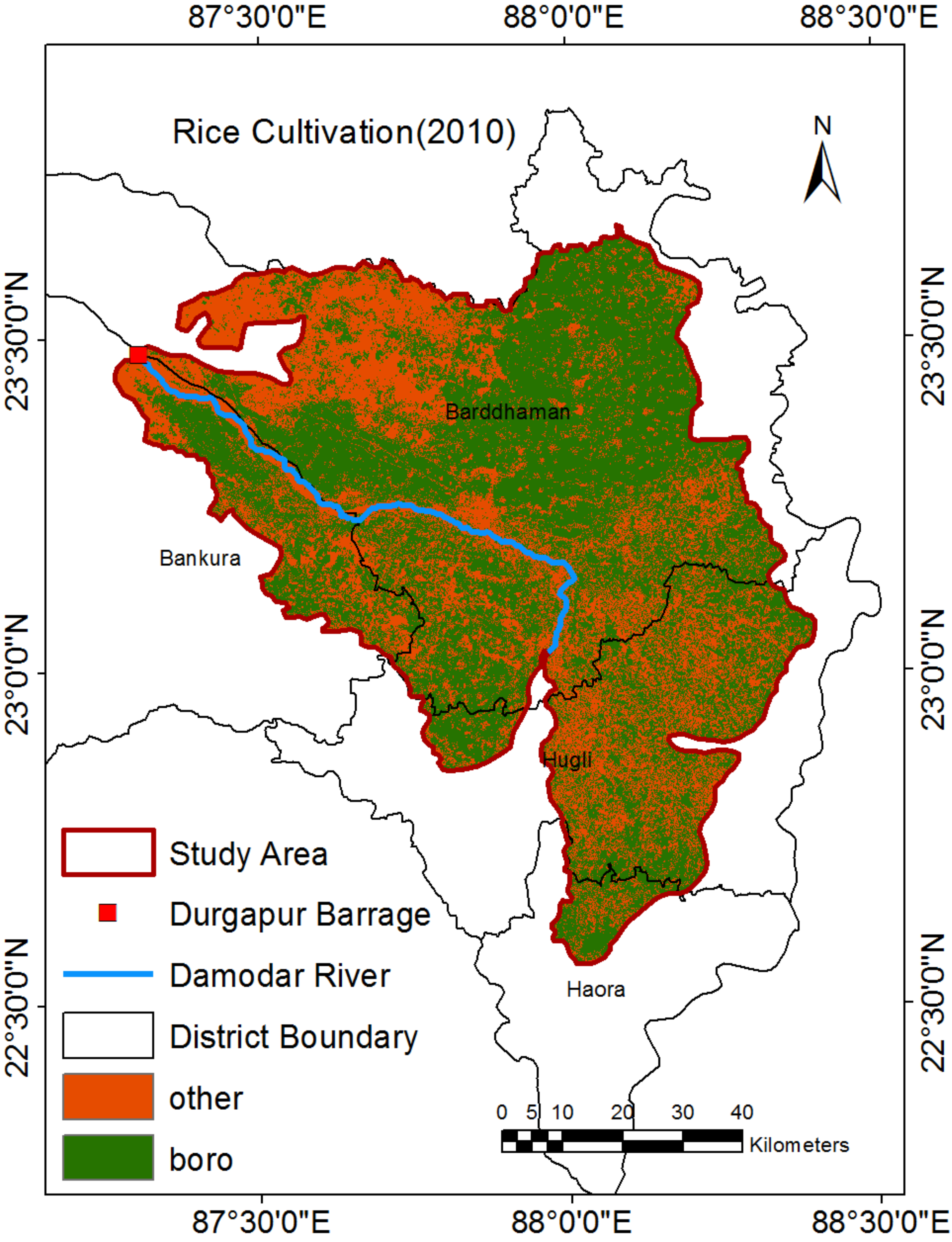


Figure 1.30: Boro rice map of DVC irrigation system in year 2010

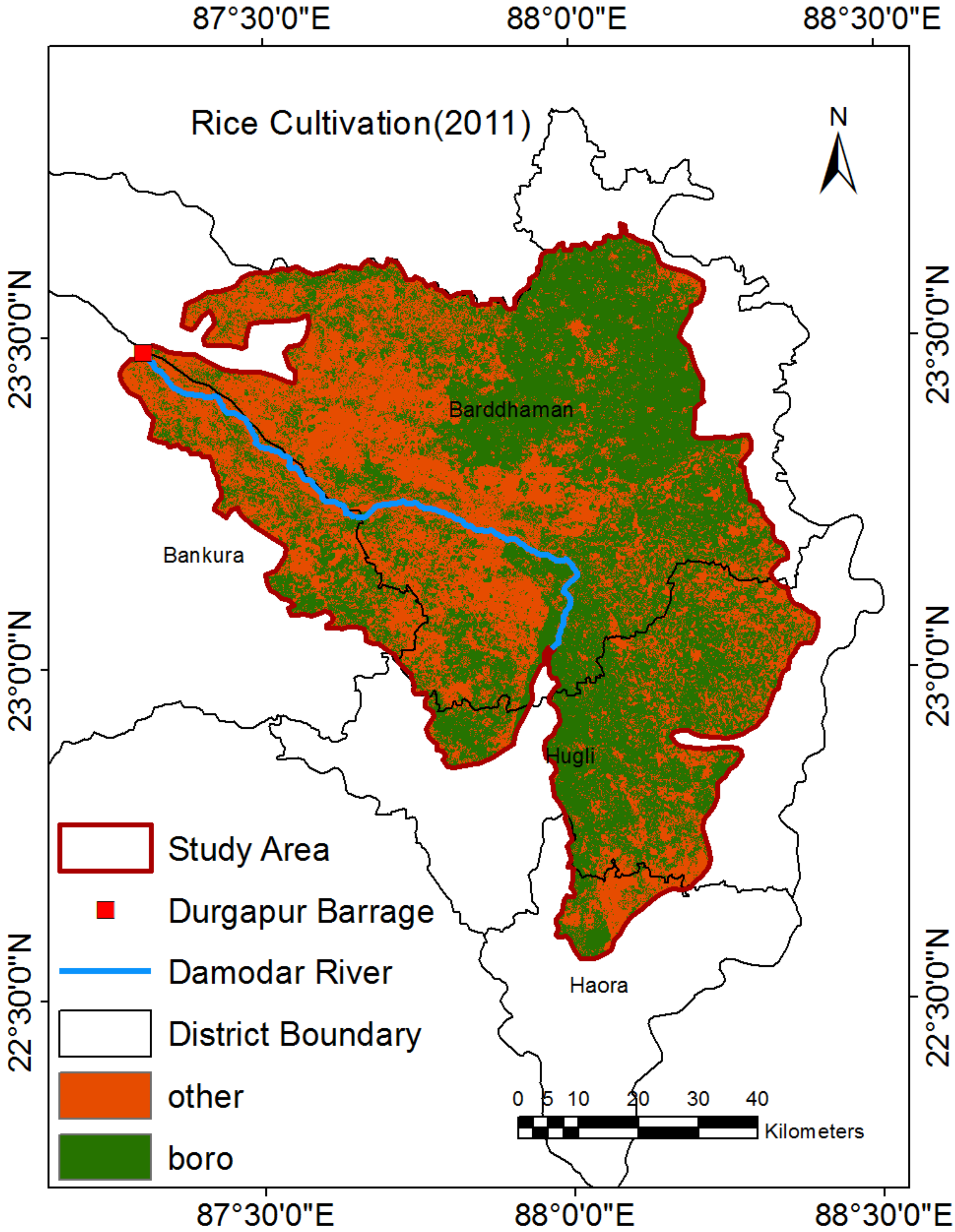


Figure 1.31: Boro rice map of DVC irrigation system in year 2011

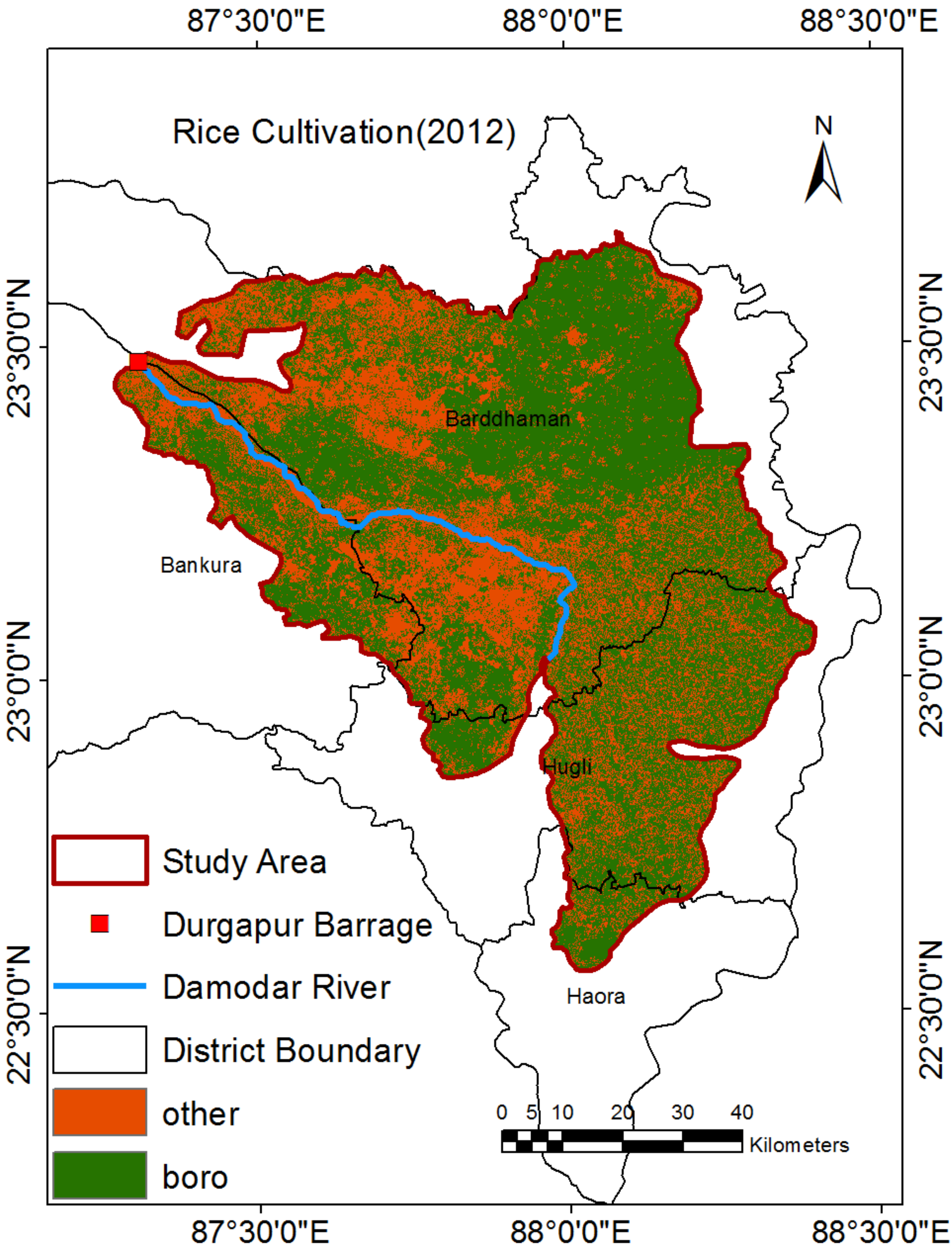


Figure 1.32: Boro rice map of DVC irrigation system in year 2012

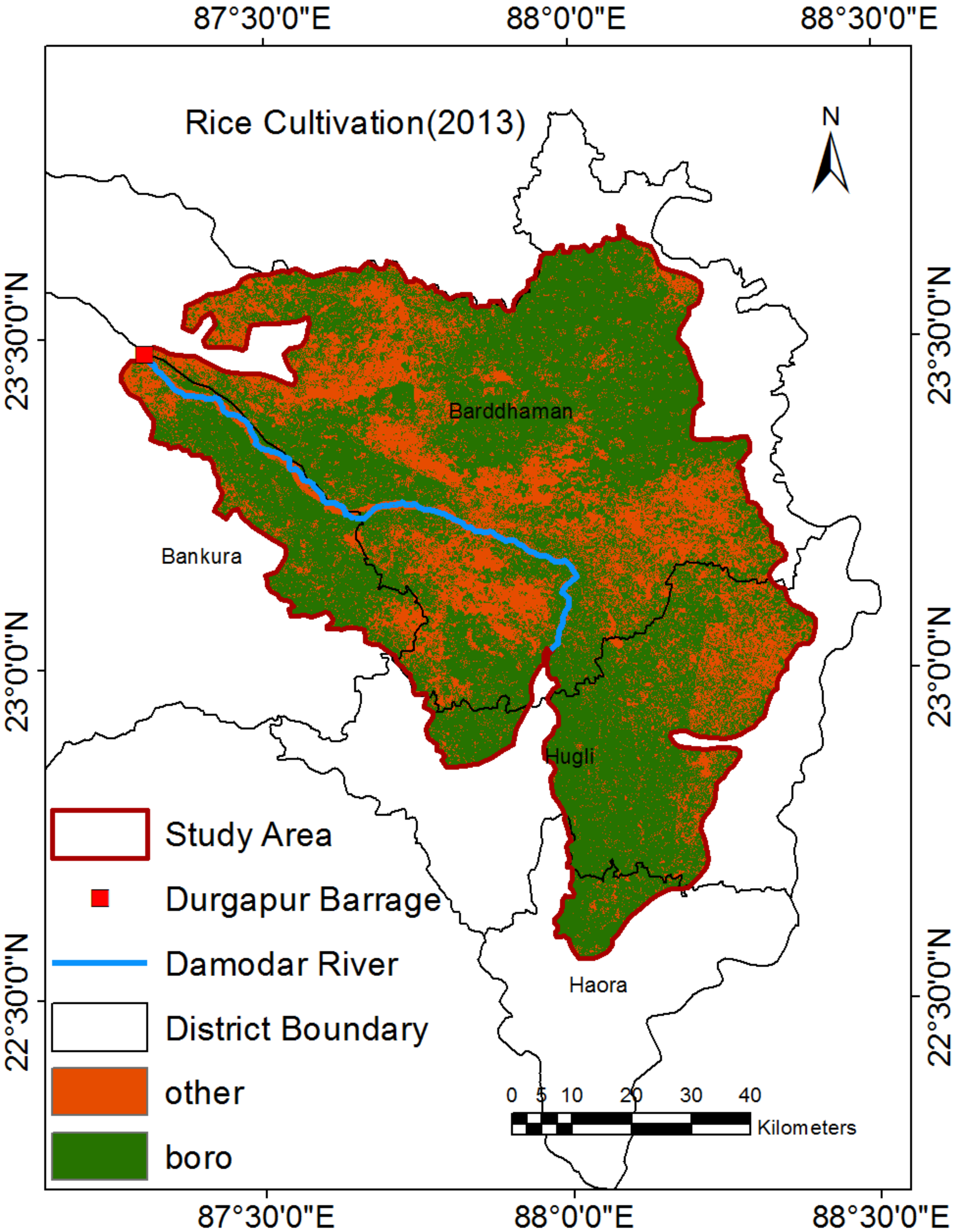


Figure 1.33: Boro rice map of DVC irrigation system in year 2013

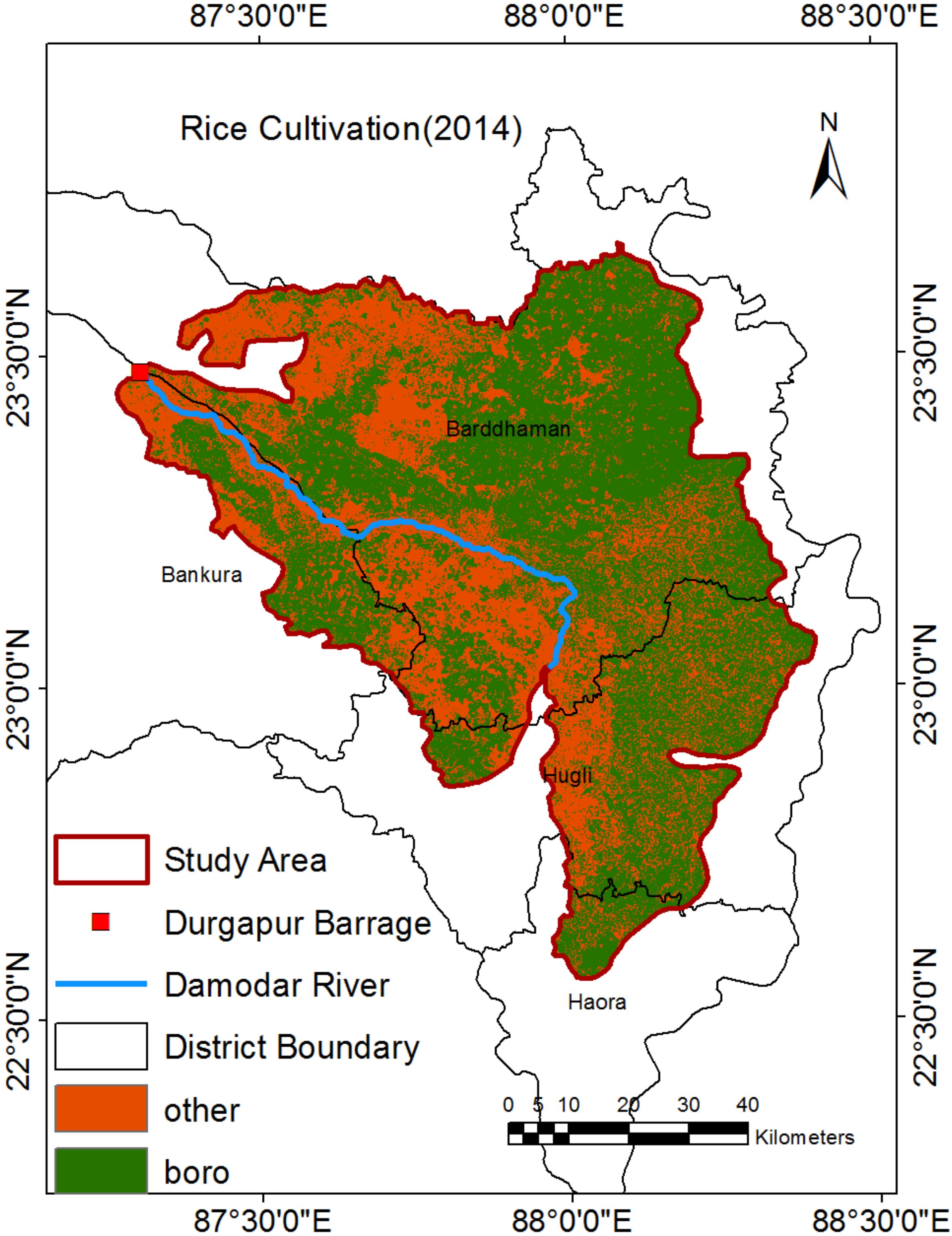


Figure 1.34: Boro rice map of DVC irrigation system in year 2014

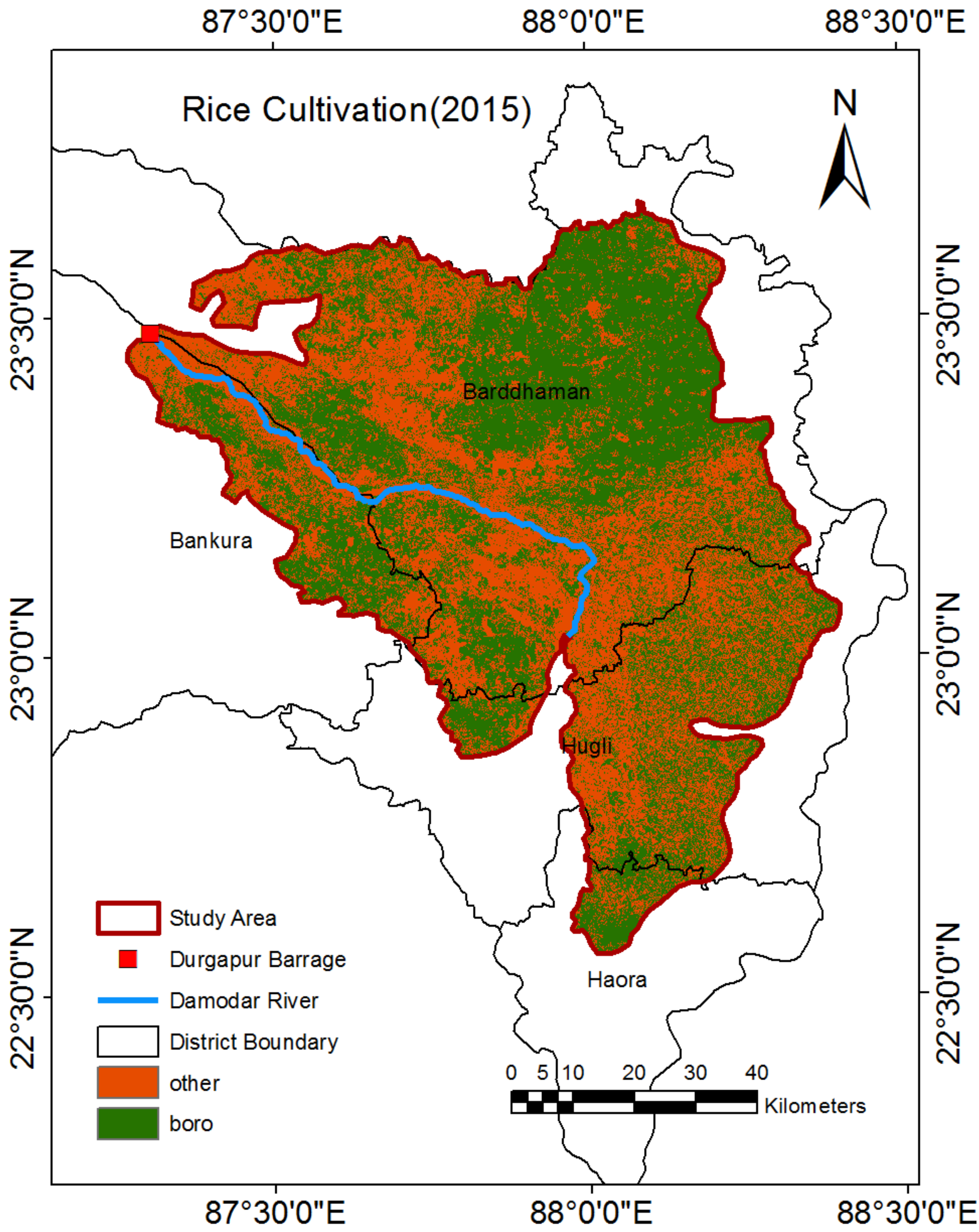


Figure 1.35: Boro rice map of DVC irrigation system in year 2015

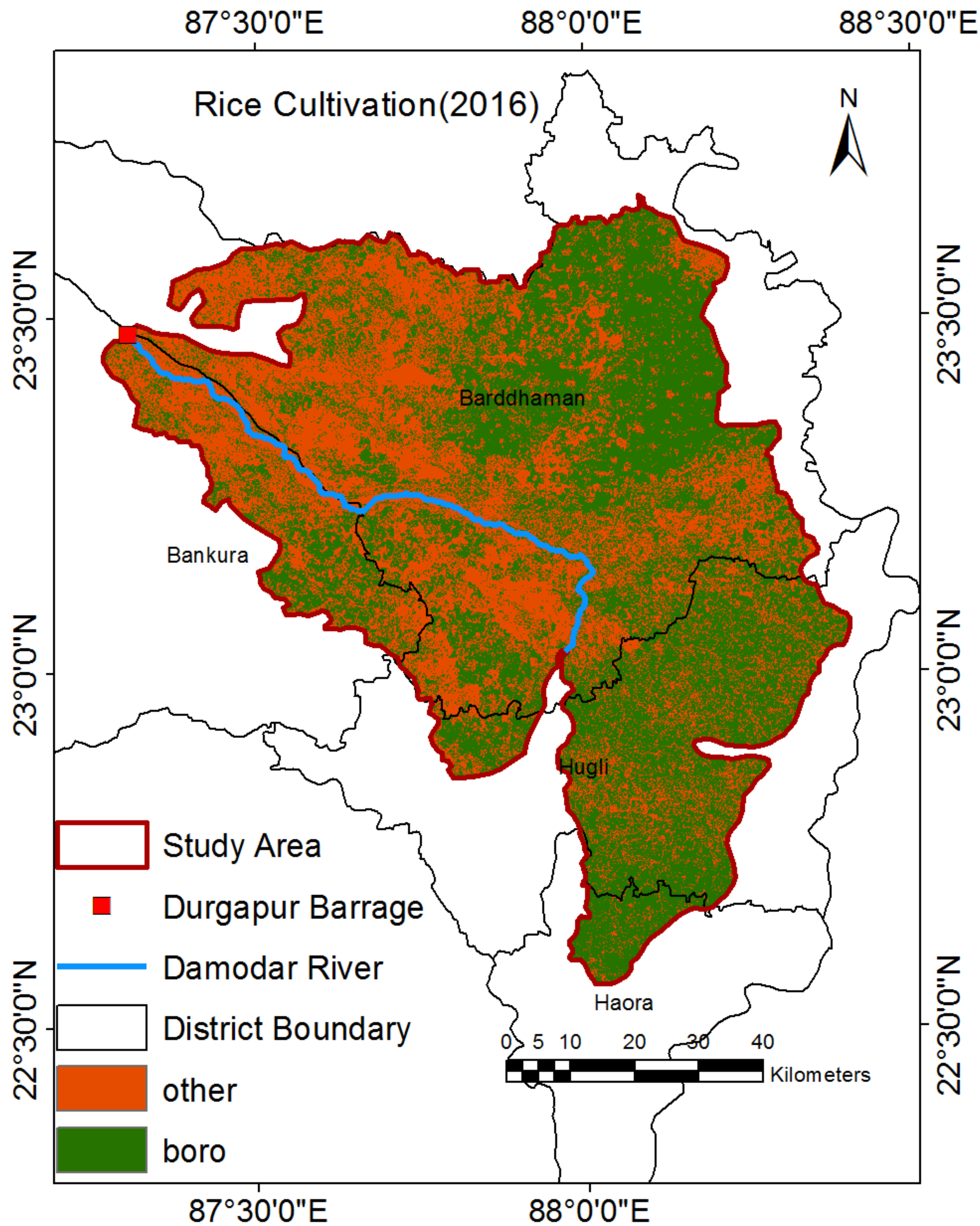


Figure 1.36: Boro rice map of DVC irrigation system in year 2016

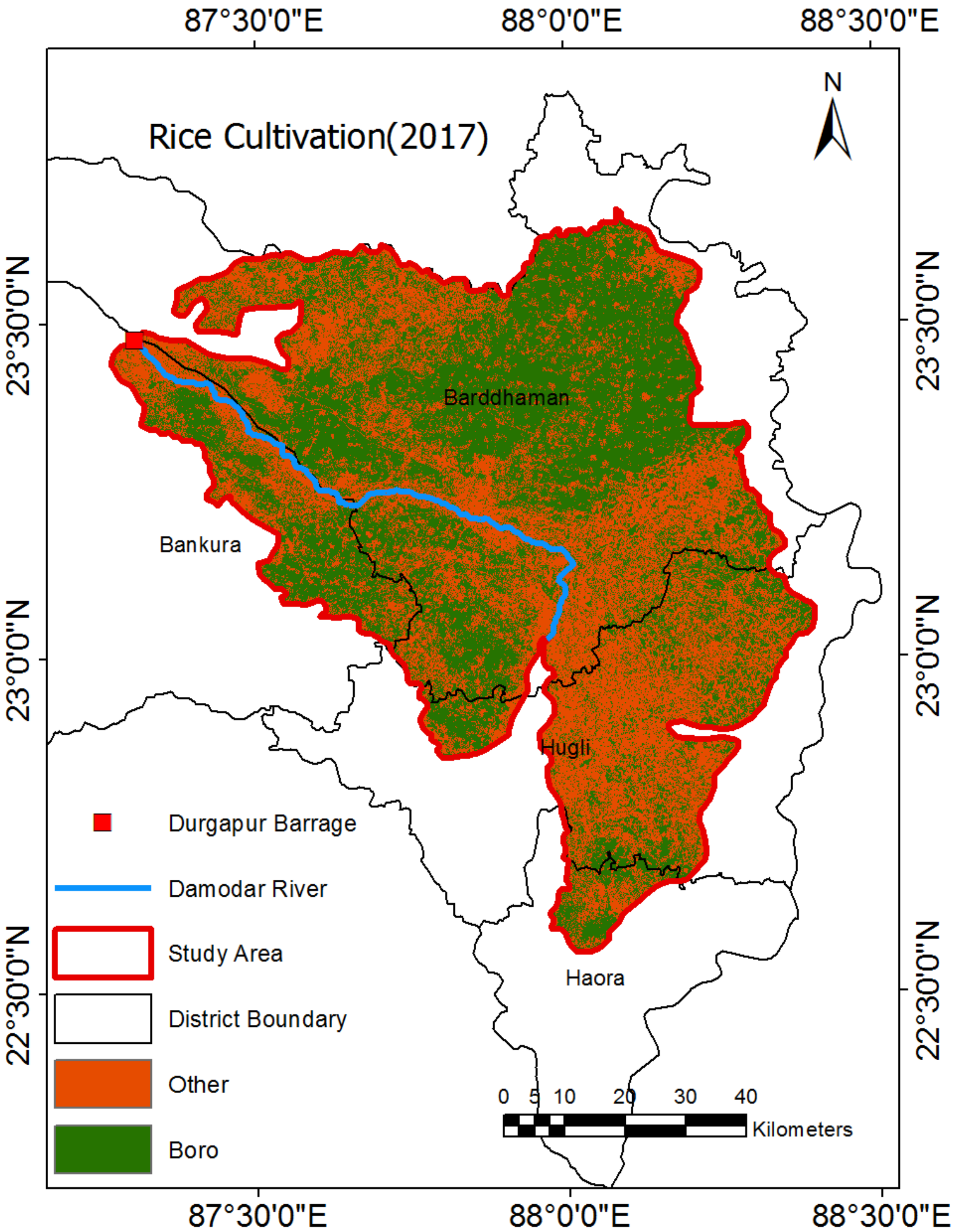


Figure 1.37: Boro rice map of DVC irrigation system in year 2017

Table 1.1: Areal expansion of Boro rice and other land use cover during 1988 to 2017 in DVC irrigation system

Year	Other Land Use	Boro	Year	Other Land Use	Boro
1988	5057.39	1935.64	2003	3562.58	3430.45
1989	5050.32	1942.71	2004	3606.54	3386.48
1990	5253.98	1739.05	2005	3649.51	3343.52
1991	5153.14	1839.90	2006	3131.48	3861.55
1992	5235.14	1757.89	2007	3484.71	3508.33
1993	4521.09	2471.95	2008	2186.05	4806.98
1994	3835.21	3157.82	2009	2686.51	4306.52
1995	5137.89	1855.15	2010	2798.96	4194.07
1996	4744.88	2248.16	2011	3124.94	3868.09
1997	3310.63	3682.40	2012	2607.90	4380.85
1998	4189.88	2803.16	2013	2202.78	4790.25
1999	3708.38	3284.66	2014	2897.33	4091.42
2000	2715.42	4277.61	2015	3358.74	3630.01
2001	4037.93	2955.10	2016	3189.71	3799.04
2002	3543.16	3449.88	2017	3620.78	3372.25

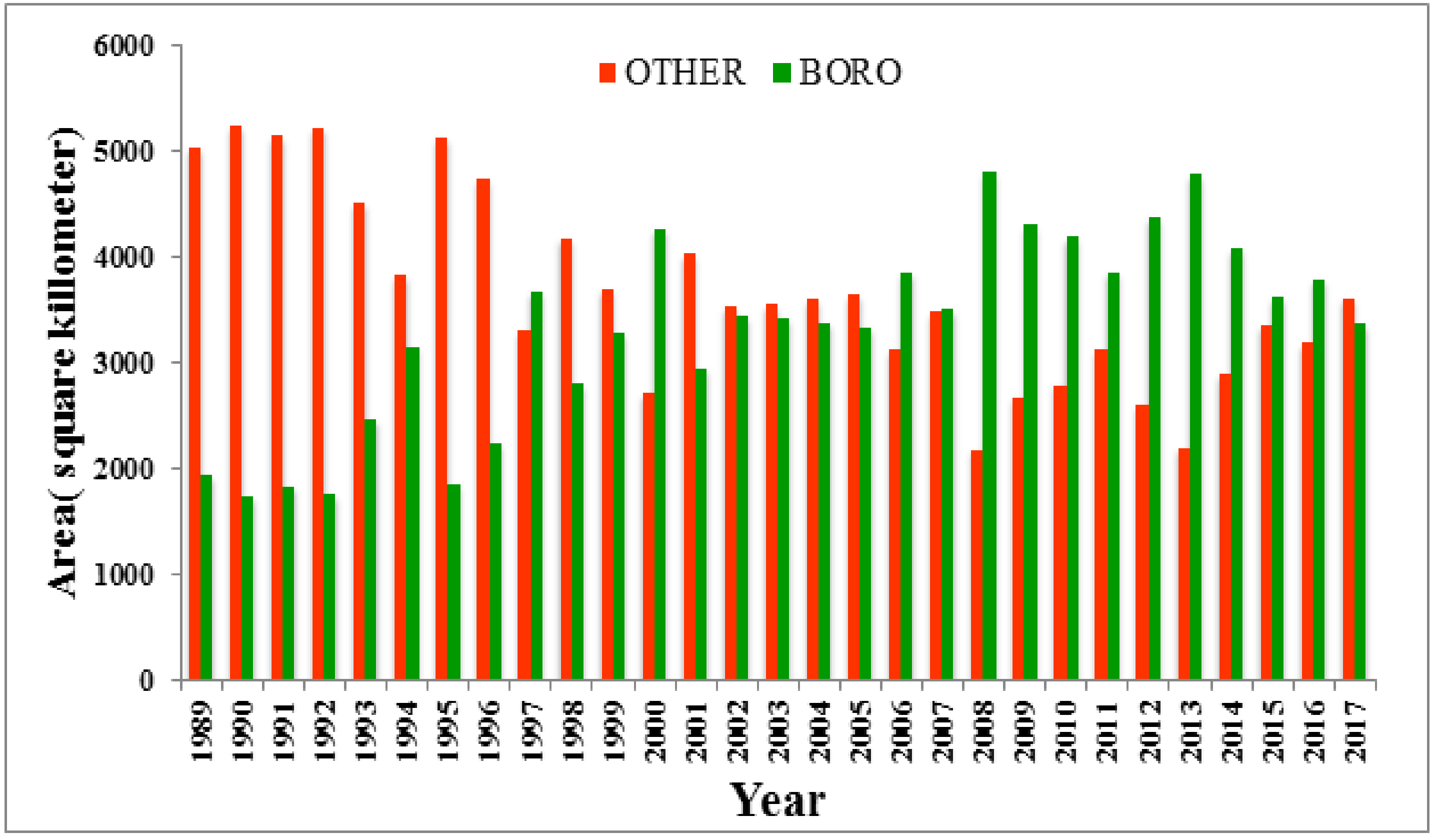


Figure 1.38: Diagrammatic illustration of areal expansion of Boro rice and other land use cover during 1988 to 2017 in DVC irrigation system

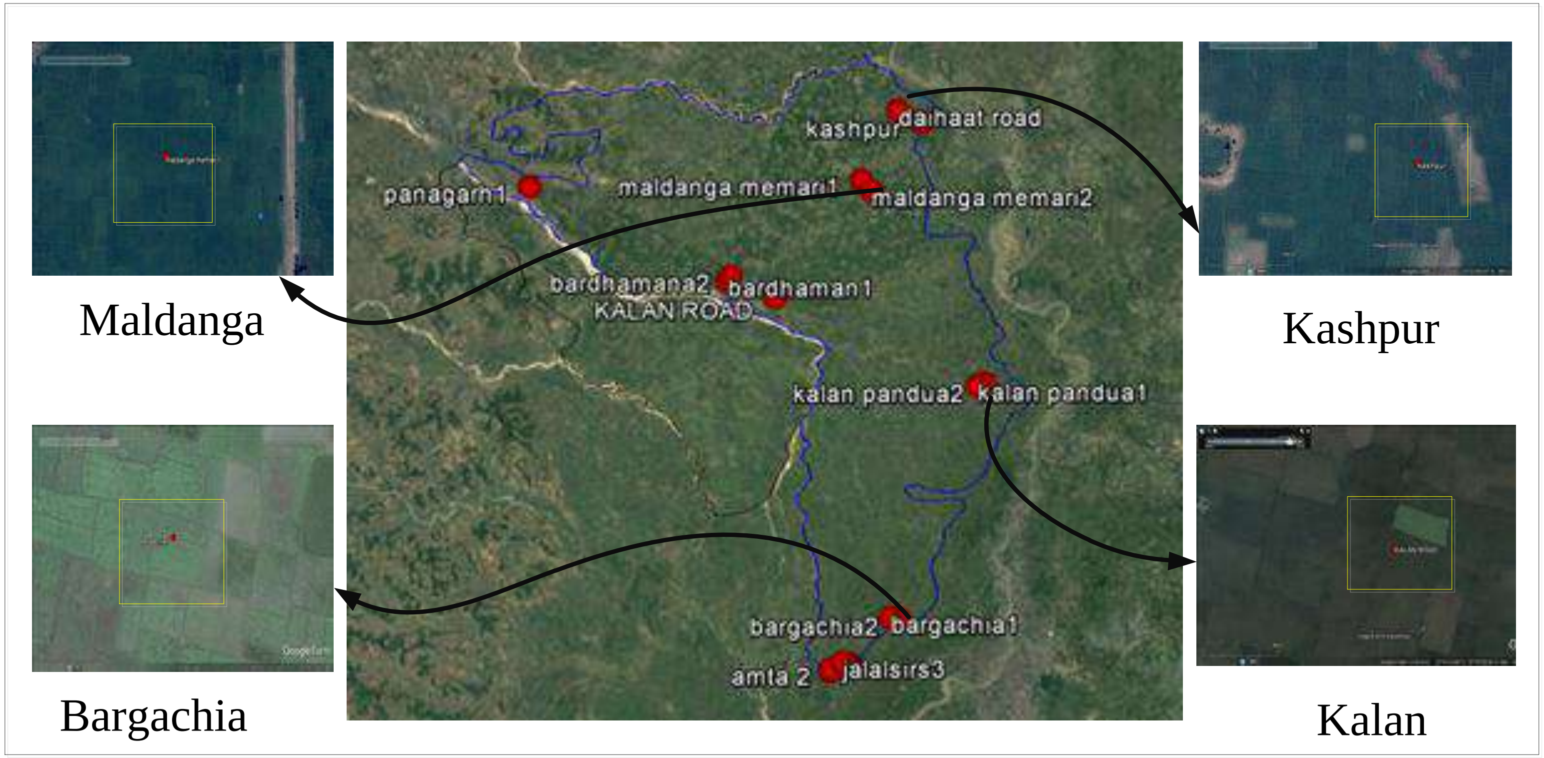


Figure 1.39: Extraction of the validation areas of interest from Google Earth for year 2017 and landscapes of the corresponding rice fields

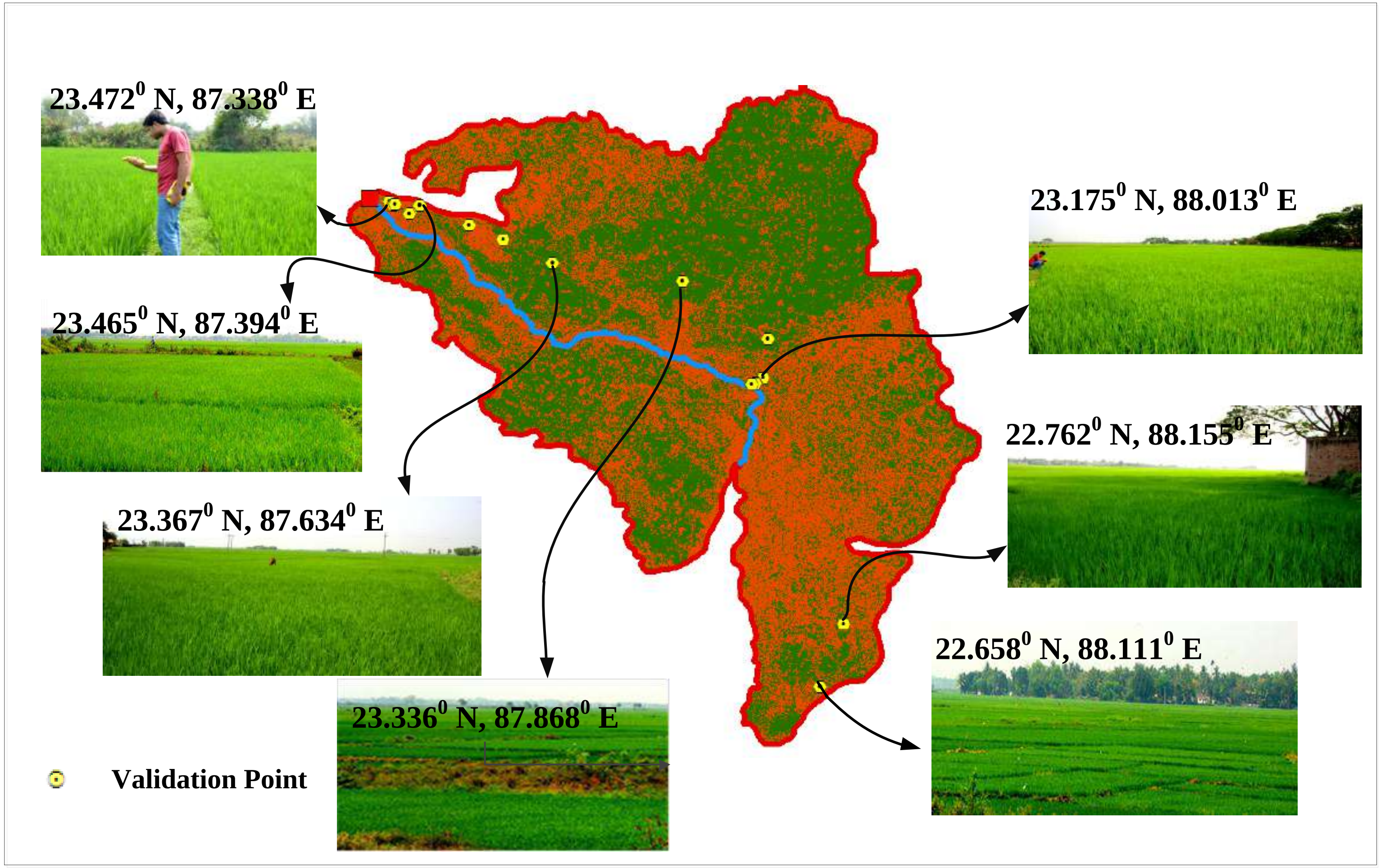


Figure 1.40: Spatial distribution of field photos of selected validation points at different location

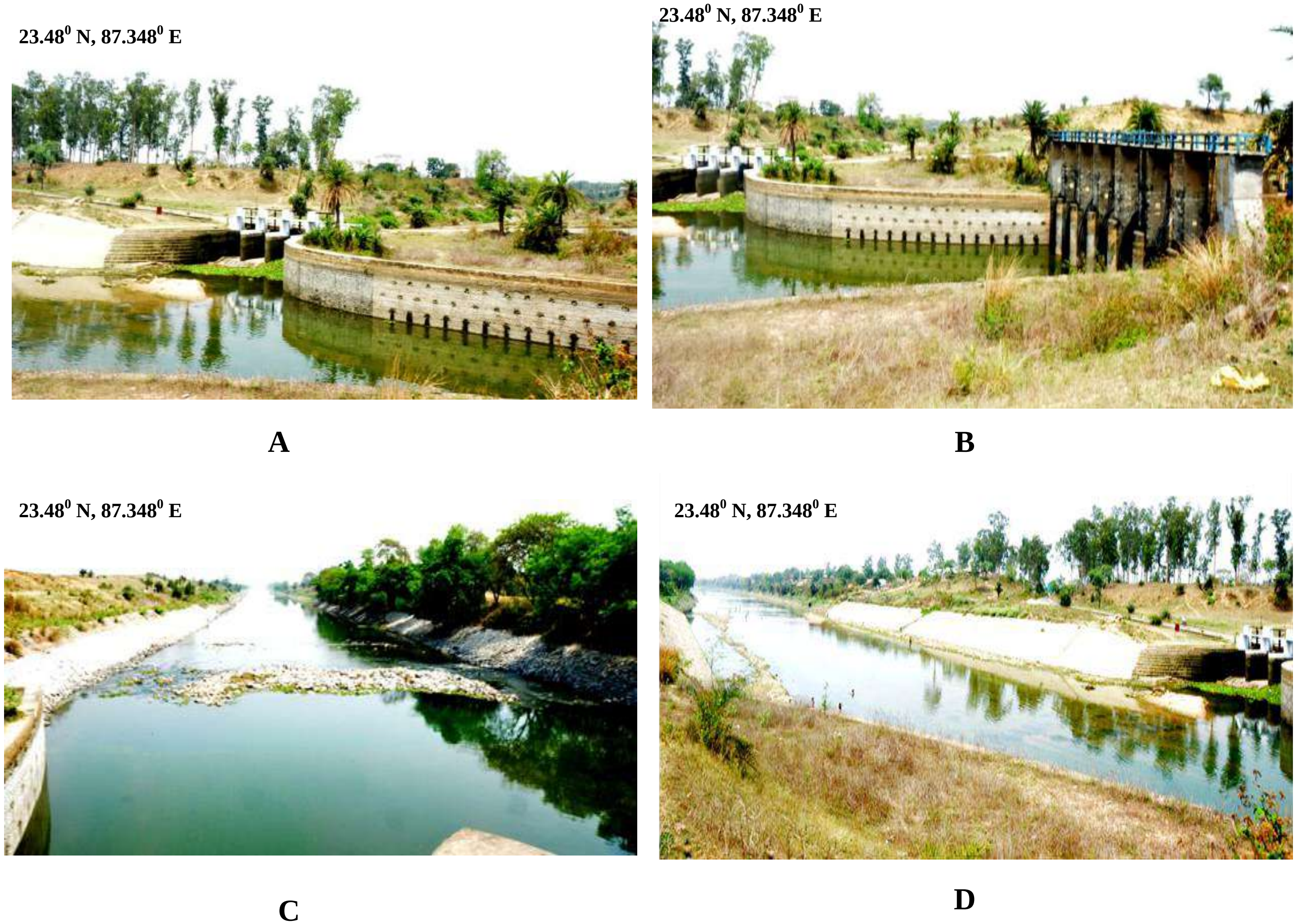


Figure 1.41: DVC left bank main canal at Bhairabpur, Durgapur

Over the year an increasing trend of Boro rice cultivation during the most water scarcity period was observed throughout the study area. As the canal water supply was not sufficient during mid-Jan to mid-April, cultivation of such high water demanding crop was highly dependent upon groundwater at middle and lower reach of DVC command area which was mainly responsible for continuous increase in groundwater draft that might be resulted in the increased exploitation of groundwater reservoir. The results obtained from analysis of remote sensing data can be used for achieving a sustainable strategy of water use along with its management in relation to its availability over the study area. Spatial and temporal variation of groundwater level from 2000 to 2013 was analyzed to examine the variability of groundwater reservoir based on fourteen piezometers as shown in Figures 1.43. Variability of groundwater reservoir from 2000 to 2013 are shown in Figures 1.44 to 1.57. In 2000, water table mount were found at Amargarh, Pandua and Metedanga sites of Bardhhaman district; Tarakeswar site of Hugly district and Patrasaye station site of Bankura district while depression of water table were found in Guskara and Rokana sites of Barddhaman district; Barjora site of Bankura district and Gopal Prasadpur site of Hugly district during pre-monsoon season. The pre-monsoon water table over the study area was varied from 1.76 m (b.g.l) at Tarakeswar site to 7.73 m (b.g.l) at Barjora site. During post monsoon period similar mount were observed around Tarakeswar, Metedanga, Pandua, Patrasayer and Amargard sites while depression of water table were found at Naity Alipur of Hugly district, Barjora site. The water table depth (b.g.l) at Gopal Prasadpur was increased to 3.2 m during post-monsoon season which was at 7.72 m during pre-monsoon season. The post monsoon water table over the study area was varied from 1.14 m at Tarakeswar site to 5.19 m at Naity Alipur site.Spatial variability of groundwater table during 2000 is shown in Figure 1.44. In 2005, during pre-monsoon season higher water table depression of 9.59 m (b.g.l) was observed at Naity Alipur site of Hugly district which was due to extensive exploitation of groundwater for Boro rice cultivation as canal water supply was insufficient. As compared to value of water table depth (b.g.l) during 2000, higher intensive depressions of water table were found around Gopal Prasadpur, Guskara, and Rokana site. The pre-monsoon water table over the study area was varied from 2.03 m (b.g.l) at Metedanga site to 9.59 m (b.g.l) at Naity Alipur site. During post monsoon season, the water table depth (b.g.l) was lower as compared to the value of water table depth (b.g.l) of pre-monsoon season. It was varied from 0.69 m at Pandua site to 5.83 m at Naity Alipur site. Spatial variability of groundwater table during 2005 is shown in Fig-

A

B

C

Figure 1.42: DVC Eden canal and it's control gate at Palla road, Bardhaman

ure 1.49. In 2010, similar kinds of depression were observed during pre-monsoon season where the water table varied from 2.18 m at Metedanga site to 9.39 m at Gopal Prasadpur. During post monsoon season, the water table depth (b.g.l) was higher as compared to the post monsoon water table depth (b.g.l) of 2005. It was varied from 1.54 m at Metedanga site to 11.09 m at Guskara site as shown in Figure 1.54. In 2013, highest water table depression of 10.84 m (b.g.l) was observed around Gopal Prasadpur site during pre-monsoon season as shown in Figure 1.57. It also revealed higher magnitude of depression around Rakona and Guskara. During pre-monsoon season water table varied from 1.97 m at Barjora site to 10.84 at Gopal Prasadpur site while during post monsoon season, water table varied from 0.21 m at Tarakeswar to 6.1 at Gopal Prasadpur site. During the study period maximum depression of water table was observed around Barjora, Rakona, Guskara, Naity Alipur and Gopal Prasadpur site while water table mount was found at Tarakeswar, Pandua and Metedanga site. From the LULC map it was observed that maximum Boro cultivation was occurred in these areas which is the primary cause behind water table depression. Temporal variation of water table depth during pre-monsoon and post monsoon season at these sites were shown in Figure 1.58 & 1.59. The maximum depth to water table in all four districts under study area was observed in pre-monsoon season whereas it was minimum during the post-monsoon season.

Daily discharges of Durgapur barrage were analyzed for a period of twenty one years i.e. from 1997 to 2017. During 1997 discharge from barrage was varied from 17 m^3/sec to 7104.07 m^3/sec. During monsoon season (August-October) 1027.31 m^3/sec to 7104.07 m^3/sec of water was released from barrage which was higher as compared to quantity of water released during other months. During Boro cultivation period the discharge varied from 17 m^3/sec to 207.64 m^3/sec. Higher amount of water was released during mid-February to last week of March which is the development and mid-season stage of Boro rice. Similar pattern was followed in 1998 with discharge of barrage varied from 14.16 m^3/sec to 7104.07 m^3/sec. In 2000 the daily discharge of barrage was varied from 28.32 m^3/sec to 237.185 m^3/sec during Boro cultivation period whereas highest amount of water i.e. 7104.07 m^3/sec was released during September. Similar pattern of water release from Durgapur barrage was followed throughout the study period. Weekly variation of average discharge was plotted for each year and shown in Figure 1.60 to 1.70.

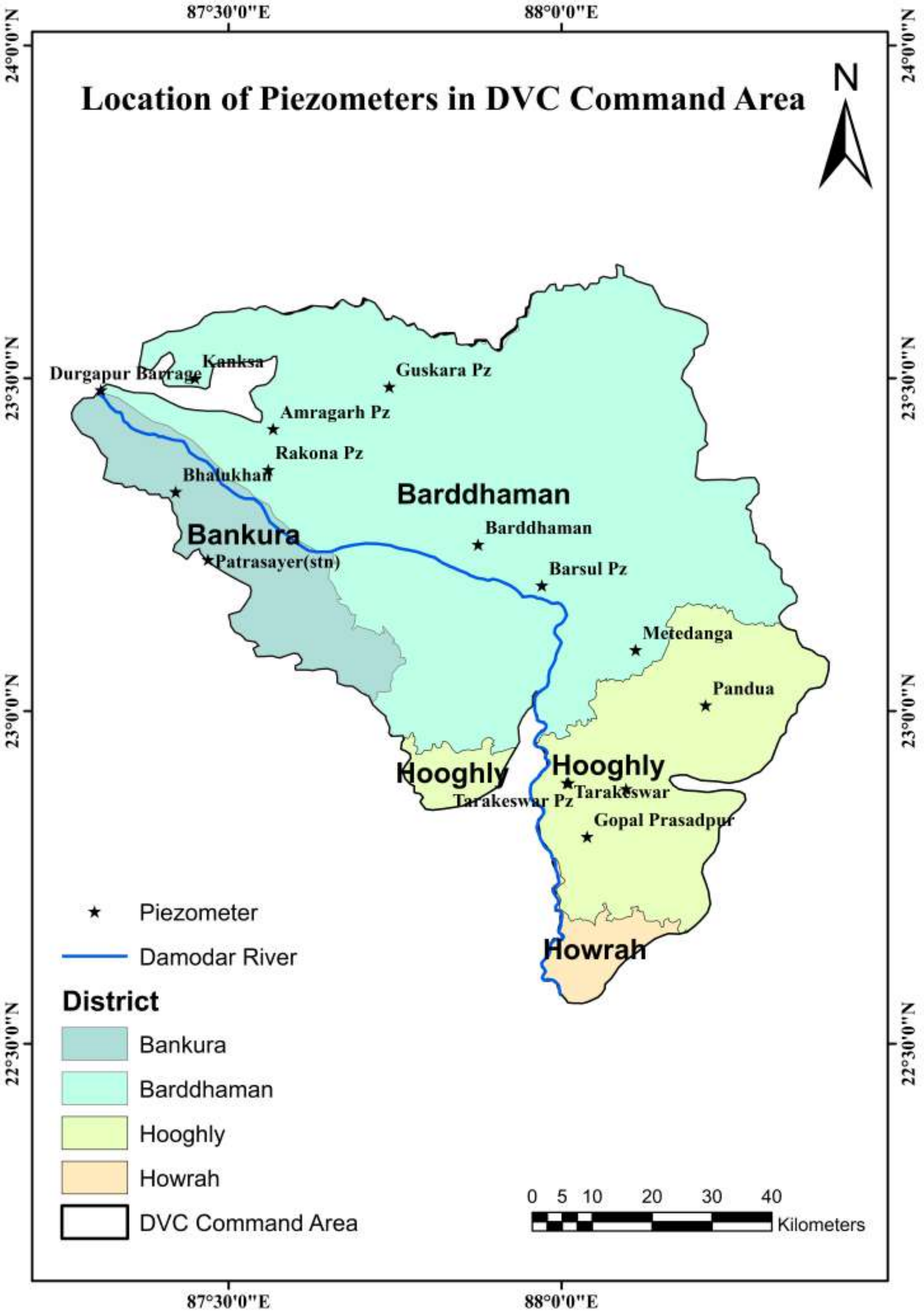


Figure 1.43: Location of piezometers in DVC canal command

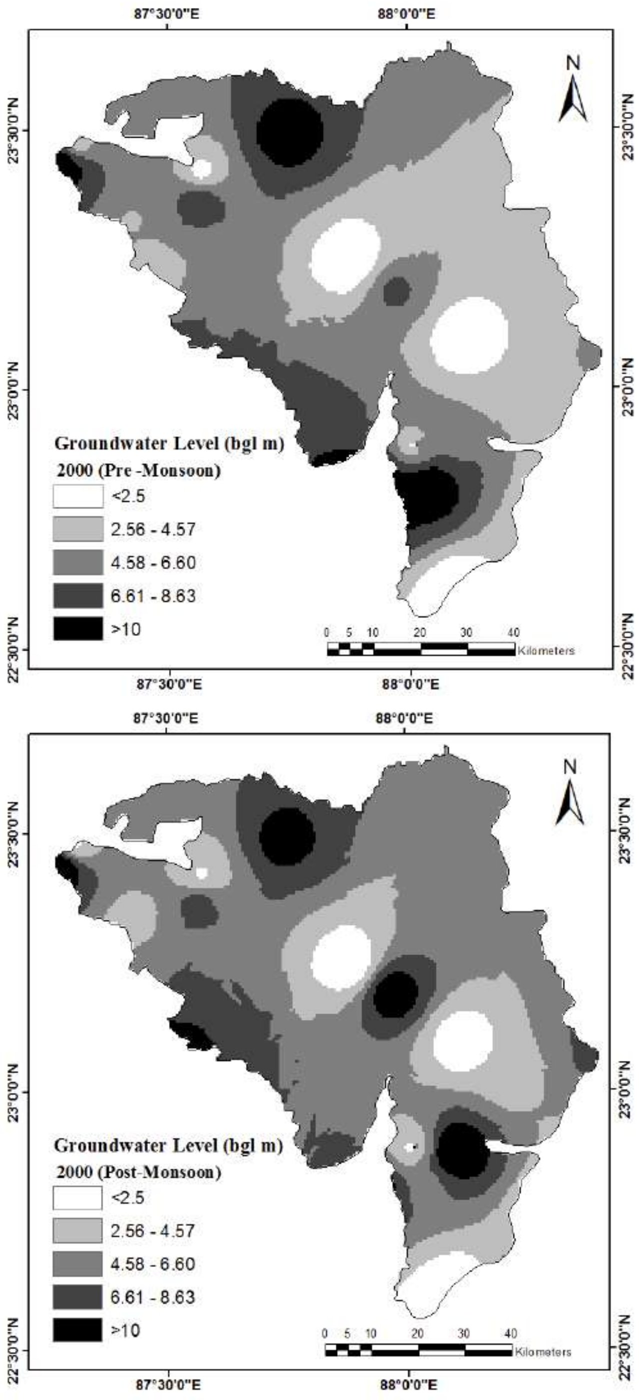


Figure 1.44: Spatial variability of pre-monsoon and post monsoon groundwater table for year 2000

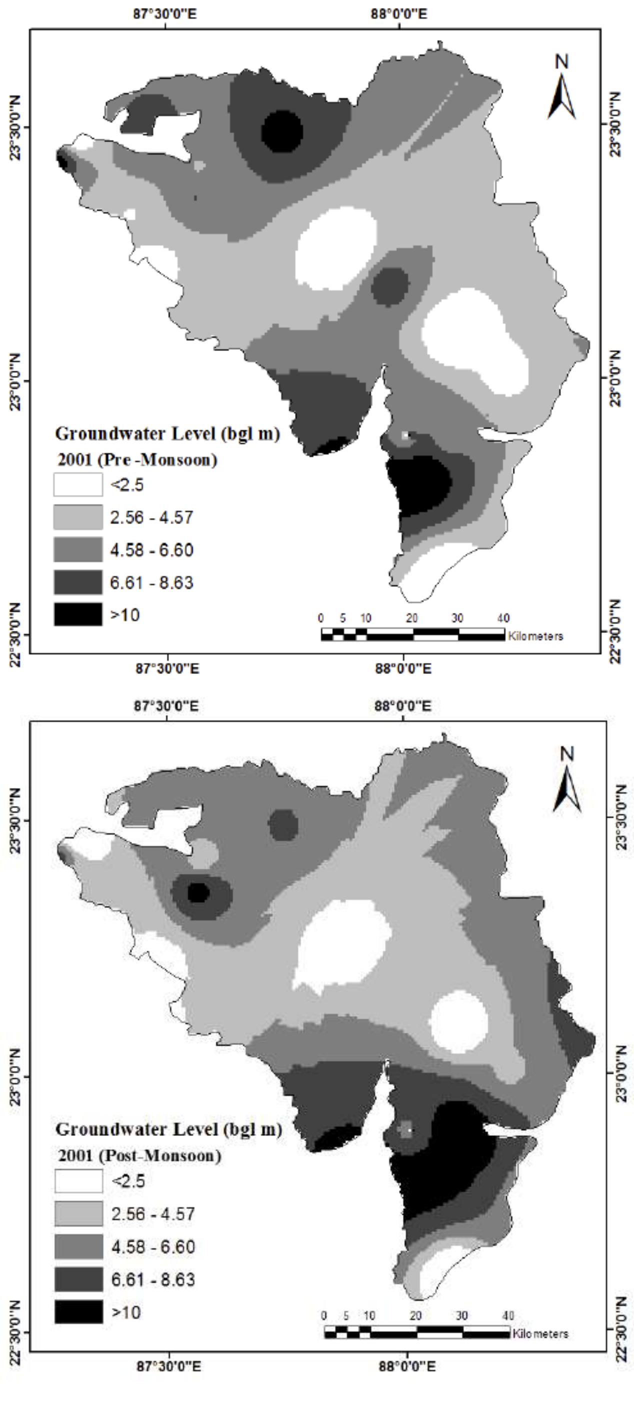


Figure 1.45: Spatial variability of pre-monsoon and post monsoon groundwater table for year 2001

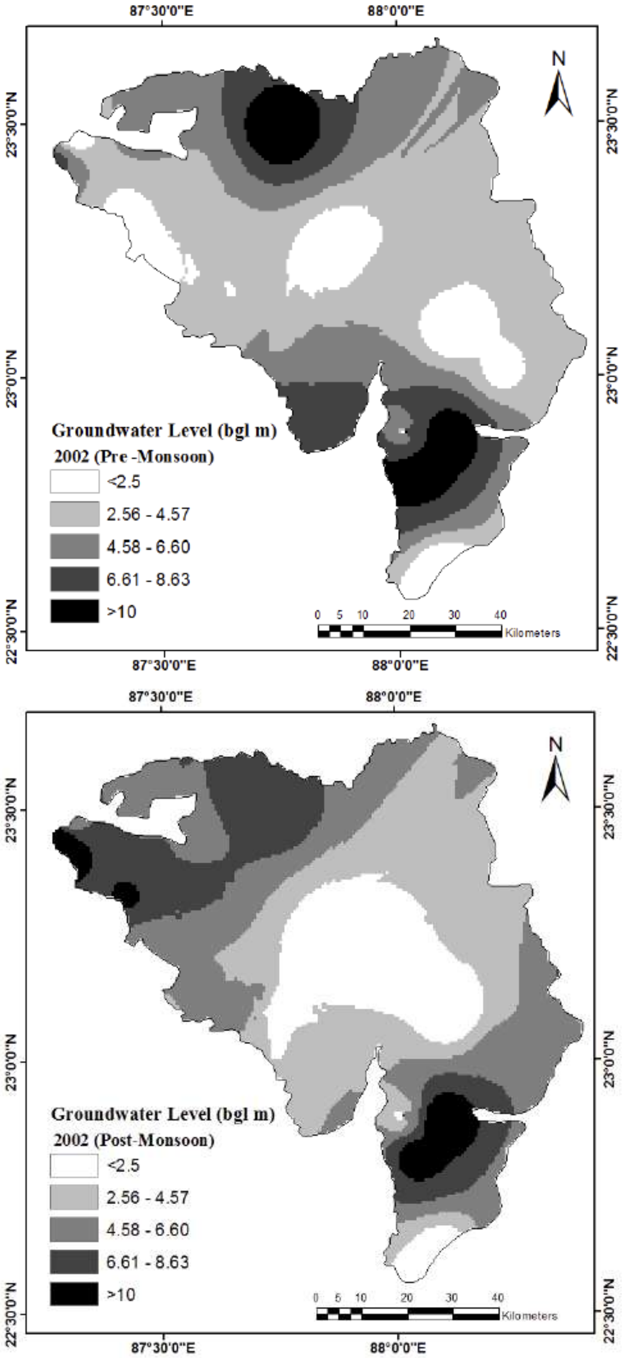


Figure 1.46: Spatial variability of pre-monsoon and post monsoon groundwater table for year 2002

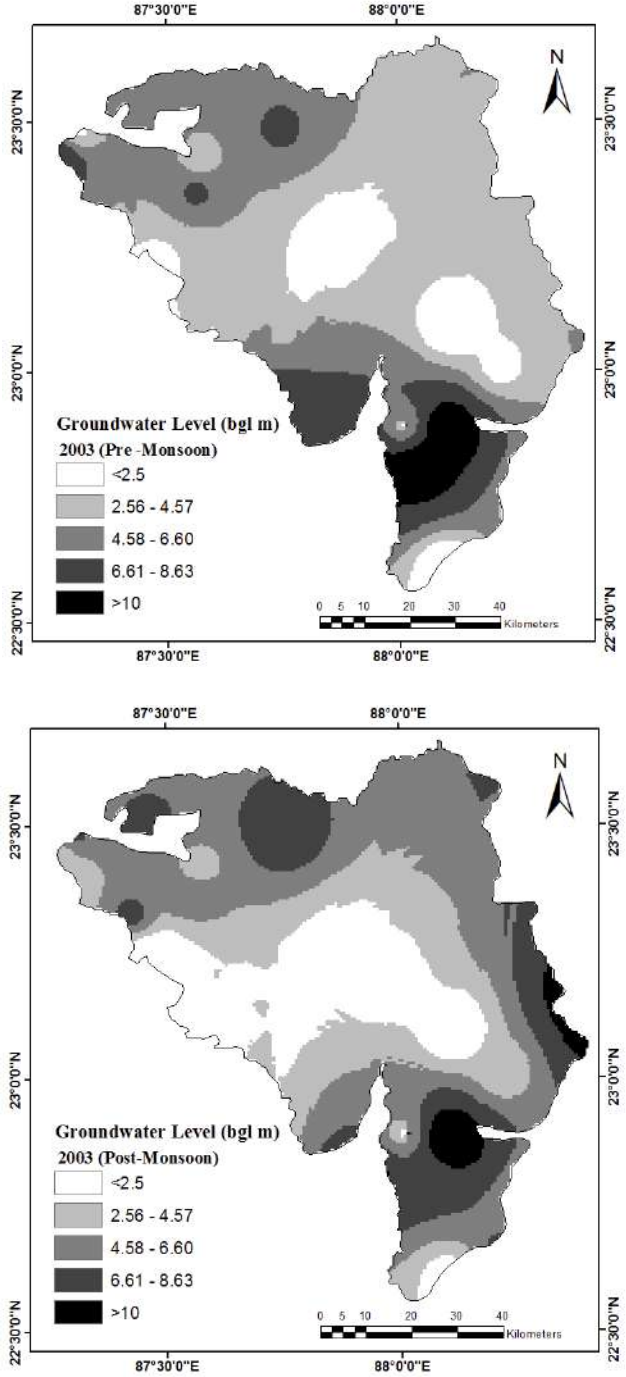


Figure 1.47: Spatial variability of pre-monsoon and post monsoon groundwater table for year 2003

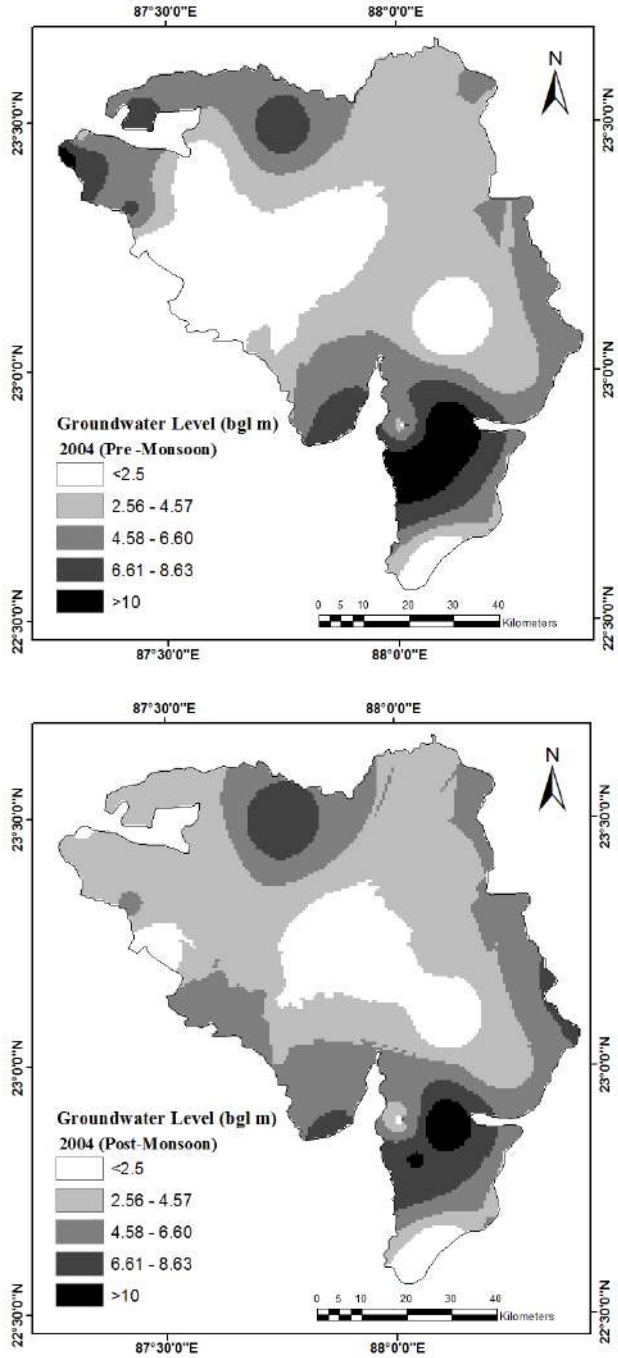


Figure 1.48: Spatial variability of pre-monsoon and post monsoon groundwater table for year 2004

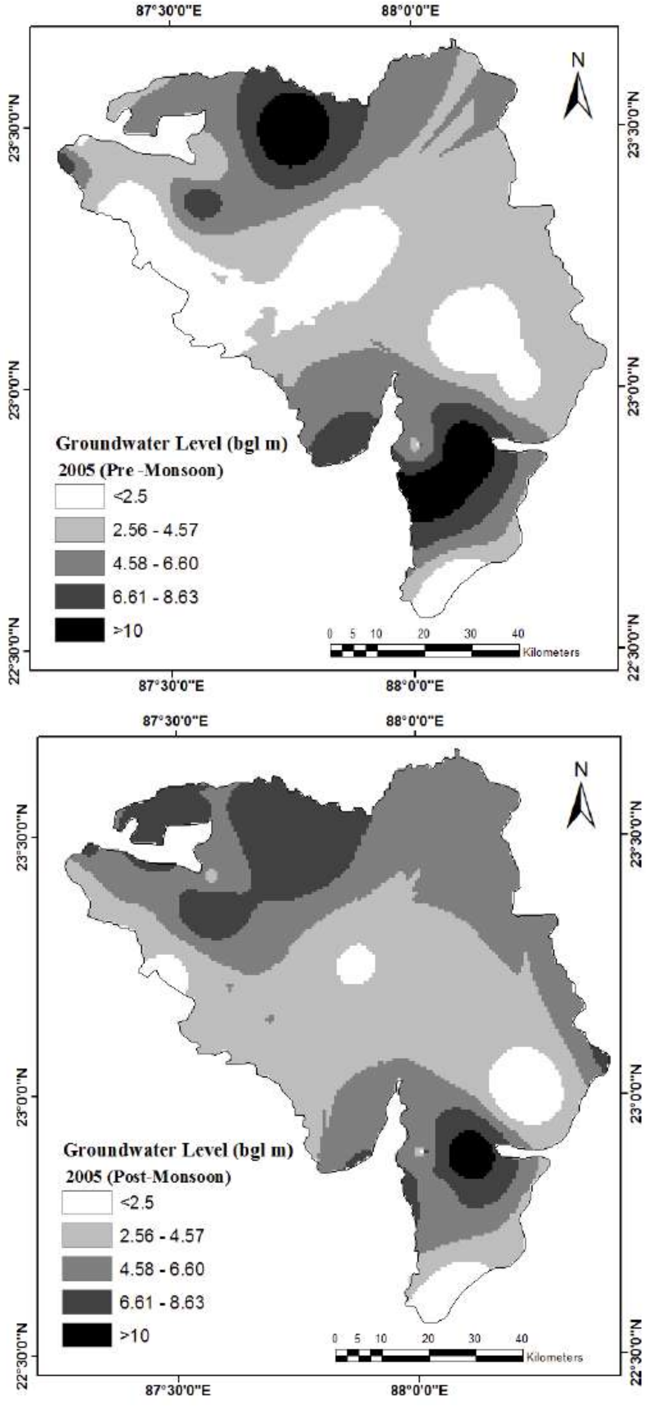


Figure 1.49: Spatial variability of pre-monsoon and post monsoon groundwater table for year 2005

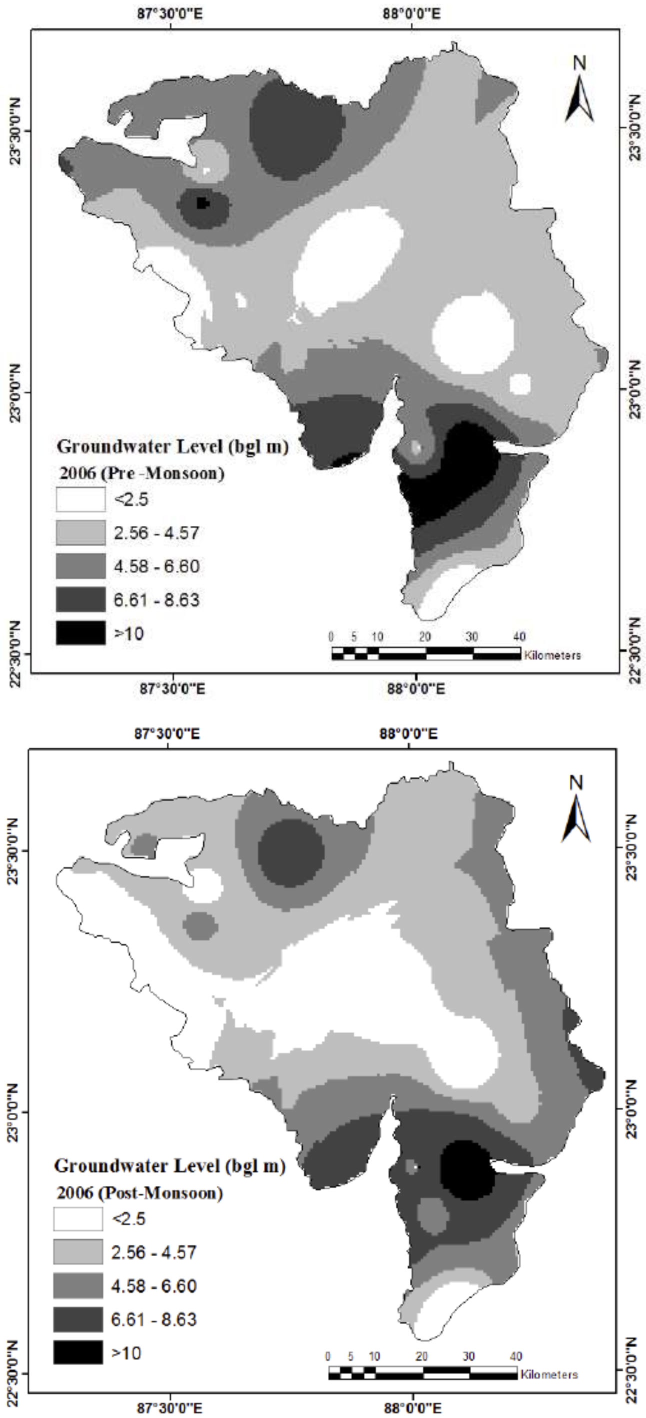


Figure 1.50: Spatial variability of pre-monsoon and post monsoon groundwater table for year 2006

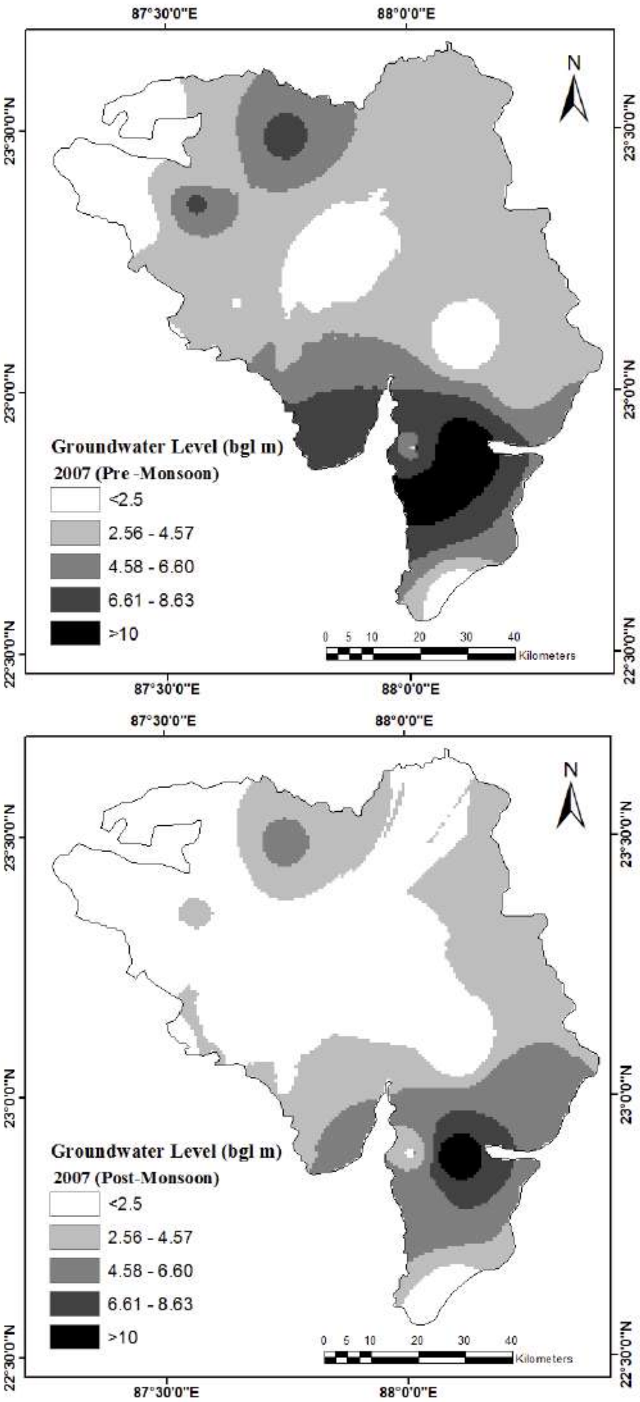


Figure 1.51: Spatial variability of pre-monsoon and post monsoon groundwater table for year 2007

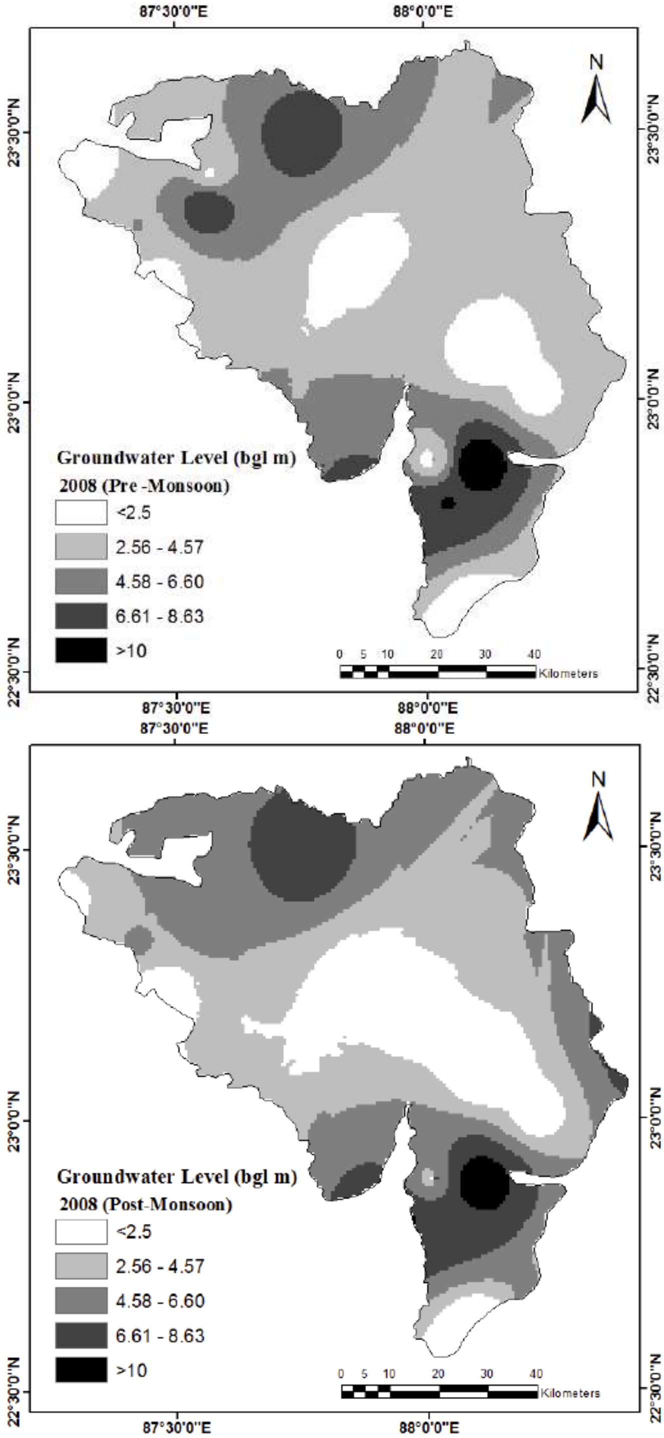


Figure 1.52: Spatial variability of pre-monsoon and post monsoon groundwater table for year 2008

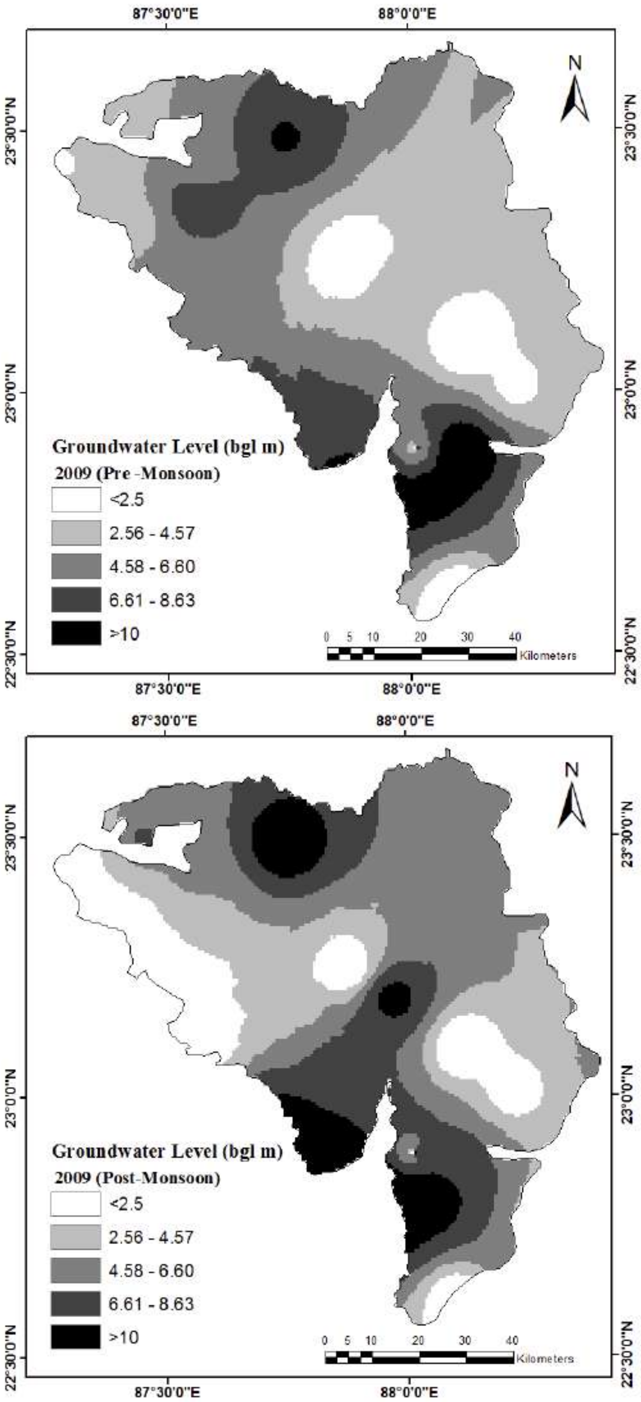


Figure 1.53: Spatial variability of pre-monsoon and post monsoon groundwater table for year 2009

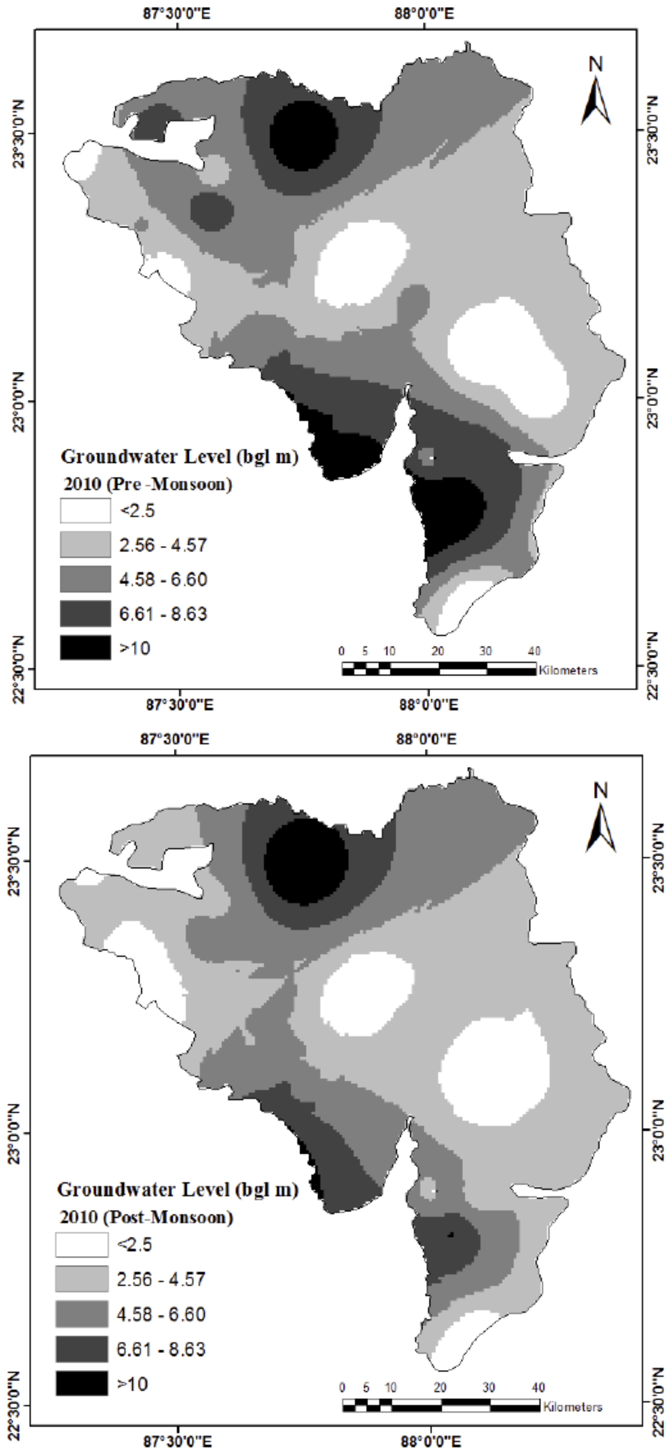


Figure 1.54: Spatial variability of pre-monsoon and post monsoon groundwater table for year 2010

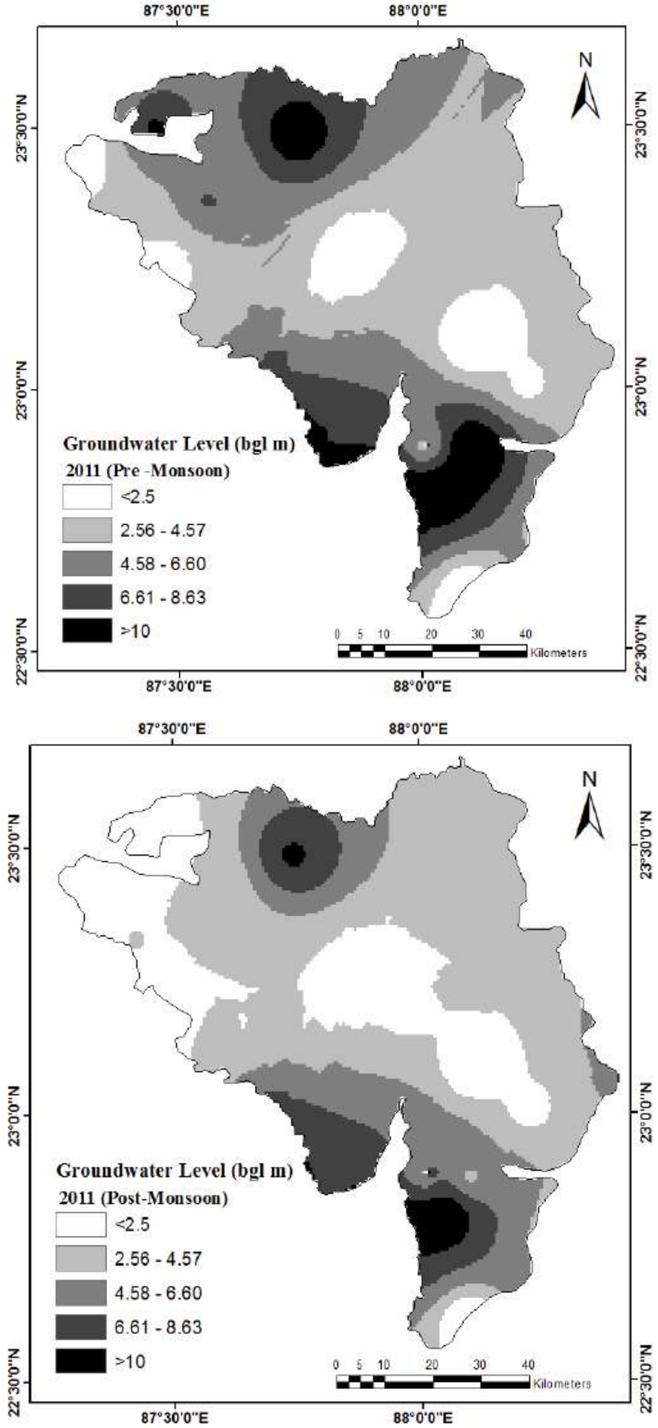


Figure 1.55: Spatial variability of pre-monsoon and post monsoon groundwater table for year 2011

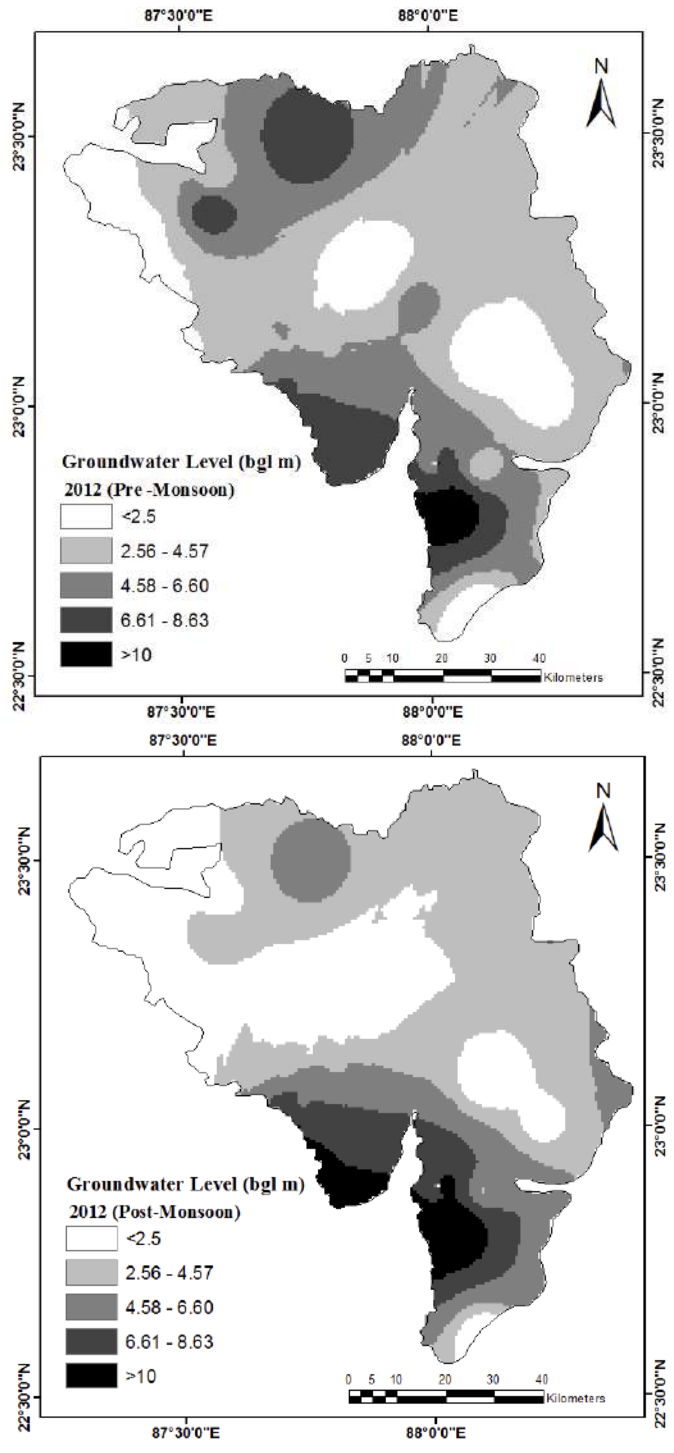


Figure 1.56: Spatial variability of pre-monsoon and post monsoon groundwater table for year 2012

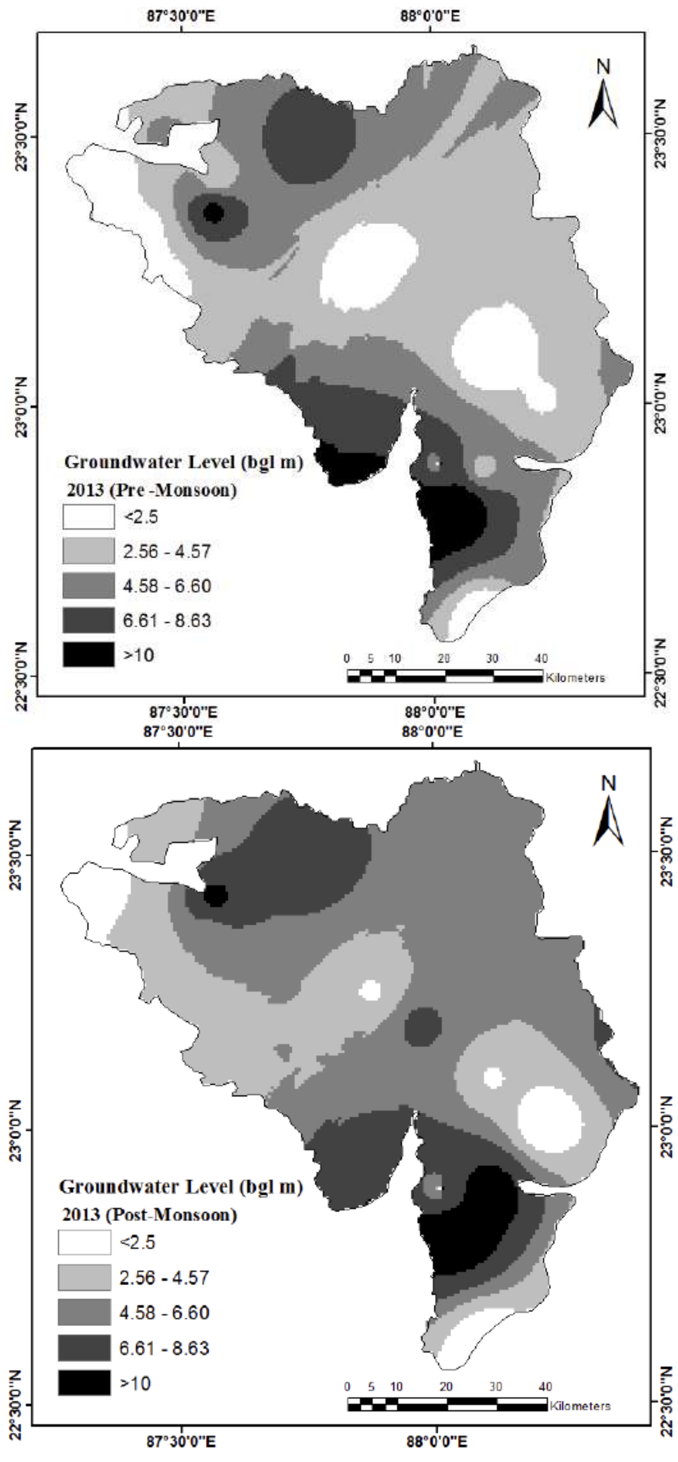


Figure 1.57: Spatial variability of pre-monsoon and post monsoon groundwater table for year 2013

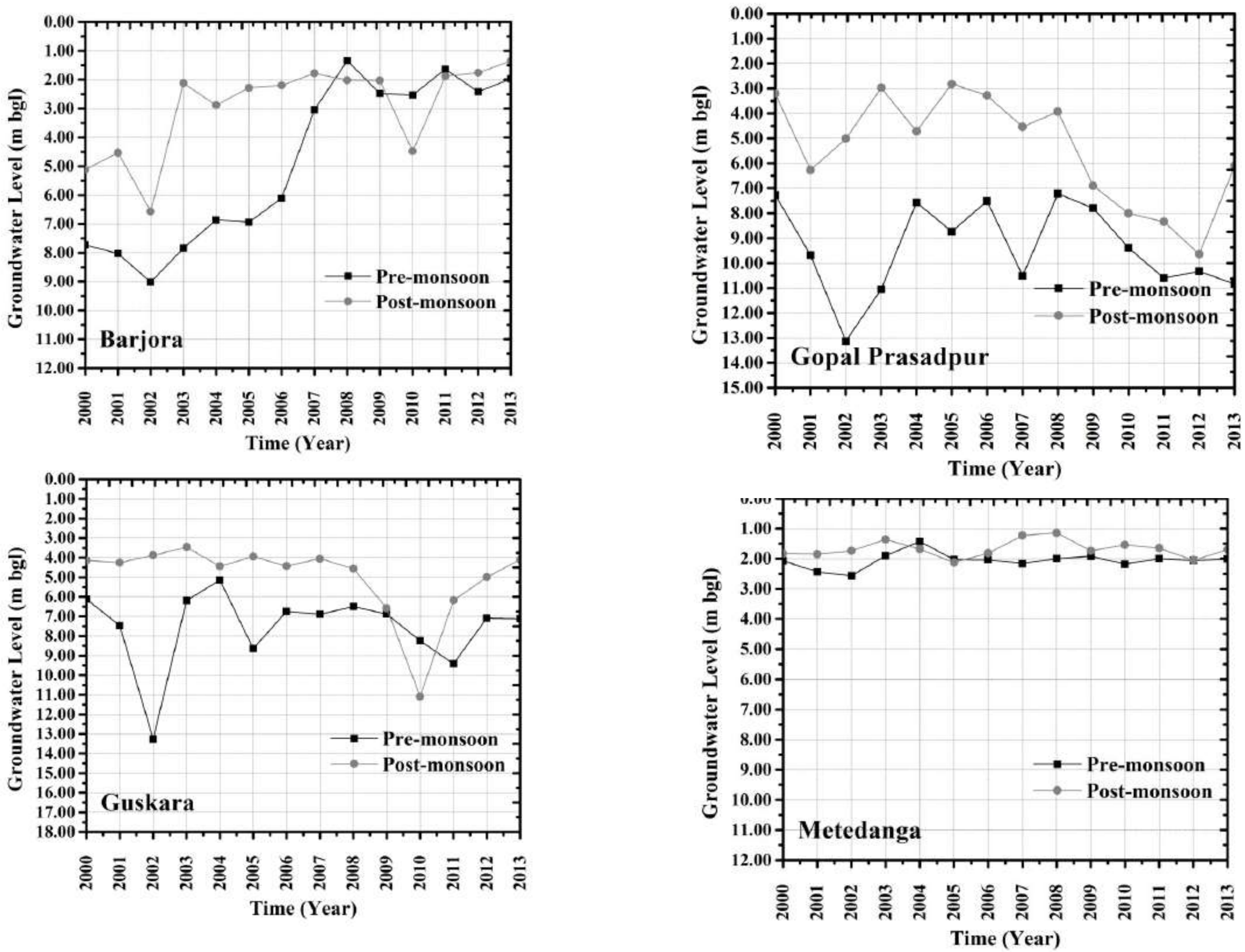


Figure 1.58: Temporal variation of water table depth during pre-monsoon and post monsoon season at station Barjora, Gopal Prasadpur,Guskara and Metedanga as per fig 1.43

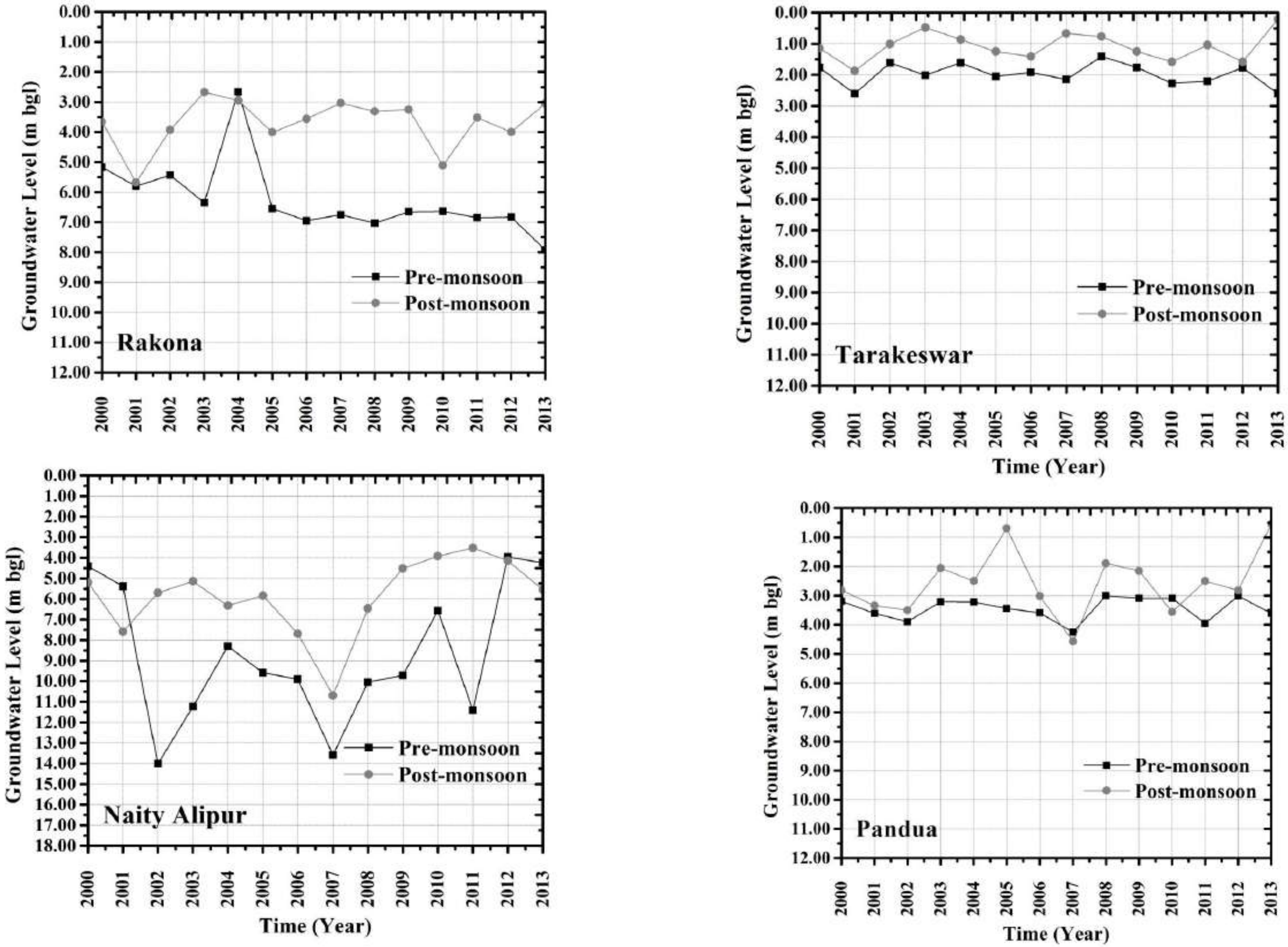


Figure 1.59: Temporal variation of water table depth during pre-monsoon and post monsoon season at station Rakona, Tarakeswar, Naity Alipur and Pandua as per fig 1.43

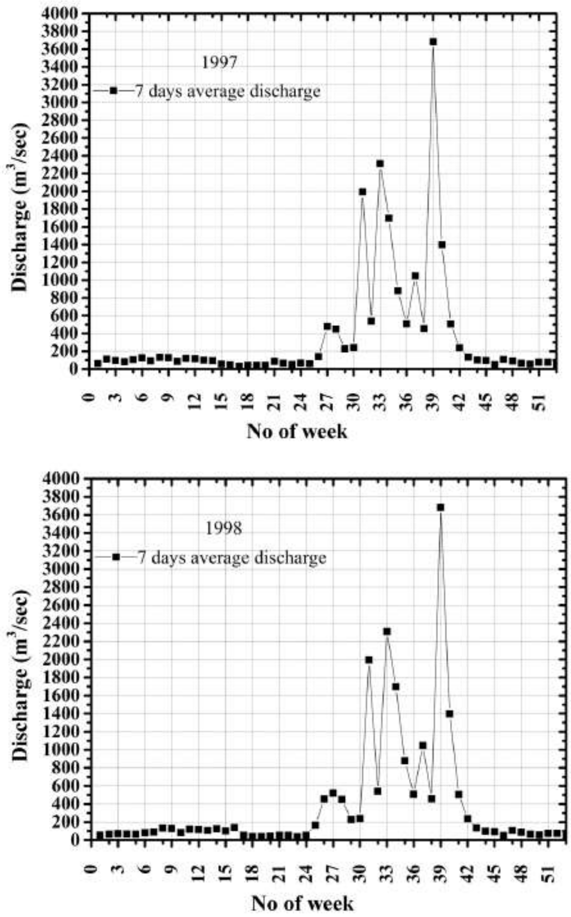
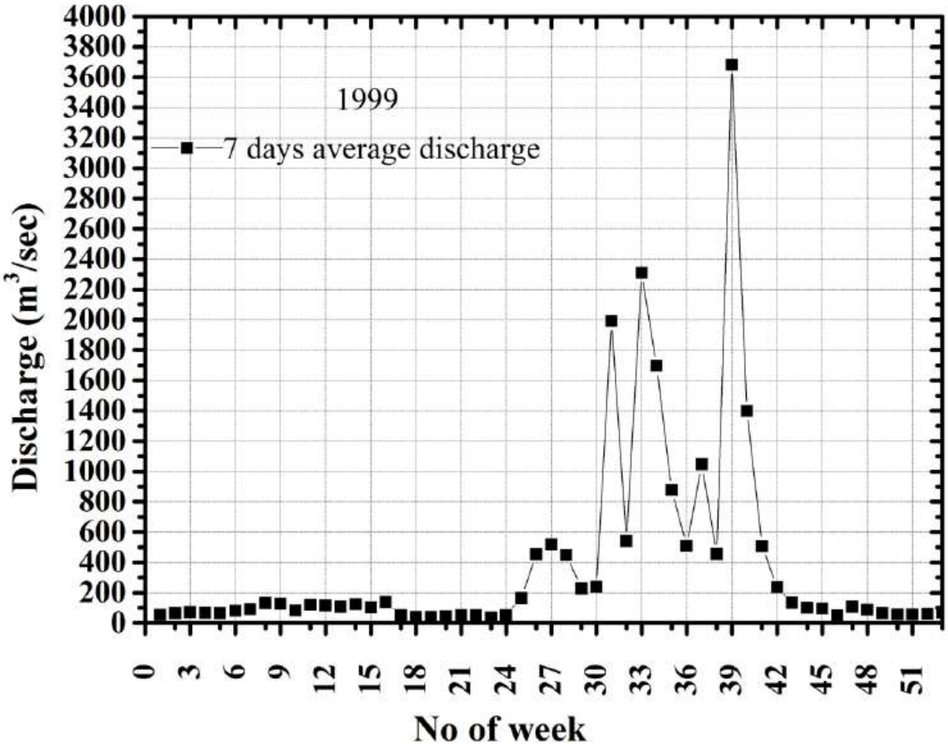


Figure 1.60: Weekly Average Discharge Released from Durgapur Barrage to Left Bank Main Canal During 1997 and 1998

The detailed canal network was delineated in GIS platform which is shown in Figure 1.71. Canal regulation (water supply) charts during Boro season from 2001 to 2018 were collected from Damodar Head Works division. These charts were transferred into map form in GIS environment.Figure 1.72 to 1.85 show the canal water supply map during Boro season from year 2001 to 2018. It was observed that canal water supply was limited to Damodar main canal, Eden canal, Bahula canal, Panagarh branch canal and Durgapur branch canal. Other portion of command area were depended upon groundwater for Boro rice cultivation.



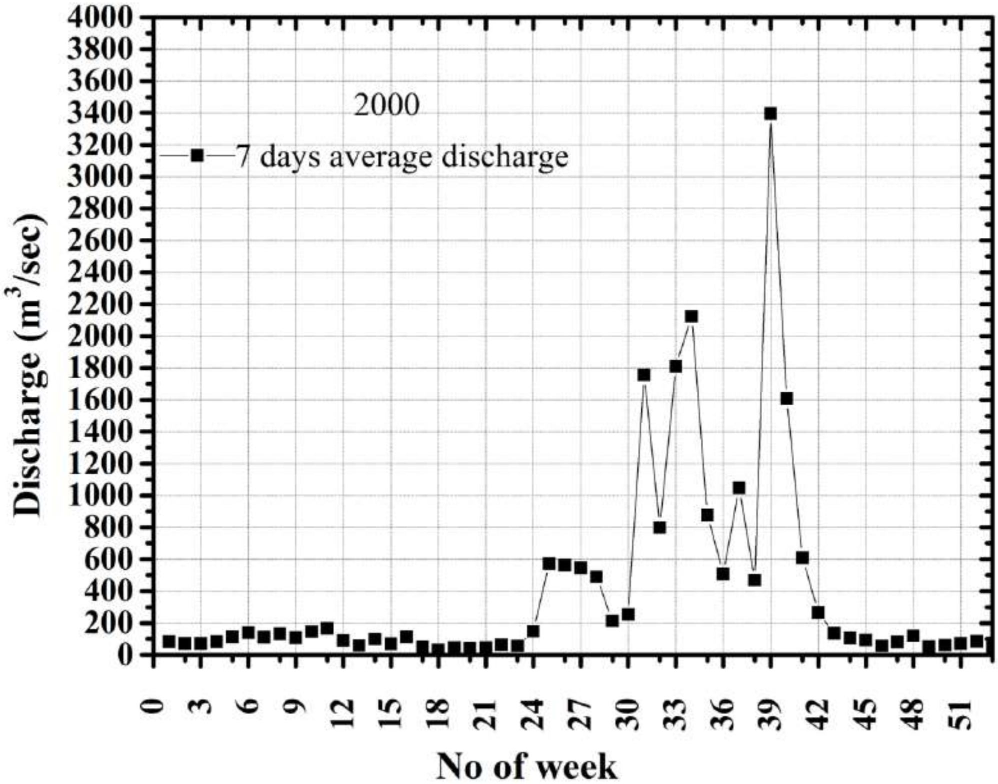


Figure 1.61: Weekly Average Discharge Released from Durgapur Barrage to Left Bank Main Canal During 1999 and 2000

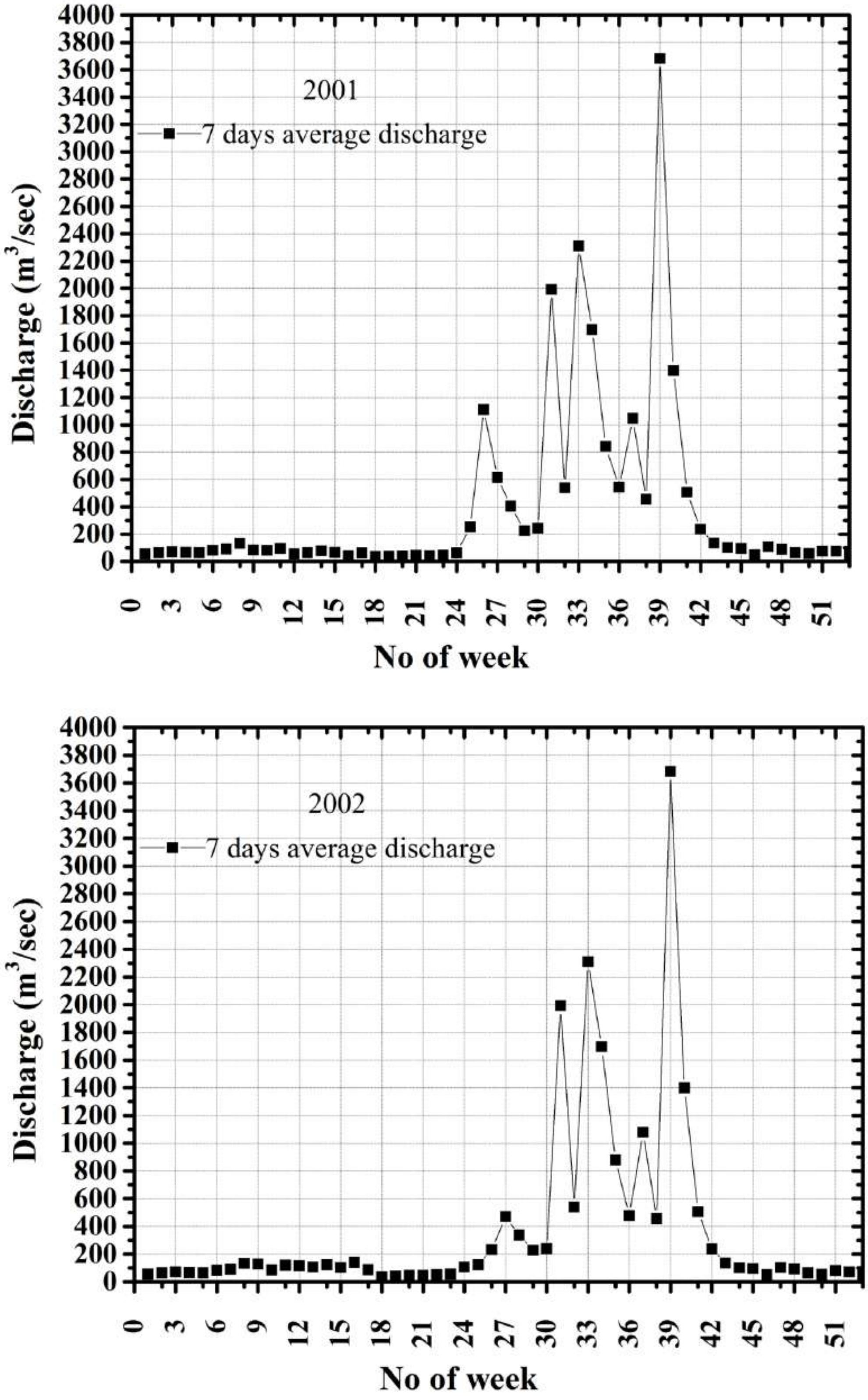


Figure 1.62: Weekly Average Discharge Released from Durgapur Barrage to Left Bank Main Canal During 2001 and 2002

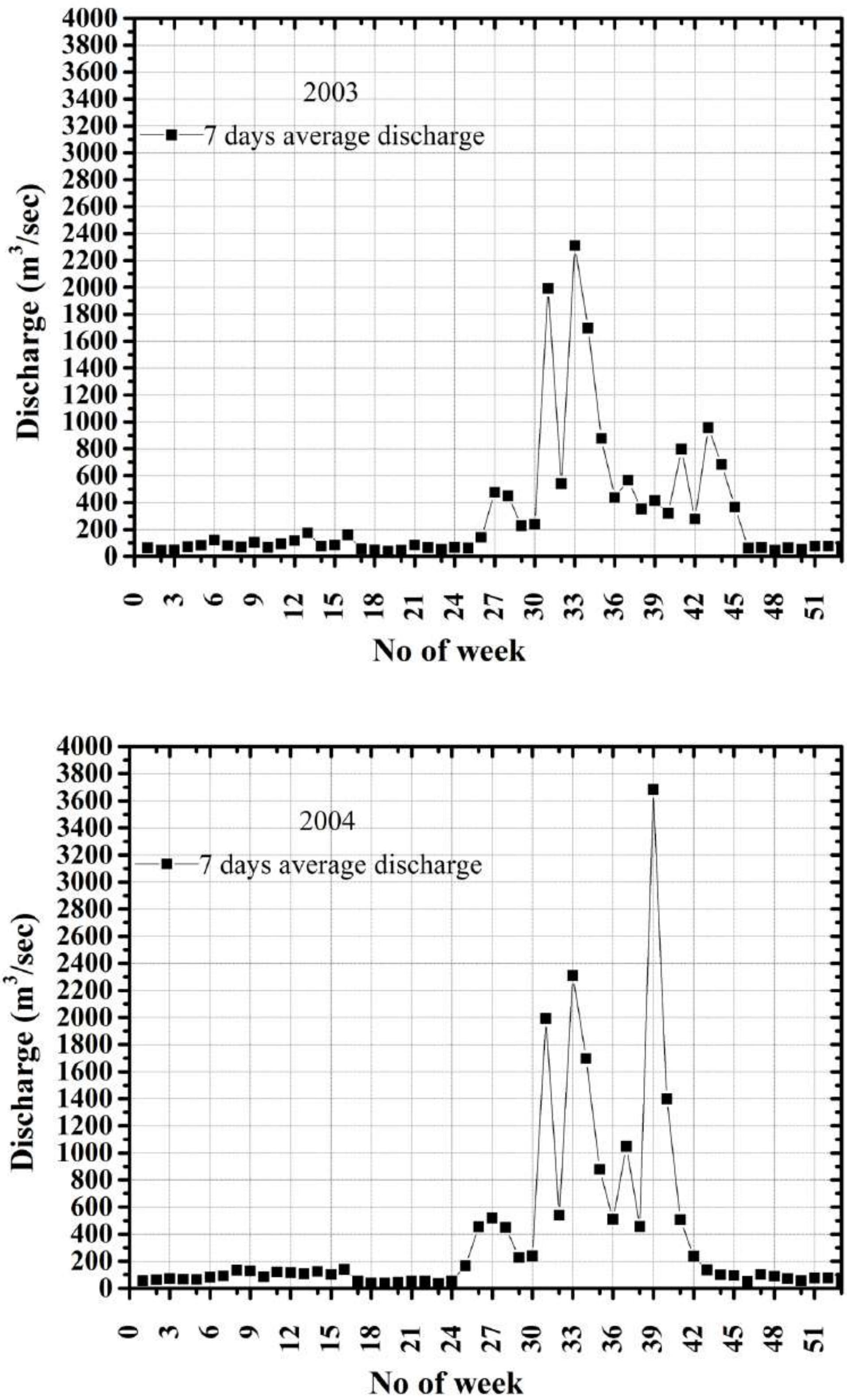


Figure 1.63: Weekly Average Discharge Released from Durgapur Barrage to Left Bank Main Canal During 2003 and 2004

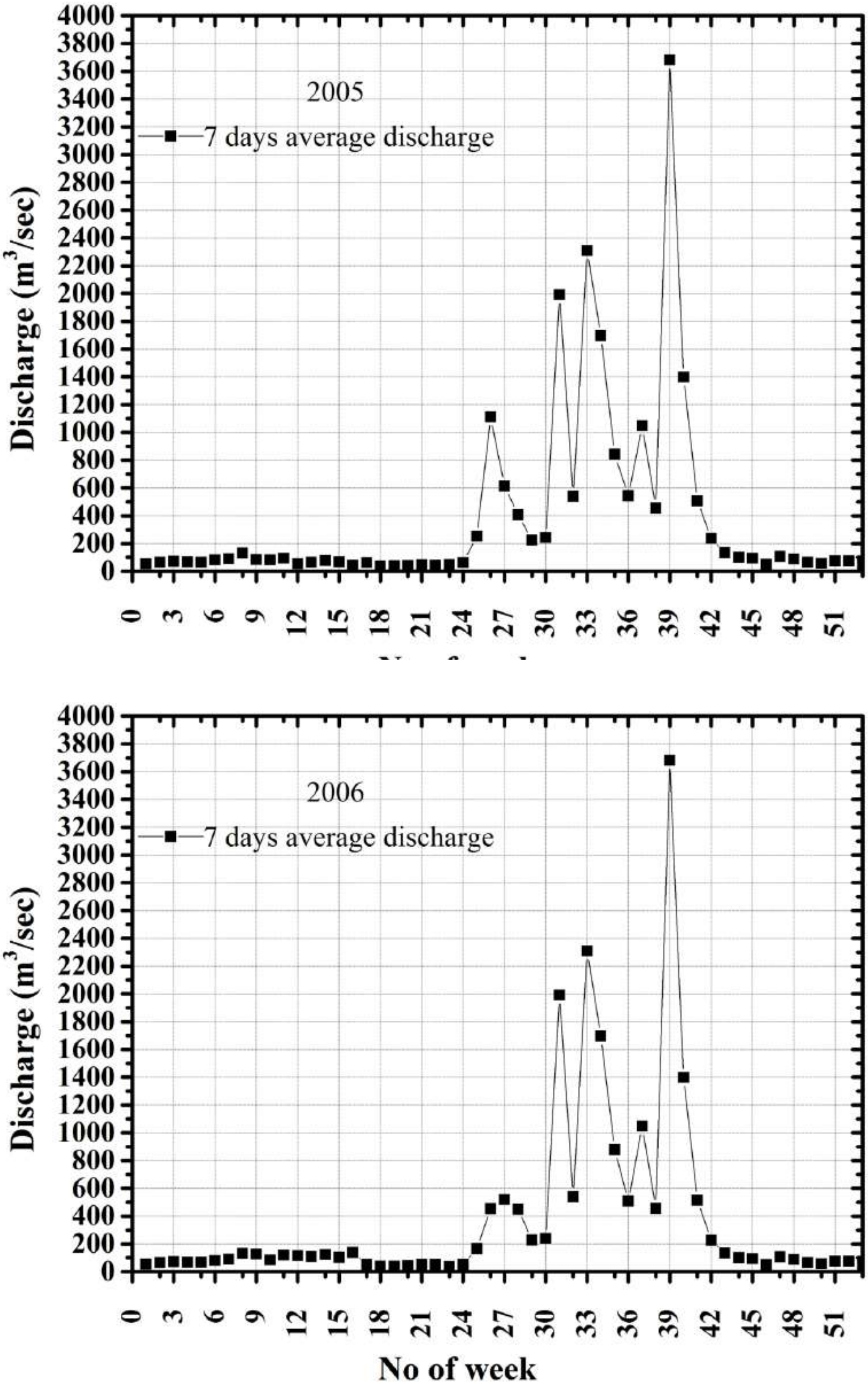


Figure 1.64: Weekly Average Discharge Released from Durgapur Barrage to Left Bank Main Canal During 2005 and 2006

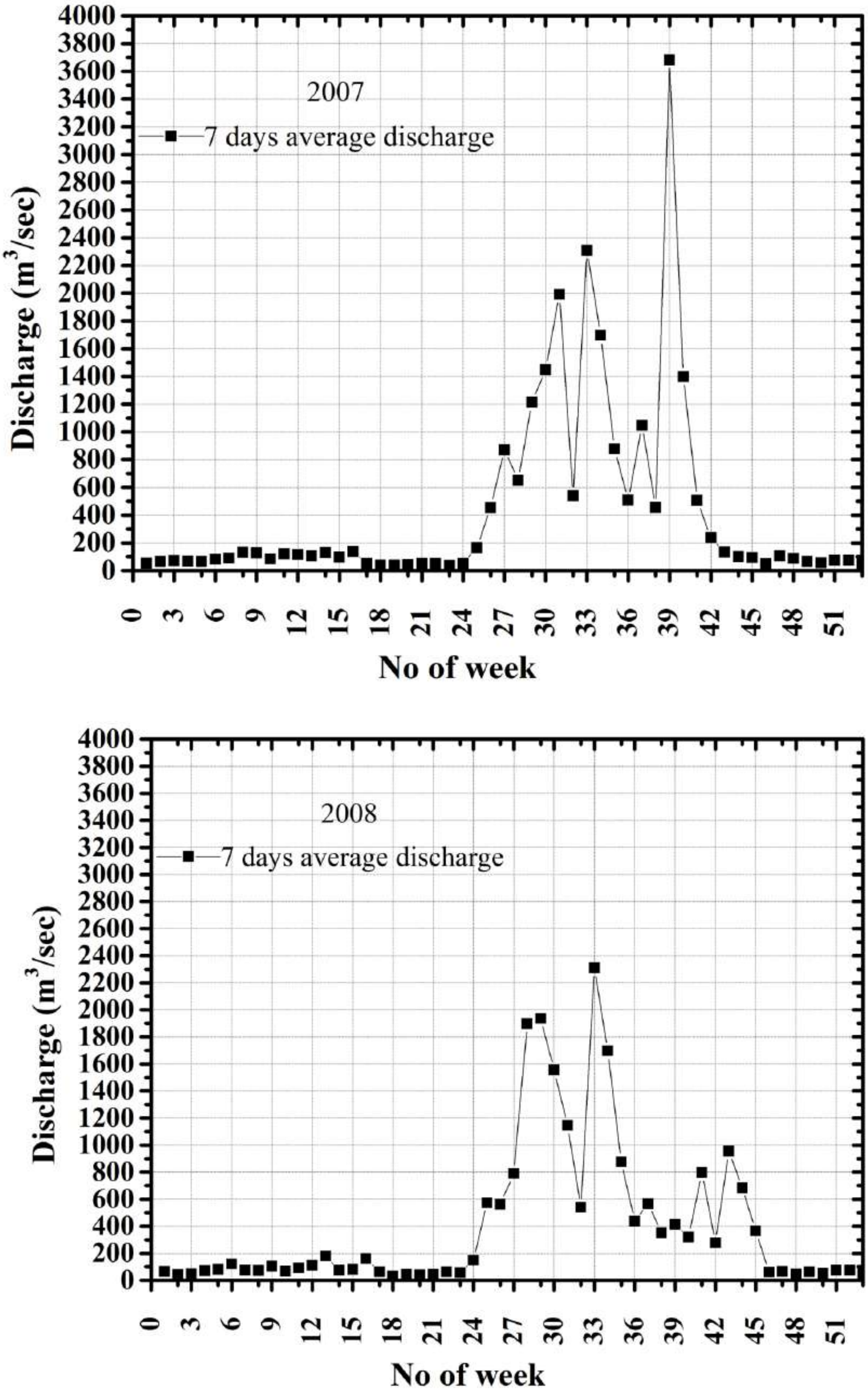


Figure 1.65: Weekly Average Discharge Released from Durgapur Barrage to Left Bank Main Canal During 2007 and 2008

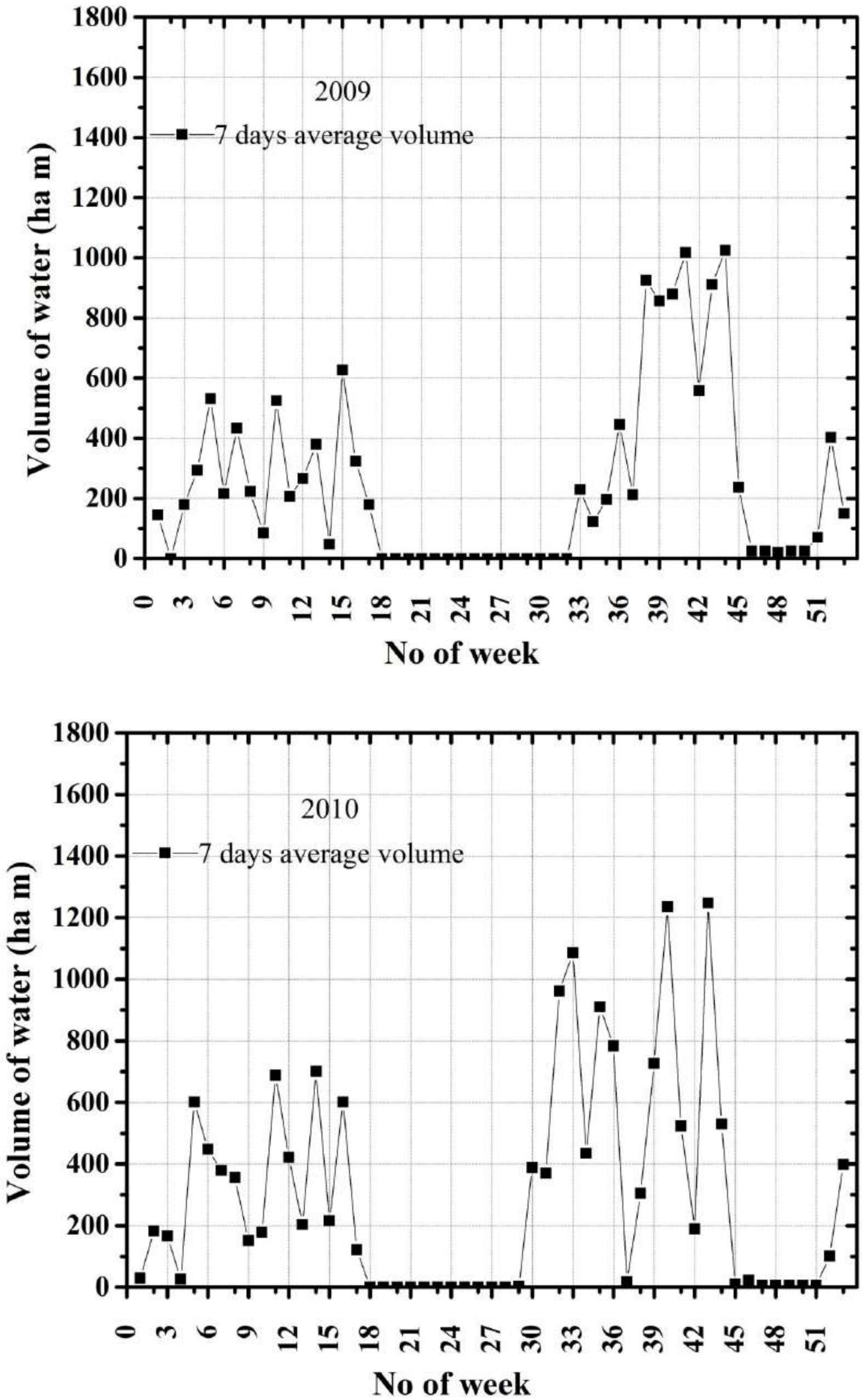


Figure 1.66: Weekly Average Volume of Water Released from Durgapur Barrage to Left Bank Main Canal During 2009 and 2010

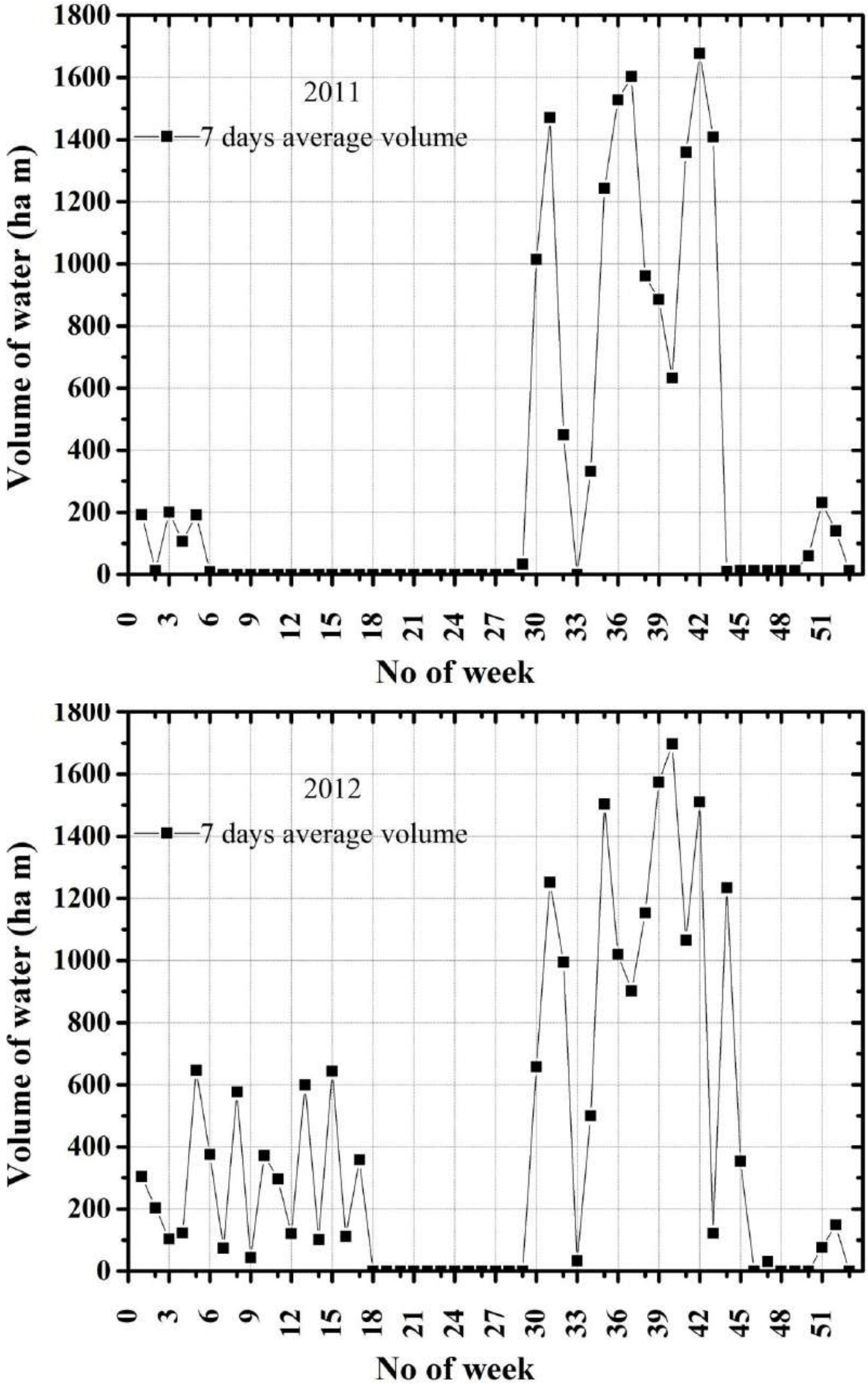


Figure 1.67: Weekly Average Volume of Water Released from Durgapur Barrage to Left Bank Main Canal During 2011 and 2012

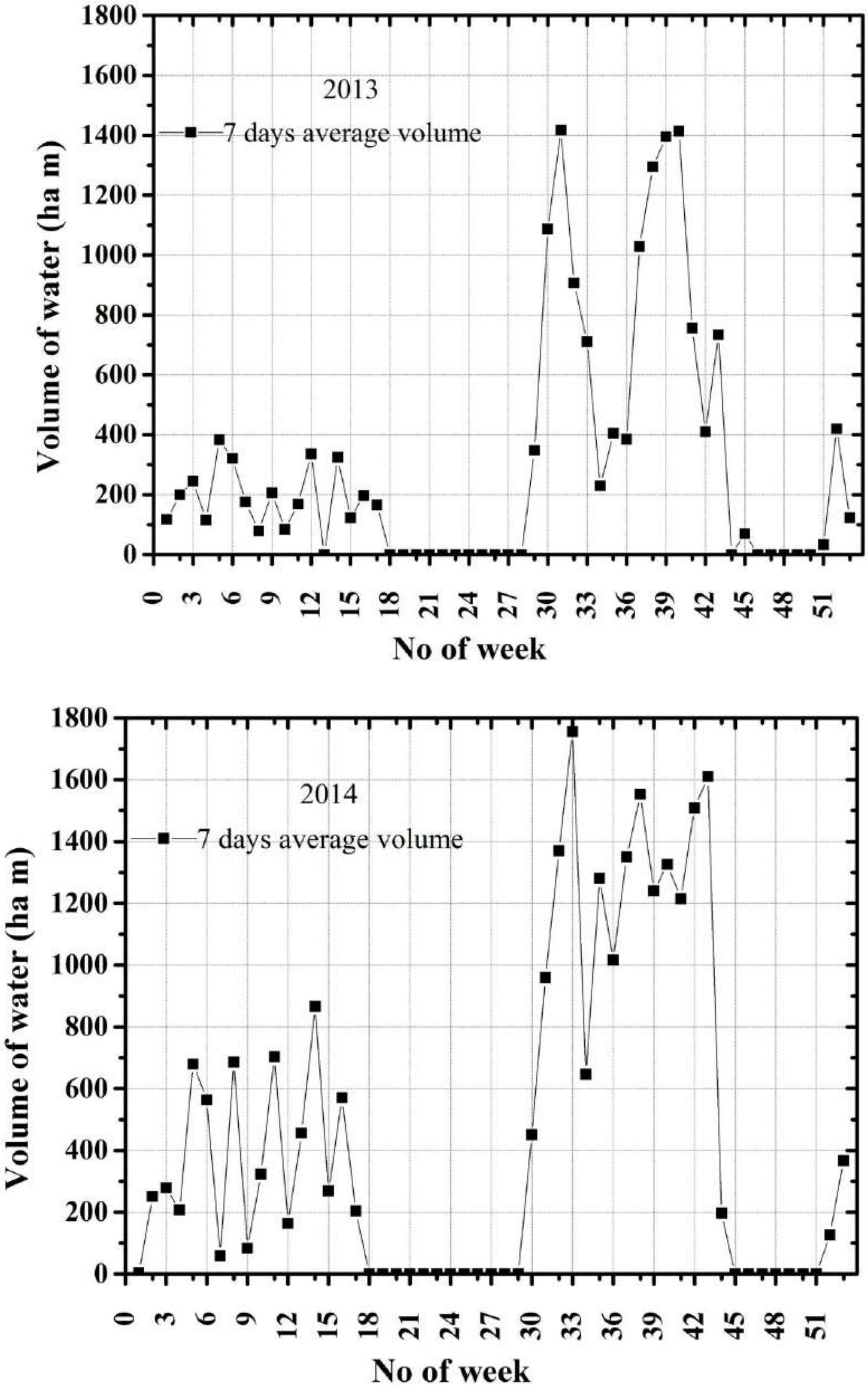


Figure 1.68: Weekly Average Volume of Water Released from Durgapur Barrage to Left Bank Main Canal During 2013 and 2014

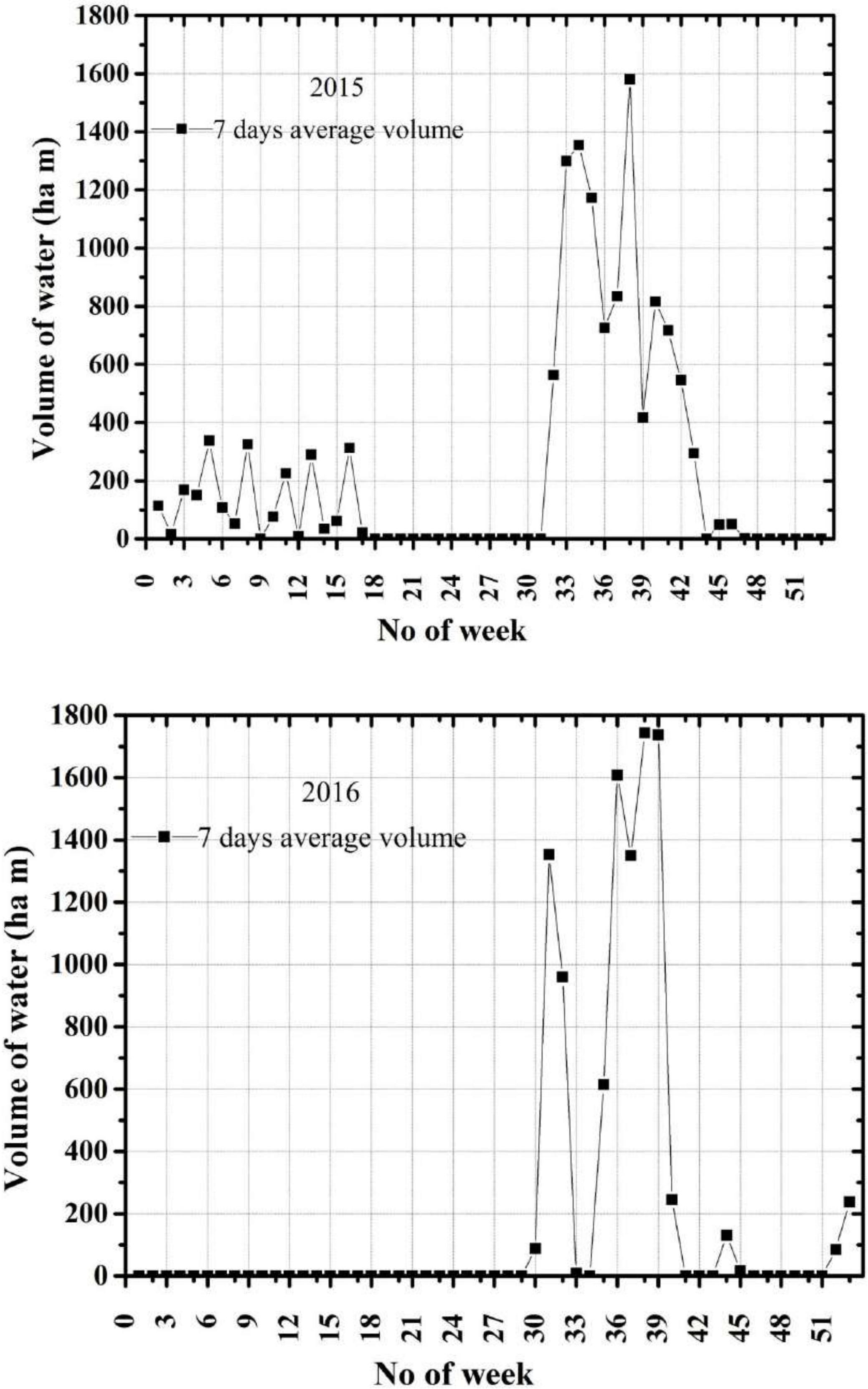


Figure 1.69: Weekly Average Volume of Water Released from Durgapur Barrage to Left Bank Main Canal During 2015 and 2016

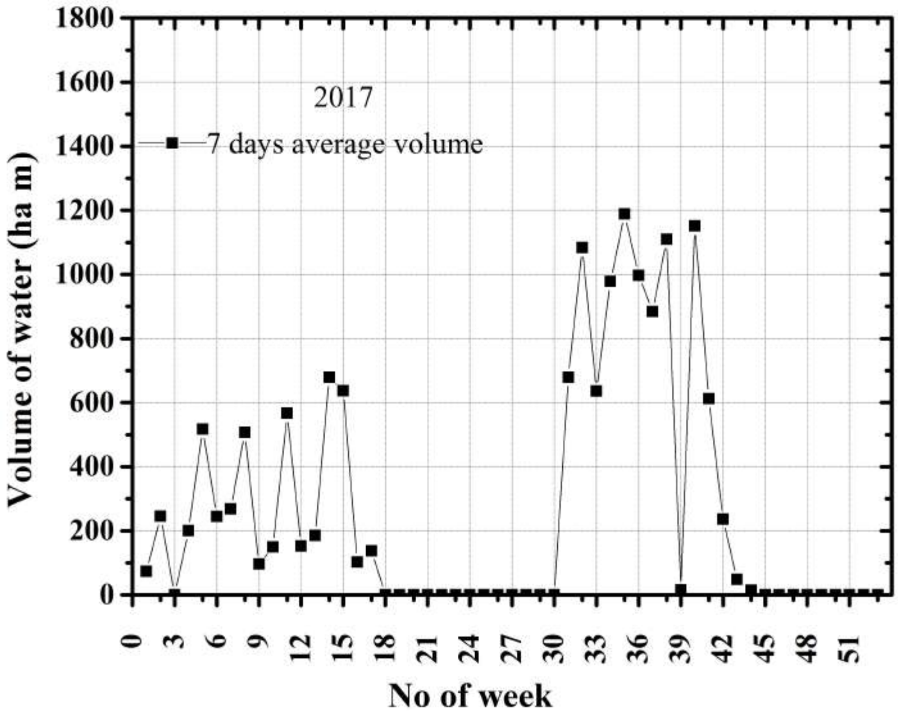


Figure 1.70: Weekly Average Volume of Water Released from Durgapur Barrage to Left Bank Main Canal During 2017

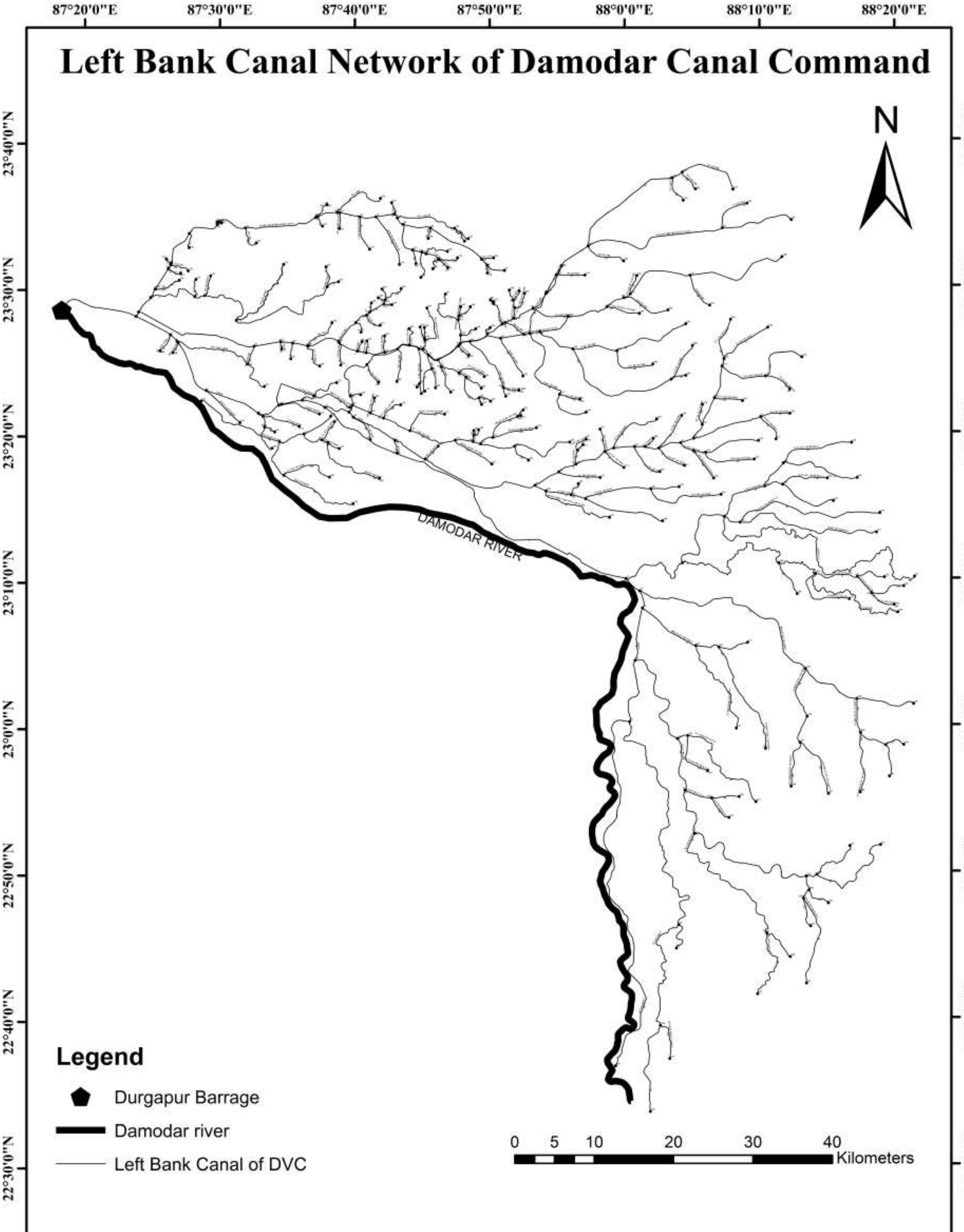


Figure 1.71: Left Bank Canal Network of DVC irrigation system

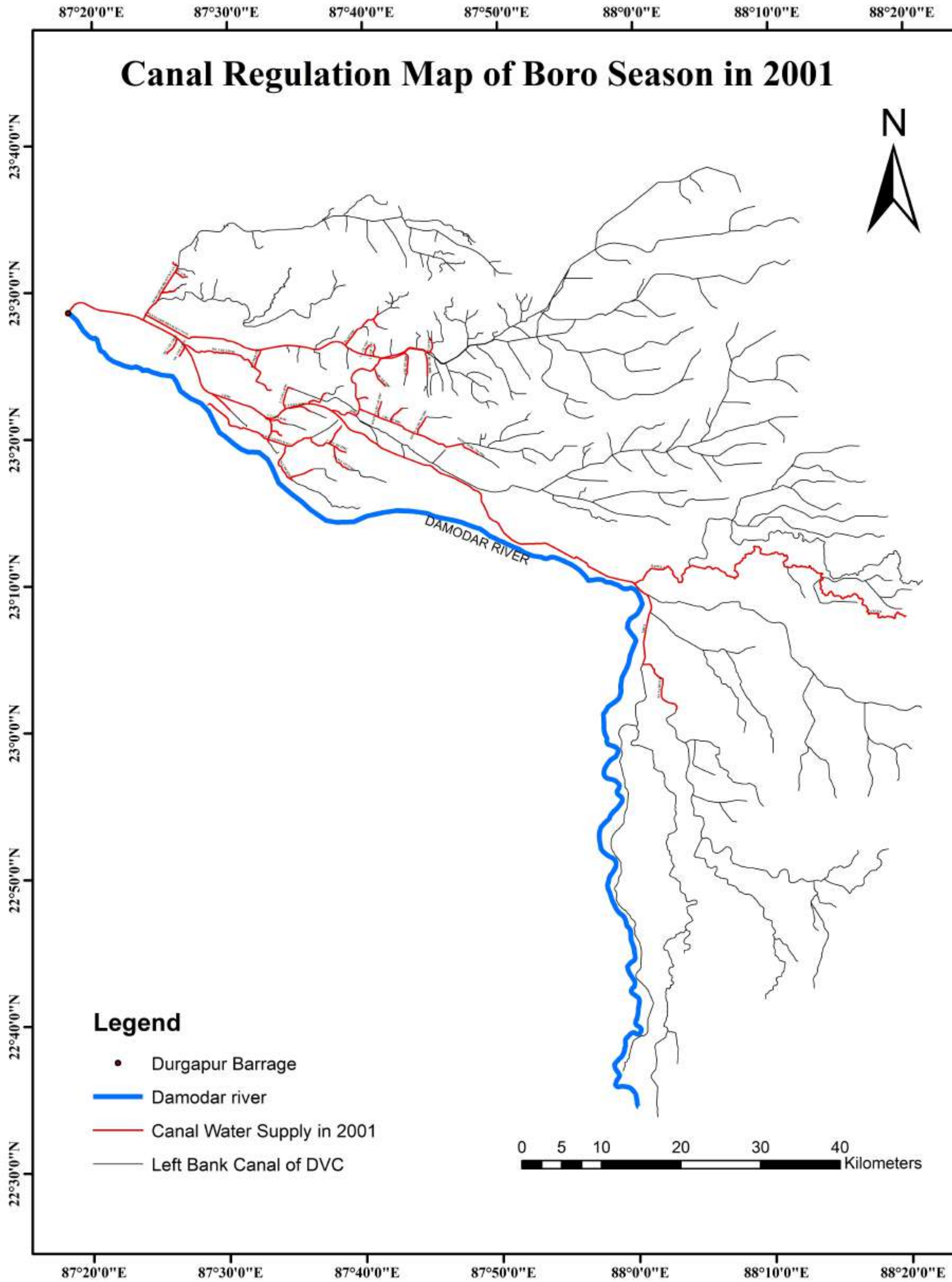


Figure 1.72: Canal Regulation Map in 2001

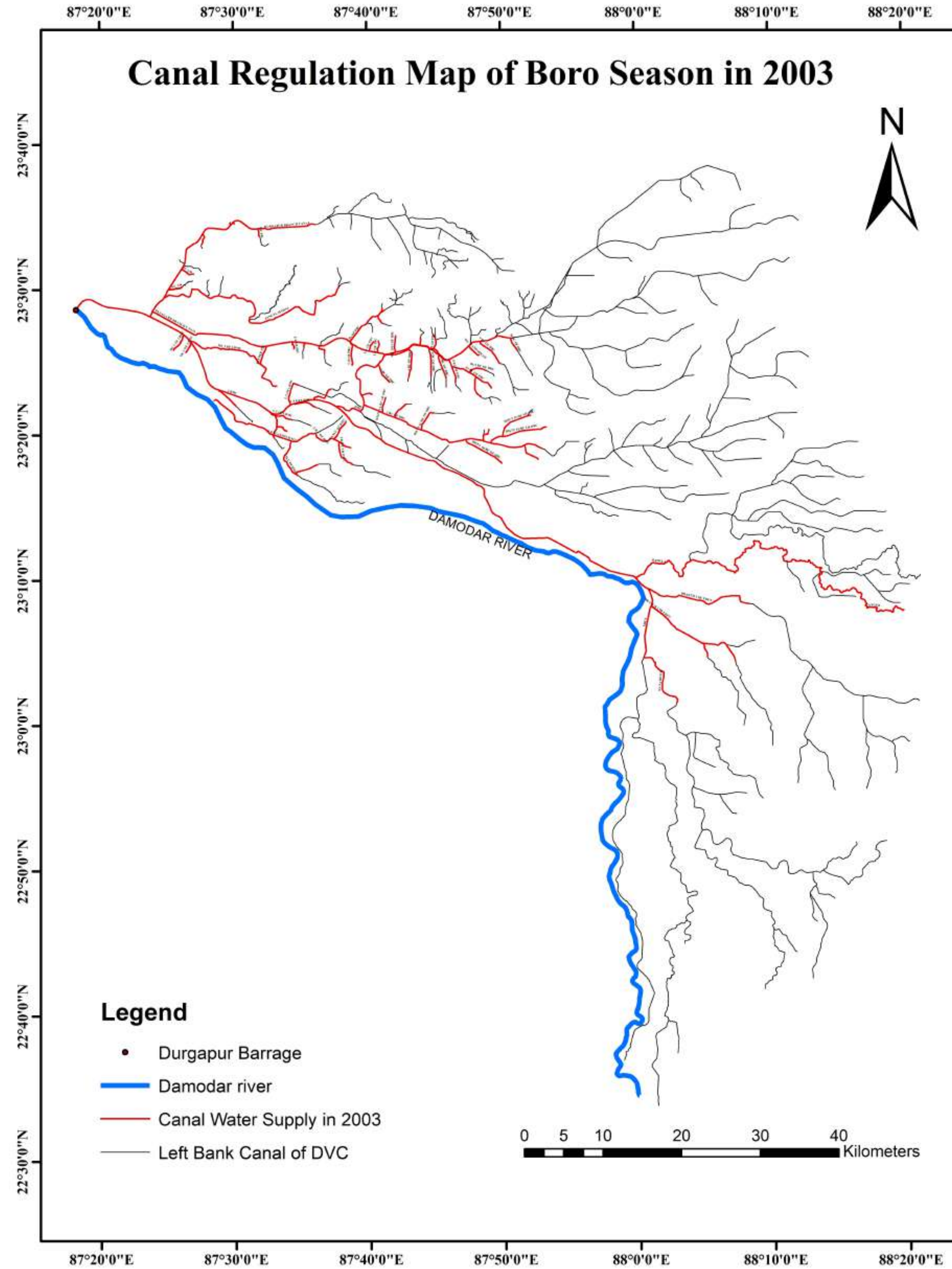


Figure 1.73: Canal Regulation Map in 2003

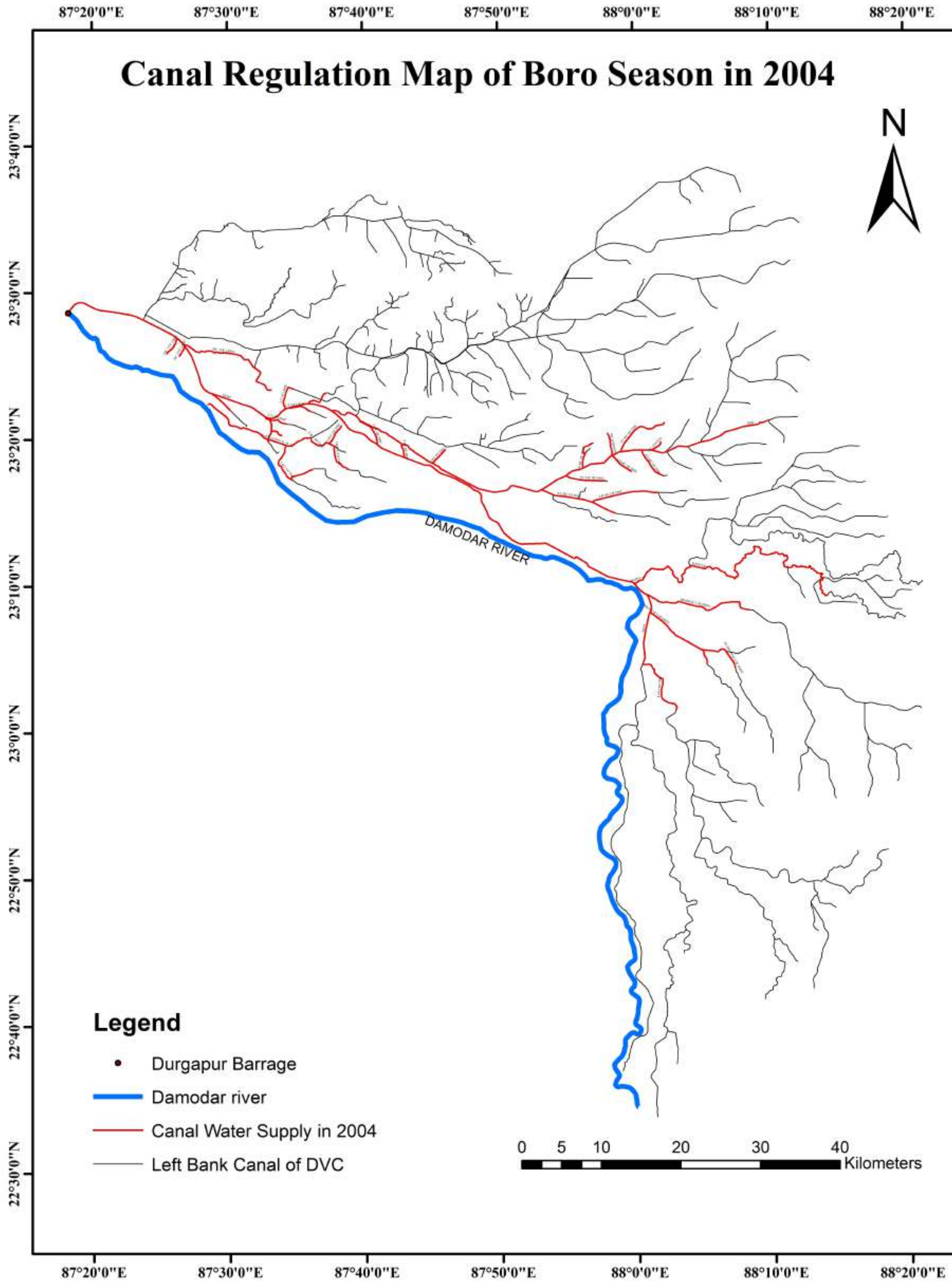


Figure 1.74: Canal Regulation Map in 2004

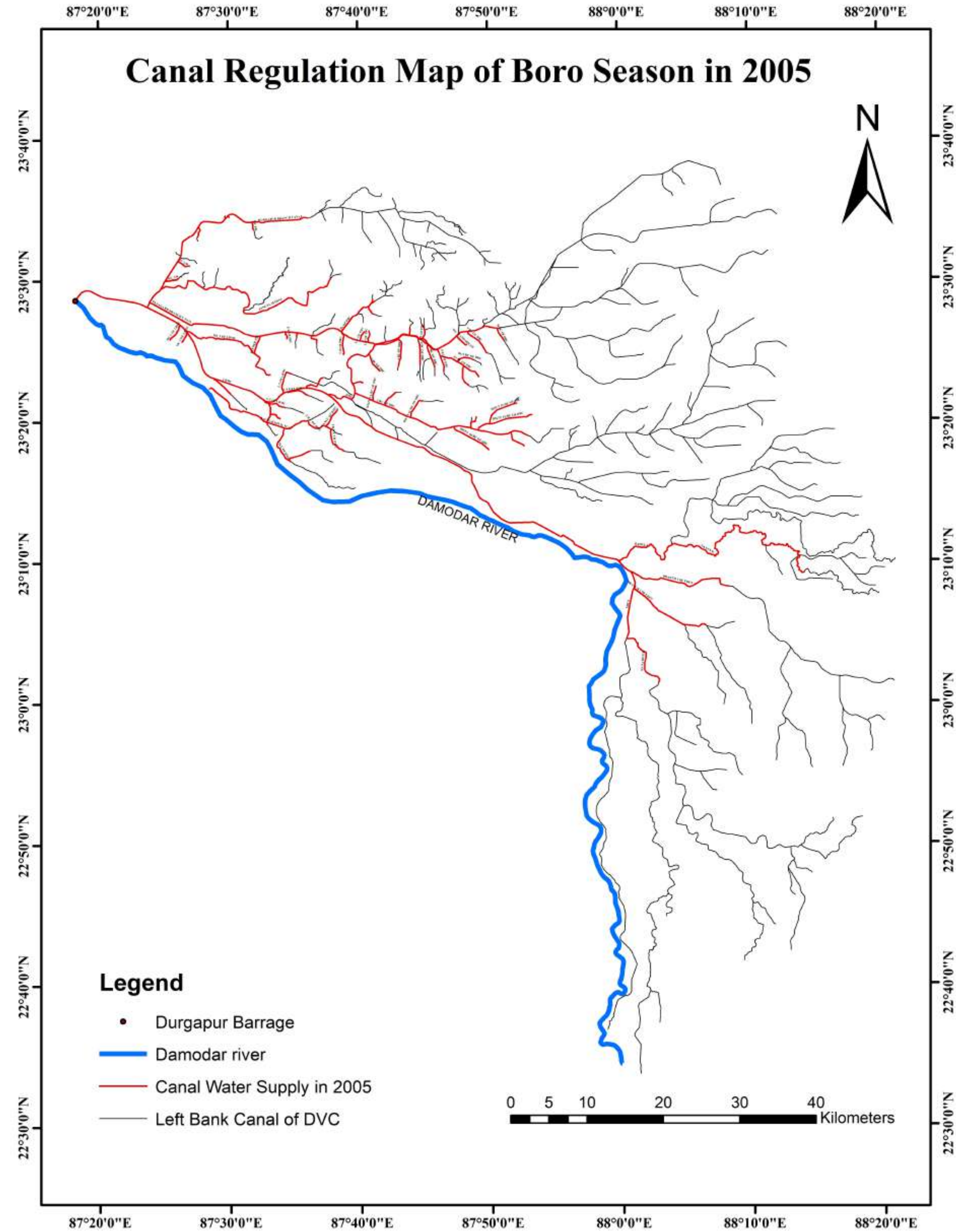


Figure 1.75: Canal Regulation Map in 2005

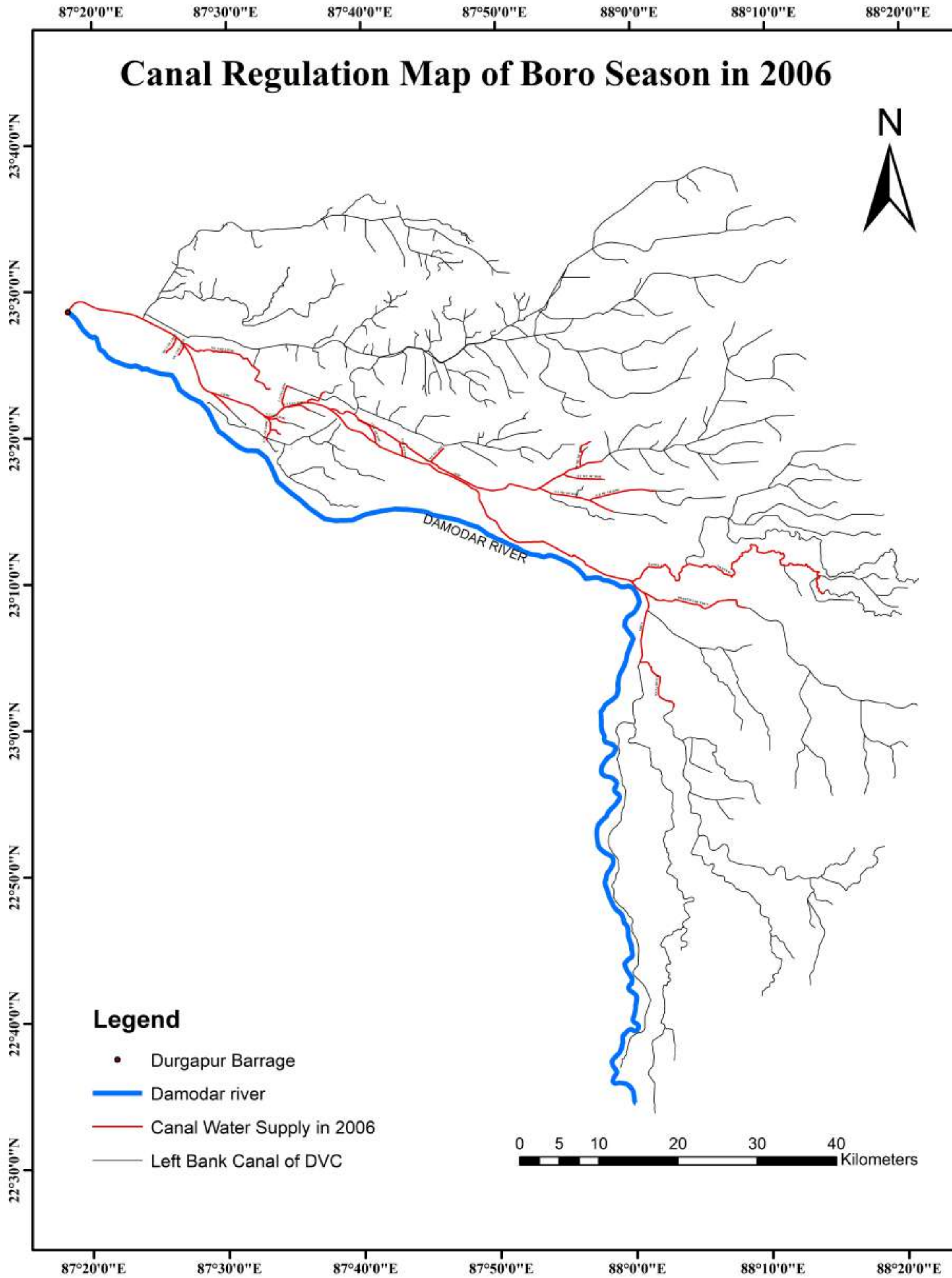


Figure 1.76: Canal Regulation Map in 2006

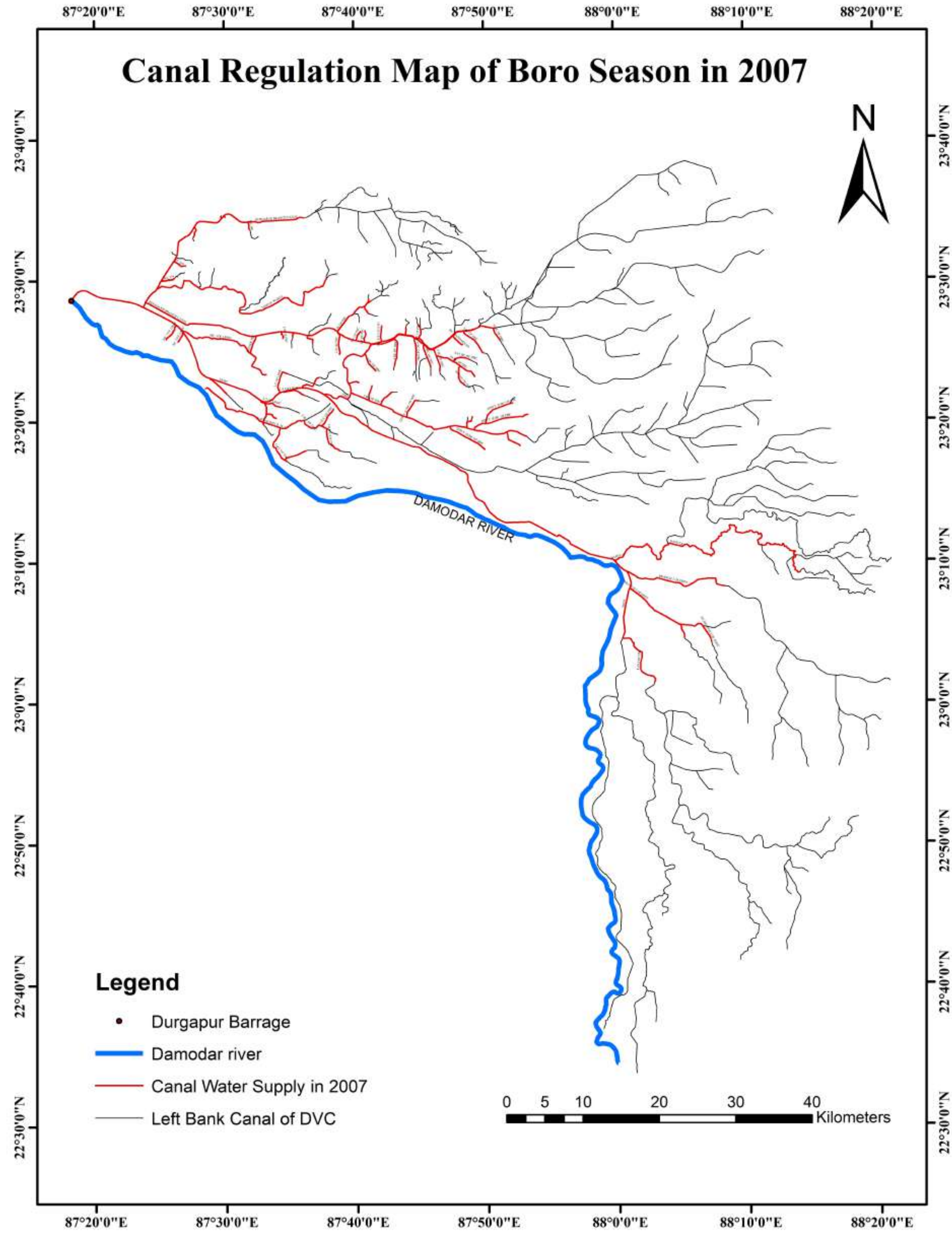


Figure 1.77: Canal Regulation Map in 2007

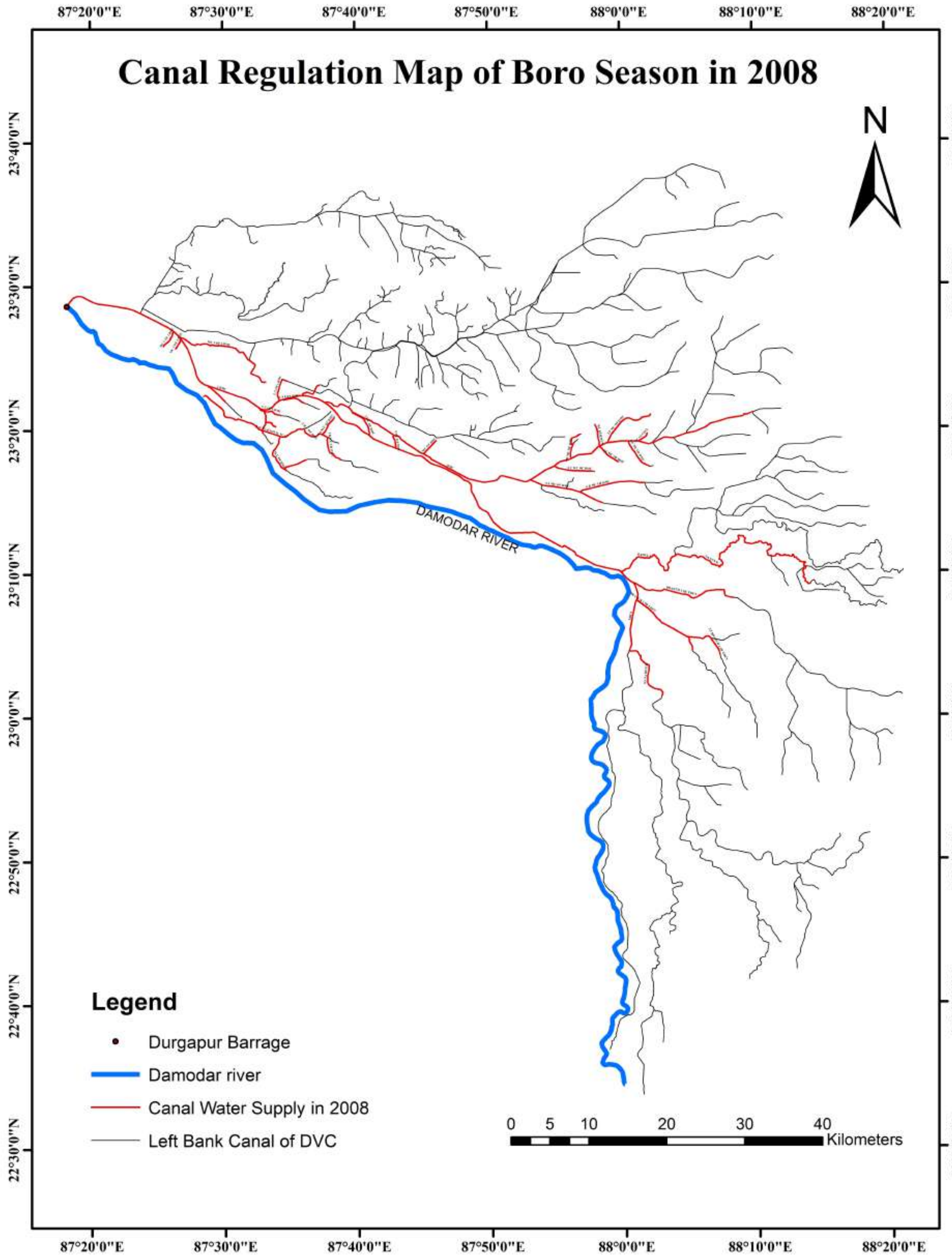


Figure 1.78: Canal Regulation Map in 2008

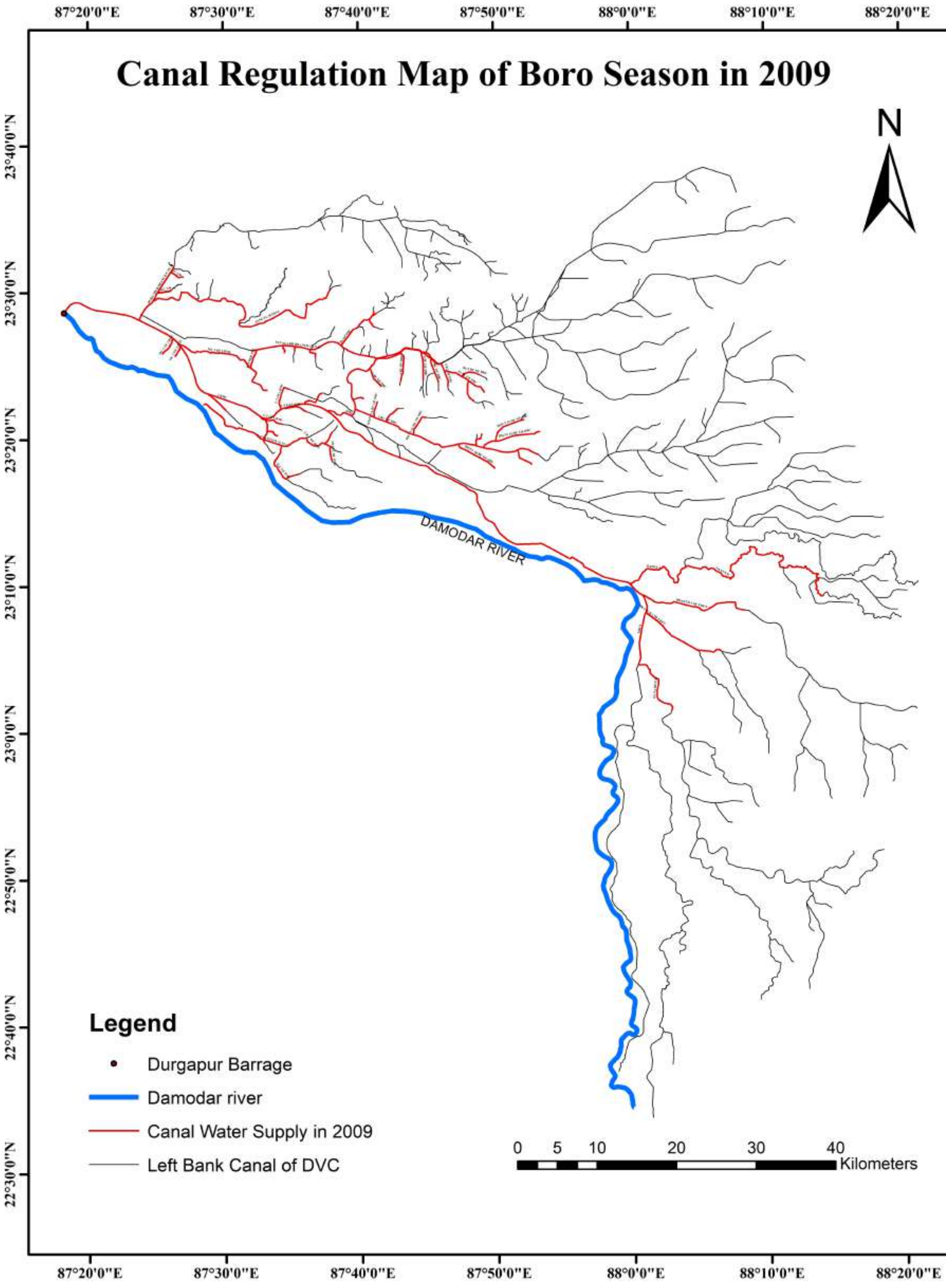


Figure 1.79: Canal Regulation Map in 2009

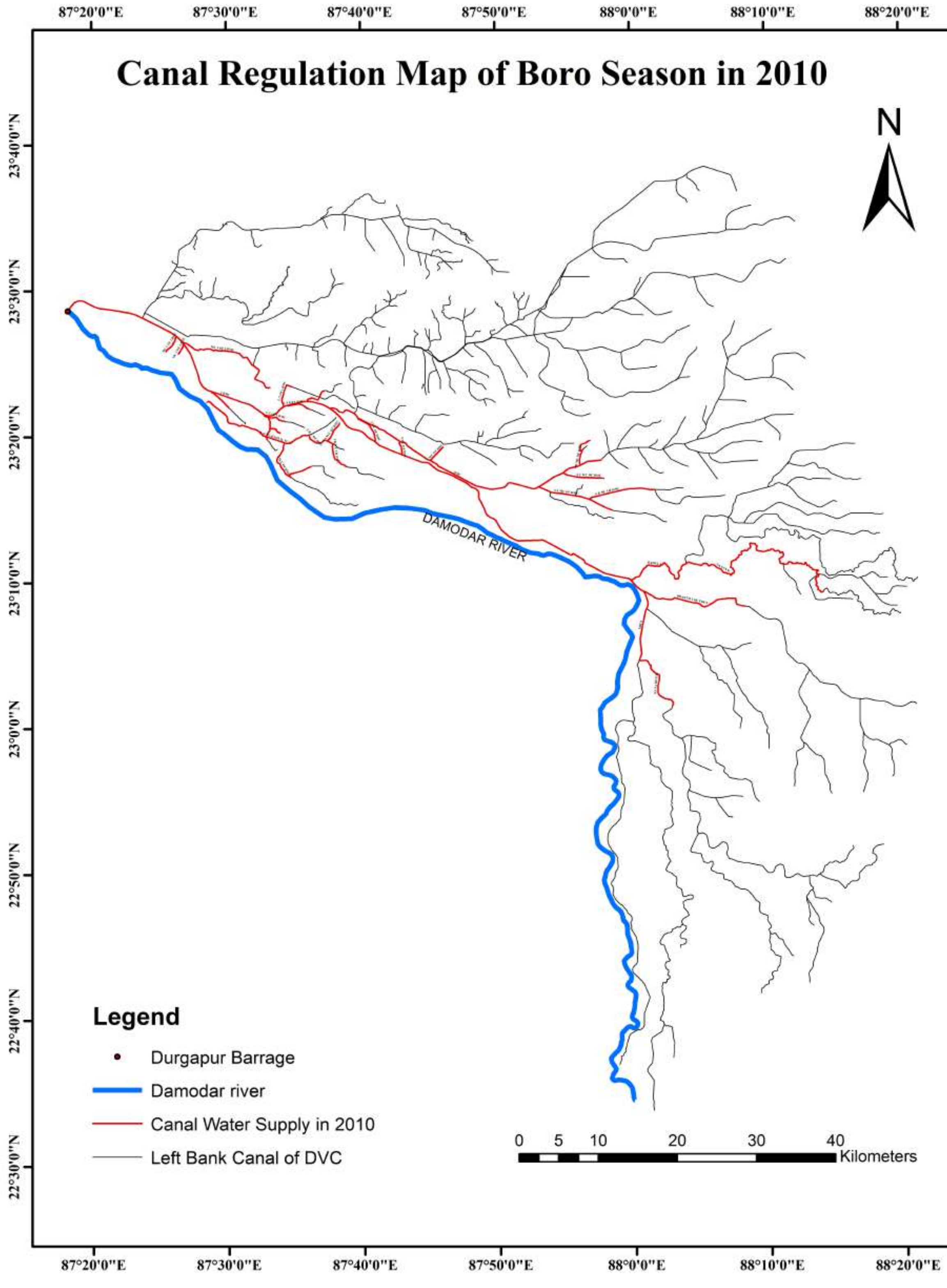


Figure 1.80: Canal Regulation Map in 2010

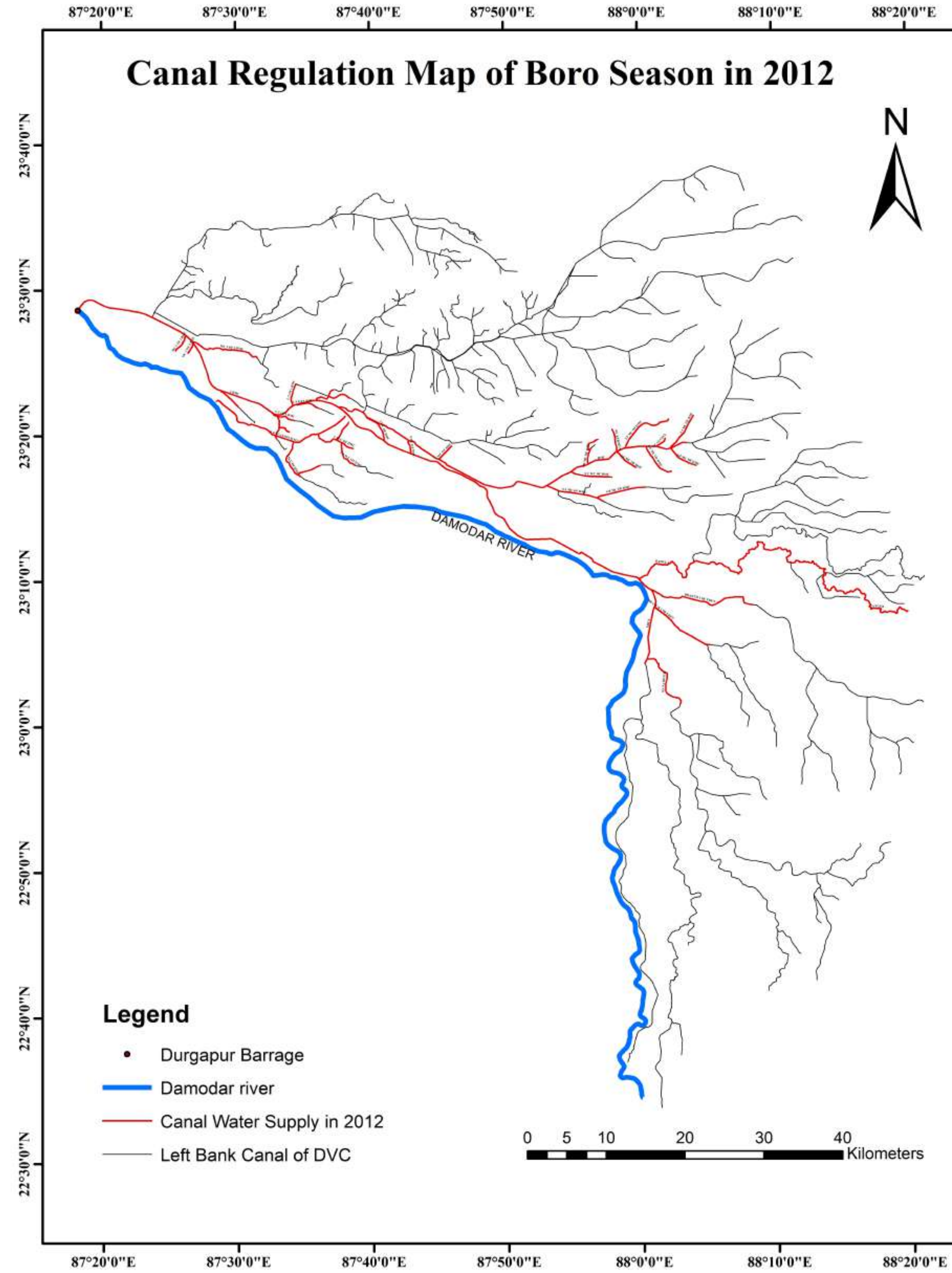


Figure 1.81: Canal Regulation Map in 2012

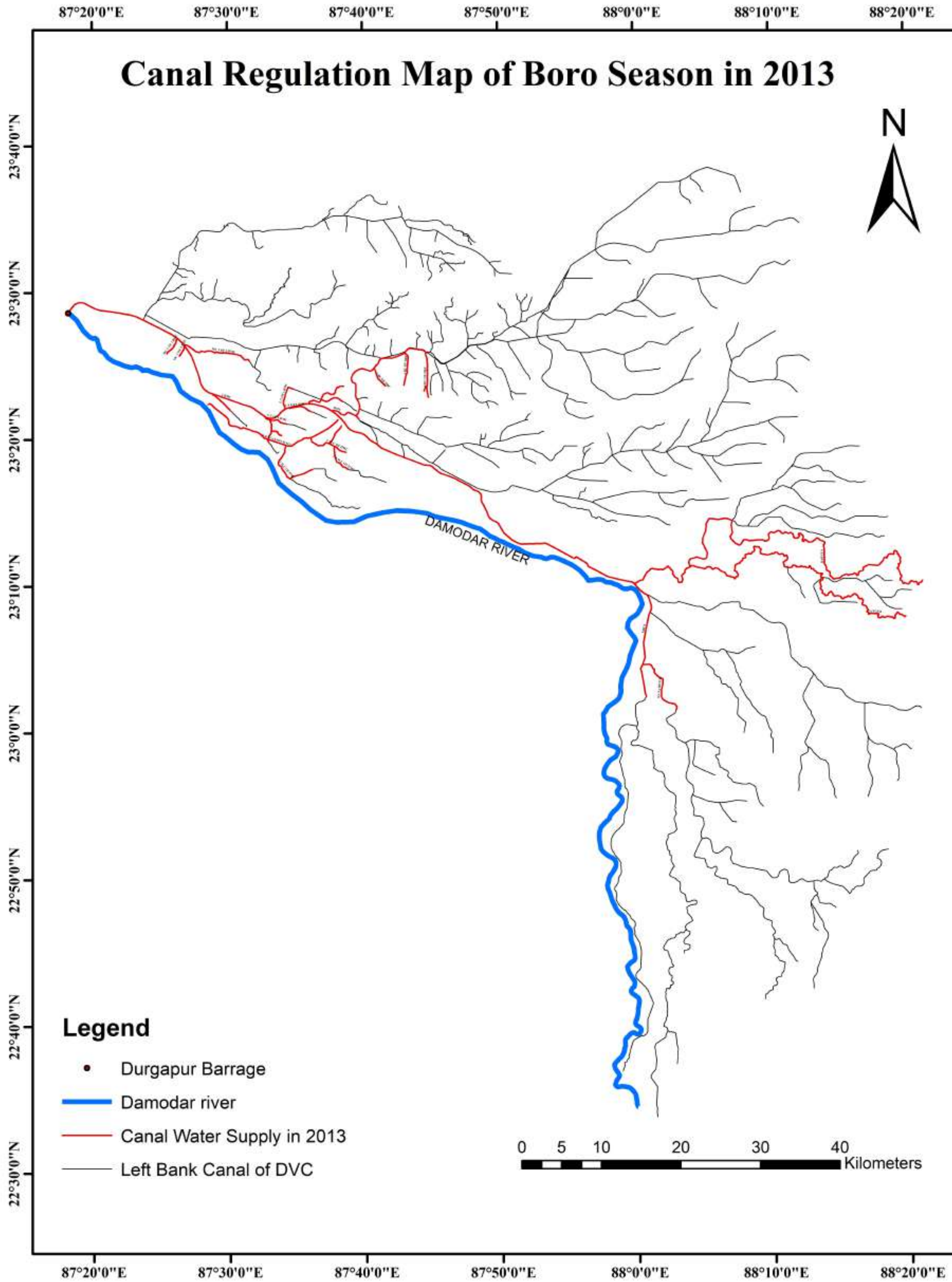


Figure 1.82: Canal Regulation Map in 2013

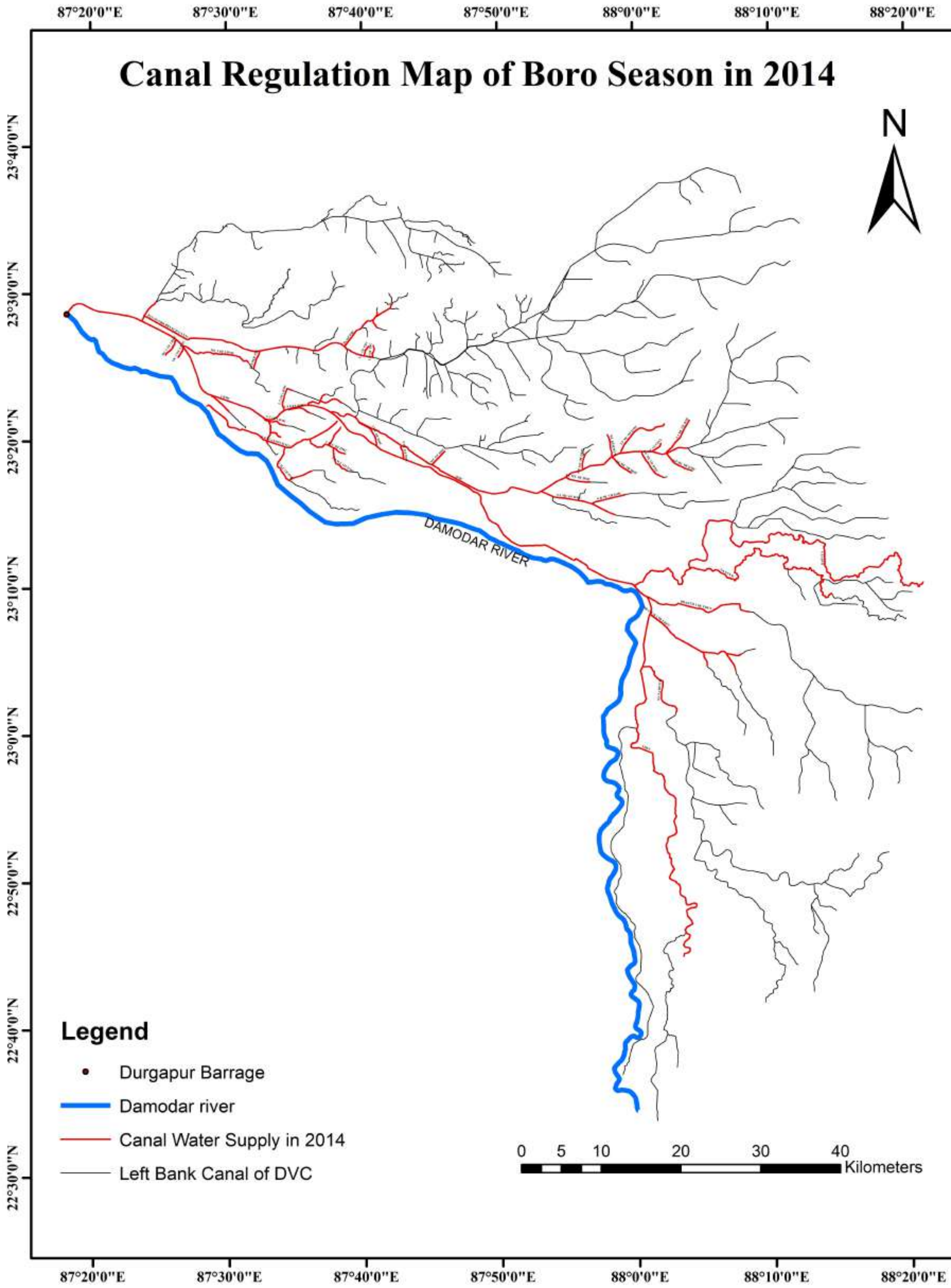


Figure 1.83: Canal Regulation Map in 2014

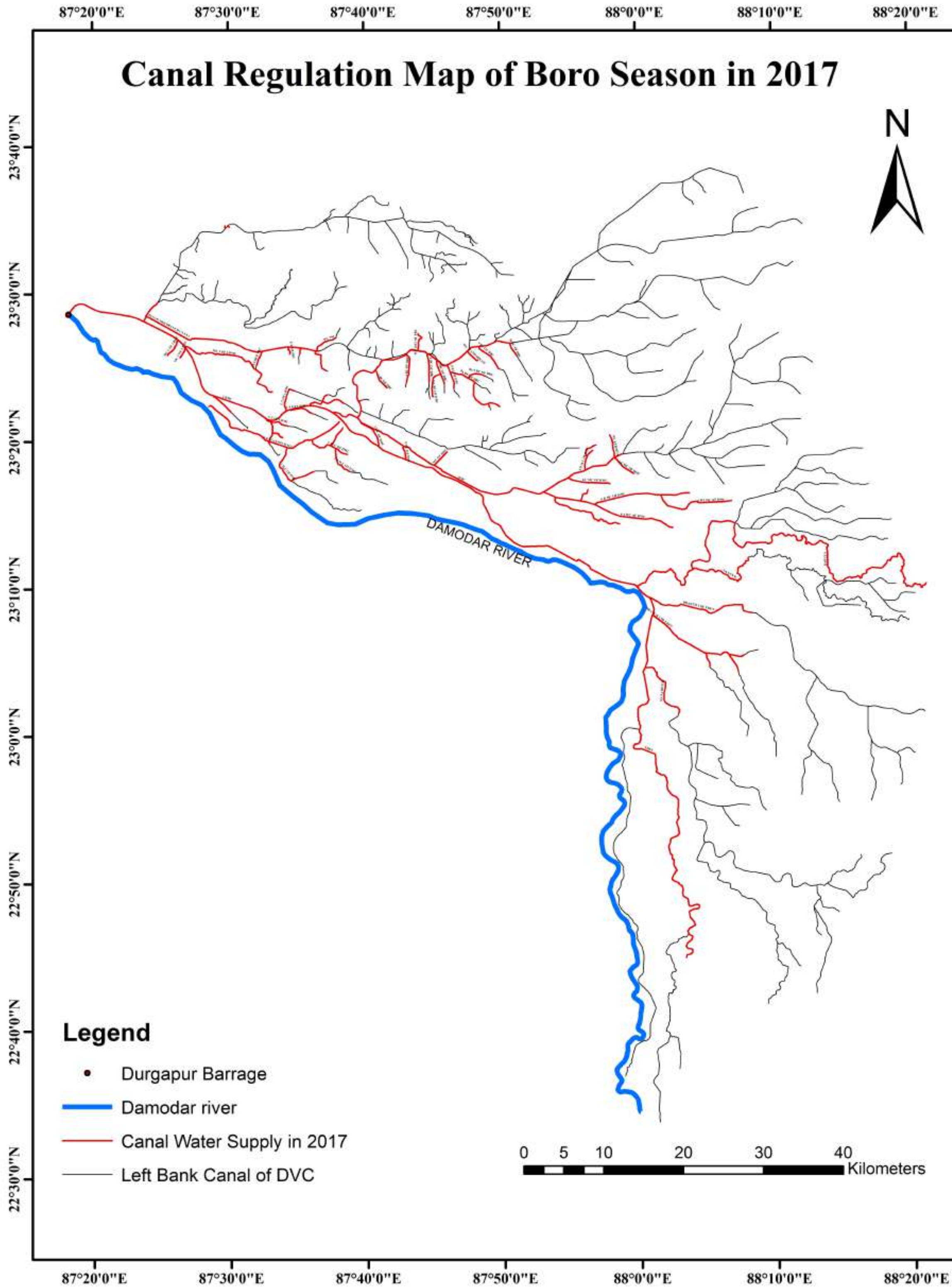


Figure 1.84: Canal Regulation Map in 2017

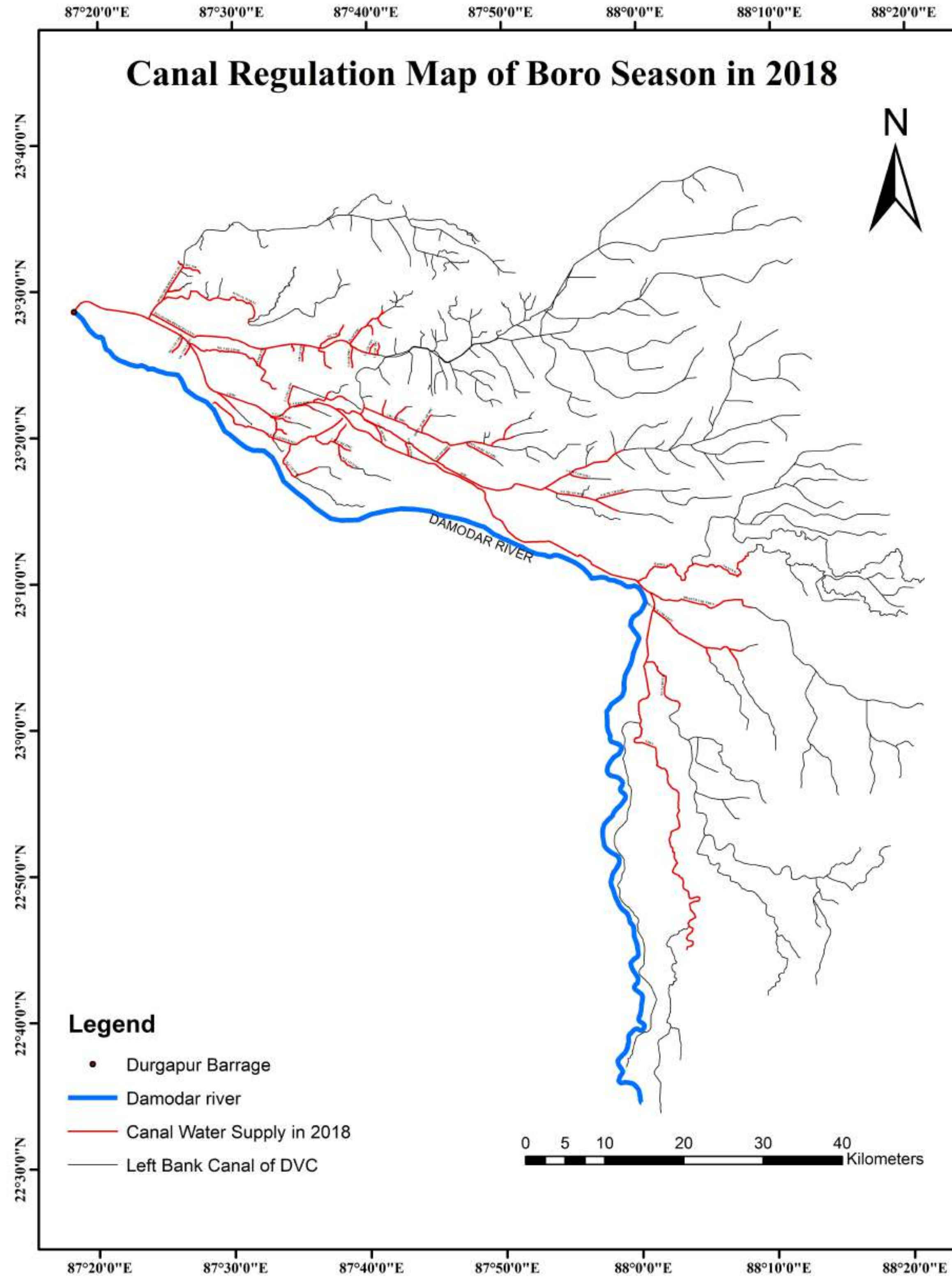


Figure 1.85: Canal Regulation Map in 2018

Chapter 2

Spatiotemporal transition analysis of rice cultivation in DVC command area (1989-2050)

2.1 Introduction

Increasing demand of finite water resource due to population growth, industrial development, urbanization has resulted in significant escalation of water scarcity, groundwater depletion, and worldwide environmental problems. At the same time, water availability pattern is changing during cultivation period due to climate change. The population growth, growing food demand, reduction in agricultural land can only be dealt by scientific allocation of land and water resources. This leads to a global pressure to increase food production with available agricultural land area. According to the Food and Agriculture Organization (FAO) report on water management in rice in Asia, highest level of water is withdrawn for agriculture in Indian subcontinent and eastern Asia with 92% and 7%, respectively. These two regions constitute about 82% of the total irrigated area in Asia. Rice is the primary food security for more than half of the world's population (GRiSP 2013). Asia constitutes about 56% of world's total irrigated area, where 40-46% irrigated area belongs to rice cultivation (GRiSP 2013). It was also estimated that irrigated rice consumes 34-43% of the world's irrigation water. Therefore, accurate monitoring of spatial and temporal distribution of rice cultivating areas is highly necessary for food security as well as water resources management (Boschetti et al. (2014); Gumma et al. (2014); Qiu et al.

(2015)). However, temporal dynamics of rice cultivated area are still poorly documented. FAO provides annual cropland area data for past decades. However, both the spatial distribution of cropland extent and temporal consistency of inter-annual statistics are not ensured (Xu et al. 2018).Remote sensing can be effectively utilized for quantification of rice cultivated area. Landsat series and Sentinel 2 are very efficient for studying different kind of land cover changes due to wide coverage, multiple spectral bands, enormous historical information, and shorter temporal resolution compared with traditional field surveys (Zhang and Lin (2019); Du et al. (2016); Qin et al. (2015); Yeom and Kim (2015); Inoue et al. (2014); Son et al. (2014); Peng et al. (2011); Sakamoto et al. (2006)). However, often it becomes difficult to map rice cultivated area due to similar spectral characteristics with other land cover. It is also vulnerable to bad weather conditions such as frequent clouds and cloud shadows in the rice planting regions (Xu et al. (2018); Dong et al. (2015); Dong et al. (2016)). Phenology based mapping using the images of certain growth stages, e.g., transplanting or early growing period are adopted as promising method to identify the rice plant among other land covers (Bridhikitti and Overcamp (2012); Xiao et al. (2005); Xiao et al. (2006); Sun et al. (2009)). This can be accomplished with the use of several vegetation indices such as time series data of land surface water index (LSWI), green difference vegetation index (GDVI), green normalized difference vegetation index (GNDVI), normalized difference vegetation index (NDVI), enhanced vegetation index (EVI) (Xiao et al. (2002); Boschetti et al. (2009); Dong et al. (2016)). This method depends upon high temporal resolution image but inadequate availability of good quality continuous data at different phenological stages hinders the use. Zhang and Lin (2019) mapped rice cultivated area by fusing Landsat-8 OLI timeseries and MODIS-NDVI timeseries data to obtain a multi-temporal dataset for classification. Qiu et al. (2015) utilized Land Surface Water Index (LSWI) and Enhanced Vegetation Index 2 (EVI2) as the primary metric for paddy rice mapping in southern China. Dong et al. (2015) analyzed Landsat images from 1986 to 2010 (498 scenes) of northeast China and tracked rice expansion in epochs with five-year increments. They assumed no change in single epoch due to unavailability of data and SLC-off gaps in Landsat 7. Dong et al. (2016) generated rice map of northeast Asia, which include northeast China, South Korea, North Korea, and Japan by using phenology and pixel-based paddy rice mapping (PPPM) algorithm from Landsat 8 imageries in 2014. They used the cloud computing technology in Google Earth Engine platform. MCD12Q1 from the Moderate-resolution Imaging Spectroradiometer (MODIS), GlobCover from the Medium

Resolution Imaging Spectrometer (MERIS) and Finer Resolution Observation and Monitoring-Global Land Cover (FROM-GLC) from Landsat contain global or national land use and land cover (LULC) datasets which have agricultural land information (Friedl et al. (2002); Arino et al. (2008); Gong et al. (2013)). But these products did not have any information on rice cultivated area. Despite the significance of information on rice cultivated area spatial maps for the scientific evaluation are rarely available.Population growth has not only triggered urban growth but also caused expansion of agricultural land particularly in country like India which serves the need of around a billon population. In 1960s and 1970s to revolutionize agricultural output, high yielding varieties cereals, especially dwarf wheat and rice were introduced as a part of the green revolution to meet increasing food demand. Many areas around the world had noticed this kind of crop land expansion in the past decades (Lambin and Meyfroidt (2011); Turner et al. (2007)). Busetto et al. (2019) analyzed spatial and temporal change in rice cultivation practice in Senegal river valley and found that in the last 10 years, rice cultivation on both the banks of river and its deltas is expanding rapidly. This makes the management of natural resources more complex while maintaining food security of the country. Hence, simulation of rice cultivated area has become essential for management of water resources and sustainable development. This needs to consider wide historical information to understand spatial and temporal relationships. The Markov Chain is being used to simulate the quantity of land use and land cover change in many studies (Kamusoko et al. (2009); Halmy et al. (2015)). Cellular Automata (CA) model has been used to simulate and predict urban growth patterns by many researchers. Flexibilities, clarity, and the capability to integrate dynamic and spatio-temporal aspects of LULC change are main reasons for the widespread application of the CA model in the prediction of future land use and land cover changes in recent years (Santé et al. (2010); Aburas et al. (2017)). Many researches had been conducted on mapping of future land use land cover changes by using GIS, RS, Cellular Automata (CA) along with Markov chain (Gong et al. (2015); Olmedo et al. (2015); Akın et al. (2015); Fathizad et al. (2015); Huang et al. (2015); Aburas et al. (2017)). Halmy et al. (2015) used random forest method integrated with CA- Markov model on Landsat TM5 data along with data from other sources to predict the future land use scenario in the northwestern desert region of Egypt. Singh et al. (2018) used CA based Markov chain model to study the spatial and temporal land use land cover changes. Moghadam and Helbich (2013) used CA based Markov chain model to predict Mumbai city's expansion for the years 2020 and 2030. Ku (2016) simulated land use change by incorporating spatial regression model into cellular automata. Chuang et al. (2011) conducted a study on Markov-chain model in Central Taiwan for vegetation restoration assessment at landslide areas caused by a catastrophic earthquake. It is important to incorporate driving forces such as physical, environment, socioeconomic causes during the prediction process to obtain better accuracy in land use land change growth pattern (Aburas et al. 2017). Hence, the CA-Markov chain model should be integrated with other models such as the Analytic Hierarchy Process (AHP), Frequency ratio (FR), and logistic regression (LR) models for further improvement of its capability (Al-sharif and Pradhan 2016). None of the previous studies were focused on simulating future rice cultivated area in canal command by considering various driving factors. In all the previous studies, especially using CA-Markov model, the factors that drove the change in land use in the past are assumed to remain same during the future. Hence, future land use patterns are generally simulated based on only two historical land use change maps instead of long-term historical trend of land use land cover class (LULC). Since this is not the case in the real world, it may lead to error during simulation. The present research aims to analyze recent changes in Boro (Indian crop growing season) rice cultivation in Damodar canal command of eastern India exploring 30 years data (from 1989 to 2018) using various vegetation indices. Singh et al. (2018) used multi criteria decision analysis to delineate groundwater potential zone of Damodar canal command. However, no research was conducted to evaluate future rice cultivation scenario of this study area. The present research also aims to improve the capability of CA-Markov model in simulating and predicting the spatio-temporal growth trend of rice planting area from satellite images. For this purpose, CA-Markov model is integrated with GIS-based AHP model to include the most significant driving forces of rice cultivated area growth for performance improvement of the model during simulation. Yearly canal regulation chart, future climate scenario along with six other features of study area are included as driving factors for future simulation of LULC. Then, the results of AHP based CA-Markov model integrated with year wise transition matrix is compared with findings of only the CA-Markov model to determine the differences in simulation accuracy between the models. Accuracy assessment is performed based on Google Earth images and ground truthing by field survey for year 2017 and 2018.

2.2 Methodology

2.2.1 Description of Study Area

The Damodar Valley Project Development is amongst the first few multipurpose water resource projects that was completed in the post-independence era of India. The main purpose of the project was to moderate the floods of the river Damodar by constructing a series of dams on the upper catchment of the river and utilizing the stored water for regulated release throughout the year. In the lower reaches farmlands are being irrigated by diversion barrage and vast network of canal systems. The major portion of the command area (80%) lies in the left bank of Damodar River and spreads over the districts of Bardhaman, Howrah and Hooghly of West Bengal, India. Hence only left bank of Damodar River was selected for this research as shown in Figure 2.1. The study area lies between latitude 22°33′36″ N to 23°40′12″ N and longitude 87°15′54″E to 88°24′00″E consisting of 36 blocks, i.e., 20 blocks of Bardhhaman district, 12 blocks of Hooghly district and four blocks of Howrah district of West Bengal, India. The geographical area of the study area is 5311.897 km^2 and the elevation above mean sea level (MSL) varies from 1 to 90 m. The average annual rainfall of the study area is 1900 mm.

The irrigation system originally envisaged an irrigation potential of 393927 ha for Kharif (July - October) and 40486 ha for Rabi (October-March) Irrigation. In addition to Kharif and Rabi irrigation, Boro rice cultivation which was not a part of the original proposal, has also been extended depending upon the availability of surplus water after considering all the committed requirements. Boro rice was introduced by the Government to the cultivators of the region at the beginning of the 70's of the last century during the green revolution. It has been cultivated during mid-January to mid-April which is the most water scarce period as rainfall during this period is minimal. It was observed from canal regulation chart of past few years that the canal water supply during this period was only limited to head reach section and in some years, it irrigated a very small part of middle and tail reach section depending upon the availability of water in Durgapur barrage. The cultivation of Boro rice was prevalent not only in the head reaches of the canal network, but almost throughout the command area. Thus, the farmers in the middle and lower reaches were entirely dependent upon groundwater. As a result, a significant decrease in groundwater has been seen over the past few

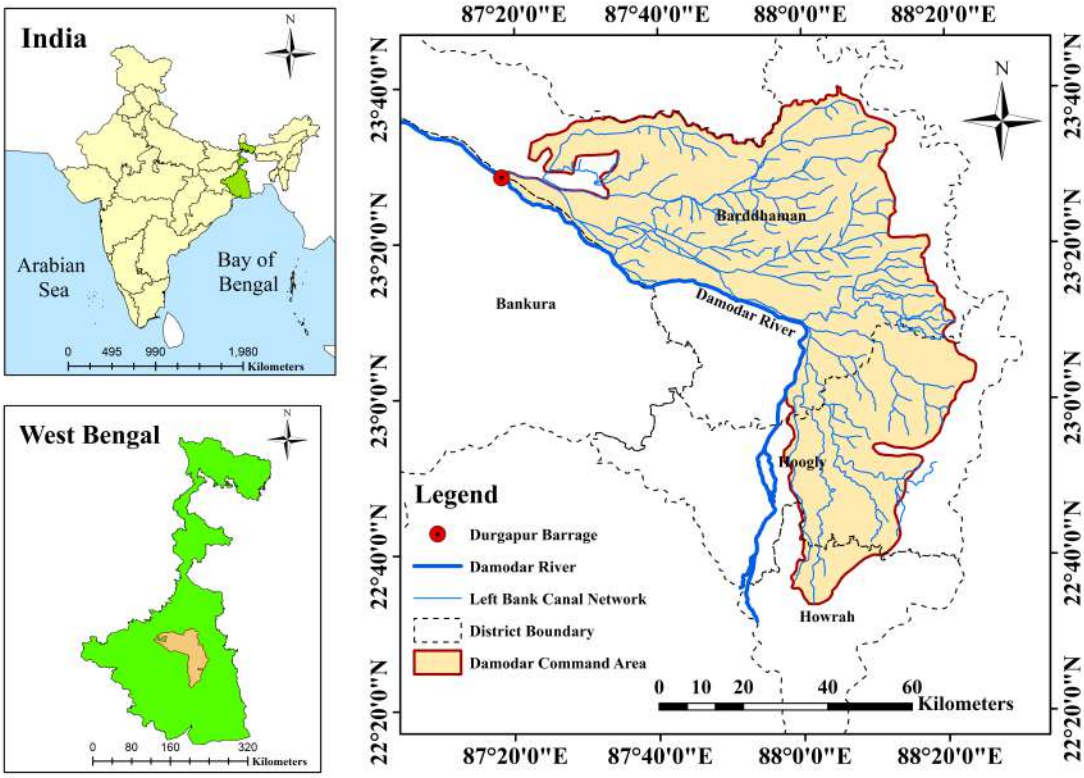


Figure 2.1: Geographical location of study area

decades.

2.2.2 Data Collection

In the study area limited number of cloud free satellite images were available during Boro cultivation period due to tropical climate and frequent cloud cover. Hence, different satellite images for the months of Feb-Mar were used as data sources to generate land use land cover (LULC) maps. Landsat TM5 images from 1989 to 2011, Landsat-7 Enhance Thematic Mapper Plus (ETM+) from 2012 to 2013, Landsat-8 Operational Land Imager (OLI) from 2014 to 2018 and Sentinel- 2 for 2017 were obtained from USGS Global Visualization Viewer (GloVis) (http://glovis.usgs.gov). Detailed canal network map and year wise canal regulation chart from 2000 to 2018 was collected from Irrigation Waterway Department, Government of West Bengal, India. Groundwater level data were obtained from Central Ground Water Board. Soil map generated by National Bureau of Soil Survey and Land Use Planning (NBSS&LUP) was used in this study. SRTM Digital Elevation Model at $90m \times 90m$ spatial resolution (http://srtm.csi.cgiar.org) was acquired and used to generate thematic layer of slope and elevation. Meteorological data of 23 rain gauge stations were obtained from the Climate Forecast System Reanalysis website (http://globalweather.tamu.edu/) for the ten years period (2000–2010). Future climate data from 2011 to 2030 for the same rain gauge stations were acquired from GCM (MIROC5) data set. MIROC5 is the most suitable GCM for this region (Raju et al. 2017). The data were obtained for RCP 4.5 scenarios (http://gismap.ciat.cgiar.org/MarksimGCM/).

2.2.3 Generation of rice map

All Landsat series data used in this study were standard Level 1 Terrain-corrected (L1T) orthorectified images while Sentinel-2 data was Level-1C top-of-atmosphere (TOA) reflectance data. Two scenes of Landsat images (path 139/row 44, path 138/row 44) and four tiles of Sentinel-2 (T45QWF, T45QWG, T45QXF, T45QXG) are falling under the study area. Landsat 7 (ETM+) scan line corrector (SLC) off data were gap filled using Environment for visualizing Images software (ENVI). Landsat 8 (OLI) data were used for analysis during the year 2017 and 2018. Only the blue, green, red, near infrared (NIR), shortwave infrared (SWIR) bands were stacked together and all the scenes covering the study area were mosaicked. Then, subsetting of the image was carried out on the basis of Area of Interest (AOI). The satellite image for the year 2017 and 2018 were classified by using Iterative Self-Organizing Data Analysis (ISODATA) clustering algorithm. Two land cover classes namely, Boro rice and other land use cover (Built up area, barren land, forest cover, plantation and water bodies) were identified in the study area. The satellite image of 2017 and 2018 were also used to calculate two vegetation indices, i.e., NDVI (Tucker 1979), EVI (Huete et al. 1997). The spectral indices were calculated using following equations:

$$NDVI = \frac{\rho_{NIR} - \rho_{\text{Red}}}{\rho_{NIR} + \rho_{\text{Red}}} \tag{2.1}$$

$$EVI = 2.5 \times \frac{\rho_{NIR} - \rho_{\text{Red}}}{\rho_{NIR} + 6 \times \rho_{\text{Red}} - 7.5 \times \rho_{Blue} + 1} \tag{2.2}$$

Where, ρ_{blue}, ρ_{red} and ρ_{NIR} are the surface reflectance values of the blue band, red band and near infrared band, respectively. The vegetation index (VI) value range of a class depend upon various factors such as its growth stage, environmental factors and topography. Hence, 20 training clusters for each land cover were taken over the vegetation index map for finding threshold value range of Boro and other land use classes. These VI ranges were applied as conditional statement over the vegetation index map created earlier. This process created composite vegetation index map for NDVI and EVI. Boro rice cropping pattern was extracted based on the performance composite vegetation index maps and image classified using ISODATA clustering algorithm.

2.2.4 Accuracy Assessment

Accuracy assessment of resulted rice maps was carried out in two aspects: 1) validation using the high resolution Google earth images 2) validation with field observations (for 2017 and 2018). As the study area is huge, in order to get a reasonable coverage of validations points images from google earth during Boro cultivation period were considered as reference data. Several random points were generated in each map where field survey was not feasible. The field shape, sizes and flooding characteristics were considered in identifying land cover information. Eighteen ground truth points were taken during each field survey in 2017 and 2018. These field photos were used to clarify land cover types. A confusion matrix of rice map and other land cover was calculated and the accuracy of the results were evaluated in terms of user's accuracy (A_u), producer's accuracy (A_p), overall accuracy (A_o) and Kappa coefficient (K_c) as follows (Story and Congalton (1986); Congalton (1991)):

$$\mathrm{A_u} = \frac{\mathrm{Numberofcorrectlyclassifiedpixelsineachcategory}}{\mathrm{Totalnumberofpixelsclassifiedinthatcategory}} \tag{2.3}$$

$$\mathrm{A_p} = \frac{\mathrm{Numberofcorrectlyclassifiedpixelsineachcategory}}{\mathrm{Numberoftrainingsetpixelsusedinthatcategory}} \tag{2.4}$$

$$\mathrm{A_p} = \frac{\mathrm{Numberofcorrectlyclassifiedpixelsineachcategory}}{\mathrm{Numberoftrainingsetpixelsusedinthatcategory}} \tag{2.5}$$

$$K_c = \frac{N \sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r} (x_{i+} \times x_{+i})}{N^2 - \sum_{i=1}^{r} (x_{i+} \times x_{+i})} \tag{2.6}$$

Where r = number of rows in the confusion matrix, x_{ii} = number of observations in row i and column i, x_{i+} = total number of observations in row i, x_{+i} = total number of observations in column i, and N = total number of observations included in matrix. The best method to generate rice map for the study area was identified based on the accuracy of composite VI maps and classified image. Then, using the best suitable method the unprecedented 30 years rice map for the study area was generated.

2.2.5 Simulation of Boro rice based on CA-Markov Model

Markov chain is a stochastic process model which describes probability of changing the state of a system at time t_2 based on the state the system at time t_1. It generates transition probability matrix which represent transition among each land use classes in different time interval. The transition probability matrix P_{ij} can be described as follows

$$P_{ij} = \begin{bmatrix} P_{11} & P_{12} & \cdots & P_{1n} \\ P_{21} & P_{22} & \cdots & P_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ P_{n1} & P_{n2} & \cdots & P_{nn} \end{bmatrix} \tag{2.7}$$

Where,and P_{11} the probability of change from land use type 1 to 1 calculated on a cell-by-cell basis. Multiplication of transition probability matrix by total area of each land use class (An) in target year generates transition area matrix (Pan) as shown below.

$$\begin{bmatrix} P_{11} & P_{12} & \cdots & P_{1n} \\ P_{21} & P_{22} & \cdots & P_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ P_{n1} & P_{n2} & \cdots & P_{nn} \end{bmatrix} \times \begin{bmatrix} A_1 \\ A_2 \\ \vdots \\ A_n \end{bmatrix} = \begin{bmatrix} P_{a1} \\ P_{a2} \\ \vdots \\ P_{an} \end{bmatrix} \tag{2.8}$$

Transition probability matrix was generated by using land use maps of 1989 and 2016. The transition area matrix was used to quantify the land use change in the allocation process. Markov chain process also develops conditional probability map for each land use classes in which each pixel has probability value of remaining in a particular land use class. The principle of operation of Markov chain is independent of the states of neighboring cell. As proximity is a very important geospatial element governing the change events, cellular automata model is also implemented in this study to consider the spatial nature and hence the direction of the simulated data. A von Neumann filter, which considers four neighboring cells of a central cell was applied together with appropriate iteration numbers (i.e., 15, 30 and 60) to simulate land cover for year 2017 and 2018. The detailed procedure is shown in Figure 2.2.

2.2.6 Simulation of integrated CA-Markov model with Multi-Criteria Decision Analysis

Year wise (1989 to 2016) transition probability matrix was calculated by using Markov chain process. Then, an integrated transition area matrix was calculated by considering each transition values generated from pair wise comparison of images. The transition potential or suitability map of both the classes were generated based on multi-criteria decision analysis (MCDA). Eight significant parameters such as elevation, soil, rainfall, slope, groundwater, canal regulation chart,road network and land use land cover that influence the Boro cultivation were utilized for generation of suitability map. These parameters are shown in Figure 2.3 and 2.4.

Canal regulation chart was supplied by Irrigation and Waterway Department to farmer each year prior to Boro rice cultivation to make them aware about

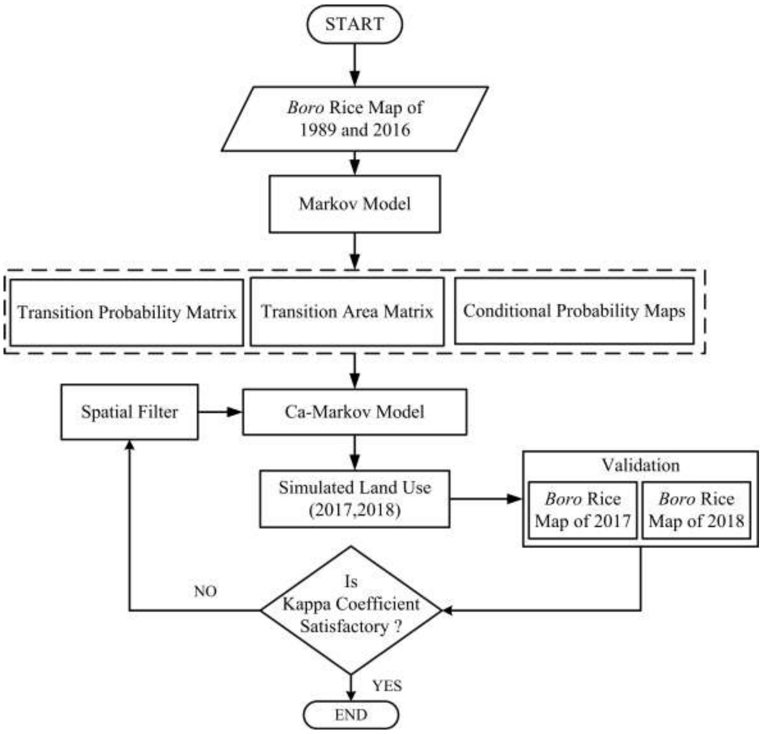


Figure 2.2: Detailed methodology for simulation of Boro rice based on CA-Markov Model

the length of canal water supply. Individual vector layer was generated for each year canal regulation chart in GIS environment. From year-wise canal regulation layer an integrated water supply vector layer was created. From literature it was found that Slope greater than 8% is not suitable for rice cultivation. Hence, a sub factor map is created excluding all area which have slope greater than 8%. It was observed from 30 years Rice map that fallow land and brushwood are much likely to shift towards Boro cultivation. Hence, these land covers were extracted from the land use land cover map generated from Sentinel -2 data. Likewise, all local level sub-parameters were derived from each main factor based on statements of local experts working in related Government departments and comprehensive literature review. Each sub-factor was standardized for both land use in 0-1 scale (Boolean map) for constraints Figure 2.5(a,b) and 0-255 scale for factors Figures 2.5(c,d),2.6 and 2.7 respectively.

Constraints are Boolean characters which serve to exclude certain areas for considering during MCDA. Factors are continuous in nature and represent relative suitability of area under consideration where 255 as highly suitable area and 0 as very low suitable area. Weights were assigned on each parameter after the formulation of pairwise comparison matrix. The normalized weight of each

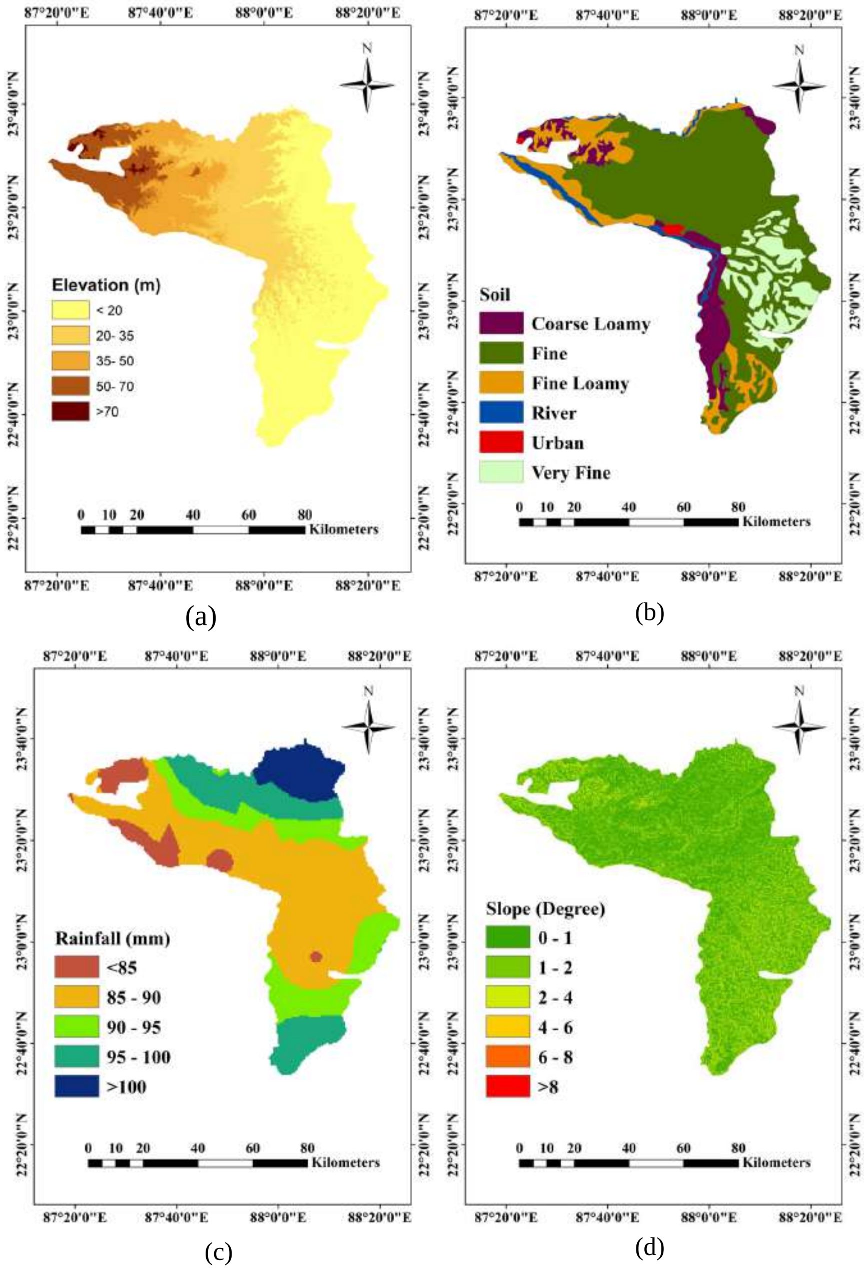


Figure 2.3: Parameters used for suitability mapping (a) Elevation (b) Soil (c) Average Rainfall during Jan-April (2000-2030) (d) Slope

parameter was calculated using Saaty's AHP process (Saaty 1980). Based on the value of consistency ratio suggested by Saaty (1980) consistency of the weight on different parameter was checked. Consistency ratio was calculated by the following equation:

$$\text{ConsistencyRatio(CR)} = \frac{\text{C.I.}}{\text{R.C.I.}} \tag{2.9}$$

C.I is the consistency index which can be calculated as

$$\mathrm{C.I.} = \frac{\lambda_{\mathrm{max}} - \mathrm{n}}{\mathrm{n} - 1} \tag{2.10}$$

where, λ_{max} is principal eigenvalue computed by eigenvector technique and n is total number of parameters. R.C.I. is the random consistency index which can be obtained from standard table. C.R. value less than 0.1 is acceptable, whereas C.R. value $\geq$ 0.1 needs revision of weight assignment process in the pairwise comparison matrix. Table 2.1 and 2.2 shows different factors and its normalized weight calculated using Saaty's AHP process.

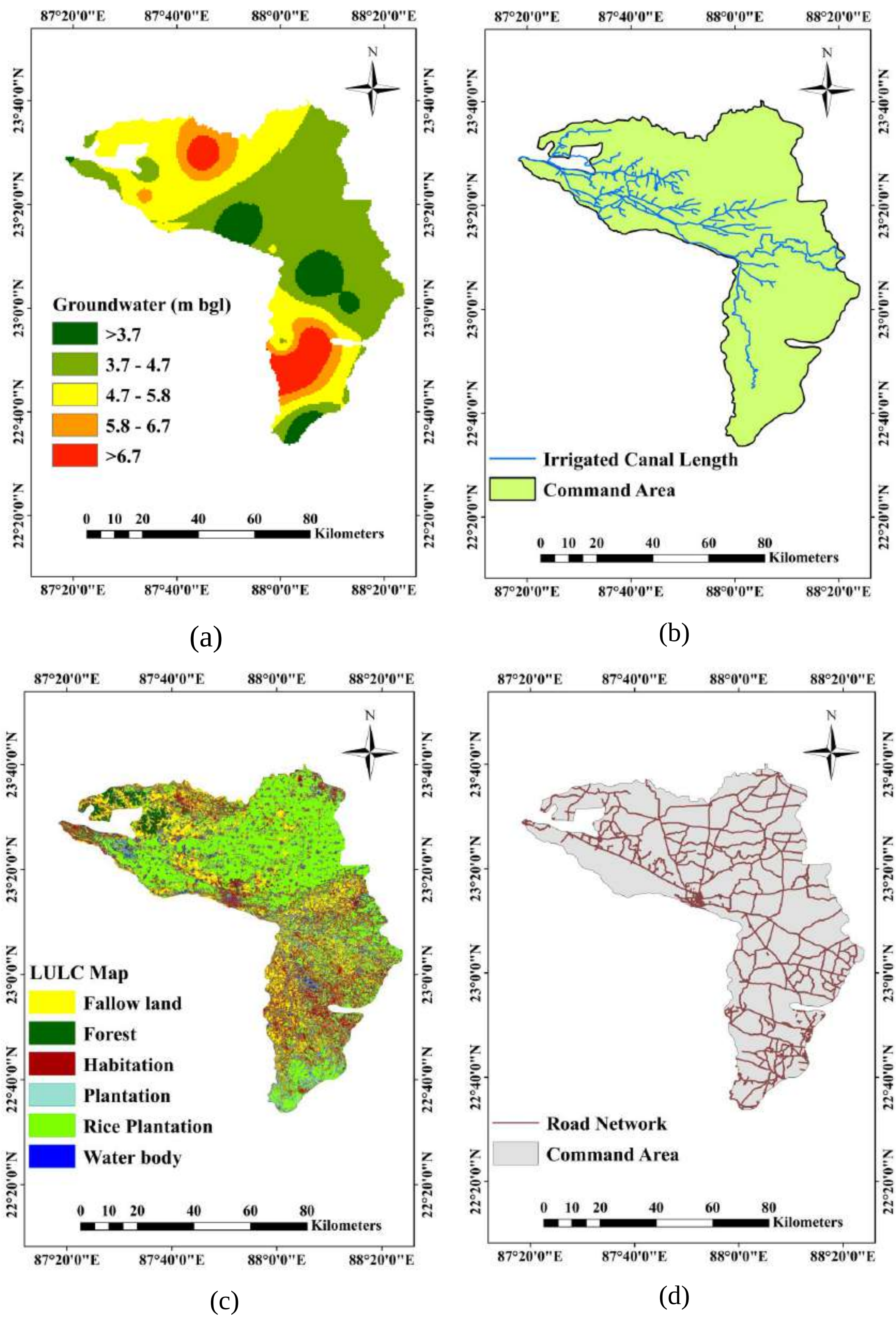


Figure 2.4: Parameters used for suitability mapping (a) Average Groundwater level Jan- April (2000-2013) (b) Canal Water Supply during Boro rice cultivation (c) Land Use Land Cover map of year 2017 (d) Road network of study area

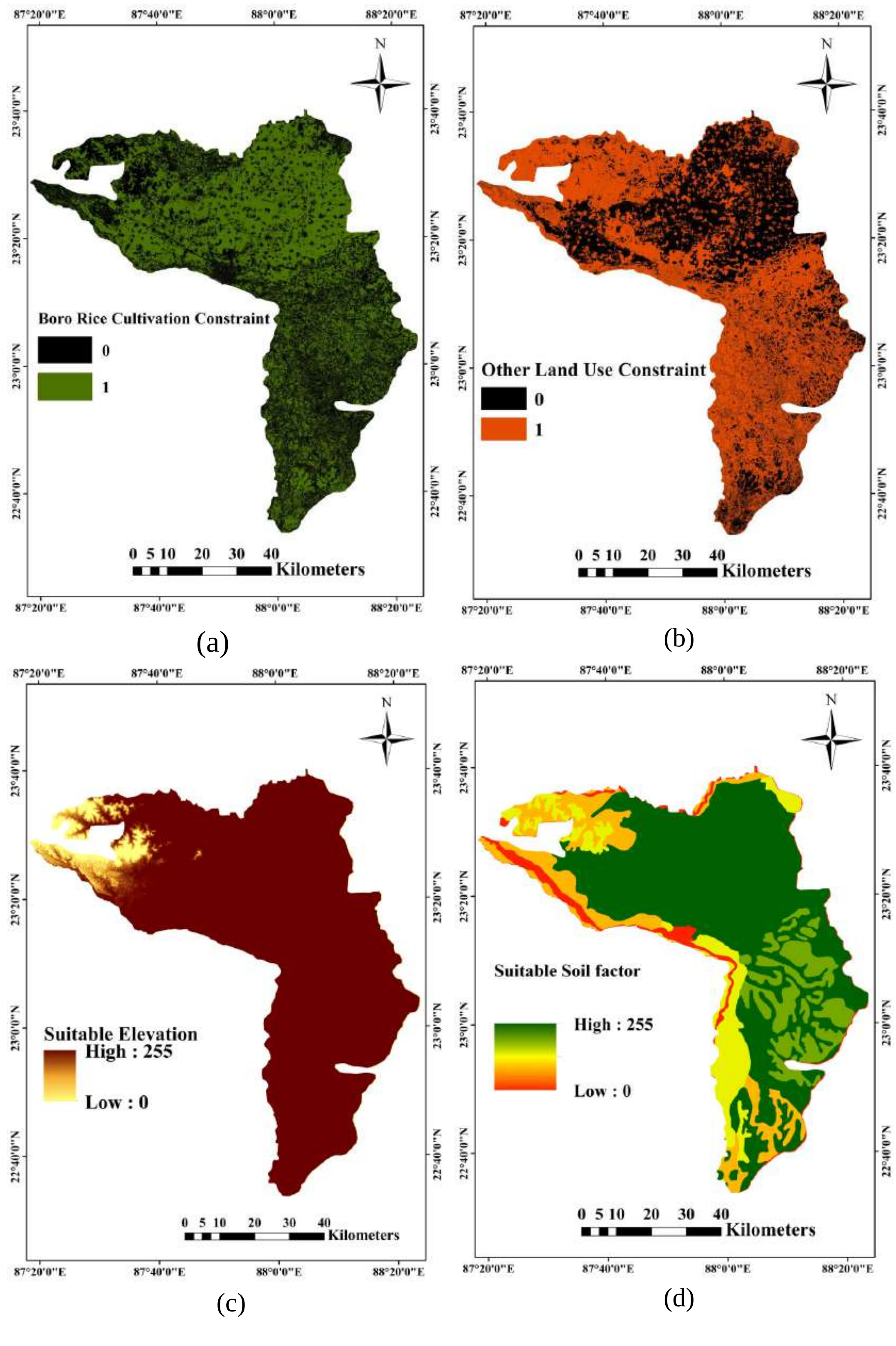


Figure 2.5: Boolean map of constraints for (a) Boro rice cultivation and (b) Other land use and Standardization of (c)Elevation (d) Soil

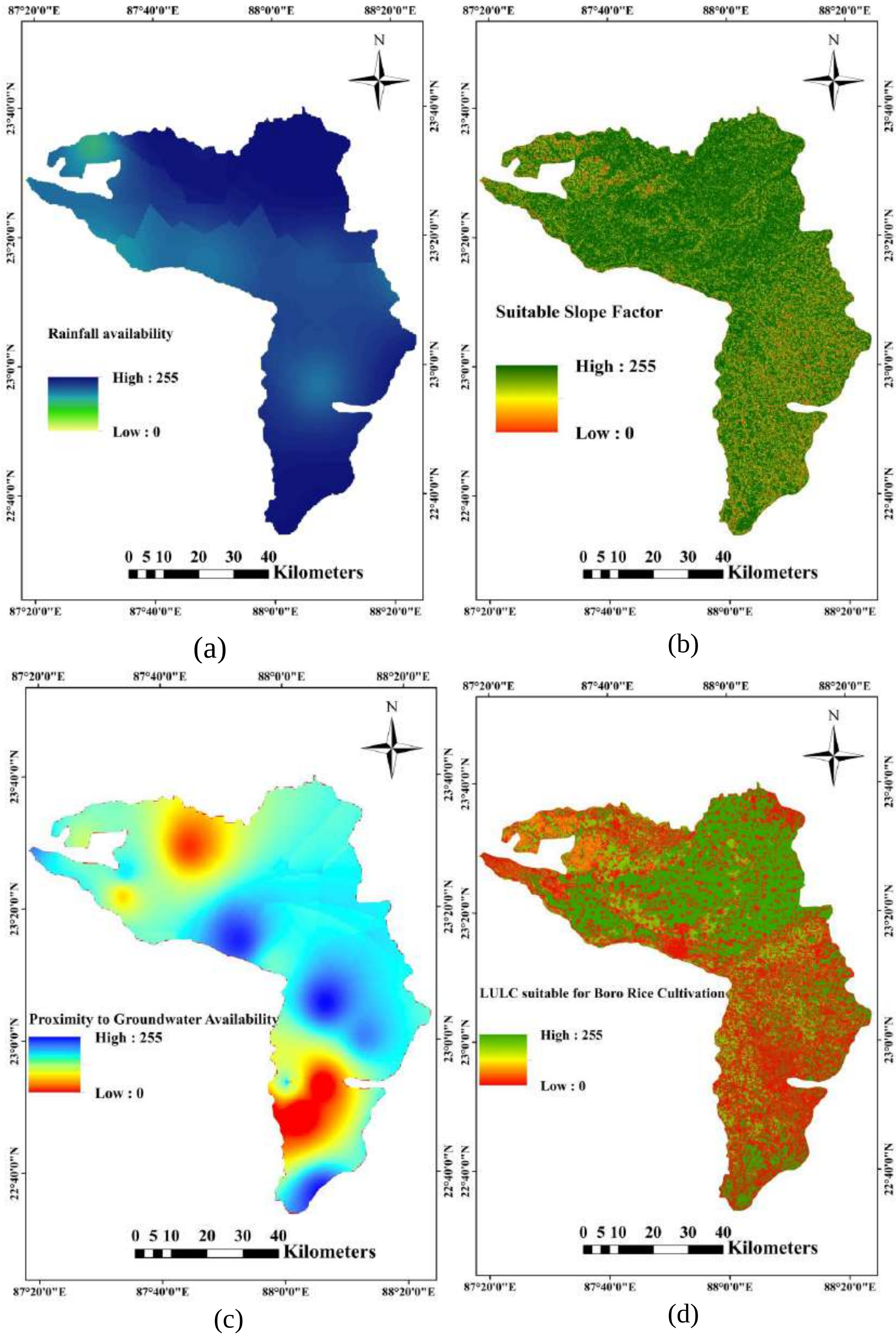


Figure 2.6: Standardization of (a) Rainfall (b) Slope (c) Groundwater (d) Land Use in 0-255 scale used for suitability mapping of Boro rice cultivation

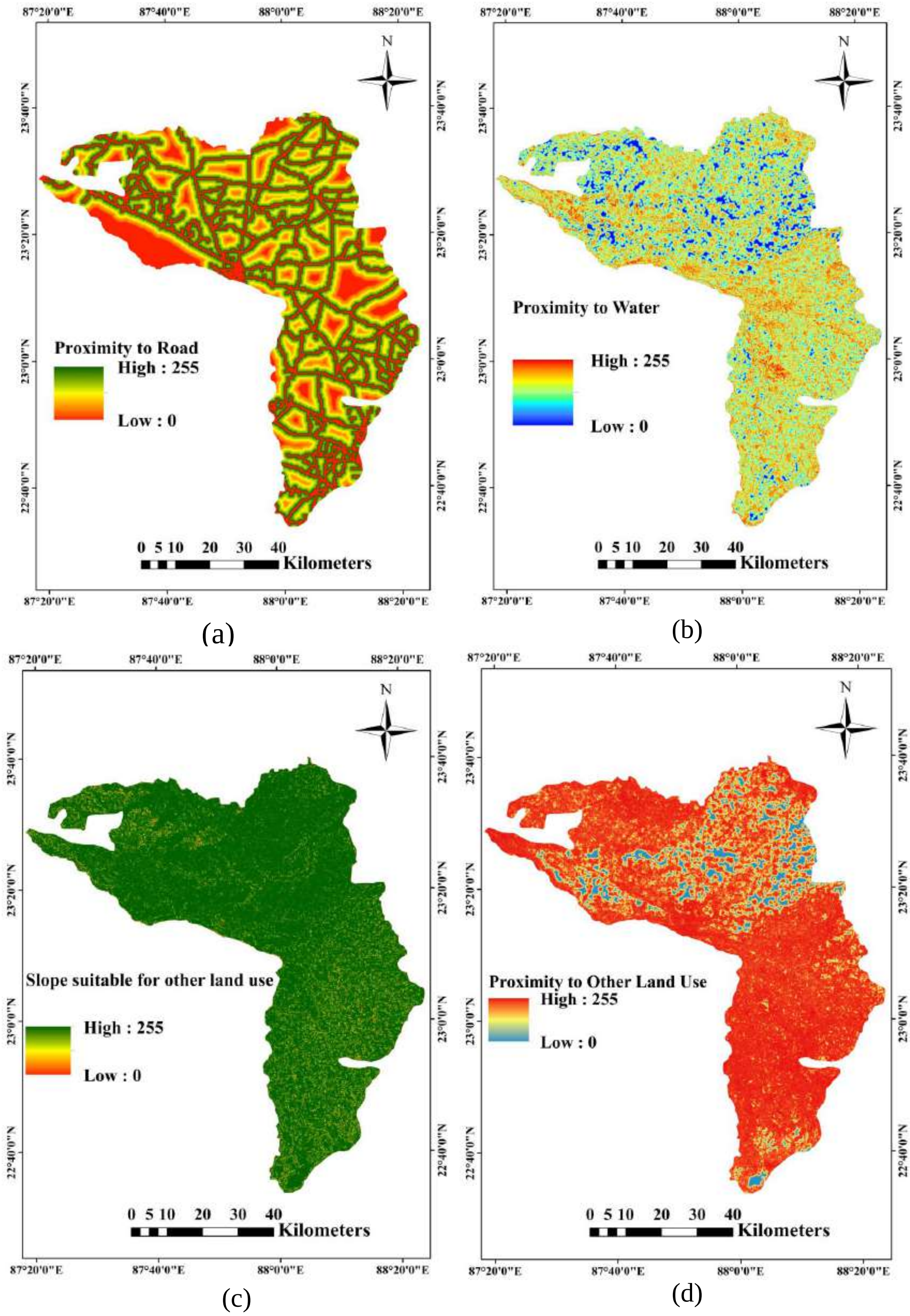


Figure 2.7: Standardization of (a) Proximity to road (b) Proximity to water (c) Proximity to other land use (d) Slope in 0-255 scale used for suitability mapping of Other land use

Table 2.1: (a) Pairwise Comparison Matrix developed in AHP for suitability mapping of Boro Cultivation

Factors	Elevation	Soil	Rainfall	Slope	Groundwater	Canal Water	LULC	Normalized Weight
Elevation	1/1	1/4	1/2	1/1	1/3	1/5	1/4	0.0500
Soil	4/1	4/4	4/2	4/1	4/3	4/5	4/4	0.2000
Rainfall	2/1	2/4	2/2	2/1	2/3	2/5	2/4	0.1000
Slope	1/1	1/4	1/2	1/1	1/3	1/5	1/4	0.0468
Groundwater	3/1	3/4	3/2	3/1	3/3	3/5	3/4	0.1500
Canal Water	5/1	5/4	5/2	5/1	5/3	5/5	5/4	0.2500
LULC	4/1	4/4	4/2	4/1	4/3	4/5	4/4	0.2032

Table 2.2: (a) Pairwise Comparison Matrix developed in AHP for suitability mapping of Boro Cultivation

Factors	Proximity to Road	Proximity to Water	Proximity to Build up land	Slope	Normalized Weight
Proximity to Road	3/3	3/1	3/2	3/6	0.2500
Proximity to Water	1/3	1/1	1/2	1/6	0.0833
Proximity to Build up land	2/3	2/1	2/2	2/6	0.1667
Slope	6/3	6/1	6/2	6/6	0.5000

Weighted linear combination was used to combine all standardized factors maps with their respective weight derived from AHP pairwise comparison matrix. Suitability map for each land cover was generated by using the following equation:

$$\text{Suitabilitymap} = \sum_{i=1}^{n} (C_n \times W_i) \tag{2.11}$$

where, C_n is cell value of a cell in i^{th} feature and W_i is normalized weight derived from AHP pairwise comparison matrix. Suitability map of both the land cover was combined as integer value between 0-255 scale and given as a raster group during CA-Markov simulation. The land use land cover was generated for the year 2017 and 2018. The iteration number was changed to get highest accuracy. Overall accuracy and Kappa Coefficient (Eq. 2.6) were used to assess the classification accuracy. The accuracy assessment was also carried out for year 2017 and 2018 by doing field survey and Google Earth images. The results of CA-Markov model and AHP based CA-Markov model were compared to determine the differences in simulation accuracy between the models. Based on the performance of both the models land use map of 2025,2035 and 2050 were simulated. The overall procedure is given in Figure 2.8.

2.3 Results

2.3.1 Spatiotemporal distribution of rice cultivated area

Two land cover classes namely, Boro rice and other land use cover were identified in the study area during unsupervised classification. All the pixels belonging to built up area, barren land, forest cover, plantation and water bodies were merged to create other land use cover. NDVI and EVI maps during two years of study periods were generated by taking 20 clusters of each land cover. The threshold values for rice and non-rice pixels were estimated using NDVI and EVI during 2017 and 2018. NDVI values between -0.344 to 0.29 and 0.778 to 0.792 were associated with non-rice pixels such as plantation, water body, brushwood, fallow land and habitation. All the rice pixels during two years study period were characterized by NDVI value between 0.29 to 0.778. EVI values between -0.616 to 1.016 were associated with non-rice pixels whereas rice pixels were characterized by EVI values between 1.016 to 1.748. The following conditional decision rules

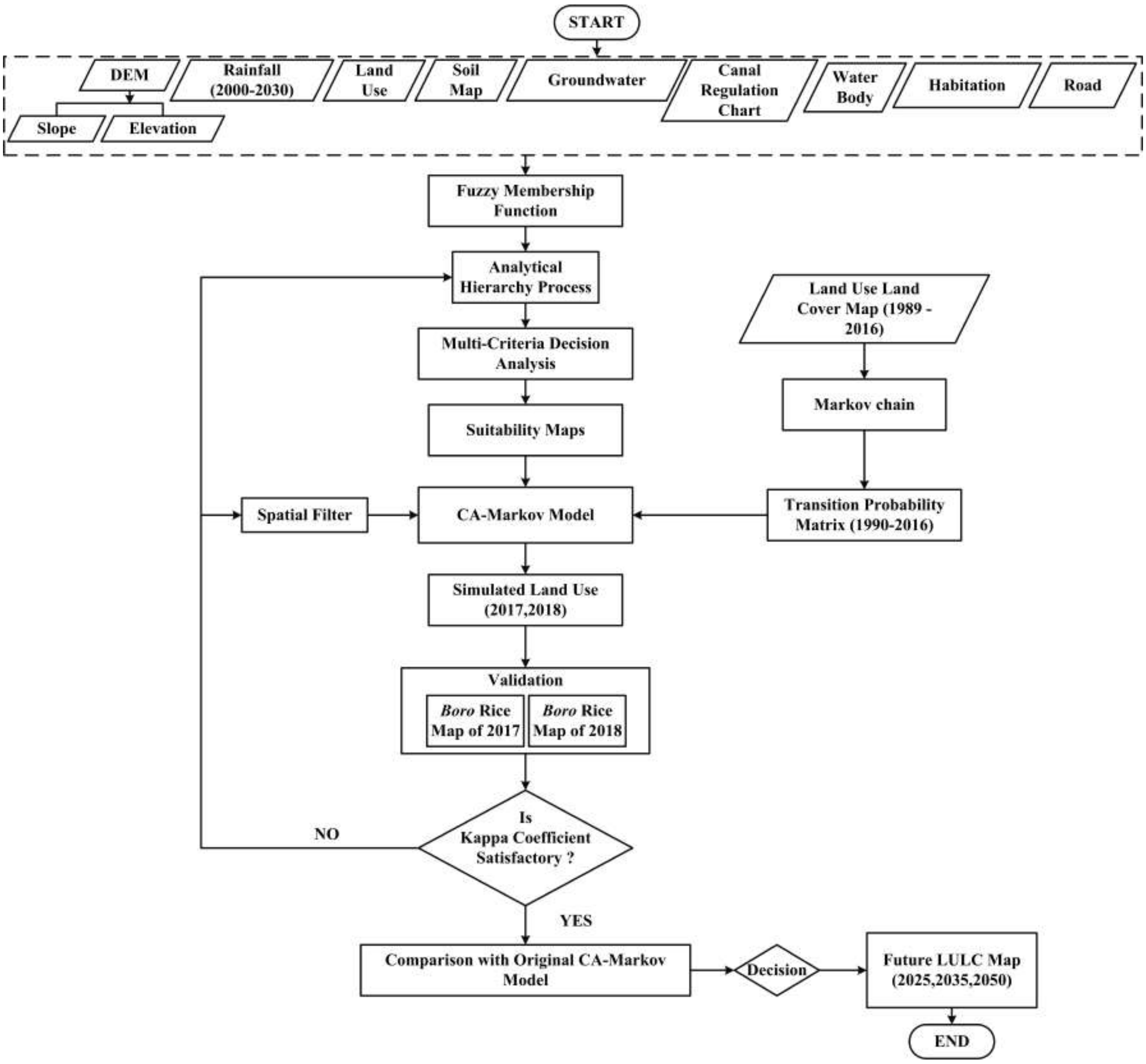


Figure 2.8: Overall methodology of integrated CA-Markov model with Analytical Hierarchy Process

(Eq. 2.12 and Eq. 2.13) were used on satellite images to extract Boro and non-Boro pixels on these NDVI and EVI maps respectively.

$$\text{BoroPixel} = \text{Con}\{(\frac{\rho_{NIR} - \rho_{\text{Red}}}{\rho_{NIR} + \rho_{\text{Red}}}) \geq 0.29\&(\frac{\rho_{NIR} - \rho_{\text{Red}}}{\rho_{NIR} + \rho_{\text{Red}}}) \leq 0.778\} \quad (2.12)$$

$$\text{BoroPixel} = \text{Con}\{(2.5 \times \frac{\rho_{NIR}-\rho_{\text{Red}}}{\rho_{NIR}+6\times\rho_{\text{Red}}-7.5\times\rho_{Blue}+1}) \geq 1.016\& (2.5 \times \frac{\rho_{NIR}-\rho_{\text{Red}}}{\rho_{NIR}+6\times\rho_{\text{Red}}-7.5\times\rho_{Blue}+1}) \leq 1.748\} \quad (2.13)$$

The area statistics of classified rice map and resultant composite VI maps were calculated. The total Boro cultivated area in unsupervised classified map, composite NDVI and EVI map was 3056.45 km^2, 3098.66 km^2, 3489.71 km^2, respectively.

2.3.2 Accuracy Assessment

The validation based on high resolution Google Earth image and field photos of 2017 is shown in Figure 2.9. During 2017 the rice map obtained from unsupervised classified resulted in 81.25% omission error, 86.67% commission error with overall accuracy of 81.48%. NDVI based rice map obtained 85.75% omission error, 75% commission error and overall accuracy of 77.78%. EVI based rice map obtained 86.67% omission error, 81.82% commission error and overall accuracy of 81.48%. The statistics of unsupervised classification, NDVI based rice map and EVI based rice map were 0.622, 0.552 and 0.622, respectively. The error matrix of these three different methods is given in Table 2.3.

As the overall accuracy and of rice map generated from unsupervised classification and EVI method were same, unsupervised classification was selected based on highest commission error. Similar accuracy results were also observed during field validation in 2018 (Figure 2.10). Hence unsupervised method was used to generate previous 28 years Boro rice map. Figure 2.11 and 2.12 show the Boro rice map of the study area in a 5-year interval. In 1989, 31% of total study areas was under Boro rice cultivation which was increased to 47% during 1994. It was observed that in 1999 the Boro rice cultivated area increased to 52% and the same was maintained till 2004. In five years, the Boro rice cultivated area reached to 66% of total command area during 2009. In 2014 and 2018, area under Boro cultivation was observed to be 63% and 60% respectively. The area under Boro rice and other land use cover during the study period of 30 years are shown diagrammatically in Figure 2.13. Over the year an increasing trend of Boro rice cultivation during the most water scarcity period was observed throughout the study area. As the canal water supply was not sufficient during mid-Jan to mid-April, cultivation of such high-water demanding crop was highly dependent upon groundwater at middle and lower reach of DVC command area. This activity of the farmers had led to excessive extraction of groundwater and hence exploitation of groundwater reservoir.

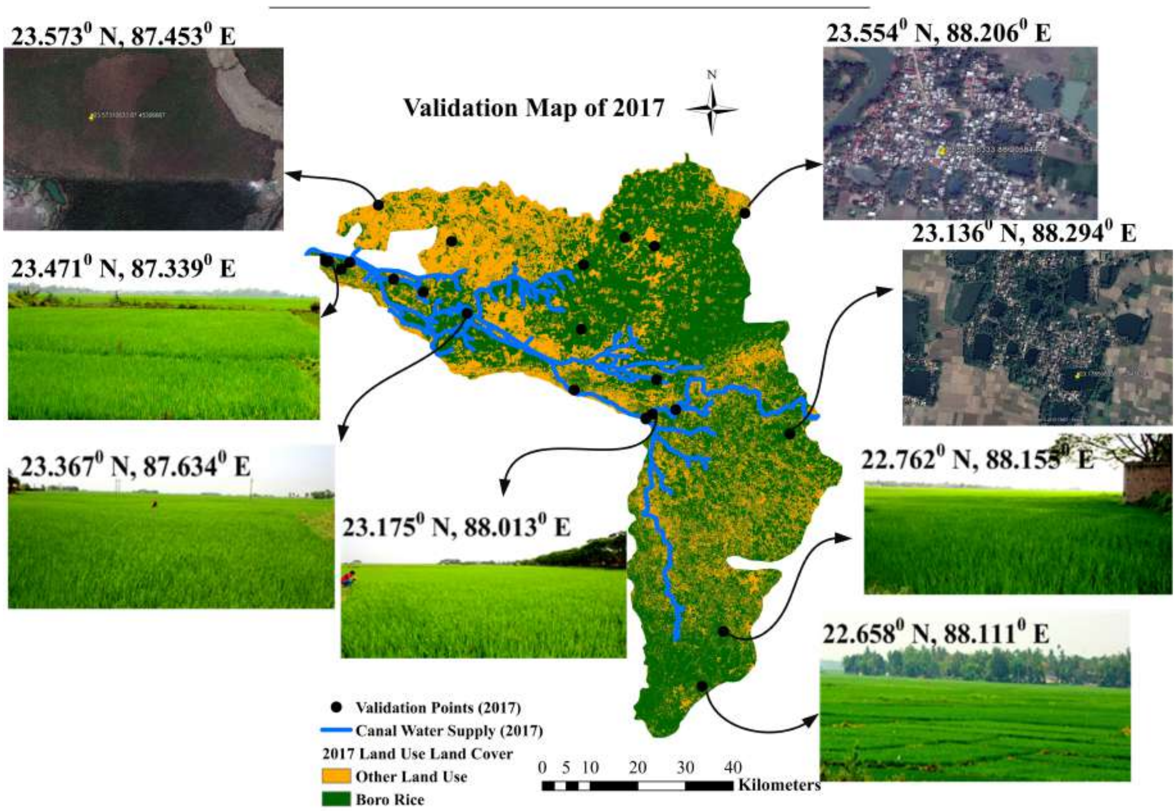


Figure 2.9: Spatial distribution of field validation points, field photos and Google Earth images during Boro cultivation period of year 2017 (canal water distribution coverage)

2.3.3 Analysis of simulation result of CA-Markov model and integrated CA-Markov model with AHP

The Markov chain model was used to calculate transition probability matrix between 1989 and 2016 as shown in Table 3. It can be observed from Table 2.4 that the probability of future transition of other land to Boro cultivation was 67.74%. The of simulated Boro rice map using CA-Markov model during 2017 and 2018 were 0.75 and 0.73, respectively. The simulated maps were also validated with ground truth data of 2017 and 2018. The overall accuracy was found to be 59.26% for 2017 and 56% during 2018. Figure 2.14 shows the suitability maps for both the land use classes generated from MCDA. Area nearer to canal water supply and north eastern part of study area were highly suitable for Boro cultivation whereas the north western part of study area was observed unsuitable during MCD analysis. The suitability maps were given as an input to CA-Markov model to simulate land use land cover during the year 2017 and 2018. The of the

Table 2.3: Error matrix of different rice map

Error Matrix of Unsupervised Classification				
Classified Data	Reference data		Omission Error (%)	Commission Error (%)
	Other	Boro Rice		
Other	9	3	81.82	75
Boro Rice	2	13	81.25	86.67
Overall Accuracy = 81.48 %				
Kappa Coefficient = 0.622				
Error Matrix of composite NDVI map				
Classified Data	Reference data		Omission Error (%)	Commission Error (%)
	Other	Boro Rice		
Other	9	2	69.23	81.82
Boro Rice	4	12	85.71	75
Overall Accuracy =77.78 %				
Kappa Coefficient = 0.552				
Error Matrix of composite EVI map				
Classified Data	Reference data		Omission Error (%)	Commission Error (%)
	Other	Boro Rice		
Other	9	2	75	81.82
Boro Rice	3	13	86.67	81.25
Overall Accuracy =81.48 %				
Kappa Coefficient = 0.622				

simulated Boro rice map generated from integrated CA-Markov and AHP model during 2017 and 2018 were 0.78 and 0.75, respectively. The overall accuracy obtained the from field validation of 25 ground truth points in 2017 and 27 ground truth points in 2018 were 63% and 60%, respectively. In both the study years integrated CA-Markov model with AHP resulted higher accuracy as compared to CA-Markov model. Hence, integrated CA-Markov model with AHP model was chosen to simulate future Boro rice map of 2025,2035 and 2050.

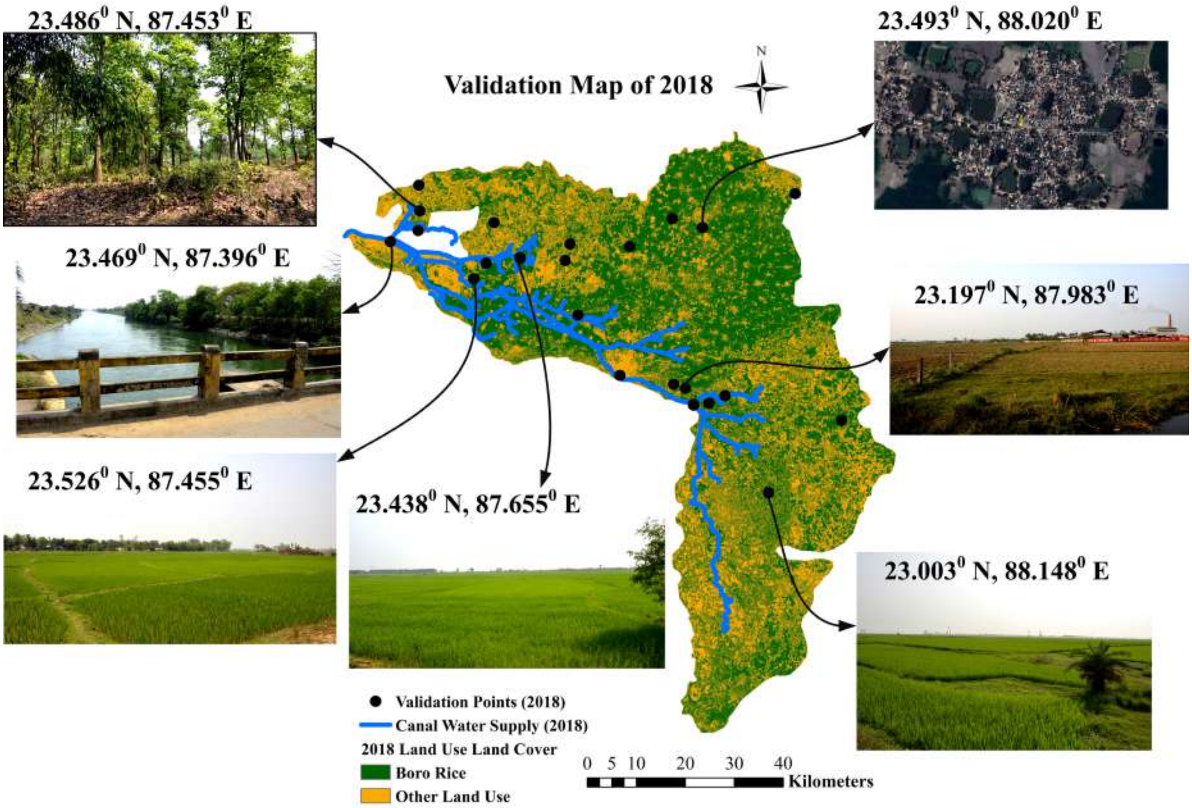


Figure 2.10: Spatial distribution of field validation point, field photos and Google Earth images during Boro cultivation period of year 2018 (canal water distribution coverage)

Table 2.4: Transition probability matrix by CA-Markov model

Class	Other Land Use	Boro Rice cultivated land
Other Land Use	0.3226	0.6774
Boro Rice cultivated land	0.4497	0.5503

2.3.4 Analysis of future Boro rice scenario

Boro rice map predicted for the year 2025, 2035 and 2050 are shown in Figure 2.15. It was observed from the simulation results that Boro rice trend will further increase in the future (Figure 2.16). The rice map of 2018 shows that there was 3185.488 km^2 of Boro cultivated land which will be increased by 5.55% i.e. 3362.41 km^2 of Boro cultivated area during 2025. In Boro rice map of 2035 and

2050, it was observed that the Boro cultivated area will be increased by 6.16% and 6.76% respectively compared to the present scenario. It can be observed from past 30 years rice cultivation scenario that Boro rice cultivation is more prevalent in south western part of Bardhamann district. However, in future simulation map of 2035 and 2050 it can be observed that Boro rice cultivation was significantly reduced in south western part of Bardhamann district. This signifies the growth of urban area i.e. Durgapur and Bardhamann city in the near future. It can be observed in Figure 2.15 (c) that proximity to highway will affect the Boro cultivation in the command area. These agricultural areas will be more prone to shift toward habitation or other land use cover. However, to mitigate the food demand of growing population, the fallow land of lower part of command area will be shifted to Boro cultivation land which can be seen from Figure 2.15 (a-c). This may lead to overexploitation of groundwater during cultivation period as canal water supply is not sufficient according current canal regulation policy.

2.4 Discussion

Thirty-year Boro rice maps were generated based on the performance ISODATA clustering algorithm and two vegetation indices, i.e., NDVI and EVI in Damodar command area, West Bengal. The results show inclusion of Boro pixels into non-Boro pixels was high in composite NDVI map and EVI map as compared to the map generated by unsupervised classification. Difference in sowing timing had resulted in different growth stage of Boro rice in the command area. Some of the validation points were taken in flooded rice field which were in early growing season with less vegetation cover. Thus, composite NDVI and EVI maps could not capture the flooding and transplanting signal in those field which were on early growing stage (Dong et al. 2016). However, clusters of different classes before generation of composite NDVI and EVI maps helped in exclusion of non-Boro pixels into Boro pixels. Similar results were also found by Mondal et al. (2014) while extracting seasonal cropping pattern in Muzaffarpur district of Bihar. It was observed during field survey that area under Boro rice was very high as compared to other crops which were cultivated during mid-January to mid-April in the command area. Due to large extent of Boro rice field (Fig.7 and 8) and distinct spectral reflectance from other crops resulted higher overall accuracy in unsupervised classification. Peña-Barragán et al. (2011) identified major crops of his study area where he found rice yielded highest omission error and commission error than other crops. They attributed this efficiency to the fact that crop growth in stagnant water and very distinguishable spectral properties due to effect of water in NIR and SWIR region. However, spectral confusion had failed the unsupervised classification to completely separate algae covered ponds and some plantation nearer to the rice field. Overall, the results indicated that among these three methods ISODATA clustering algorithm can be used for more accurate classification in single cropping system with large extend of cultivation area. Sahoo et al. (2018) also observed more quality controls during visual interpretation over digital classification in analyzing medium resolution satellite data. The results of this study will provide a vision to the water management community and decision makers to monitor and control excessive water withdrawal in the study area. No previous attempt was made to predict the rice cultivation area in major canal irrigation system in India for water resource management point of view. In some of the previous studies it was found that simulation accuracy can be improved by combining CA with Markov chain model but cannot consider the effect of different physical factors (Guan et al. 2011). Therefore, in the present study AHP was combined with CA-Markov model to consider the effect of various significant driving factors (elevation, soil, rainfall, slope, groundwater, canal regulation chart, LULC, and road network). The integrated CA-Markov model with AHP has performed well in comparison to CA-Markov model during both the study period. The accuracy results were higher and more reliable than that generated from CA-Markov model. Utilization of future rainfall data along with historical trend of canal regulation chart may have contributed towards the improvement of performance of the model. Some of the previous literature had achieved better accuracies in combining CA model with frequency ratio model or AHP model in comparison to CA model for simulating urban growth trend (Aburas et al. (2017); Al-sharif and Pradhan (2016)). Aburas et al. (2017) obtained 0.872 value in CA-Markov model combined with AHP model to simulate urban growth trend in Seremban, Malaysia. The simulation accuracy depends upon certain factors such as image quality, processing methods, selection of influencing factors that affect land use change and quality of data used for analysis of those factors. The higher accuracy obtained by Aburas et al. (2017) was due to use of good spatial resolution (i.e. 10 m) spot images. The spatial resolution of Landsat data (i.e. 30 m) used in this study may have affected the value of 0.78 during 2017 and 0.75 during 2018. Furthermore, the simulation accuracy can be affected by variance in assignment of weight according to level of expertise during AHP process. In the present study a special attention was given to mitigate the gap between scientific proficiency and actual situation by interviewing field level experts. The increasing area under Boro cultivation confirmed that more scientific research should focus on simulation of rice cultivation area especially in major canal irrigation system. The results of the present study may be improved by the inclusion of socio-economic factors of the study area which we could not include due to lack of data. However, not only the identification of influencing factor but also selection of model will make the simulation more accurate and realistic.

2.5 Summary

Monitoring and simulating rice cultivation area in a multipurpose water resources project is an important step forward focusing on integrated water resources management in developing countries. The spatiotemporal changes of rice cultivation were captured by analyzing long term historical satellite data from 1989 to 2018 which provided information on rates at which they occurred and helps to identify drivers that drive these changes. The increasing trend of Boro rice cultivation was observed over the last thirty years (1989-2018) in the study area. The area under rice cultivation was found to increase from 1657.83 km^2 in year 1989 to 3185.488 km^2 in year 2018. From the analysis of 30 years rice cultivation scenario, Boro rice cultivation is more prevalent in south western part of Bardhamann district where the canal water was supplied during cultivation period. CA-Markov model and integrated CA-Markov with multi criteria decision analysis (MCDA) were used to simulate future Boro cultivation area change in the study area. Based on model validation original CA-Markov model and integrated CA-Markov with MCDA achieved value of 0.75 and 0.78 during 2017 and 0.73 and 0.75 during 2018. Consideration of hydrological and physical factors during simulation by integrated CA-Markov with MCDA led to higher accuracy and more realistic results than CA-Markov model. Future rice map during 2025, 2035 and 2050 were generated by using integrated CA-Markov model with MCDA. A continuous increase of Boro cultivated area along with urban growth was observed from the simulation results. In future simulation map of 2035 and 2050 Boro rice cultivation was significantly reduced in most prevailing cultivated area i.e. south western part of Bardhamann district due to urbanization and industrialization.

However, fallow land of lower part of command area will be shifted to Boro cultivation land to mitigate food demands. This shifting may lead to overexploitation of groundwater of lower command area unless a change in current canal regulation policy will be taken into consideration. If the current situation will remain unchanged, then it may improve economic status of people but will create a huge impact on the water resources system of the study area. Therefore, rice cultivation area transition map is essential for all rice growing area of Southeastern Asia for predictive analysis study providing useful information on dynamics of land-use planning. The results obtained from analysis of remote sensing data can be used for achieving a sustainable strategy of water use and its management in relation to its availability over the study area.

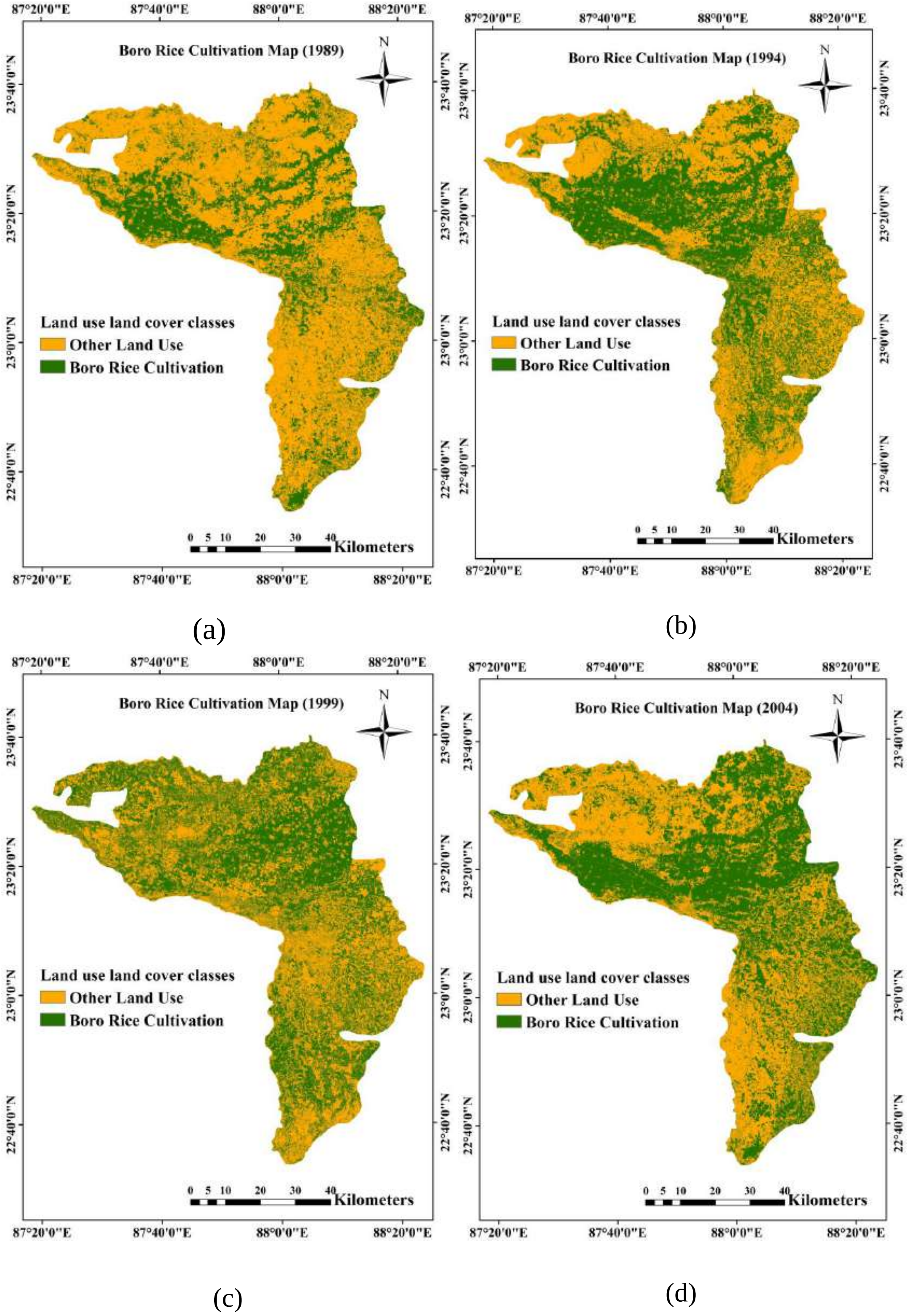


Figure 2.11: Boro rice map of the study area in a 5-year interval (a) Boro Rice map in 1989 (b) Boro Rice map in 1994 (c) Boro Rice map in 1999 (d) Boro Rice map in 2004

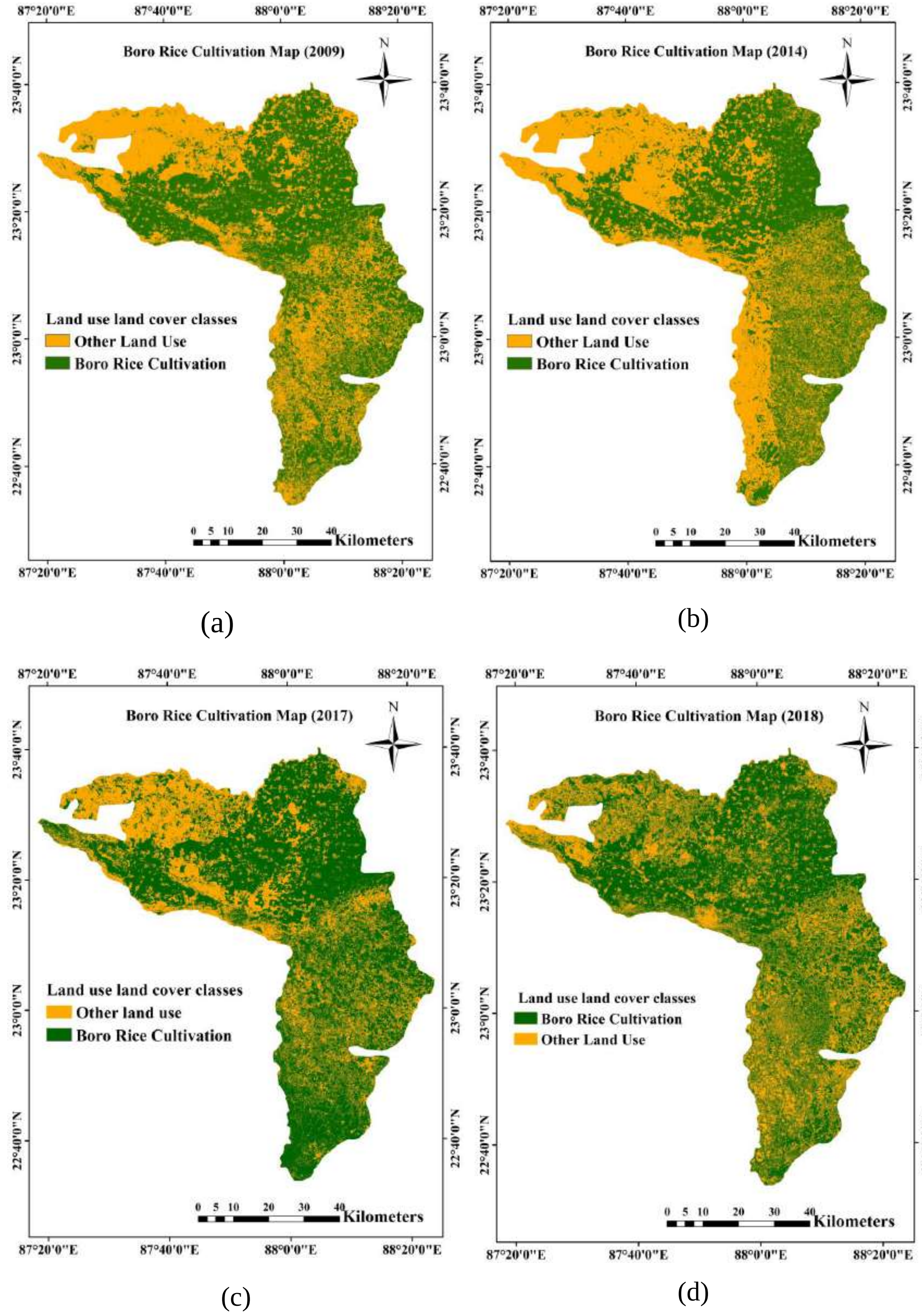


Figure 2.12: Boro rice map of the study area in a 5-year interval (a) Boro Rice map in 2009 (b) Boro Rice map in 2014 (c) Boro Rice map in 2017 (d) Boro Rice map in 2018

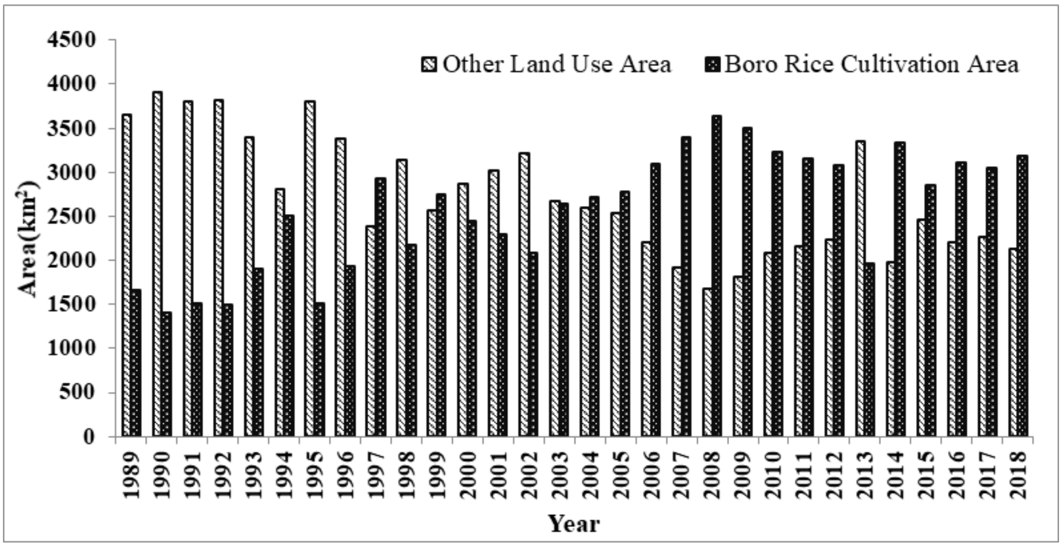


Figure 2.13: Diagrammatic illustration of areal expansion of Boro rice and other land use cover during 1989 to 2018 in left bank irrigation system

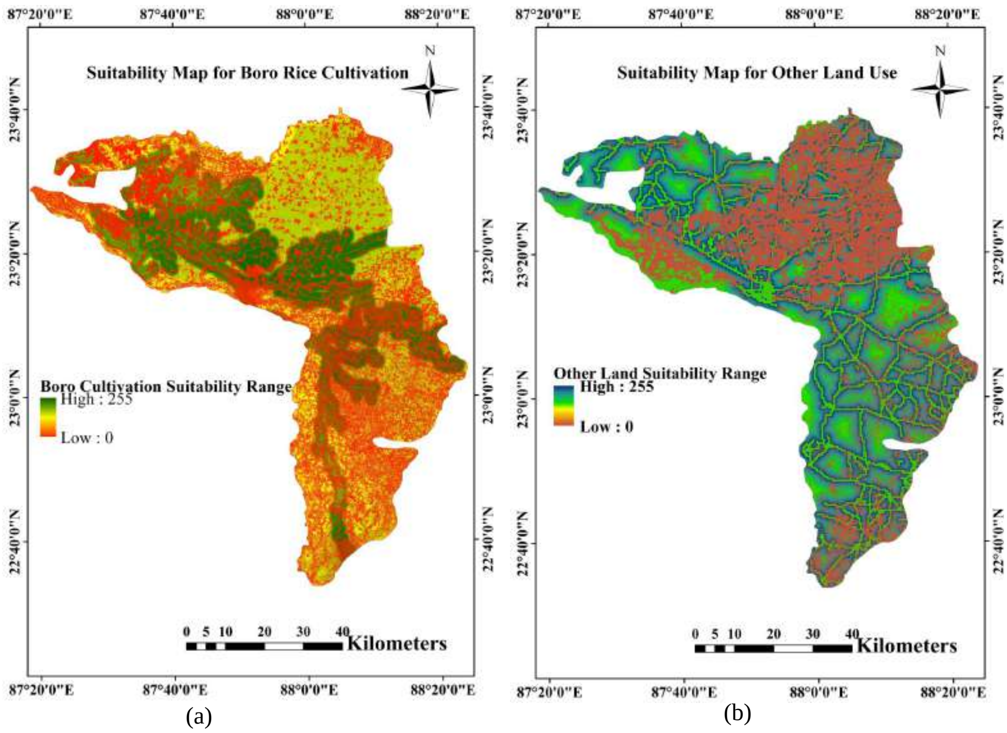


Figure 2.14: Suitability Map generated from MCDA for (a) Boro Cultivation (b)Other Land Use

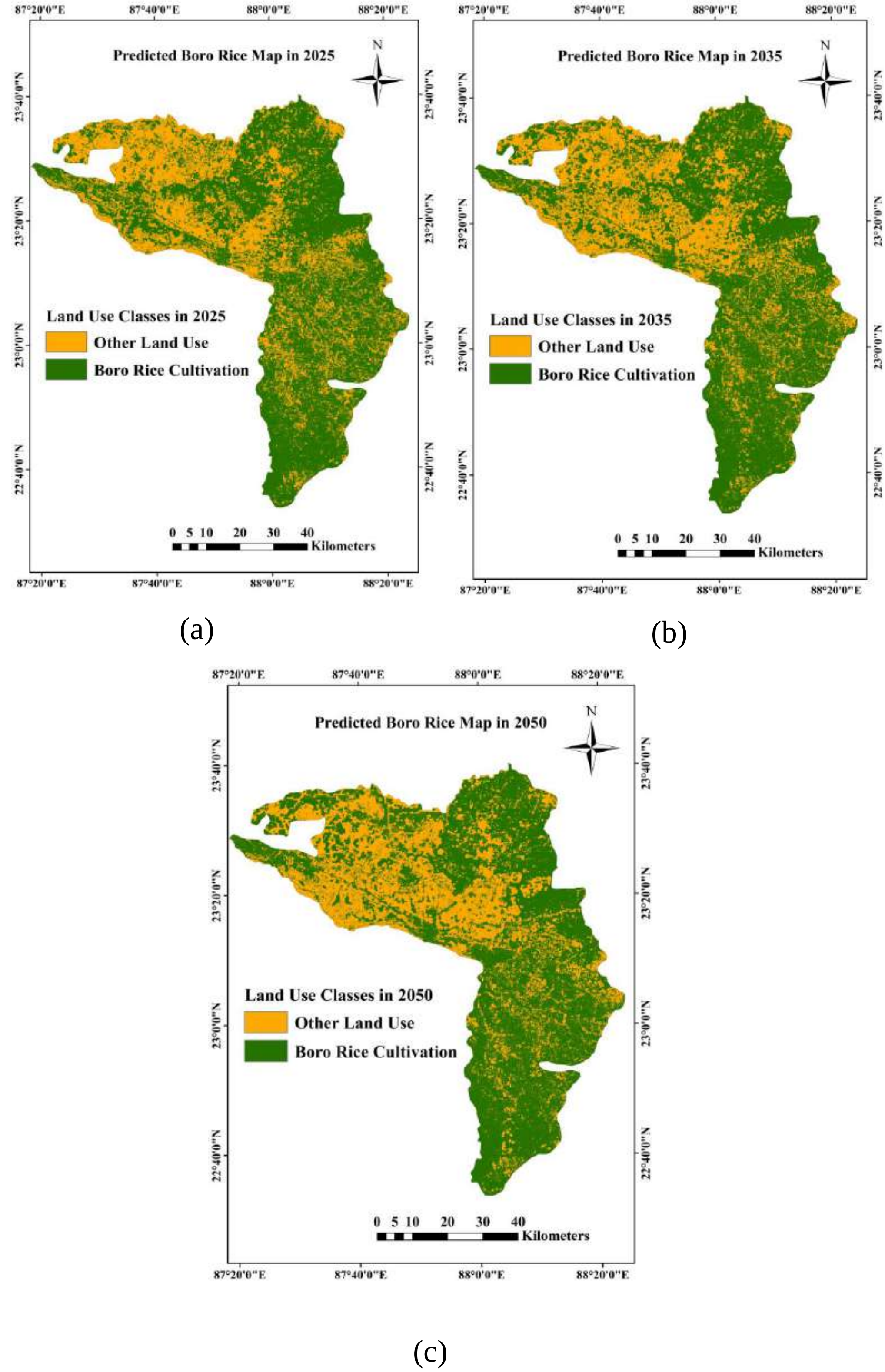


Figure 2.15: Future Scenario of Boro Rice Cultivation Area during (a) 2025, (b) 2035 and (c) 2050

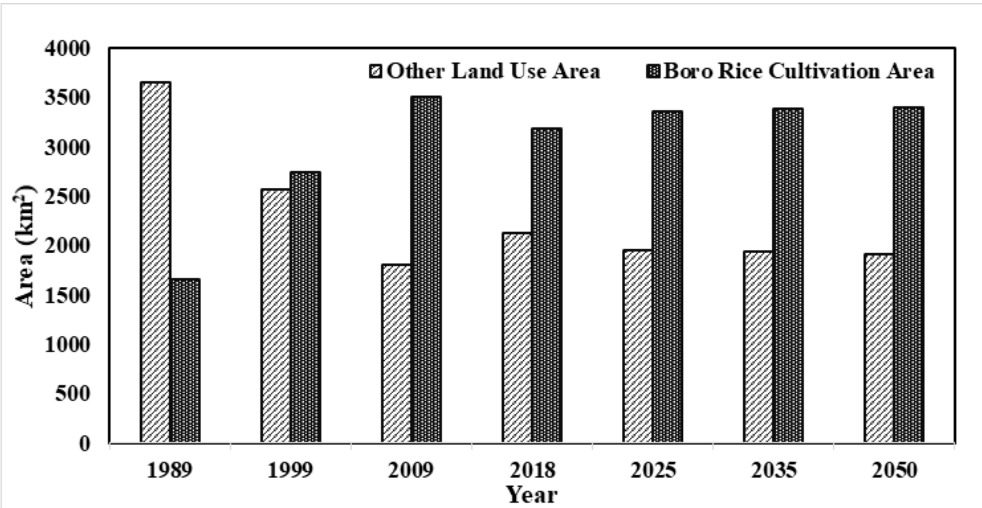


Figure 2.16: Quantity of previous and predicted Boro rice and other land use using integrated CA-Markov with AHP model

Chapter 3

Modelling of irrigation water requirement and evaluation of application efficiency

3.1 Surface Flooding Model

Almost all the reported literature on basin hydrodynamics is oriented towards estimating the spread of water over an initially dry basin surface as the water from the source is allowed to enter the fields from the water courses. However, in the present study, the two-dimensional spread of the water front is not considered significant, both from the time it takes to fill the basin (in order of minutes, for small basins, to within an hour, for larger ones), and the volume of water it consumes during this time including the water lost due to infiltration. Rather, this work focuses on the volume of water accumulated in the basins during the ponding of the basins and the time it takes to do so. In a volume-balance approach expressed as a differential equation, the water lost during this process by way of infiltration, plant water consumption (evapotranspiration) and overflow to adjacent basins by the cascading effect, and any water received from other sources like rainfall and groundwater are considered in this work to carry out the numerical simulations. It may be recalled that although basin irrigation is suitable for other types of crops as well, this thesis considers paddy cultivation which require standing water in the basins. Further, the movement of water in the fields, after it is let out from the watercourses through the field outlets, is assumed to fill a basin up to the bund height and then overflow to the next which, in reality, is often initiated through small cuts in the bunds.

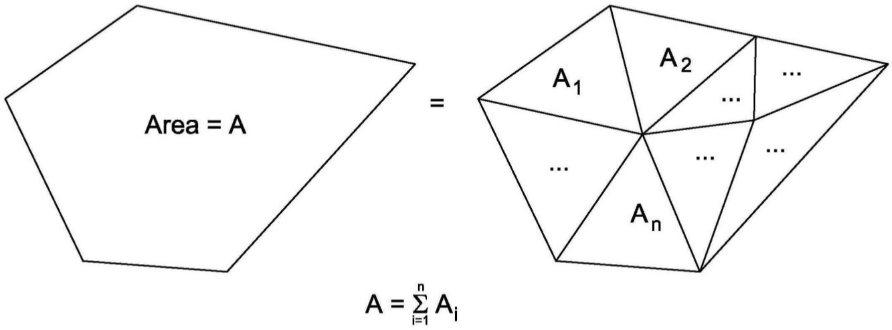


Figure 3.1: Subdivision of an irrigated basin into smaller triangular domains, or "basin cells".

For the ease of numerical computation, one further assumption has been made in basin representation in this work. Although basins as encountered in the fields are of any general shape and size, the basins considered here are assumed to be in the form of triangular patches of land with a specified height of border bunds (dykes) to induce ponding. The height of the bunds is kept according to the normal standing depth required for paddy cultivation, but may be changed, if necessary. The triangular shape of the basins is adopted for helping in easy representation of the terrain by the Triangulated Irregular Network (commonly referred to as the TIN) digital terrain model. Although a triangular basin may be uncommon in practice but the basic equation adopted for simulating ponding in the basins is the storage change equation (Eq. 3.1),

$$A\frac{dh}{dt} = Q \tag{3.1}$$

where A is the cross-sectional area of the plot (L^2); h is the depth of water (L); t is the time (T), and Q is the net inflow of water to the plot (L^3T^{-1}), would yield the same result if the area A is subdivided into smaller patches, which could be triangular, as shown in Figure 3.1. The right hand side of Equation 3.1 is the "Source Term", which includes the addition of all inflows including the water received from canal, groundwater, precipitation, and subtraction of outflows including infiltration, and evapotranspiration.

3.2 Derivation of the equations for flow movement in basins

In this section, the basic governing equations for the water depth variation with time for a single basin, henceforth designated as "cell", that receives water from a source and also from neighbouring cell(s), may be derived following Cunge (1975), as follows (Eq. 3.2, referring to Figure 3.2).

$$A_i \frac{\Delta z_i}{\Delta t} = P_i + \sum_j Q_{i,j} + \sum_j \frac{\partial Q_{i,j}}{\partial z_i} \Delta z_i + \sum_j \frac{\partial Q_{i,j}}{\partial z_j} \Delta z_j \tag{3.2}$$

where A_i is the area of cell i, Δz_i is the change of the depth of flow in cell i, $Q_{i,j}$ is the flow discharge from cell i to cell j, P_i is the rainfall in cell i, Δt is the time, Q_i is the inflow from canal to cell.

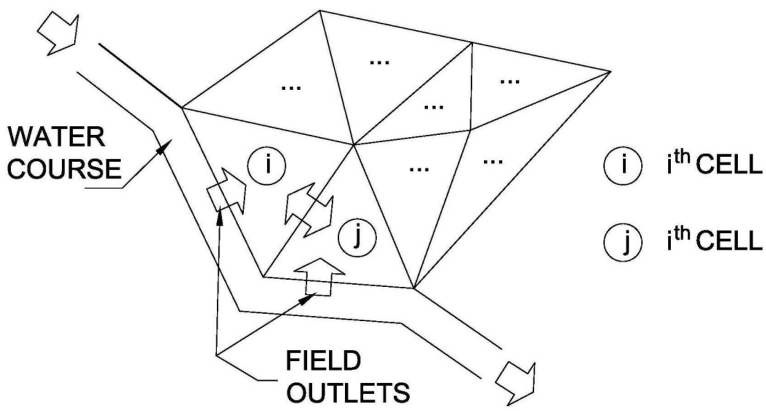


Figure 3.2: Two cells "i" and "j" exchanging flows / receiving flows from watercourse

Equation 3.2 may be generalised for any number of cells that are hydraulically connected, that is, which exchange flows amongst themselves at any point of time.

The equation for flow exchange between cells (Figure 3.3) may be modelled by a "weir type equation" (Cunge 1975), as in Eq. 3.3, for free flow condition, and Eq. 3.4 for drowned flow condition:

$$Q_{i,j} = \Phi_F (z_j - z_w)^{3/2} \tag{3.3}$$

$$Q_{i,j} = \Phi_D (z_i - z_w) \sqrt{z_j - z_i} \tag{3.4}$$

In the above equations, Φ_F and Φ_D are the weir discharge coefficients, generally expressed as:

$$\Phi_F = \mu b\sqrt{2g} \tag{3.5}$$

$$\Phi_D = 2b\sqrt{2g} \tag{3.6}$$

b being the effective width of the weir and μ a discharge coefficient.

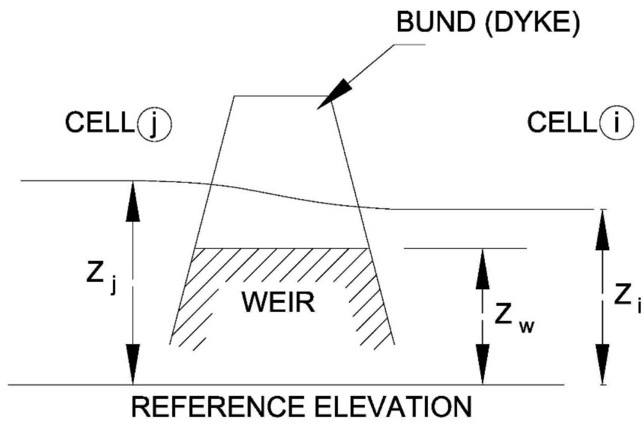


Figure 3.3: Weir type link between cells "i" and "j" [adapted from Cunge (1975)]

3.3 Solution of the inter-cell flow simulation model

The computation for simulating the progressive movement of basin water from one cell (basin) to another is initiated from an assumed dry cell condition for all the cells. As and when a watercourse receives a discharge from the branch canal or distributary, considered steady, its distribution to the different beneficiary cells (assumed connected to the watercourse by weir type links) is worked out. This may be illustrated as in Figure 3.4, where the basin cells receiving water are shaded. These cells may be considered as the initial "wet" cells for computation purpose.

Once the "wet cells" are identified, the flow accumulation equations (Eq. 3.2, appropriately modified dynamically by including the wet basin cells) are solved to estimate the rise in water depth in each of these cells with time. The computations proceed till some of these cells start overflowing once their water depth exceed the prescribed bund height. At this stage, the cells that receive water from one or more of the overflowing cells are also designated as "wet" and are considered hydraulically connected to the other "wet cells". The computation thus proceeds in time, with the updated number of cells considered exchanging flow amongst each other.

It may be appreciated that as the water accumulates in the "wet cells" that are hydraulically connected, simultaneous loss of water also takes place by infiltration of water into the soil and for meeting evapotranspiration requirement of the cultivated plants. These water loss terms, or "sinks" are introduced into the overall equation by changing the appropriate term (P in Eq. 3.2). Thus, a point of dynamic equilibrium is reached when the water flowing into the cells from the watercourse is all spent up by the corresponding sink terms assigned to each cell. It may be pointed that the sink term is computed separately for each cell, by carrying out the appropriate infiltration computations with information regarding the type of crop and its corresponding evapotranspiration requirement. At this stage, the flow condition in the field may be graphically illustrated as in Figure 3.5. Those cells that receive water, but have not filled up to the bund height, are termed as "partially wet cells". These cells are hydraulically connected to the wet cells but do not donate water to other neighbouring cells. The number of "wet", "partially wet" and the remaining cells, termed "dry", vary dynamically depending upon the net water available to the flow domain.

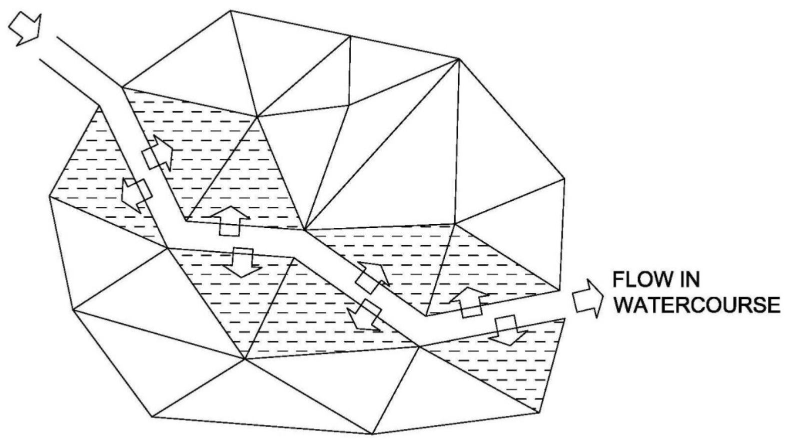


Figure 3.4: Basin cells, shown shaded, receive water from the watercourse on initiation of flow.

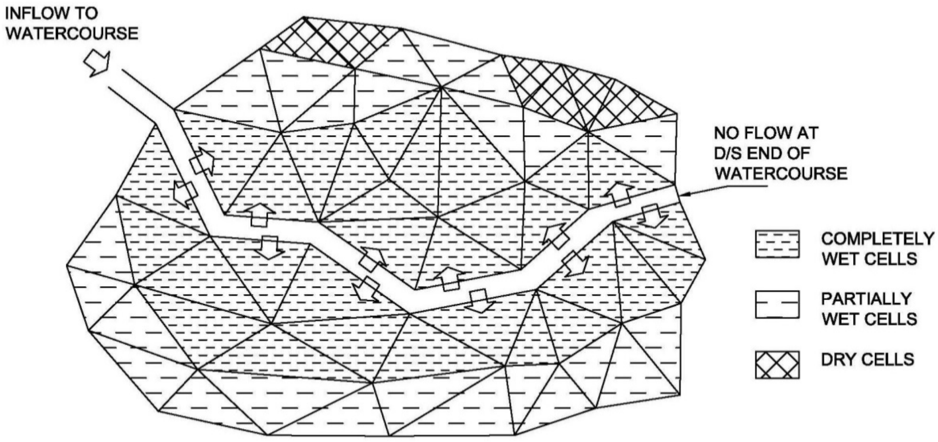


Figure 3.5: "Wet", "Partially wet" and "Dry" cells in dynamic equilibrium receiving water from a watercourse (water loss from infiltration and evapotranspiration).

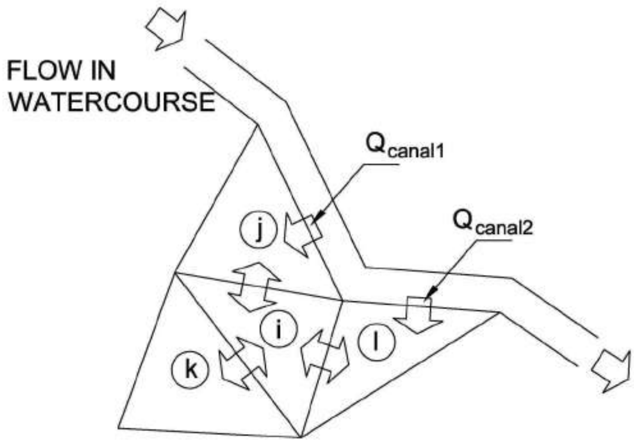


Figure 3.6: Four hydraulically connected cells receiving/exchanging water

3.4 Theoretical example of inter-cell flow simulation model

In order to explain in detail the computation for flow simulation within cells, a hypothetical example of four hydraulically connected cells is considered and the corresponding equations derived. Assuming the cells numbered as "i", "j", "k", and "l", and connected as in Figure 3.6, the four sets of equations for the four cells may be expressed respectively as in Eq. 3.7 to 3.10. The notation $Q_{p,q}$ represent the flow between cells p and q.

Now if an area is composed of four triangular cells as above then flow equations for consecutive four cells i.e., cell i to cell l are as follows: For cell i

$$A_i \frac{\Delta z_i}{\Delta t} - \left\{ \frac{\partial Q_{i,j}}{\partial z_i} \Delta z_i + \frac{\partial Q_{i,k}}{\partial z_i} \Delta z_i + \frac{\partial Q_{i,l}}{\partial z_i} \Delta z_i \right\} - \left\{ \frac{\partial Q_{i,j}}{\partial z_j} \Delta z_j + \frac{\partial Q_{i,k}}{\partial z_k} \Delta z_k + \frac{\partial Q_{i,l}}{\partial z_l} \Delta z_l \right\} = P_i + \{Q_{i,j} + Q_{i,k} + Q_{i,l}\} \quad (3.7)$$

For cell j

$$A_j \frac{\Delta z_j}{\Delta t} = P_j + \{Q_{j,i}\} + \{Q_{canal1}\} + \left\{ \frac{\partial Q_{j,i}}{\partial z_j} \Delta z_j \right\} + \left\{ \frac{\partial Q_{j,i}}{\partial z_i} \Delta z_i \right\} \quad (3.8)$$

For cell k

$$A_l \frac{\Delta z_l}{\Delta t} = P_l + \{Q_{l,i}\} + \left\{ \frac{\partial Q_{l,i}}{\partial z_l} \Delta z_j \right\} + \left\{ \frac{\partial Q_{j,i}}{\partial z_i} \Delta z_i \right\} \quad (3.9)$$

For cell l

$$A_k \frac{\Delta z_k}{\Delta t} = P_k + \{Q_{k,i}\} + \{Q_{canal2}\} + \left\{ \frac{\partial Q_{k,i}}{\partial z_k} \Delta z_k \right\} + \left\{ \frac{\partial Q_{k,i}}{\partial z_i} \Delta z_i \right\} \quad (3.10)$$

The four equations, written in a matrix form as in Eq. 3.11, are to be solved simultaneously.

$$\begin{pmatrix} \frac{A_i}{\Delta t} - \left\{ \frac{\partial Q_{i,j}}{\partial z_i} + \frac{\partial Q_{i,k}}{\partial z_i} + \frac{\partial Q_{i,l}}{\partial z_i} \right\} & -\frac{\partial Q_{i,j}}{\partial z_j} & -\frac{\partial Q_{i,k}}{\partial z_k} & -\frac{\partial Q_{i,l}}{\partial z_l} \\ -\frac{\partial Q_{j,i}}{\partial z_i} & \frac{A_j}{\Delta t} - \frac{\partial Q_{j,i}}{\partial z_j} & 0 & 0 \\ -\frac{\partial Q_{k,i}}{\partial z_i} & 0 & \frac{A_k}{\Delta t} - \frac{\partial Q_{k,i}}{\partial z_k} & 0 \\ -\frac{\partial Q_{l,i}}{\partial z_i} & 0 & 0 & \frac{A_l}{\Delta t} - \frac{\partial Q_{l,i}}{\partial z_l} \end{pmatrix} \begin{pmatrix} \Delta z_i \\ \Delta z_j \\ \Delta z_k \\ \Delta z_l \end{pmatrix}$$

$$= \begin{pmatrix} P_i + Q_{i,j} + Q_{i,k} + Q_{i,l} \\ P_j + Q_{j,i} + Q_{canal1} \\ P_k + Q_{k,i} \\ P_l + Q_{l,i} + Q_{canal2} \end{pmatrix} \quad (3.11)$$

Derivatives in the above equations are evaluated for two types of links i.e., 1. River Type link and 2. Weir Type link. These are explained below.

Weir Type links:

i) For free flow broad crested weir type links:

$$Q = \Phi_F h^{3/2} \tag{3.12}$$

Flow to cell i, from neighbouring cells j, k and l can be expressed as follows:

$$Q_{i,j} = \Phi_F (z_j - z_w)^{3/2} \tag{3.13}$$

$$Q_{i,k} = \Phi_F (z_k - z_w)^{3/2} \tag{3.14}$$

$$Q_{i,l} = \Phi_F (z_l - z_w)^{3/2} \tag{3.15}$$

Other terms for are to be derived in the same way for considering j, k and l cell to be receiver

Differential terms in the coefficients can be expressed as:

$$\frac{\partial Q_{i,j}}{\partial z_i} = 0.0 \tag{3.16}$$

$$\frac{\partial Q_{i,k}}{\partial z_i} = 0.0 \tag{3.17}$$

$$\frac{\partial Q_{i,l}}{\partial z_i} = 0.0 \tag{3.18}$$

$$\frac{\partial Q_{i,j}}{\partial z_j} = 1.5\Phi_F (z_j - z_w)^{1/2} \tag{3.19}$$

$$\frac{\partial Q_{i,j}}{\partial z_k} = 1.5\Phi_F (z_k - z_w)^{1/2} \tag{3.20}$$

$$\frac{\partial Q_{i,j}}{\partial z_l} = 1.5\Phi_F (z_l - z_w)^{1/2} \tag{3.21}$$

ii) For submerged flow broad crested weir type links:

$$Q_{i,j} = \Phi_D(z_i - z_w)\sqrt{z_j - z_i} \tag{3.22}$$

$$Q_{i,k} = \Phi_D(z_i - z_w)\sqrt{z_k - z_i} \tag{3.23}$$

$$Q_{i,l} = \Phi_D(z_i - z_w)\sqrt{z_l - z_i} \tag{3.24}$$

$$\frac{\partial Q_{i,j}}{\partial z_i} = \Phi_D\left(\sqrt{z_j - z_i} - 0.5\frac{z_i - z_w}{\sqrt{z_j - z_i}}\right) \tag{3.25}$$

$$\frac{\partial Q_{i,j}}{\partial z_j} = \Phi_D\left(0.5\frac{z_i - z_w}{\sqrt{z_j - z_i}}\right) \tag{3.26}$$

$$\frac{\partial Q_{i,k}}{\partial z_i} = \Phi_D\left(\sqrt{z_k - z_i} - 0.5\frac{z_i - z_w}{\sqrt{z_k - z_i}}\right) \tag{3.27}$$

$$\frac{\partial Q_{i,k}}{\partial z_k} = \Phi_D\left(0.5\frac{z_i - z_w}{\sqrt{z_k - z_i}}\right) \tag{3.28}$$

$$\frac{\partial Q_{i,l}}{\partial z_i} = \Phi_D\left(\sqrt{z_l - z_i} - 0.5\frac{z_i - z_w}{\sqrt{z_l - z_i}}\right) \tag{3.29}$$

$$\frac{\partial Q_{i,l}}{\partial z_l} = \Phi_D\left(0.5\frac{z_i - z_w}{\sqrt{z_l - z_i}}\right) \tag{3.30}$$

Note that the right hand vector of Eq. 3.11 contains the source and the sink terms for each of the cells. Hence, all appropriate quantities of inflows from surface or ground-water sources, precipitation or outflows in the form of infiltration and evapotranspiration have to be included appropriately in the P term. Since the partial derivative terms in the left side matrix of Eq. 3.11 are dependent upon other variables as well (related by the weir flow terms given by Eq. 3.3 or 3.4), the set of simultaneous equations happen to be non-linear. The set of equations may, therefore, be conveniently solved using the Newton Raphson method, iteratively, till the desired accuracy is reached. These computations are carried out repetitively for each time step.

3.5 Comparison of basin flow model and a hydrodynamic model

An example is considered in this section that demonstrates the performance of the proposed numerical model for simulation of water movement within the "basin

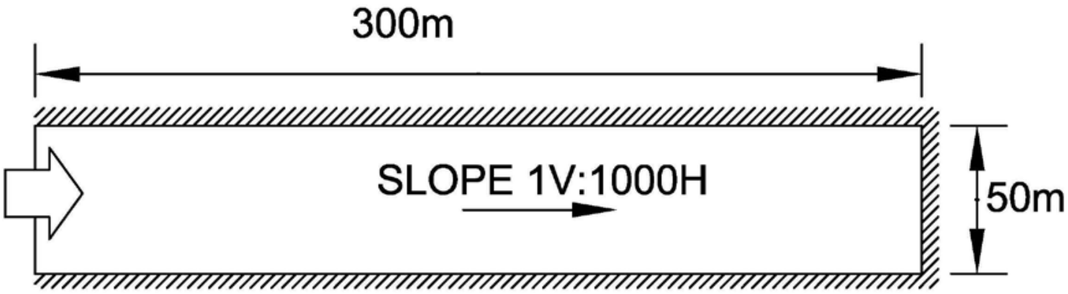


Figure 3.7: Test plot for flow movement simulation.

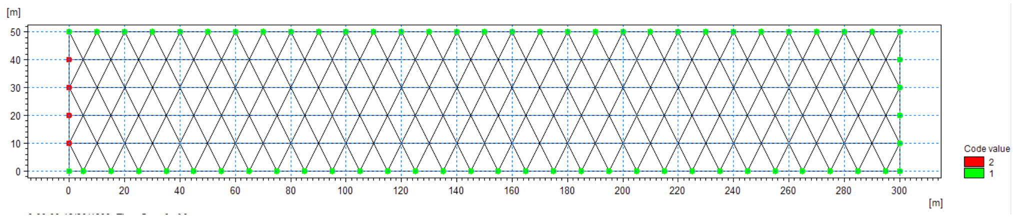


Figure 3.8: Discretised domain of the test plot for flow movement simulation (Figure 3.7) into triangular basin cells. (Green dots signify no-flow boundaries; Red dots represent inflow boundary).

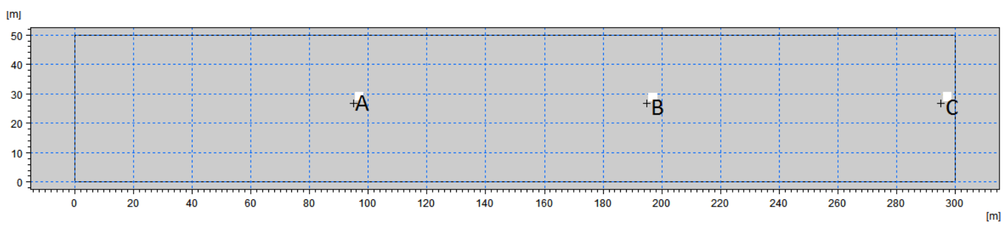


Figure 3.9: Domain of the test plot for flow movement simulation showing points A, B, and C, where the flow depths have been compared.

cells" with respect to a hydrodynamic model. Although there is a great difference between the equation of solved by the two models, it may be interesting to see the differences or similarities for the flow conditions encountered in basin irrigation. A hypothetical domain comprising of a rectangular field of length 300 m and width 50 m is considered with a gently sloping gradient of 0.0001 (Figure 3.7). No other source or sink of water is considered for this field, apart from a uniformly distributed flow along the west boundary. Three different rates of flow are considered: 0.75, 1.0 and 1.5 m^3/s assumned to enter the field uniformly spread over the entire width. The remaining three sides of the plot are considered bounded by impervious walls. The proposed model is run on a discretised domain (305 basin cells) as shown in Figure 3.8. The same model, with similar boundary and hydraulic conditions, is also run with the commercial two-dimensional flow simulation software package, MIKE 21 (DHI 2012), which solves the two-dimensional hydrodynamic equations. The comparisons are made for the following points in the domain (with the coordinate origin being assumed to be at the lower left hand corner of the domain and lengths measured in metres): A (95, 26.67); B(195, 26.67); C (295, 26.67), as shown in Figure 3.9. The following parameters have been considered for the simulation runs:

1. In the proposed model, the "bund height", bordering the basin cells is considered as 5 mm, and the time step is kept as 1sec.

2. In the simulation runs of MIKE 21, the Manning friction coefficient is kept at 0.03, considering the rough texture of the fields, and a time step of 1 sec.

The time plots for the depth of water computed by the two models for the three imposed discharges, and for the three test locations are shown in Figures 3.10 to 3.18.

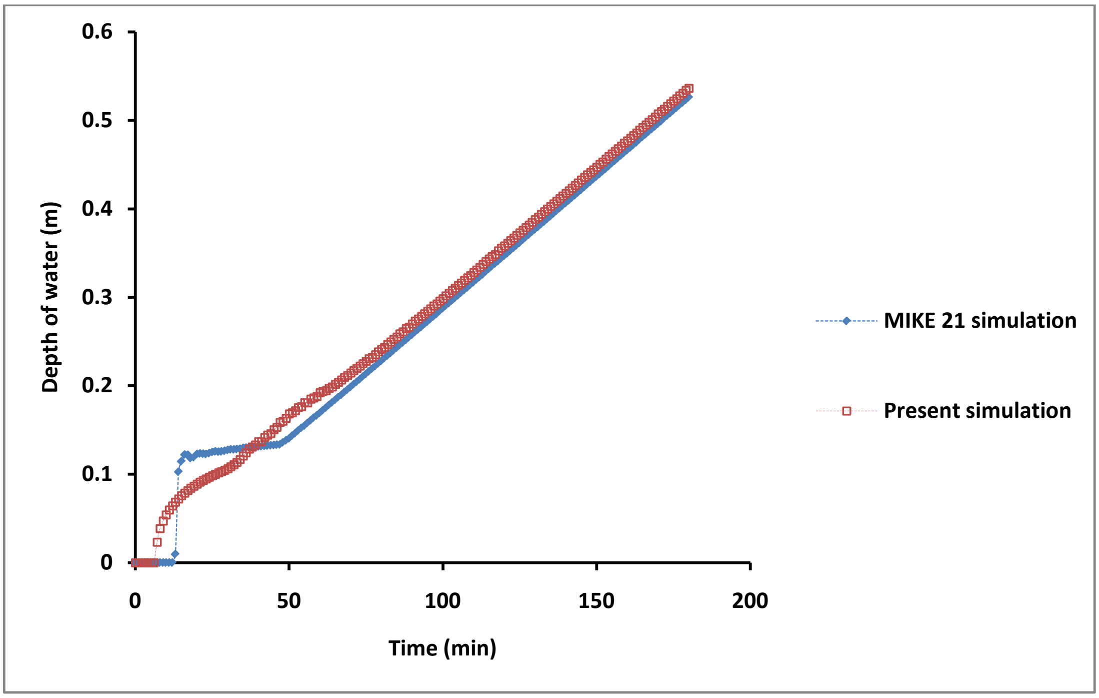


Figure 3.10: Time plot at location A for inflow discharge of 0.75 m^3/s.

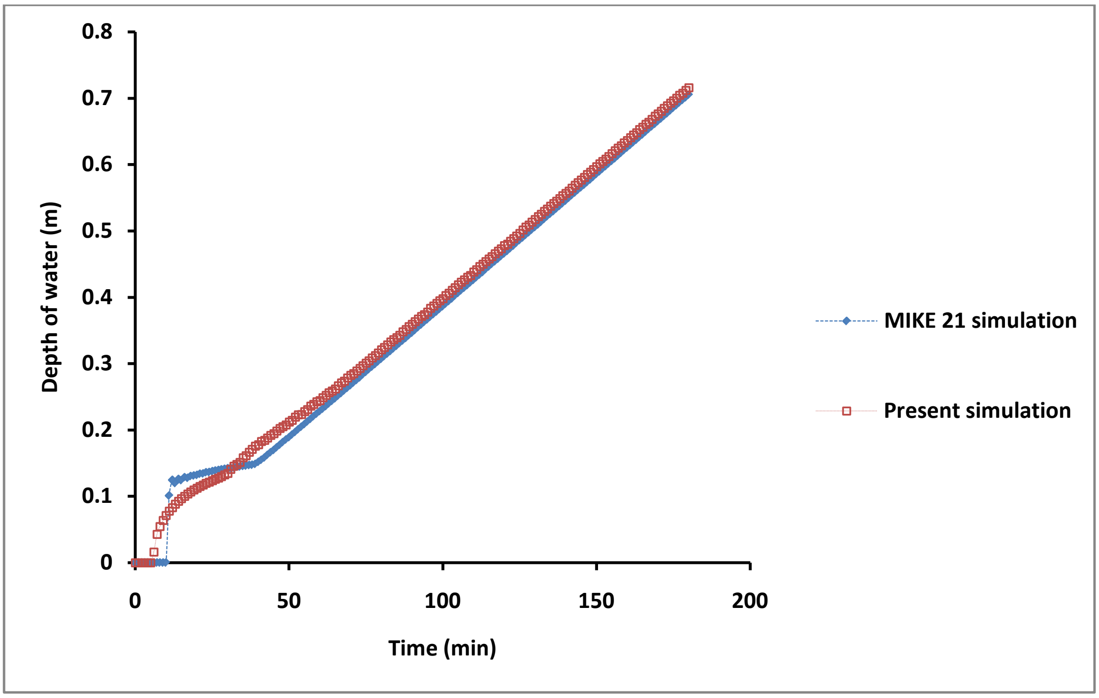


Figure 3.11: Time plot at location A for inflow discharge of 1.0 m^3/s.

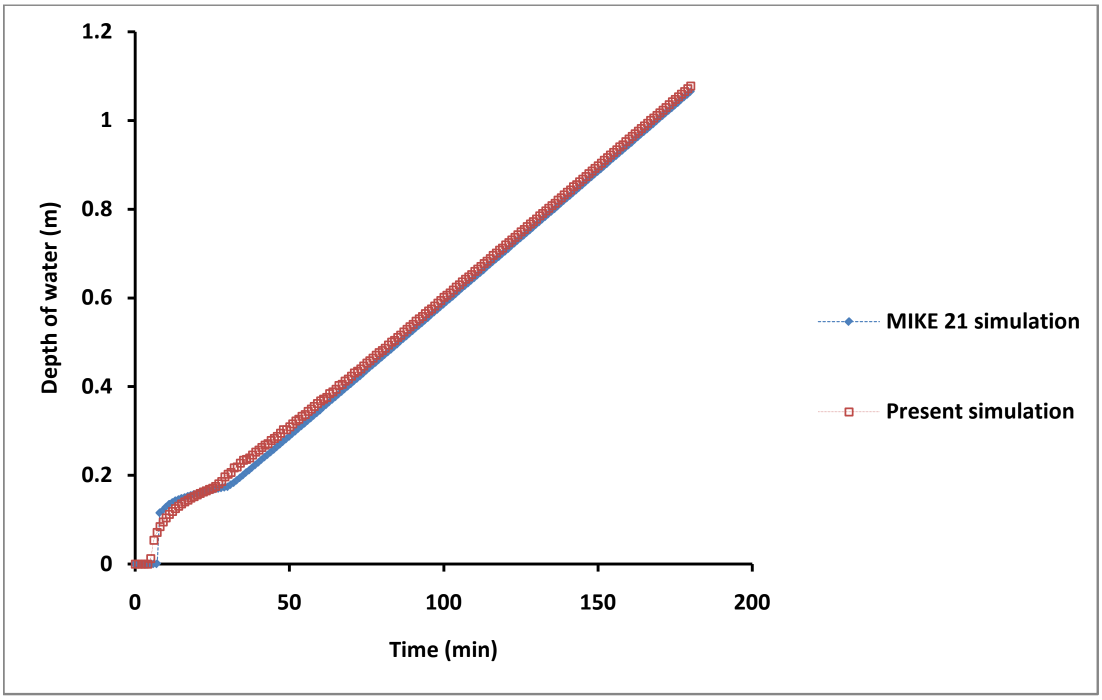


Figure 3.12: Time plot at location A for inflow discharge of 1.5 m^3/s.

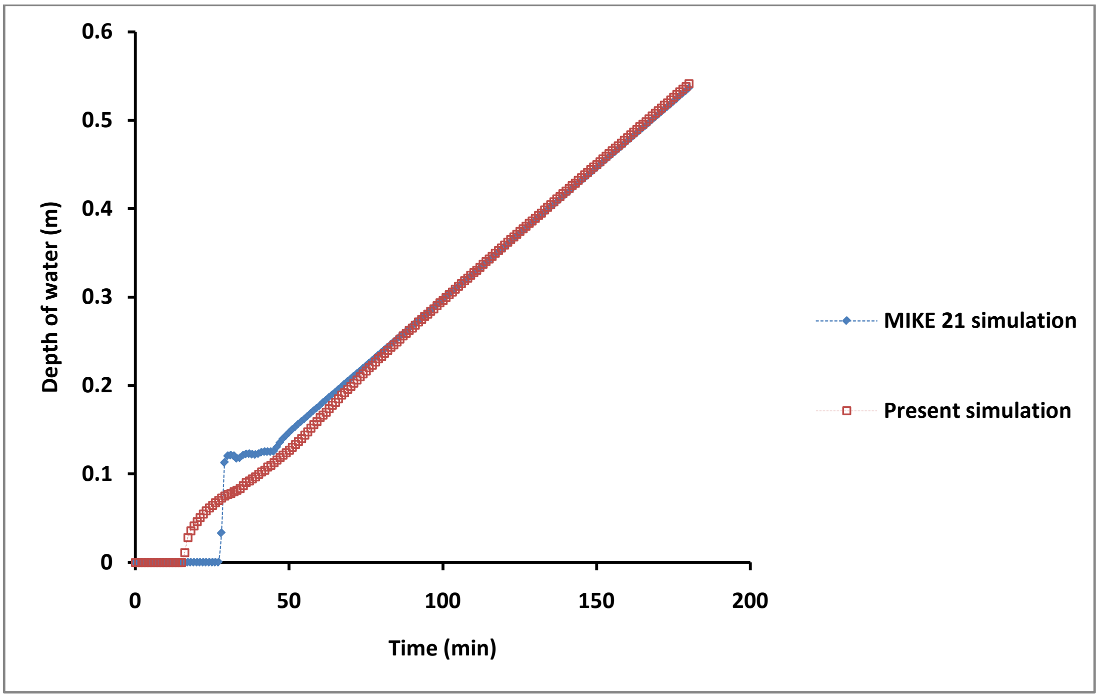


Figure 3.13: Time plot at location B for inflow discharge of 0.75 m^3/s.

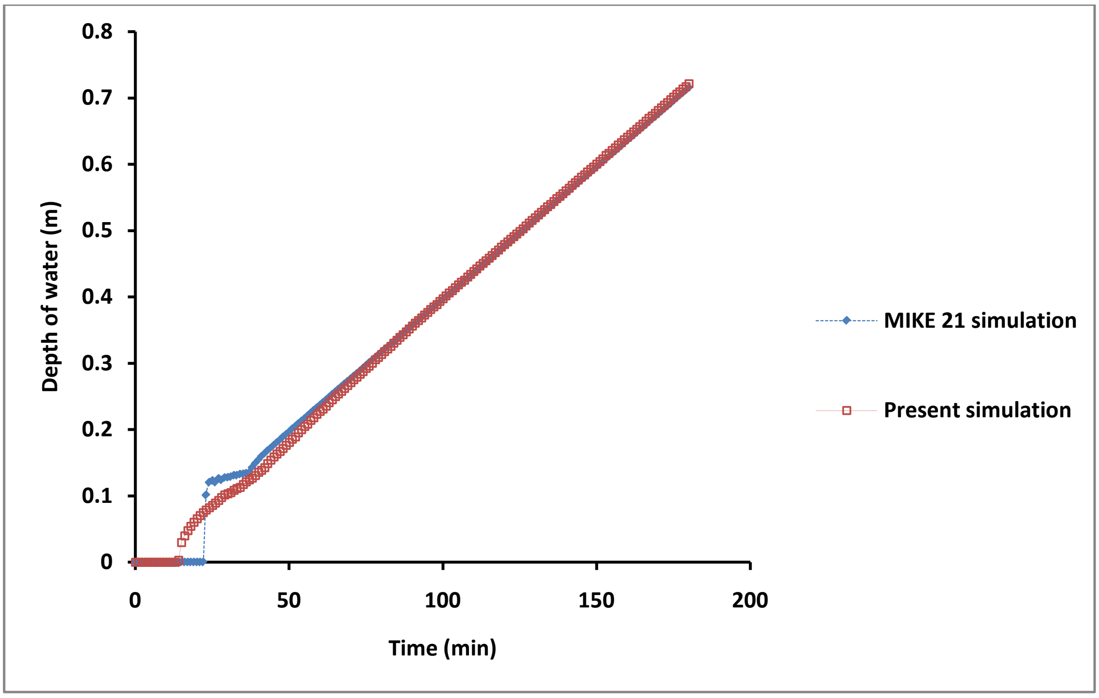


Figure 3.14: Time plot at location B for inflow discharge of 1.0 m^3/s.

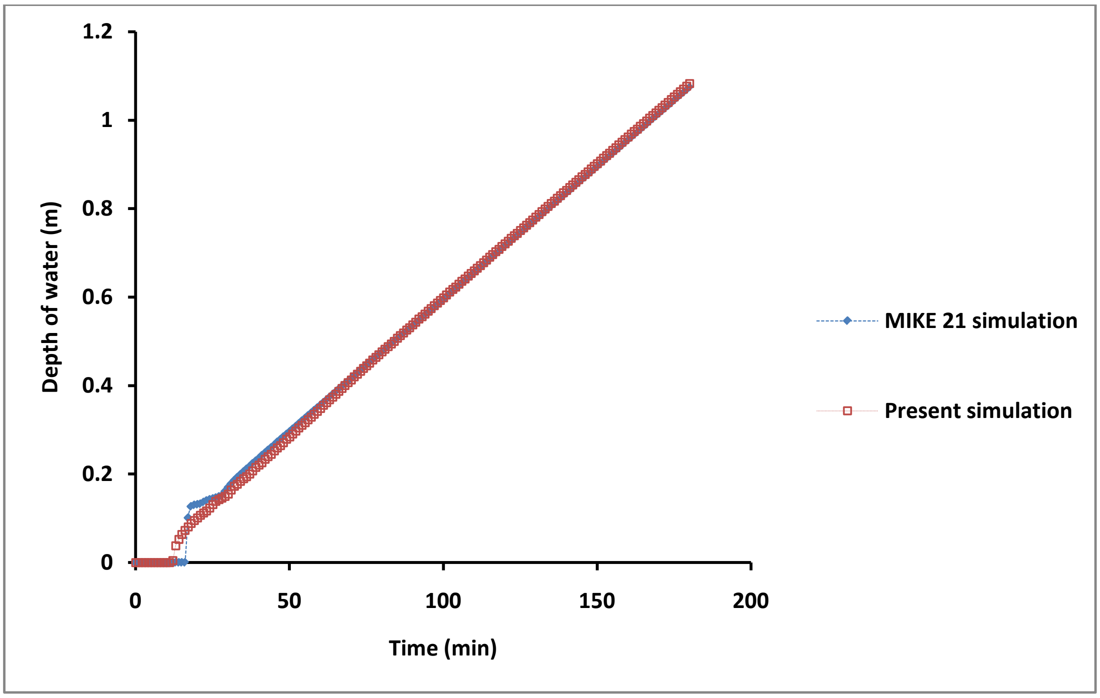


Figure 3.15: Time plot at location B for inflow discharge of 1.5 m^3/s.

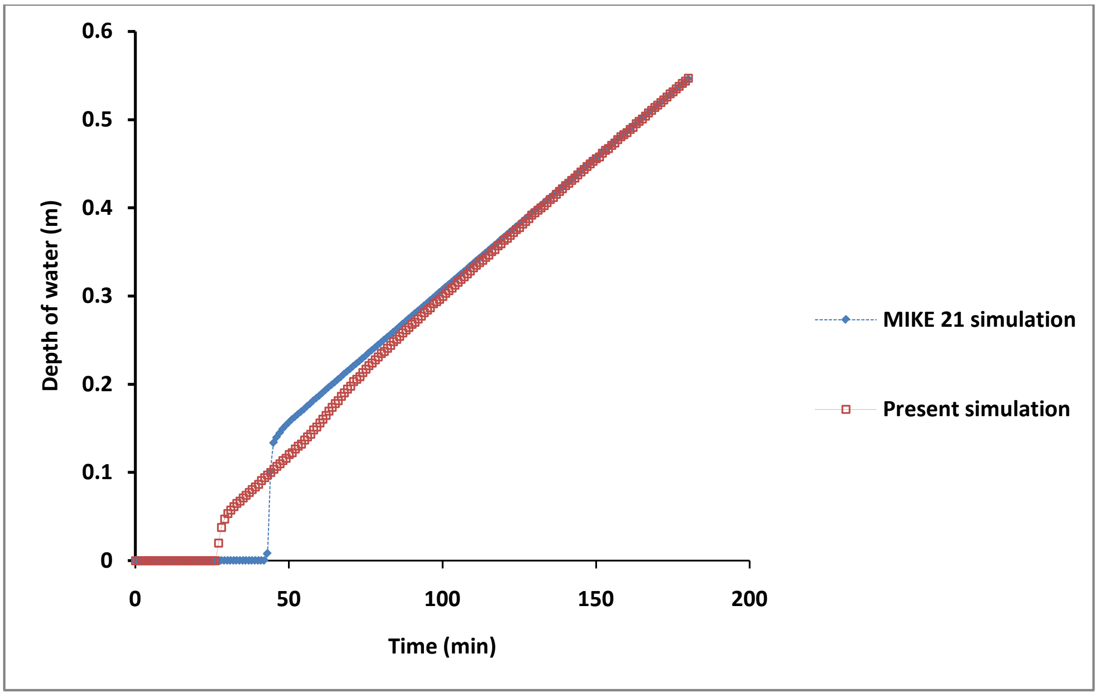


Figure 3.16: Time plot at location C for inflow discharge of 0.75 m^3/s.

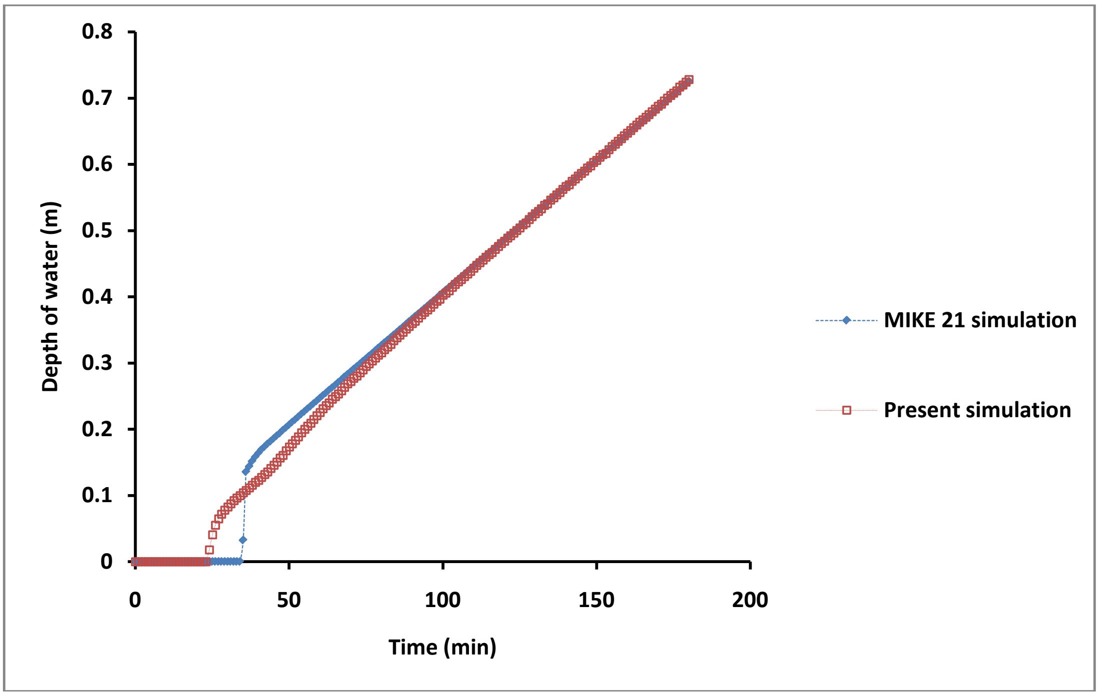


Figure 3.17: Time plot at location C for inflow discharge of 1.0 m^3/s.

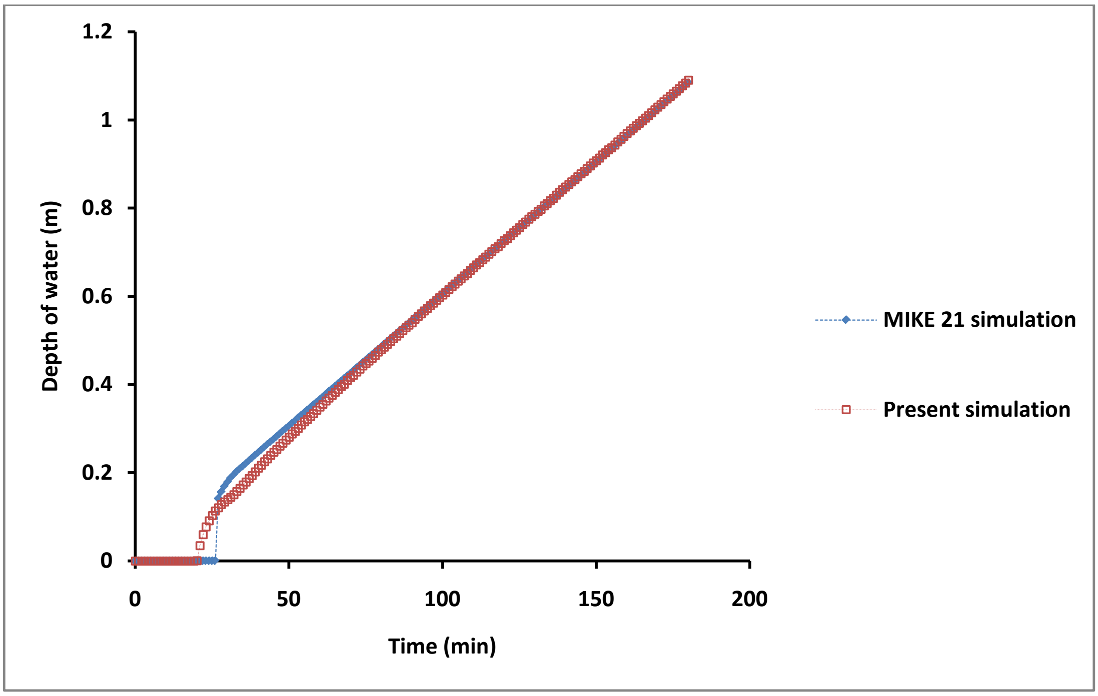


Figure 3.18: Time plot at location C for inflow discharge of 1.5 m^3/s.

3.6 Illustrative example of watercourse distribution

This section presents a numerical experiment to demonstrate the progress of surface flooding of the basin cells using the proposed model on a hypothetical region that recieves water from a network of watercourse through field outlets. The test plot is considered (Figure 3.19), having a central watercourse with two branches. The plot measures 3.5 km in length and 2.59 km in width, discrtetised into 348 triangular basin cells. The general land gradient is 0.0001 from West to East. A cross slope is also assumed to exist towards the north and the south (slope 0.00005) from a central median line cutting through the field along the alignment channel of the main watercourse channel.

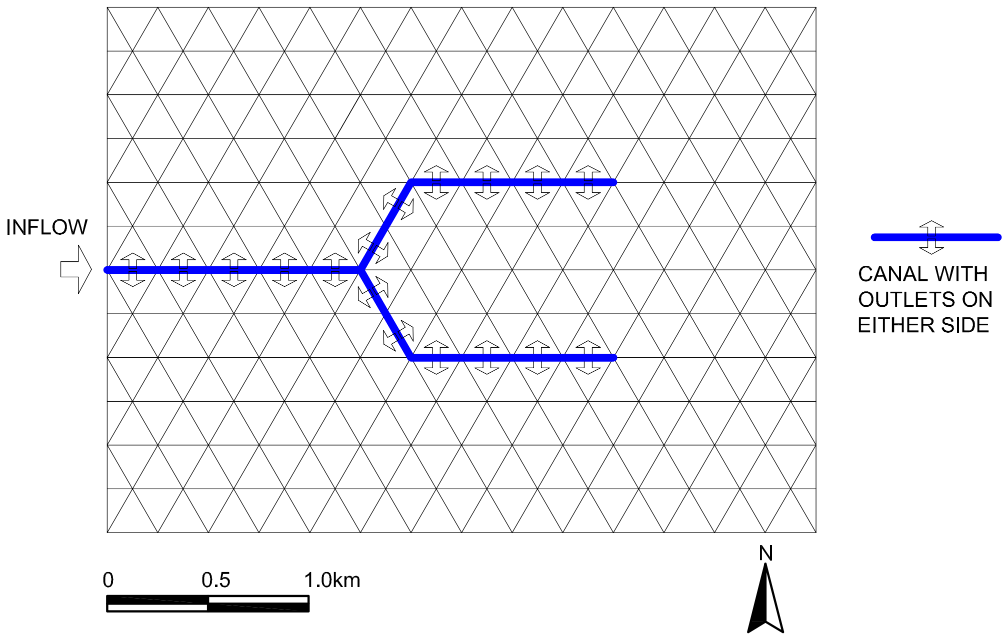


Figure 3.19: Subdivision of an irrigated basin into smaller triangular domains, or "basin cells".

No loss of water by the way of infiltration or evapotranspiration is assumed to take place through the basin cells. A Manning coefficient of 0.01 is assumed for the watercourse channel and its branches, which are taken as trapezoidal in section (side slope 2H:1V). The bund (or weir) height is varied between 50 mm, 75 mm, 100 mm and 150 mm for understanding its effect on the rate of flood propagation. Slope of the channel is assumed as 0.001. A constant flow of water is assumed to enter the main watercourse at a rate of 3.4 m^3/s. Figures 3.20 to Figures 3.23 demonstrate the spread of inundation from cell to cell with time, at intervals of a day, for each of the cases considered.

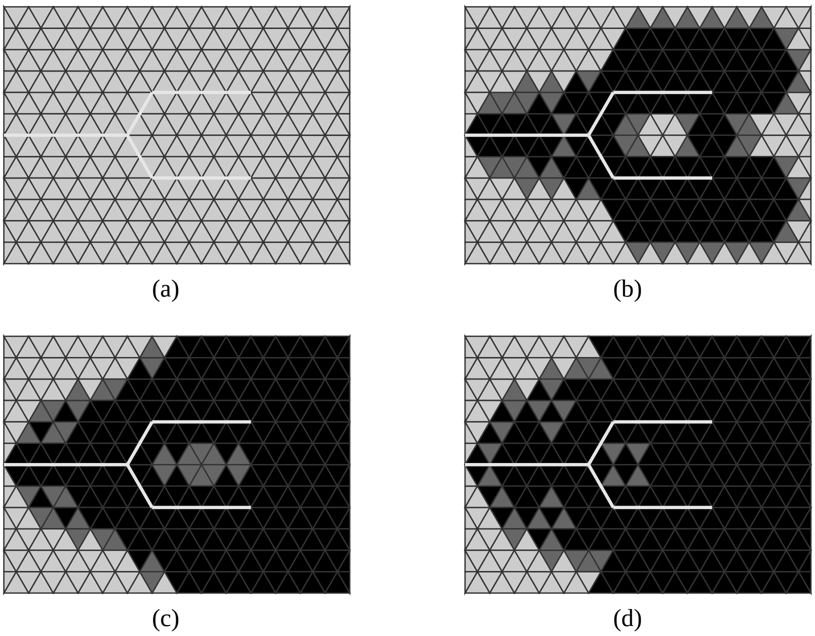


Figure 3.20: Propagation of inundation in the basin cells for bund height of 50 mm.

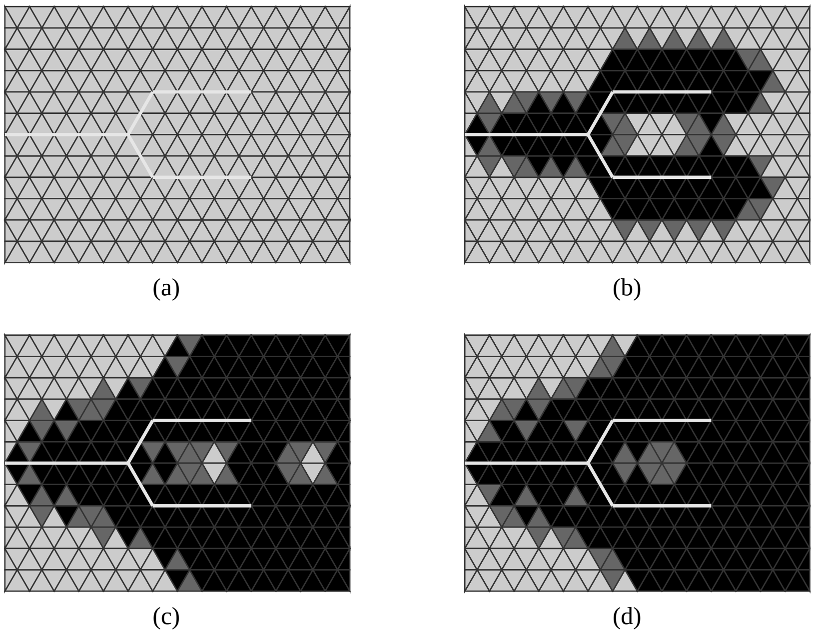


Figure 3.21: Propagation of inundation in the basin cells for bund height of 75 mm.

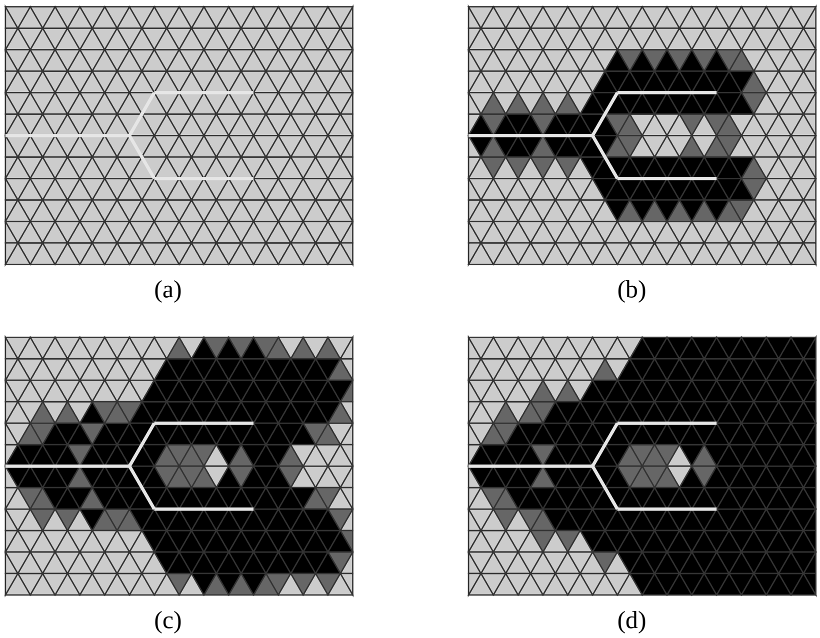


Figure 3.22: Propagation of inundation in the basin cells for bund height of 100 mm.

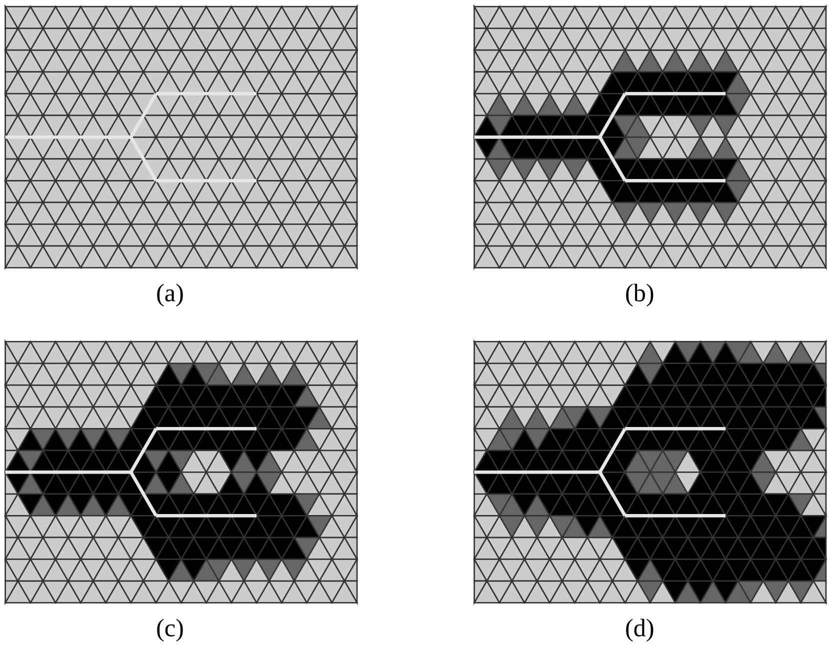


Figure 3.23: Propagation of inundation in the basin cells for bund height of 150 mm.

3.7 Summary

From the results of the numerical simulation experiments presented in this chapter, the following points may be inferred: 1. The two-dimensional hydrodynamic model, MIKE 21, captures the advancement of the waterfront over land and is thus able to replicate the sharp rise of water initially. 2. The proposed model reacts to the inflow discharge faster at the same location in comparison to MIKE 21 which is expected from a simplified mass balance equation such as this. However, eventually when ponding starts taking place over the entire domain because of the impermeable boundary on the three remaining sides, the proposed model is able to satisfactorily replicate the rise of water level in the cells. Hence, for the problem of basin flooding considered in this report, where the time of the front movement (which takes place in minutes, or within a few hours) is much smaller to the total time of ponding (which is generally counted in days), the relatively simple simulation model based upon a mass balance approach is acceptable enough to carry out further applications.

Chapter 4

Modelling of groundwater flow and conjunctive use with surface water

Different processes need to be modeled for conjunctive use modeling. The individual processes are described in the following sections

4.1 Unsaturated Zone Modelling

Unsaturated zone controls the interaction of surface water and groundwater. Interaction takes place with the exchange information in terms of infiltration, evapotranspiration, and recharge. Flow through non-swelling unsaturated zone with air-phase at atmospheric pressure can be effectively modeled by using Richards Equation (Richards 1931). Water flow through unsaturated zone is predominantly vertical and can be simulated as one dimensional flow in a range of applications (Romano et al. 1998). System water balances can be achieved through one dimensional flow model with various meteorological conditions, soil properties, crop characteristics (Hopmans and Stricker 1989). Except for few simplified cases Richards Equation does not have any closed form analytical solution. Even numerical solution is difficult to obtain due to presence of nonlinearity in governing equation and soil water characteristic model (Feddes et al. 1988; Ross 1990; Van Dam and Feddes 2000; Downer and Ogden 2004; Varado et al. 2006; Lai and Ogden 2015). Accuracy of calculated moisture flux during numerical simulation largely depends on structure of the numerical scheme, spatial discretization and time stepping (Van Genuchten 1982; Milly 1985; Celia et al. 1990; Warrick 1991; Zaidel and Russo 1992; Baker 1995; Pan et al. 1996; Miller et al. 1998; Romano et al. 1998).

4.2 Governing equations

Integrated model may encounter saturated flow during unsaturated flow calculations. Three standard forms of Richards Equation are possible: a) head based form, b) water content based form, and c) mixed form (Celia et al. 1990). To describe the processes in unsaturated zone pressure head based and mixed form of Richards Equation are used. Head based form is valid for both saturated and unsaturated zone (Haverkamp et al. 1977). However, mixed form is not suitable for saturated zone (Lai and Ogden 2015). The one dimensional presure head based form of Richards Equation is

$$C\left(h\right)\frac{\partial h}{\partial t}=\frac{\partial}{\partial z}\left[K\left(h\right)\frac{\partial h}{\partial z}-K\left(h\right)\right]+S \tag{4.1}$$

where h is pressure head, $C(h)$ is specific capacity, $K(h)$ is hydraulic conductivity, S is source/ sink term, z is the vertical coordinate positive downward, t is time. The one dimensional mixed form of Richards Equation is

$$\frac{\partial\theta}{\partial t}=\frac{\partial}{\partial z}\left[K\left(h\right)\frac{\partial h}{\partial z}-K\left(h\right)\right]+S \tag{4.2}$$

where θ is water content. In integrated model, Richards Equation is solved using a semi-implicit finite volume approach. The soil column below each surface flow cell is divided into number of unsaturated cells.

The Richards equation is discretized (Lai and Ogden 2015) by using cell-centred Finite Volume Method (FVM). Soil column (Figure 4.1) is sub-divided into finite number of non-overlapping cells $[z_{i-1/2}, z_{i+1/2}]$ of mesh size $\Delta z_i (= z_{i+1/2} - z_{i-1/2})$. Head and moisture content values are considered at the cell centre i. A predictor-corrector approach was employed to solve the unsaturated flow equations. A predictor-corrector approach is employed to solve the unsaturated flow equations.

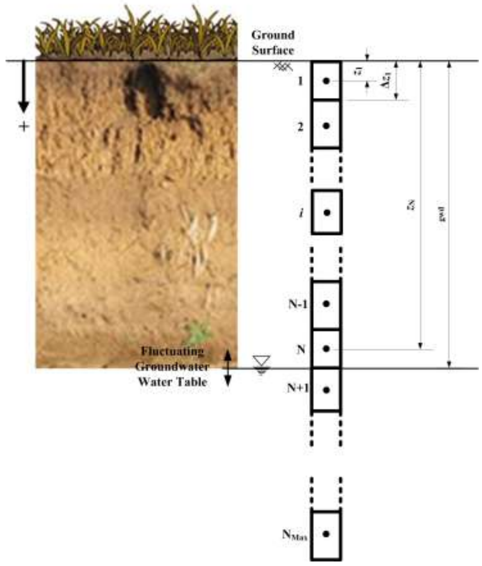


Figure 4.1: Soil Profile with Finite Volume Cells

4.3 Soil water characteristic model

Soil hydraulic properties (water content, hydraulic conductivity, and specific capacity) are required for complete description of Richards Equation. The van Genuchten-Mualem (van Genuchten 1980) model is used in the present work. The water content is expressed as a nonlinear function of pressure head,

$$\theta = \begin{cases} \theta_r + \dfrac{\theta_s - \theta_r}{(1+|\alpha h|^n)^m}, & h < 0 \\ \theta_s, & h \geq 0 \end{cases} \tag{4.3}$$

where θ_r is residual water content, θ_s is saturated water content, α is a parameter related to inverse of air entry sunction, m and n are related $(m = 1 - 1/n, n > 1)$ nondimensional pore-size distribution parameters. Dregree of saturation(S_e is expressed as

$$S_e(\theta) = \frac{\theta - \theta_r}{\theta_s - \theta_r} = \begin{cases} \dfrac{1}{(1+|\alpha h|^n)^m}, & h < 0 \\ 1, & h \geq 0 \end{cases} \tag{4.4}$$

Hydraulic conductivity is defined as

$$K(h) = \begin{cases} K_s S_e^{0.5}[1 - (1 - S_e^{1/m})^m]^2, & h < 0 \\ K_s, & h \geq 0 \end{cases} \tag{4.5}$$

where K_s is saturated hydraulic conductivity. Specific capacity depends on the pressure the pressure head. It is defined as the change in water content with respect to head.

$$C(h) = \frac{\partial \theta}{\partial h} = \begin{cases} \frac{\alpha mn(\theta_s - \theta_r)|\alpha h|^{n-1}}{(1+|\alpha h|^n)^{m+1}}, & h < 0 \\ 0, & h \geq 0 \end{cases} \tag{4.6}$$

This numerical model for simulating the flow of water through the unsaturated zone of soil is linked to each basin cell, which computes the cells' infiltration loss. Further, the outflows from this infiltration model at its lower boundary is used as a source for recharging the underlying unconfined groundwater aquifer.

4.4 Groundwater model

Saturated groundwater flow needs to be modelled for effective representation of interaction between surface and subsurface processes (in terms of soil moisture, infiltration, evapotranspiration). Unsaturated zone model supplies recharge information (positive or negative) to the groundwater model. Groundwater model provides moving water table information, which becomes bottom boundary condition for unsaturated zone. Saturated groundwater flow is modeled to simulate two-dimensional lateral water movement in unconfined aquifer. .

4.4.1 Governing equation

Continuity (mass-balance) equation for two dimensional (2D) transient groundwater flow in unconfined aquifer for homogenous fluid with constant density is

$$S_y \frac{\partial H}{\partial t} = \frac{\partial}{\partial x}\left(K_x E \frac{\partial H}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_y E \frac{\partial H}{\partial y}\right) + W \tag{4.7}$$

where S_y is the Specific Yield, H is the groundwater head (L) and $K_x,\ K_y$ are the hydraulic conductivity (L/T) in the x- and y- directions respectively, E is the thickness (L) of fully saturated groundwater inside the aquifer, W is the source/sink (L^3/T) term and t is time (T).

The governing equation can be written in terms of fluxes as:

$$S_y \frac{\partial H}{\partial t} = \frac{\partial f_x}{\partial x} + \frac{\partial f_y}{\partial y} + W \tag{4.8}$$

where $f_x = K_x E \frac{\partial H}{\partial x}$ and $f_y = K_y E \frac{\partial H}{\partial y}$.

Finite difference is the most widely used method for solving groundwater flow equation, e.g., MODFLOW (Harbaugh and McDonald 1996). Erduran et al. (2005) present an integrated shallow surface and saturated groundwater model. 2-D shallow water equations and groundwater equation are combined to get a finite volume based solution of the surface-subsurface modeling problem.

4.4.2 Finite volume formulation

The equations is solved by using Finite Volume Method (FVM). For solution by FVM, the domain is subdivided into irregular triangular cells.

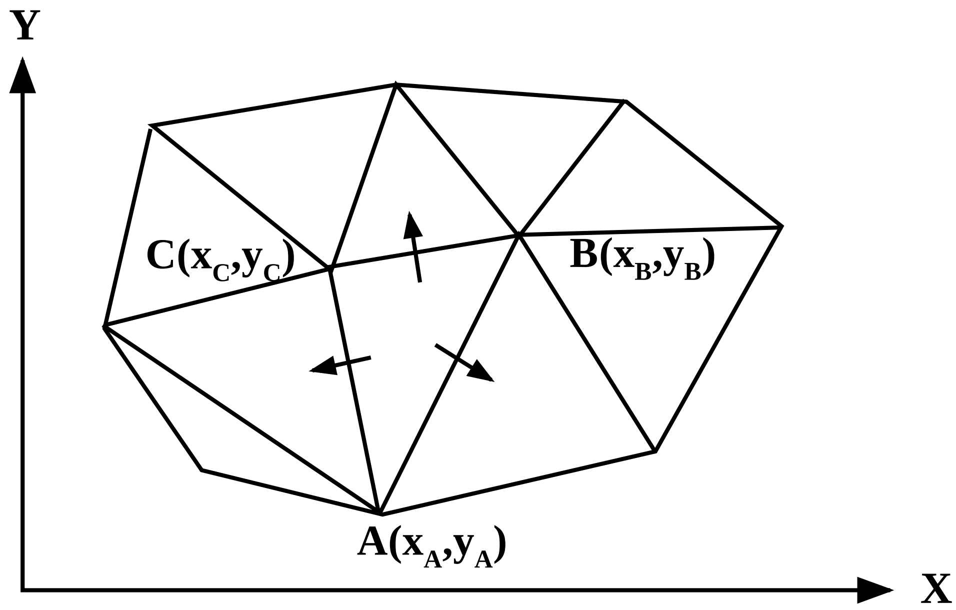


Figure 4.2: Finite Volume Domain

The modified governing equation is then integrated within the subdomain as:

$$\int_V \left(S_y \frac{\partial H}{\partial t} \right) dV = \int_V \left(\frac{\partial f_x}{\partial x} + \frac{\partial f_y}{\partial y} + W \right) dV = \int_S (\boldsymbol{F}.\boldsymbol{n}) dS + \int_V W dV \tag{4.9}$$

Where $\boldsymbol{F} = f_x\boldsymbol{i} + f_y\boldsymbol{j}$ and $\boldsymbol{n}$ is the outward normal vector, S denotes the surface integral. This method is applicable to unstructured no non-uniform grid if the hydraulic conductivity values are provided for all outward normal vector directions at every cell interfaces.

For a triangular cell ABC, one may write the edge vectors as:

$$\overrightarrow{AB} = (x_B - x_A)\boldsymbol{i} + (y_B - y_A)\boldsymbol{j} \tag{4.10}$$
$$\overrightarrow{BC} = (x_C - x_B)\boldsymbol{i} + (y_C - y_B)\boldsymbol{j} \tag{4.11}$$
$$\overrightarrow{CA} = (x_A - x_C)\boldsymbol{i} + (y_A - y_C)\boldsymbol{j} \tag{4.12}$$

Thus, the normal vectors to the edges AB, BC and CA may be found out as:

$$\boldsymbol{n}_{AB} = \overrightarrow{AB} \times \boldsymbol{k} = (y_B - y_A)\boldsymbol{i} - (x_B - x_A)\boldsymbol{j} \tag{4.13}$$
$$\boldsymbol{n}_{BC} = \overrightarrow{BC} \times \boldsymbol{k} = (y_C - y_B)\boldsymbol{i} - (x_C - x_B)\boldsymbol{j} \tag{4.14}$$
$$\boldsymbol{n}_{CA} = \overrightarrow{CA} \times \boldsymbol{k} = (y_A - y_C)\boldsymbol{i} - (x_A - x_C)\boldsymbol{j} \tag{4.15}$$

The discrete form of the differential equation may, therefore, be written for a triangular cell of area AC as:

$$A_C S_y \frac{\partial H}{\partial t} = f_x^{AB}(y_B - y_A) - f_y^{AB}(x_B - x_A) + f_x^{BC}(y_C - y_B) - f_Y^{BC}(x_C - x_B)$$
$$+ f_x^{CA}(y_A - y_C) - f_y^{CA}(x_A - y_C) + \int_V W dV \tag{4.16}$$

In the above equation, the functions for the fluxes through the respective cell edges are as follows:

$$f_x^{AB} = K_x^{AB} E^{AB} \frac{\partial H^{AB}}{\partial x}; \quad f_y^{AB} = K_y^{AB} E^{AB} \frac{\partial H^{AB}}{\partial y}$$
$$f_x^{BC} = K_x^{BC} E^{BC} \frac{\partial H^{BC}}{\partial x}; \quad f_y^{BC} = K_y^{BC} E^{BC} \frac{\partial H^{BC}}{\partial y}$$
$$f_x^{CA} = K_x^{CA} E^{CA} \frac{\partial H^{CA}}{\partial x}; \quad f_y^{CA} = K_y^{CA} E^{CA} \frac{\partial H^{CA}}{\partial y}$$

To evaluate the thickness of the fully saturated groundwater of the aquifer at the cell edge interfaces, and averaging is carried out for the respective values on either side of the edge. Thus, if the cell under consideration is i and the neighbouring cells j, k and l (Figure 4.3) and the depth of the hydraulic head is also assumed to be constant within the cell,

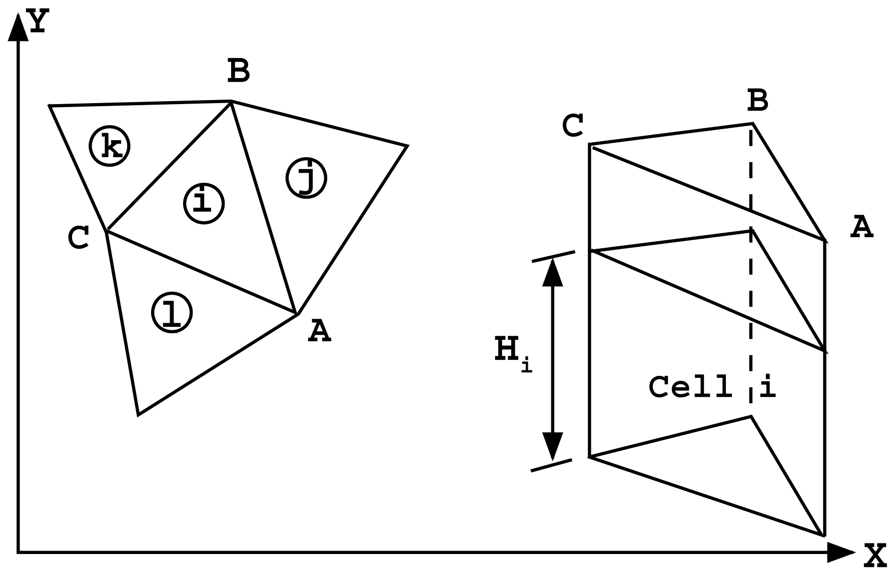


Figure 4.3: Discretised triangular cells.

Then,

$$
\begin{aligned}
E^{AB} &= (H_i + H_j)/2 \\
E^{BC} &= (H_i + H_k)/2 \\
E^{CA} &= (H_i + H_l)/2
\end{aligned}
$$

and

$$
\begin{aligned}
\frac{\partial H^{AB}}{\partial x} &= \frac{H_j - H_i}{|\Delta x_{ij}|}; \quad & \frac{\partial H^{AB}}{\partial y} &= \frac{H_j - H_i}{|\Delta y_{ij}|} \\
\frac{\partial H^{BC}}{\partial x} &= \frac{H_k - H_i}{|\Delta x_{ik}|}; \quad & \frac{\partial H^{BC}}{\partial y} &= \frac{H_k - H_i}{|\Delta y_{ik}|} \\
\frac{\partial H^{CA}}{\partial x} &= \frac{H_l - H_i}{|\Delta x_{il}|}; \quad & \frac{\partial H^{CA}}{\partial y} &= \frac{H_l - H_i}{|\Delta y_{il}|}
\end{aligned}
$$

Where Δx_{ij} and Δy_{ij} are the x- and y- components of the distance between the centroids of the cells i and j, respectively. Similar definitions hold for Δx_{ik} and Δy_{ik} and Δx_{il} and Δy_{il}.

For the edges of the cells aligned along the boundary, the given hydraulic head at the specific location have to be substituted in the above equations to find the values of E, $\frac{\partial H}{\partial x}$ and $\frac{\partial H}{\partial y}$ for the respective edges.

The following notations may be substituted into the discretised governing equation:

$$\Delta x^{AB} = (x_B - x_A)$$
$$\Delta y^{AB} = (y_B - y_A)$$
$$\Delta x^{BC} = (x_C - x_B)$$
$$\Delta y^{BC} = (y_C - y_B)$$
$$\Delta x^{CA} = (x_A - x_C)$$
$$\Delta y^{CA} = (y_A - y_C)$$

And, after time differencing, we may obtain the following form of the discretised governing equation:

$$\begin{aligned} A_C S_y \frac{H_i^{t+\Delta t} - H_i^t}{\Delta t} &= \int_V W dV \\ +K_x^{AB} \frac{(H_i^t + H_j^t).(H_j^t - H_i^t)}{2|\Delta x_{ij}|} &(\Delta y^{AB}) - K_y^{AB} \frac{(H_i^t + H_j^t).(H_j^t - H_i^t)}{2|\Delta y_{ij}|}(\Delta x^{AB}) \\ +K_x^{BC} \frac{(H_i^t + H_k^t).(H_k^t - H_i^t)}{2|\Delta x_{ik}|} &(\Delta y^{BC}) - K_y^{BC} \frac{(H_i^t + H_k^t).(H_k^t - H_i^t)}{2|\Delta y_{ik}|}(\Delta x^{BC}) \\ +K_x^{CA} \frac{(H_i^t + H_l^t).(H_l^t - H_i^t)}{2|\Delta x_{il}|} &(\Delta y^{CA}) - K_y^{CA} \frac{(H_i^t + H_l^t).(H_l^t - H_i^t)}{2|\Delta y_{il}|}(\Delta x^{CA}) \end{aligned} \tag{4.17}$$

If it is assumed that the hydraulic conductivities in the x- and y- directions, $K_x,\ K_y$, respectively the same for one element (or cell), and equal to K, we may rewrite the above equations as:

$$\begin{aligned} A_C S_y \frac{H_i^{t+\Delta t} - H_i^t}{\Delta t} &= \int_V W dV + K \frac{(H_j^t)^2 - (H_i^t)^2}{2} \left(\frac{\Delta y^{AB}}{|\Delta x_{ij}|} - \frac{\Delta x^{AB}}{|\Delta y_{ij}|} \right) \\ +K \frac{(H_k^t)^2 - (H_i^t)^2}{2} &\left(\frac{\Delta y^{BC}}{|\Delta x_{ik}|} - \frac{\Delta x^{BC}}{|\Delta y_{ik}|} \right) + K \frac{(H_l^t)^2 - (H_i^t)^2}{2} \left(\frac{\Delta y^{CA}}{|\Delta x_{il}|} - \frac{\Delta x^{CA}}{|\Delta y_{il}|} \right) \end{aligned} \tag{4.18}$$

The above equations may be solved explicitly for each cell, based upon an initial guess values provided for all the cells and given heads along the boundaries.

For example, the following domain may be considered for solution:

The domain (Figure 4.4) may then be discretised with TIN (Triangulated Irregular Network of triangular cells), in the following fashion (Figure 4.5):

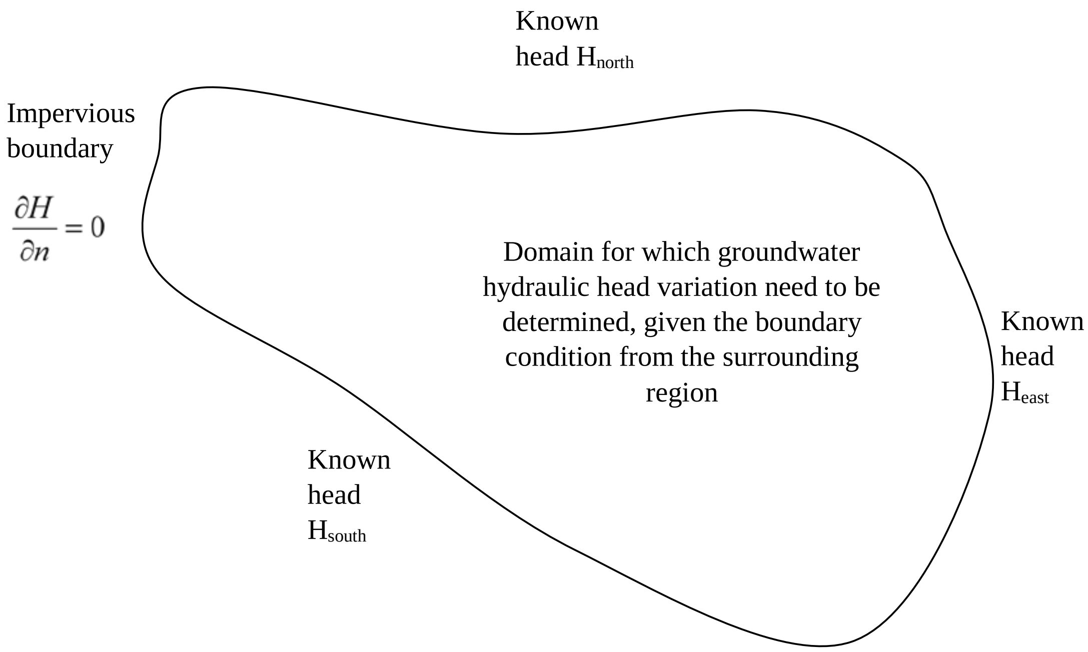


Figure 4.4: Representative domain.

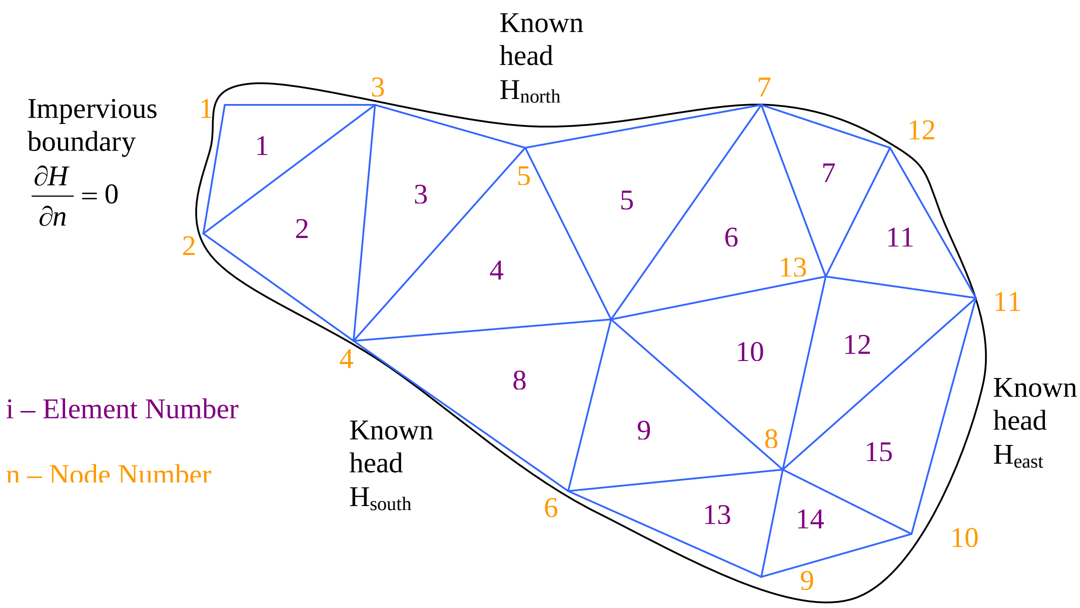


Figure 4.5: Discretised representative domain.

In the explicit solution method, the hydraulic head in each cell has to be found iteratively.

In order to solve the variables implicitly, by the method of Newton-Raphson, we have to find the Jacobian of the corresponding equation which as follows:

$$\begin{aligned} A_C S_y \frac{H_i^{t+\Delta t} - H_i^t}{\Delta t} = \int_V W dV + K \frac{(H_j^{t+\Delta t})^2 - (H_i^{t+\Delta t})^2}{2} \left(\frac{\Delta y^{AB}}{|\Delta x_{ij}|} - \frac{\Delta x^{AB}}{|\Delta y_{ij}|} \right) \\ + K \frac{(H_k^{t+\Delta t})^2 - (H_i^{t+\Delta t})^2}{2} \left(\frac{\Delta y^{BC}}{|\Delta x_{ik}|} - \frac{\Delta x^{BC}}{|\Delta y_{ik}|} \right) \\ + K \frac{(H_l^{t+\Delta t})^2 - (H_i^{t+\Delta t})^2}{2} \left(\frac{\Delta y^{CA}}{|\Delta x_{il}|} - \frac{\Delta x^{CA}}{|\Delta y_{il}|} \right) \end{aligned} \tag{4.19}$$

The correction for the flux was done considering the resultant flux for the isotropic soil (K is same for X and Y direction).

$$\begin{aligned} A_C S_y \frac{H_i^{t+\Delta t} - H_i^t}{\Delta t} = \\ + K \frac{(H_j^{t+\Delta t})^2 - (H_i^{t+\Delta t})^2}{2} \left(\frac{\sqrt{(\Delta y^{AB})^2 + (\Delta x^{AB})^2}}{\sqrt{|\Delta x_{ij}|^2 + |\Delta y_{ij}|^2}} \right) \\ + K \frac{(H_k^{t+\Delta t})^2 - (H_i^{t+\Delta t})^2}{2} \left(\frac{\sqrt{(\Delta y^{BC})^2 + (\Delta x^{BC})^2}}{\sqrt{|\Delta x_{ik}|^2 + |\Delta y_{ik}|^2}} \right) \\ + K \frac{(H_l^{t+\Delta t})^2 - (H_i^{t+\Delta t})^2}{2} \left(\frac{\sqrt{(\Delta y^{CA})^2 + (\Delta x^{CA})^2}}{\sqrt{|\Delta x_{il}|^2 + |\Delta y_{il}|^2}} \right) + A_C \times \text{pumping rate} \times \Delta t \end{aligned} \tag{4.20}$$

The above equation may be written as:

$$f(H_i, H_j, H_k, H_l) = 0 \tag{4.21}$$

In the above equation, $H_i,\ H_j,\ H_k,\ H_l$ are the unknowns at time $t + \Delta t$.

The derivatives of the Jacobian may be found out as follows, considering that each equation will contain 4 variables, the hydraulic head of the central cell i, and the 3 other surrounding cells, j, k and l.

$$\frac{\partial f}{\partial H_i} = \frac{A_C S_y}{\Delta t} + KH_i[\left(\frac{\sqrt{(\Delta y^{AB})^2 + (\Delta x^{AB})^2}}{\sqrt{|\Delta x_{ij}|^2 + |\Delta y_{ij}|^2}}\right)$$
$$+ \left(\frac{\sqrt{(\Delta y^{BC})^2 + (\Delta x^{BC})^2}}{\sqrt{|\Delta x_{ik}|^2 + |\Delta y_{ik}|^2}}\right) + \left(\frac{\sqrt{(\Delta y^{CA})^2 + (\Delta x^{CA})^2}}{\sqrt{|\Delta x_{il}|^2 + |\Delta y_{il}|^2}}\right)]$$
$$\frac{\partial f}{\partial H_j} = -KH_j\left(\frac{\sqrt{(\Delta y^{AB})^2 + (\Delta x^{AB})^2}}{\sqrt{|\Delta x_{ij}|^2 + |\Delta y_{ij}|^2}}\right)$$
$$\frac{\partial f}{\partial H_k} = -KH_k\left(\frac{\sqrt{(\Delta y^{BC})^2 + (\Delta x^{BC})^2}}{\sqrt{|\Delta x_{ik}|^2 + |\Delta y_{ik}|^2}}\right)$$
$$\frac{\partial f}{\partial H_l} = -KH_l\left(\frac{\sqrt{(\Delta y^{CA})^2 + (\Delta x^{CA})^2}}{\sqrt{|\Delta x_{il}|^2 + |\Delta y_{il}|^2}}\right) \tag{4.22}$$

The above equations have to be solved simultaneously for all the variables, considering the appropriate boundary conditions. Also, the equations have to be modified for recharge, which will include a source term for each cell.

Boundary conditions:
Boundary conditions play an important role in the dynamics of groundwater movement. Two types of boundary conditions are considered here i.e i) Dirichlet boundary ii) Neumann boundary.

Dirichlet boundary:
If AB face is specified or Dirichlet type boundary then

$$E^{AB} = (H_A + H_B)/2$$
and
$$\frac{\partial H^{AB}}{\partial x} = \left(\frac{H_A + H_B}{2} - H_i\right) / \left|\frac{x_A + x_B}{2} - x_i\right|$$
$$\frac{\partial H^{AB}}{\partial y} = \left(\frac{H_A + H_B}{2} - H_i\right) / \left|\frac{y_A + y_B}{2} - x_i\right|$$
$$f_x^{AB} = K_x^{AB} E^{AB} \frac{\partial H^{AB}}{\partial x}; \quad f_y^{AB} = K_y^{AB} E^{AB} \frac{\partial H^{AB}}{\partial y} \tag{4.23}$$

For discretized equation for i^{th} element considering that BC and CA edge

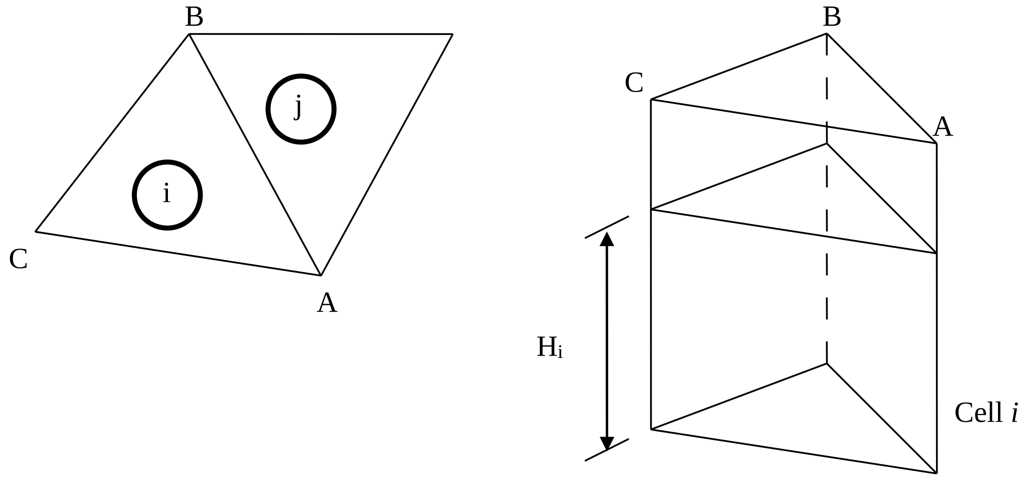


Figure 4.6: Triangular cell boundary.

represent boundary is as follows

$$A_C S_y \frac{H_i^{t+\Delta t} - H_i^t}{\Delta t} = K \frac{(H_i^{t+\Delta t})^2 - (H_i^{t+\Delta t})^2}{2} \left(\frac{\Delta y^{AB}}{|\Delta x_{ij}|} - \frac{\Delta x^{AB}}{|\Delta y_{ij}|} \right)$$
$$+K \frac{H_B + H_C}{2} \left(\frac{H_B + H_C}{2} - H_i \right) \left(\frac{\Delta y^{BC}}{|\frac{x_B + x_C}{2} - x_i|} - \frac{\Delta x^{BC}}{|\frac{y_B + y_C}{2} - y_i|} \right)$$
$$+K \frac{H_C + H_A}{2} \left(\frac{H_C + H_A}{2} - H_i \right) \left(\frac{\Delta y^{CA}}{|\frac{x_C + x_A}{2} - x_i|} - \frac{\Delta x^{CA}}{|\frac{y_C + y_A}{2} - y_i|} \right) \quad (4.24)$$

If the head for the boundary edges are considered to be uniform throughout all the points of an edge then we can take the heads as H_{AB}, H_{BC} and H_{CA}. So we can rewrite it as

$$A_C S_y \frac{H_i^{t+\Delta t} - H_i^t}{\Delta t} = K \frac{(H_j^{t+\Delta t})^2 - (H_i^{t+\Delta t})^2}{2} \left(\frac{\sqrt{(\Delta y^{AB})^2 + (\Delta x^{AB})^2}}{\sqrt{|\Delta x_{ij}|^2 + |\Delta y_{ij}|^2}} \right)$$
$$+K H_{BC}(H_{BC} - H_i) \left(\frac{\sqrt{(\Delta y^{BC})^2 + (\Delta x^{BC})^2}}{\sqrt{|\frac{x_B + x_C}{2} - x_i|^2 + |\frac{y_B + y_C}{2} - y_i|^2}} \right)$$
$$+K H_{CA}(H_{CA} - H_i) \left(\frac{\sqrt{(\Delta y^{CA})^2 + (\Delta x^{CA})^2}}{\sqrt{|\frac{x_C + x_A}{2} - x_i|^2 + |\frac{y_C + y_A}{2} - y_i|^2}} \right) + A_C^* Q \quad (4.25)$$

For implicit solution, by the Newton-Raphson method we have to find the jacobian of the above equation considering the boundary condition.

$$\frac{\partial F_i}{\partial H_i} = \frac{A_C S_y}{\Delta t} + KH_i \left(\frac{\sqrt{(\Delta y^{AB})^2 + (\Delta x^{AB})^2}}{\sqrt{|\Delta x_{ij}|^2 + |\Delta y_{ij}|^2}} \right)$$
$$K \left(\frac{\sqrt{(\Delta y^{BC})^2 + (\Delta x^{BC})^2}}{\sqrt{|\frac{x_B + x_C}{2} - x_i|^2 + |\frac{y_B + y_C}{2} - y_i|^2}} \right) + K \left(\frac{\sqrt{(\Delta y^{CA})^2 + (\Delta x^{CA})^2}}{\sqrt{|\frac{x_C + x_A}{2} - x_i|^2 + |\frac{y_C + y_A}{2} - y_i|^2}} \right) \tag{4.26}$$

$$\frac{\partial F_i}{\partial H_j} = -KH_j \left(\frac{\sqrt{(\Delta y^{AB})^2 + (\Delta x^{AB})^2}}{\sqrt{|\Delta x_{ij}|^2 + |\Delta y_{ij}|^2}} \right) \tag{4.27}$$

$$\frac{\partial F_i}{\partial H_k} = 0 \tag{4.28}$$

$$\frac{\partial F_i}{\partial H_l} = 0 \tag{4.29}$$

Neumann boundary:
If AB face is no-flow boundary:

$$A_C S_y \frac{H_i^{t+\Delta t} - H_i^t}{\Delta t} = K \frac{(H_k^t)^2 - (H_i^t)^2}{2} \left(\frac{\sqrt{(\Delta y^{BC})^2 + (\Delta x^{BC})^2}}{\sqrt{|\Delta x_{ik}|^2 + |\Delta y_{ik}|^2}} \right) + K \frac{(H_l^t)^2 - (H_i^t)^2}{2} \left(\frac{\sqrt{(\Delta y^{CA})^2 + (\Delta x^{CA})^2}}{\sqrt{|\Delta x_{il}|^2 + |\Delta y_{il}|^2}} \right) \tag{4.30}$$

If BC face is no-flow boundary:

$$A_C S_y \frac{H_i^{t+\Delta t} - H_i^t}{\Delta t} = K \frac{(H_j^t)^2 - (H_i^t)^2}{2} \left(\frac{\sqrt{(\Delta y^{AB})^2 + (\Delta x^{AB})^2}}{\sqrt{|\Delta x_{ij}|^2 + |\Delta y_{ij}|^2}} \right) + K \frac{(H_l^t)^2 - (H_i^t)^2}{2} \left(\frac{\sqrt{(\Delta y^{CA})^2 + (\Delta x^{CA})^2}}{\sqrt{|\Delta x_{il}|^2 + |\Delta y_{il}|^2}} \right) \tag{4.31}$$

If CA face is no-flow boundary:

$$A_C S_y \frac{H_i^{t+\Delta t} - H_i^t}{\Delta t} = K \frac{(H_j^t)^2 - (H_i^t)^2}{2} \left(\frac{\sqrt{(\Delta y^{AB})^2 + (\Delta x^{AB})^2}}{\sqrt{|\Delta x_{ij}|^2 + |\Delta y_{ij}|^2}} \right)$$
$$+K \frac{(H_k^t)^2 - (H_i^t)^2}{2} \left(\frac{\sqrt{(\Delta y^{BC})^2 + (\Delta x^{BC})^2}}{\sqrt{|\Delta x_{ik}|^2 + |\Delta y_{ik}|^2}} \right) \qquad (4.32)$$

If there is flow through a particular face then on can use directly specify flux values (f_x and f_y) is discretized equation.

Solution technique:

$$F_i(H_i, H_j, H_k, H_l) = 0, \quad \forall i \in 1, 2, ..., n_{el} \qquad (4.33)$$

$$F_i(H_1, H_2, ..., H_i, ...H_{n_{el}}) = 0, \quad \forall i \in 1, 2, ..., n_{el} \qquad (4.34)$$

$$J_{ij} \equiv \frac{\partial F_i}{\partial x_j} \qquad (4.35)$$

$$J \equiv \begin{pmatrix} \frac{\partial F_1}{\partial H_1} & \frac{\partial F_1}{\partial H_2} & \cdots & \cdots & \cdots & \frac{\partial F_1}{\partial H_{n_{el}}} \\ \frac{\partial F_2}{\partial H_1} & \frac{\partial F_2}{\partial H_2} & \cdots & \cdots & \cdots & \frac{\partial F_2}{\partial H_{n_{el}}} \\ \vdots & \vdots & \ddots & \cdots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \cdots & \cdots \\ \vdots & \vdots & \cdots & \cdots & \frac{\partial F_{n_{el-1}}}{\partial H_{n_{el-1}}} & \frac{\partial F_{n_{el-1}}}{\partial H_{n_{el}}} \\ \frac{\partial F_{n_{el}}}{\partial H_1} & \frac{\partial F_{n_{el}}}{\partial H_2} & \cdots & \cdots & \frac{\partial F_{n_{el}}}{\partial H_{n_{el-1}}} & \frac{\partial F_{n_{el}}}{\partial H_{n_{el}}} \end{pmatrix}$$

$$J.\delta H = -F \qquad (4.36)$$

$$H_{new} = H_{old} + \delta H \qquad (4.37)$$

4.4.3 Validation

The present groundwater model for two dimensional, isotropic, homogeneous and unconfined aquifer was run for an illustrative area of 1 km^2 including recharge and withdrawal for steady state condition and the results were compared with that of MODFLOW. The domain is divided (Figure 4.7) in Visual MODFLOW with 400

Scenario	Maximum draw-down simulated by MODFLOW (m)	Maximum draw-down simulated by present model (m)	RMSE
A	NA	NA	0.019
B	11.32	11.45	0.085
C	10.54	10.79	0.101
D	9.52	9.83	0.132
E	8.43	9.01	0.243
F	11.18	11.6	0.225

Table 4.1: Groundwater model validation results for different scenarios

square cells each having an area of 2500 m^2 . The same domain is divided into 220 unstructured triangular irregular cells. The boundaries for northern side and southern side are considered to be 15 m and 14 m above a datum respectively. The western side and eastern side boundaries are considered to be no flow zone. The initial head is considered to be 14 m uniform throughout the entire area. The specific yield and hydraulic conductivity of the aquifer material is taken as 0.35 and the 1.27 m/day respectively. Both the present model and MODFLOW is simulated for six scenarios i.e, a) No pumping; b) Pumping from a single location at the rate of 100 cubic meters per day; c) Pumping from 3 locations at the rate of 40, 50 and 100 cubic meter per day; d) Pumping from 3 locations at the rate of 100, 100 and 100 cubic meter per day; e) Pumping from 5 locations at the rate of 60, 80, 100, 100 and 100 cubic meter per day; and f) Pumping from 5 locations at the rate of 60, 80, 100, 100 and 100 cubic meter per day and an uniform recharge of 100 mm per year. The RMSE (root mean square error) of the simulated heads between present model and MODFLOW for the six scenarios stated earlier are presented in Table 4.1. between the are found to be 0.0193, 0.085, 0.101, 0.132, 0.243 and 0.453 respectively. Groundwater head contour maps for the aforesaid scenarios are given in Figure **??** to Figure 4.13. The Figure 4.13 included to validate the model for recharge scenario along with pumping wells.

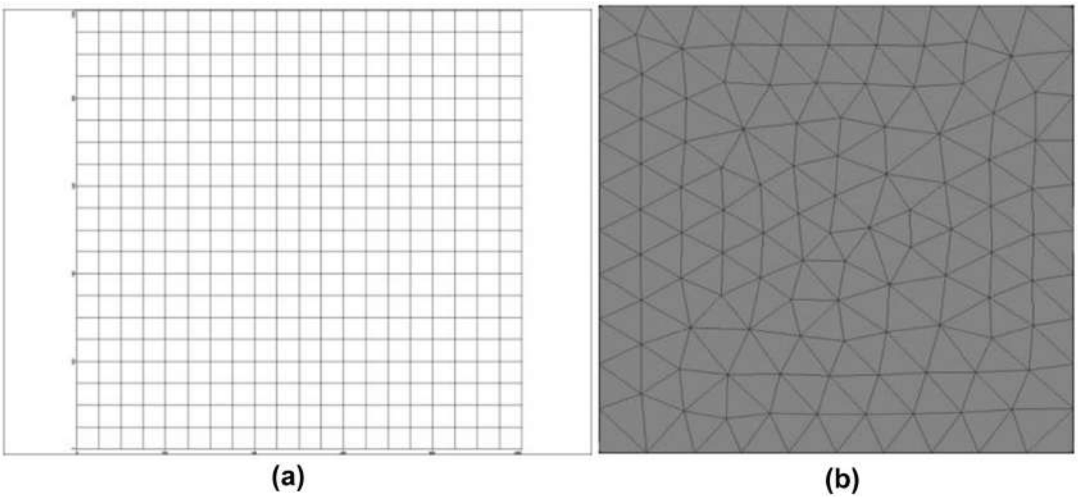


Figure 4.7: (a) Rectangular discretization for MODFLOW simulation, and (b) Triangular grid discretization for present model.

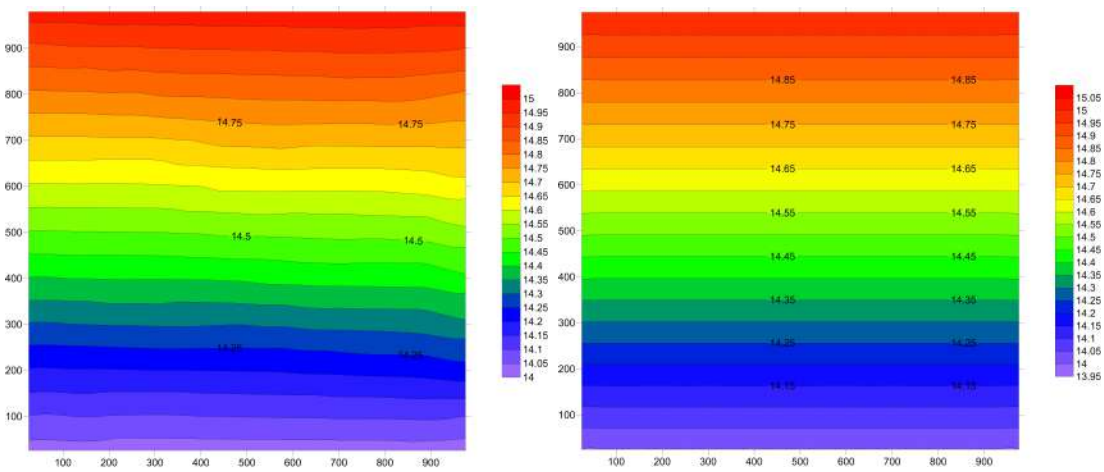
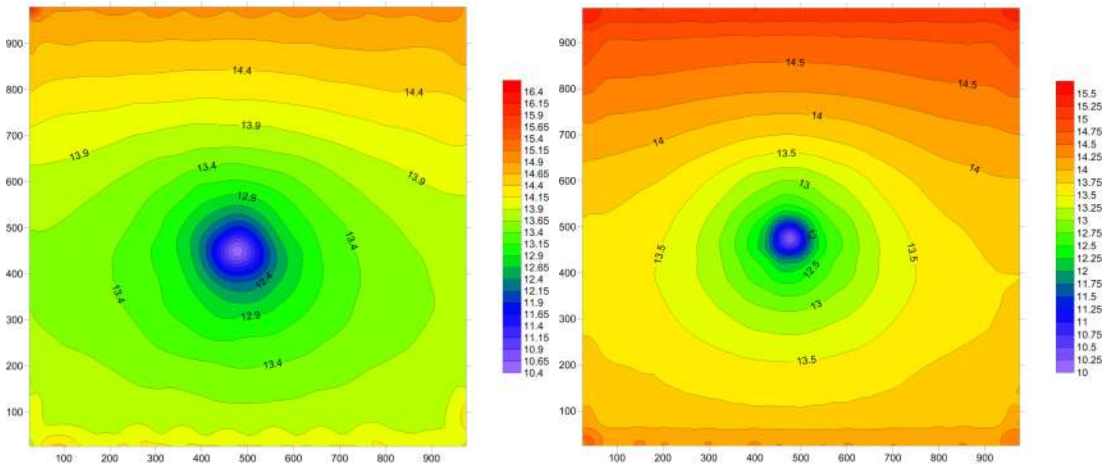
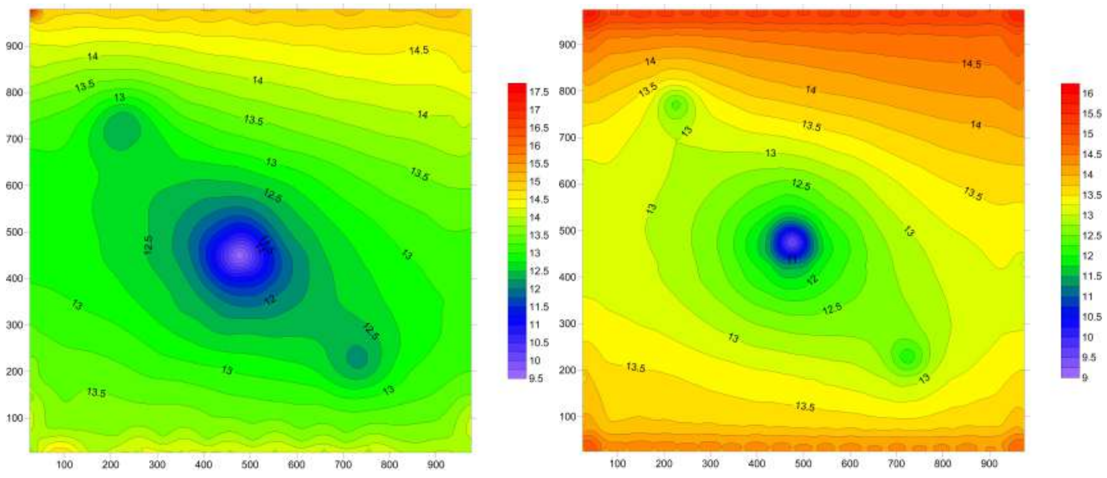


Figure 4.8: Groundwater contour map of steady state flow without pumping and recharge (a) the present model, and (b) MODFLOW.



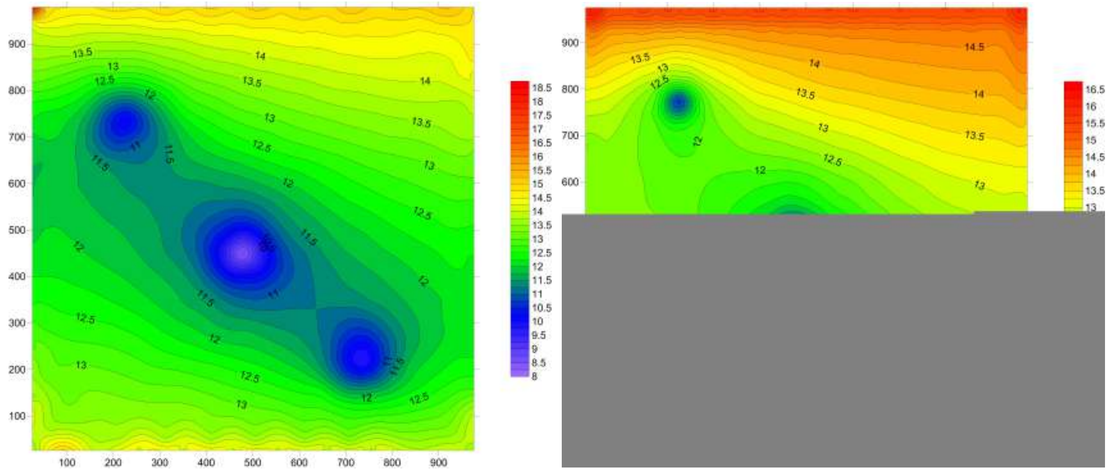
(a) (b)

Figure 4.9: Groundwater contour map of steady state flow (a) the present model, and (b) MODFLOW with single well discharge of 100 m^3/day.



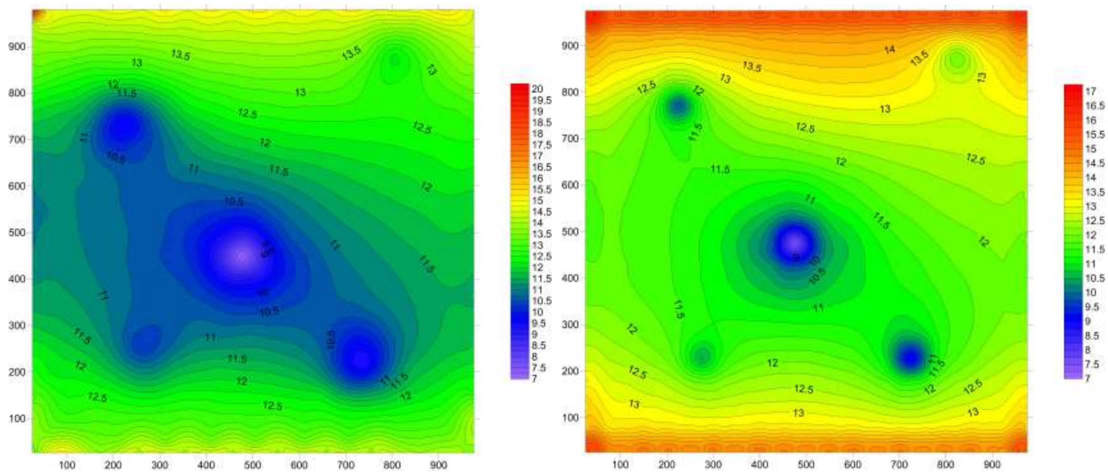
(a) (b)

Figure 4.10: Groundwater contour map of steady state flow (a) the present model, and (b) MODFLOW for three wells with discharges of 40 m^3/day, 50 m^3/day and 100 m^3/day.



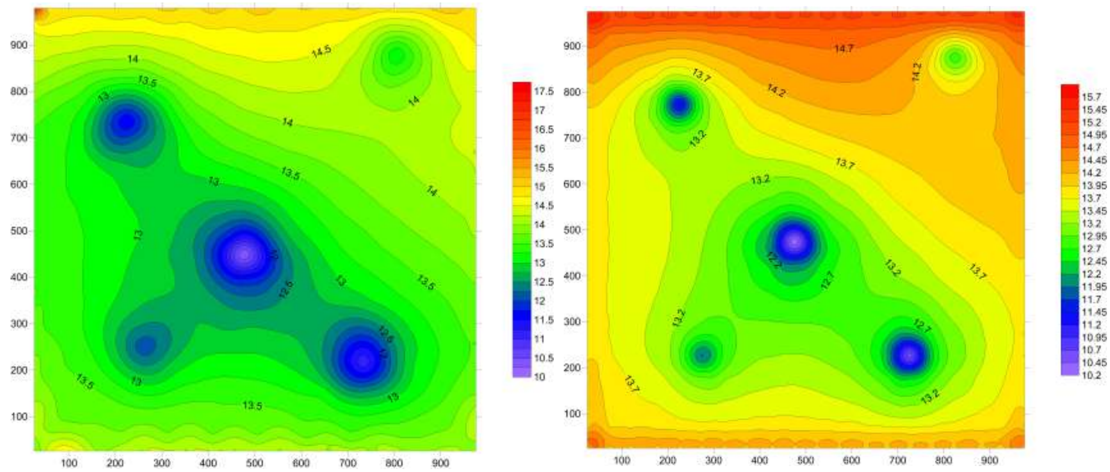
(a) (b)

Figure 4.11: Groundwater contour map of steady state flow (a) the present model, and (b) MODFLOW for three wells with discharges of 100 m^3/day from each well.



(a) (b)

Figure 4.12: Groundwater contour map of steady state flow (a) the present model, and (b) MODFLOW for five wells with discharges of 60 m^3/day, 80 m^3/day, 100 m^3/day, 100 m^3/day and 100 m^3/day.



(a) (b)

Figure 4.13: Groundwater contour map of steady state flow (a) the present model, and (b) MODFLOW for five wells with discharges of 60 m^3/day, 80 m^3/day, 100 m^3/day, 100 m^3/day and 100 m^3/day, and 100 $mm/year$.

From the results of the numerical simulation, the following conclusions may be drawn.

1. The groundwater response to different situations arising out of withdrawal and recharge scenarios are not very different from those simulated by MODFLOW.
2. The proposed model can be used efficiently for simulating groundwater dynamics for different scenarios of withdrawal and recharge and, hence, may be linked to the other flow simulation models of this work with confidence.

This chapter presents the modelling framework for unsaturated flow and groundwater flow in shallow unconfined aquifer. The governing equations of flow used in the numerical model are also presented.

Chapter 5

Development and implementation of computer program for canal network flow simulation

5.1 Canal and Watercourse Modelling

The diverted flow to a canal system from a river is controlled through the head-regulator of the main canal. The concerned irrigation management authority releases a regulated discharge depending upon the available flow in the river at a given time and on the projected availability in future (where the storages of the dams on the upstream are also considered). The discharge through the main canal as well as through the distributaries and further branches of the network is regulated using cross- and head-regulators of the respective branch. The discharge in each branch is generally held constant for a period of around ten-days such that each month the branches in the canal system convey three fixed discharges, normally held steady as far as possible, with some transient condition occurring during the changeovers. Only when the water is finally released to the watercourses, it is allowed to flow out through lateral unregulated outlets.

In this chapter, the one dimensional flow equations and solution techniques used for modelling the flow through (i) the main and branch canals; and (ii) the watercourses, are presented. The hydraulic conditions experienced by the two flow systems, though similar, have a few differences. A few assumptions and simplifications are also made for the sake of the present research work. All these may be summarised as under:

i) Main and branch canals: The upstream end of these channels receives a constant discharge from the respective head regulator and is assumed to remain constant for a period of ten days at a stretch. Hence, the flow may be considered steady, though there may be fluctuations during the changeover periods. However, the ten-day discharge in these irrigation canals is generally not varied too drastically. Thus the situation as experienced in some hydropower channels during the sudden closure of the downstream gate (on load rejection) is not assumed to take place for the irrigation canals under consideration. At the downstream end of these channels, a cross regulator is assumed to exist, which may be (a) a free-flowing weir (Figures 5.1a and 5.1c); or (b) a gated sluice over a weir (Figure 5.1b and 5.1d). Further, it is assumed here that the branch of the canal downstream of the regulator is well below the level of the parent channel and drowned conditions as depicted in Figures 5.1c and 5.1d do not occur. The smaller branches off-taking from these canal branches are assumed to receive water through an unregulated sluice type canal outlet. The flow through these outlets is assumed to depend only on the depth of flow in the canal and remains unaffected by that on the downstream.

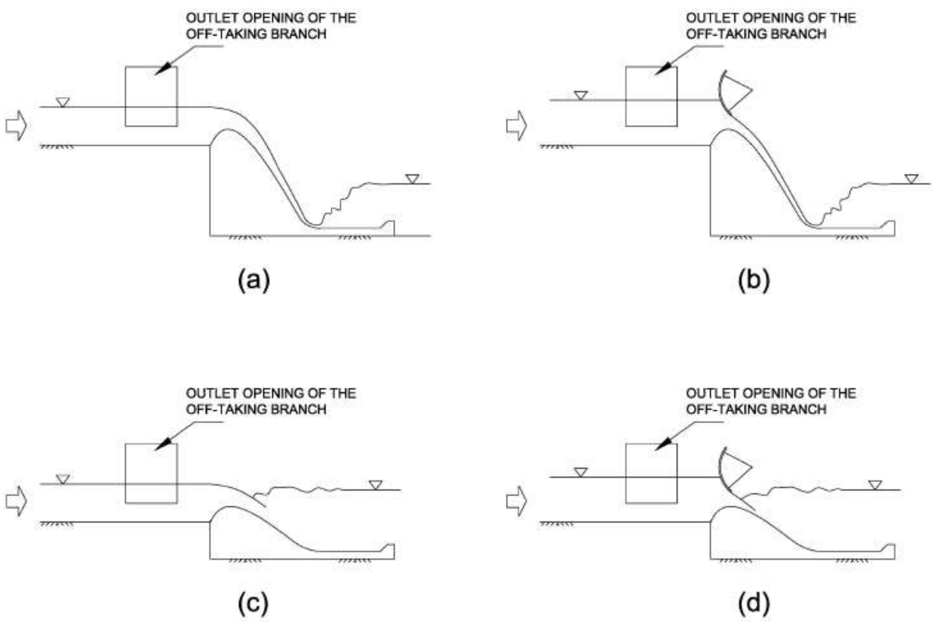


Figure 5.1: Types of canal diversion regulators and possible flow conditions (a) Un-gated weir, free flow; (b) Gated sluice, free flow; (c) Un-gated weir, submerged flow; and (d) Gated sluice, submerged flow.

ii) Watercourses: The watercourses are assumed to receive water at its upstream end from a State controlled canal branch through a canal outlet. The flow, therefore, is assumed to be steady (since no variation is expected to occur in ten-days). The flow in a watercourse, however, may get divided at any branch bifurcation point. Uncontrolled field outlets release water from a watercourse and its branches to the adjoining fields and a no-flow (zero-discharge) condition is assumed to exist at the downstream ends of its branches.

From the above observations, it may be noticed that in this work only free flow condition on the downstream of the control structures has been considered. This implies that each canal reach between the respective head regulator and downstream cross regulator may be considered single branched, with the flow and water levels of the downstream and off-taking channels not influencing in the computations of the parent channel. At the upstream of any branch, the inflowing discharge is governed only by the outflow of the donor branch.

Watercourses are assumed to have channel flow division points similar to the unregulated canal networks bifurcations described by Sen and Garg (2002) or Islam et al. (2005). The flows through the field-outlets of these watercourses (considered as unregulated sluices) are also assumed to be governed by the depth of water in the watercourse channel and not influenced by that in the fields (basins).

5.2 Governing equations of flow and computation techniques

The flow of water in the branches of the canal system as well as in the watercourses is considered one-dimensional and the governing equations (de St. Venant equations) are as presented below, adapted from Chaudhry (2007). This includes the outlet flow equation also (Eq. 5.1), which is treated here as a lateral loss function in the continuity equation (Eq. 5.2). The effect of the lateral outflow in the momentum equation (Eq. 5.1) is neglected.

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x}(QV) + gA\frac{\partial h}{\partial x} - gA(S_0 - S_f) = 0 \tag{5.1}$$

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} + q_{lateral} = 0 \tag{5.2}$$

$$q_{lateral} = n\frac{\pi d^2}{4}\frac{C_d\sqrt{2g(h^* - c)}}{D} \tag{5.3}$$

where, Q = rate of discharge (L^3/T); A = flow area (L); h = flow depth (L); x = distance measured along channel length (L), t = time (T); S_0 = channel bottom slope (L/L), S_f = friction slope (L/L); $q_{lateral}$ = lateral outflow through the outlets (L^3/T); n = number of outlets (-); d = diameter of outlet orifice (L); C_d = Coefficient of discharge of orifice outlet; c = height of outlet above canal bed (L); D = distance between outlets (L); h^* = depth of flow at the location of the outlet (L).

The governing equations (Eq. 5.1) and (Eq. 5.2), along with the outflow equations are numerically solved using the implicit scheme of Preissmann (Chaudhry 2007) for different inflow discharges in the channels. The discretized forms of the governing equations are as follows:

$$\begin{aligned}
&\left\{(Q_{i+1}^{k+1}+Q_i^{k+1})-(Q_{i+1}^{k}+Q_i^{k})\right\}\\
&+\frac{2\Delta t}{\Delta x}\left[\alpha\left\{\left(\frac{Q^2}{A}\right)_{i+1}^{k+1}-\left(\frac{Q^2}{A}\right)_{i}^{k+1}\right\}+(1-\alpha)\left\{\left(\frac{Q^2}{A}\right)_{i+1}^{k}-\left(\frac{Q^2}{A}\right)_{i}^{k}\right\}\right]\\
&+\frac{2\Delta t}{\Delta x}g\big[\alpha\left\{\left(\frac{Bh^2}{2}+\frac{Sh^3}{3}\right)_{i+1}^{k+1}-\left(\frac{Bh^2}{2}+\frac{Sh^3}{3}\right)_{i}^{k+1}\right\}\\
&+(1-\alpha)\left\{\left(\frac{Bh^2}{2}+\frac{Sh^3}{3}\right)_{i+1}^{k}-\left(\frac{Bh^2}{2}+\frac{Sh^3}{3}\right)_{i}^{k}\right\}]\\
&-\Delta t g[\alpha\left\{A_{i+1}^{k+1}(S_0-S_f)_{i+1}^{k+1}+A_i^{k+1}(S_0-S_f)_i^{k+1}\right\}\\
&+(1-\alpha)\left\{A_{i+1}^{k}(S_0-S_f)_{i+1}^{k}+A_i^{k}(S_0-S_f)_i^{k}\right\}]=0
\end{aligned}\tag{5.4}$$

$$\begin{aligned}
&\frac{2\Delta t}{\Delta x}\left\{\alpha(Q_{i+1}^{k+1}-Q_i^{k+1})+(1-\alpha)(Q_{i+1}^{k}-Q_i^{k})\right\}\\
&+\left[\{(Bh+Sh^2)_{i+1}^{k+1}+(Bh+Sh^2)_i^{k+1}\}-\{(Bh+Sh^2)_{i+1}^{k}+(Bh+Sh^2)_i^{k}\}\right]\\
&+n\frac{\pi d^2C_d\sqrt{2g}}{4}\frac{\Delta t}{\Delta x}\alpha\left\{\left(\sqrt{\frac{h_i+h_{i+1}}{2}}-c\right)^{k+1}\right\}\\
&++n\frac{\pi d^2C_d\sqrt{2g}}{4}\frac{\Delta t}{\Delta x}(1-\alpha)\left\{\left(\sqrt{\frac{h_i+h_{i+1}}{2}}-c\right)^{k}\right\}=0
\end{aligned}\tag{5.5}$$

$$Q_{lateral} = n\frac{\pi d^2}{4}C_d\sqrt{2g\left[\frac{h_i + h_{i+1}}{2} - c\right]} \qquad (5.6)$$

In the above equations, i and $i + 1$ are two adjacent computation nodes in the channel and the following additional variables are introduced: Δt = computational time step (T); Δx = computation domain length (L); α = weighting factor in time.

The boundary conditions applied for solving the equations are the following:

1. Prescribed discharge on the upstream, which is considered generally steady for both the branches of the canal system as well for the watercourses. However, a few unsteady runs are carried out for the canal branches to check the effect of temporal variation of upstream flow on the discharges of the off-taking channels.

2. At the downstream end, the following conditions are applied:
a. Main and branch canals: Either an un-gated weir or a gated sluice, each specified with given sill crest height above the canal bed and known relation of flow passing over or through the structure and the flow depth. The equations considered are:

i. Ungated weir: $Q_{out} = C_d L(h - c)^{1.5}$

ii. Gated sluice: $Q_{out} = C_d A[2g(h - c)]^{0.5}$

In the above equations, Q_{out} = discharge out-flowing through the terminal structure; L = length of the weir (L); A is the area of cross-section of the sluice (L^2); C_d = coefficient of discharge (-); h = depth of flow at the downstream end of the channel (L); g = acceleration due to gravity (LT^{-2}); c = crest height of weir sill (L).

b. Watercourses: Dead-end (no-flow) at the tail ends, that is, $Q_{out} = 0$.

3. Intermediate conditions for watercourse flow bifurcation points: The watercourses are assumed to get divided into smaller channels and at the flow division points, the following conditions are applied (following Sen and Garg 2002):

a. Continuity equation, for conservation of mass, and

b. Equality of energy at the tail-end of the inflowing branch to those at the heads of the out-flowing branches.

Equations (Eq. 5.4) and (Eq. 5.5) are solved simultaneously along with the appropriate boundary conditions to arrive at the solution for the variables (h, flow depth, and Q, discharge) at the computational nodes. The spacing between the computational nodes is kept the same as that between the side outlets (which is assumed to be constant in the entire domain) such that the outlets fall within two consecutive computational nodes.

5.3 Simulation of flows in canal branch and watercourse

Sample flow examples are run for the canal branch and watercourses to demonstrate the numerical model explained in Section 3.2. Simulations are carried out for each of the following cases:

1. For the canal branches, unsteady simulations are carried out to check the effect of varying discharge on lateral canal outflow discharges.

2. For the watercourses, steady discharges are tested to check the variation in water distribution through the field outlets.

5.3.1 Flow simulation in a canal branch

A 20 km long canal branch is considered with two types of downstream boundary conditions, viz.: (a) ungated weir (Figure 5.2a), or (b) a gated sluice (Figure 5.2b) at its downstream end. The channels in either case are trapezoidal (side slope $2H : 1V$) with the beds sloped at $1H : 0.0001V$. The Manning friction coefficient is taken as 0.01 for both cases. Coefficient α for numerical simulation using the Preissmann Scheme is also kept as 0.8 for all the simulations. Two off-taking channels are considered (sluice type), one at the middle of the canal reach and the downstream end of the channel.

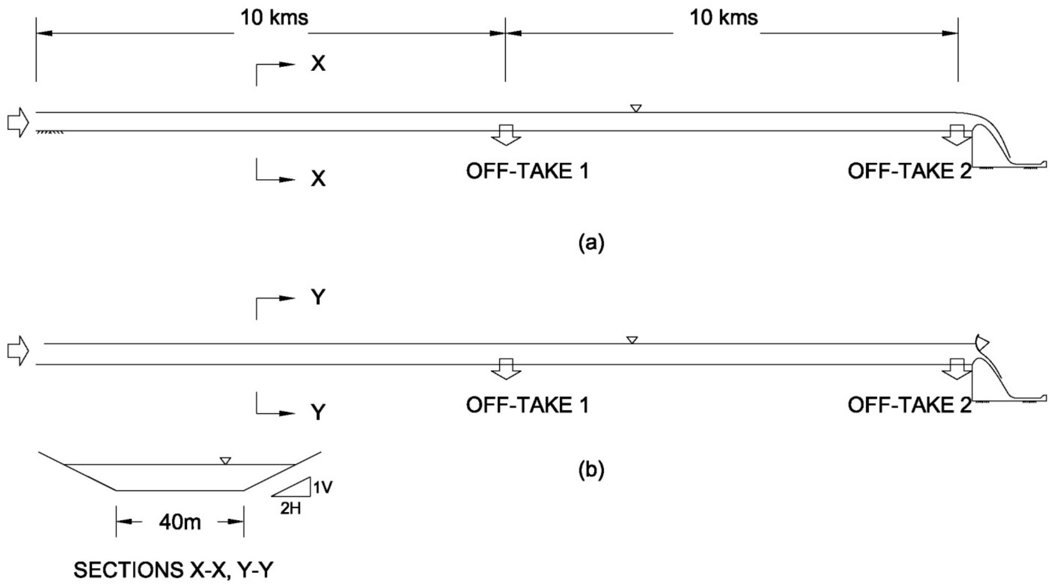


Figure 5.2: Canal branch examples for flow simulation: (a) Branch with un-gated weir at downstream end, and (b) Branch with gated sluice at the downstream end.

The hydraulic conditions that were tested for the two types of downstream control are listed in Figure 5.3.

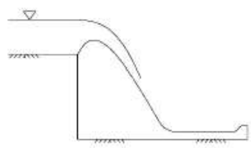
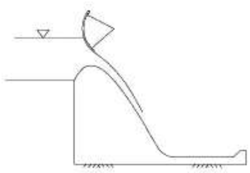
Un-gated Weir (crest of weir 0.5m above bed) 	***Discharge variation with time***	
	0 to 83.3 hrs: 5 $m^3/3$	
	83.3 to 833.3 hrs: $(5 + Q)m^3/s$	
	833.3 to 1000 hrs: 5 m^3/s	
	Q = 20, 10 and 5 m^3/s	
Gated Sluice (crest of sluice weir 0.1m above bed) 	***Discharge variation with time***	***Gate opening variation with time***
	0 to 83.3 hrs: 5 $m^3/3$	0 to 333.3 hrs: 100%
	83.3 to 833.3 hrs: $(5 + Q)\ m^3/s$	333.3 to 1000 hrs: x% of original area
	833.3 to 1000 hrs: 5 m^3/s	x = 10, 50, and 80
	Q = 20, 10 and 5 m^3/s	

Figure 5.3: Hydraulic conditions tested for a typical canal branch shown in Figure 5.2

The simulations are carried out up to a time of 1000 hours to check the response of the unsteady model for the sudden rise and drop of inflow discharges, and sudden decrease of the sluice gate opening, as shown in the Figure 5.3. It may be mentioned that an initial time is allowed for achieving a steady state condition before the rise of inflow discharge is imposed.

The constants in the discharge equations for the lateral outlets and those for the terminal structures are combined together so that the discharges may be written as under:

$$
\begin{aligned}
&Q_{lateral} = Z_{off-take}[h^* - c]^{0.5} \\
&Q_{out}(ungated\ weir) = Z_{weir}[h - c]^{1.5} \\
&Q_{out}(gated\ sluice) = Z_{sluice}[h - c]^{0.5}
\end{aligned} \tag{5.7}
$$

For the examples considered here, the following values were assumed:

$$
\begin{aligned}
&Z_{off-take} = 5.0\ m \\
&Z_{weir} = 10.0\ m \\
&Z_{sluice} = 10.0\ m
\end{aligned}
$$

A few of results of computed discharges from the simulations are presented below (notations mentioned in Figure 5.3). The depth variation graphs are not presented for brevity. The colour legends in Figures 5.3 to 5.7 are as under:

1. Deep blue line: Inflow discharge

2. Red line: Outflow through off-take 1

3. Light Blue line: Outflow through off-take 2

Example 1: Ungated Weir; initial discharge 5 m^3/s, then increased by 20 m^3/s. Variation of discharge with time shown in Figure 5.4.

Example 2: Ungated Weir; initial discharge 5 m^3/s, then increased by 5 m^3/s. Variation of discharge with time shown in Figure 5.5.

Example 3: Gated sluice; initial discharge 5 m^3/s, then increased by 20

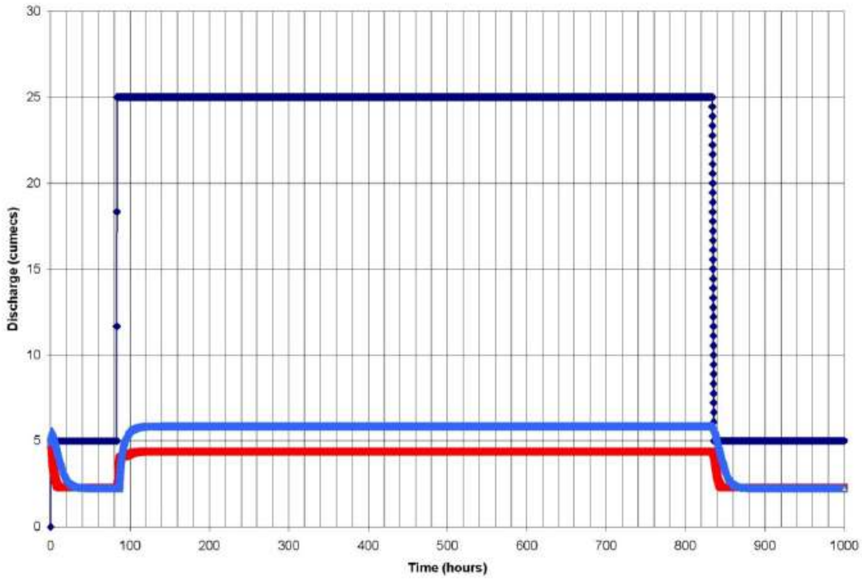


Figure 5.4: Variation of discharge with time, Example 1

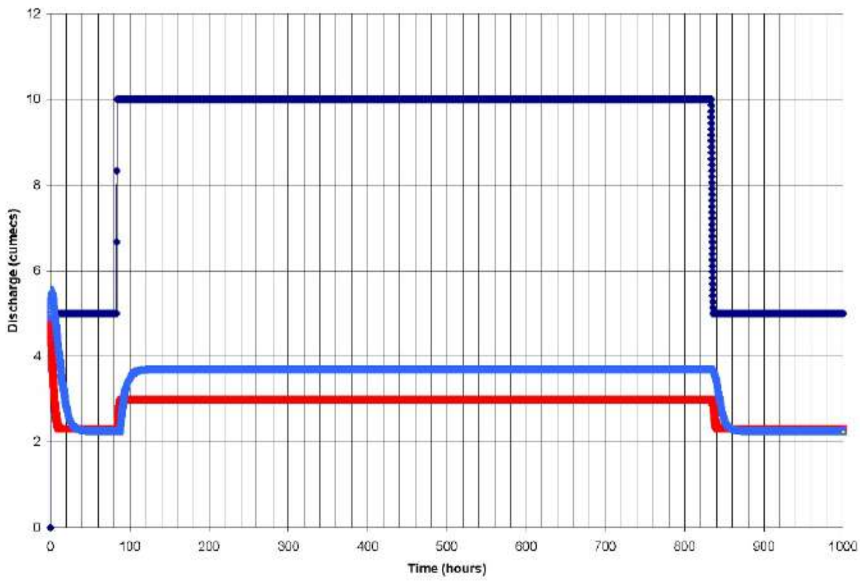


Figure 5.5: Variation of discharge with time, Example 2

m^3/s; gate opening reduced to 10% of original area; Variation of discharge with time shown in Figure 5.6. (This is an extreme case, and as such a situation like this is not expected to occur during normal flow distribution in canals).

Example 4: Gated sluice; initial discharge 5 m^3/s, then increased by 10 m^3/s; gate opening reduced to 50% of original area; Variation of discharge with

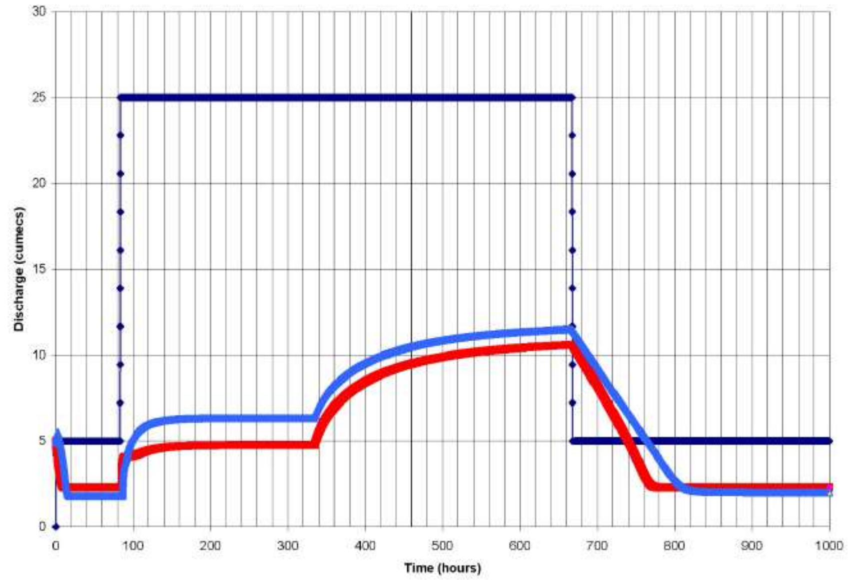


Figure 5.6: Variation of discharge with time, Example 3

time shown in Figure 5.7.

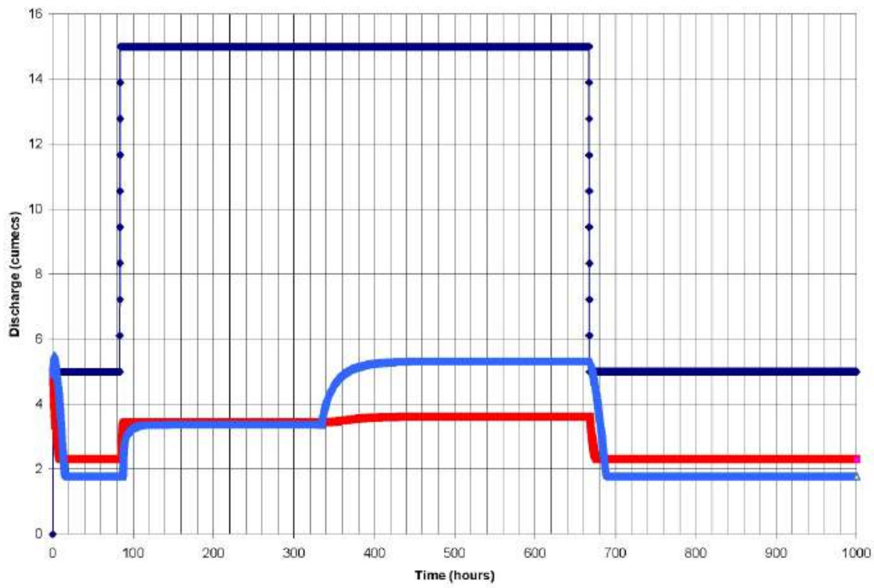


Figure 5.7: Variation of discharge with time, Example 4

Example 5: Gated sluice; initial discharge 5 m^3/s, then increased by 5 m^3/s; gate opening reduced to 80% of original area; Variation of discharge with time shown in Figure 5.8.

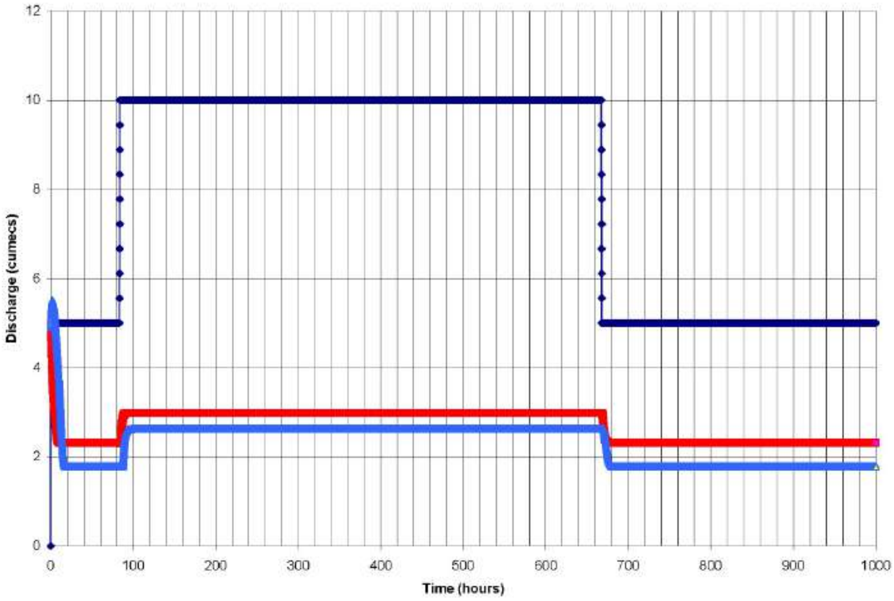


Figure 5.8: Variation of discharge with time, Example 5

From the above results, and the other tests conducted for the conditions mentioned in Figure 5.3, the following inferences may be drawn:

1. Simulations for the un-gated weir flows show a quicker convergence to steady state values than the gated sluice simulations.

2. The outflow of off-take 1 is smaller than that of off-take 2, which is logical as the water depth increases towards the downstream end and is higher for off-take 2.

3. For gated sluice simulations, the depths take longer to converge to a steady solution than the discharges.

4. Also for gated sluice simulations, greater off-take discharges result in quicker convergence of the solutions.

5. Greater reduction of sluice opening area causes longer to converge to a steady state solution.

From the above, it may be concluded that unless a very drastic variation in the hydraulic conditions is imposed on the canal flow, the results converge to a steady state solution quite rapidly to a steady state. Since in the irrigation system considered in this thesis the canal flows are approximately held steady for ten-days at a stretch with only slight changes taking place during the changeover to the flow of the next ten-day period, the flows in the canal branches and consequently the discharges of the off-taking channels can also be assumed to be steady for all practical purposes.

5.3.2 Flow simulation in a watercourse

The off-taking discharges from the typical canal reach as shown in the preceding section is seen to remain steady for moderate changes in the hydraulic conditions. This situation is commensurate with the irrigation water schedule followed by the irrigation management authorities. Hence, the inflow to a watercourse may also be considered steady for all practical purposes.

This section illustrates the flow distribution in the hypothetical example shown in Figure 5.9 for different variation in the physical parameters of the water course and field outlets. The inflow discharge to branch 1 is assumed to be a steady 20 m^3/s and the Manning friction coefficient of all the channels is taken as equal to 0.01. The bed widths of the three branches are, however, different. These are as follows: Branch 1: 4m, Branch 2: 3m, and Branch 3: 2m.

The boundary conditions for the simulations are as follows: 1. A specified constant discharge at the upstream end (considered here as 20 m^3/s), and 2. Zero discharge condition at the downstream end.

In the examples considered, the bed slopes of the channels are varied as also the C_d values of the orifice outlets. The variation in the flow through the outlets is studied from the results of the examples presented.

Example 1: Slopes of all branches of the network: 0.00001; C_d of all outlets: 0.45; Variation of discharges through the field outlets for Branch 1, 2 and 3 are presented in Figures 5.9, 5.10,and 5.11 respectively.

Example 2: Slopes of all branches of the network: 0.00001; C_d of outlet of Branch 1: 0.25; C_d of outlet of Branch 2: 0.45; C_d of outlet of Branch 3: 0.35

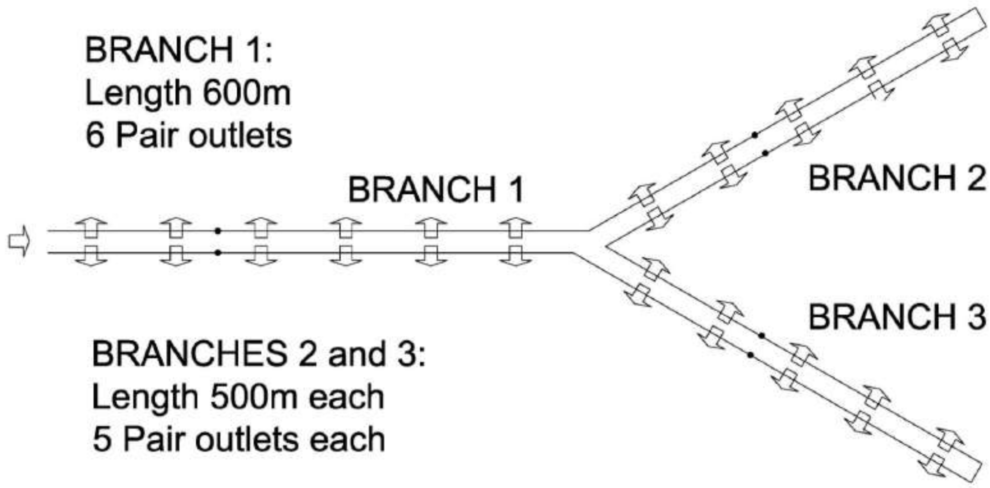


Figure 5.9: Branched watercourse network geometry for Examples 1 to 3.

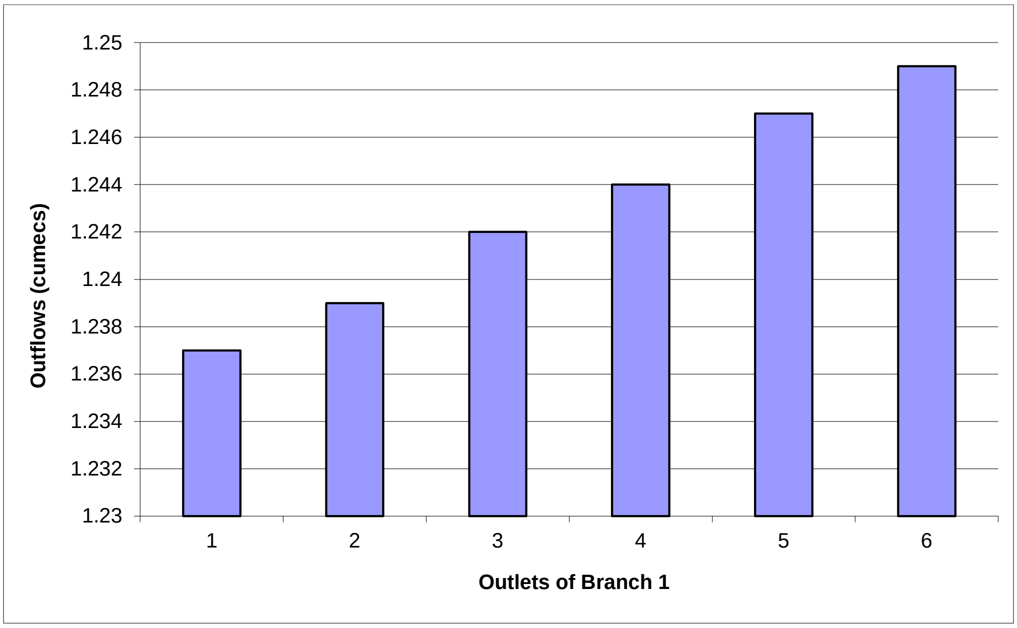


Figure 5.10: Distribution of flow through the outlets of Branch 1, Example 1

Example 3: Slopes of all branches of the network: 0.001; C_d of outlet of Branch 1: 0.25; C_d of outlet of Branch 2: 0.45; C_d of outlet of Branch 3: 0.35

From the results of the discharges through the field outlets of the different branches of the watercourses, the following conclusions may be drawn:

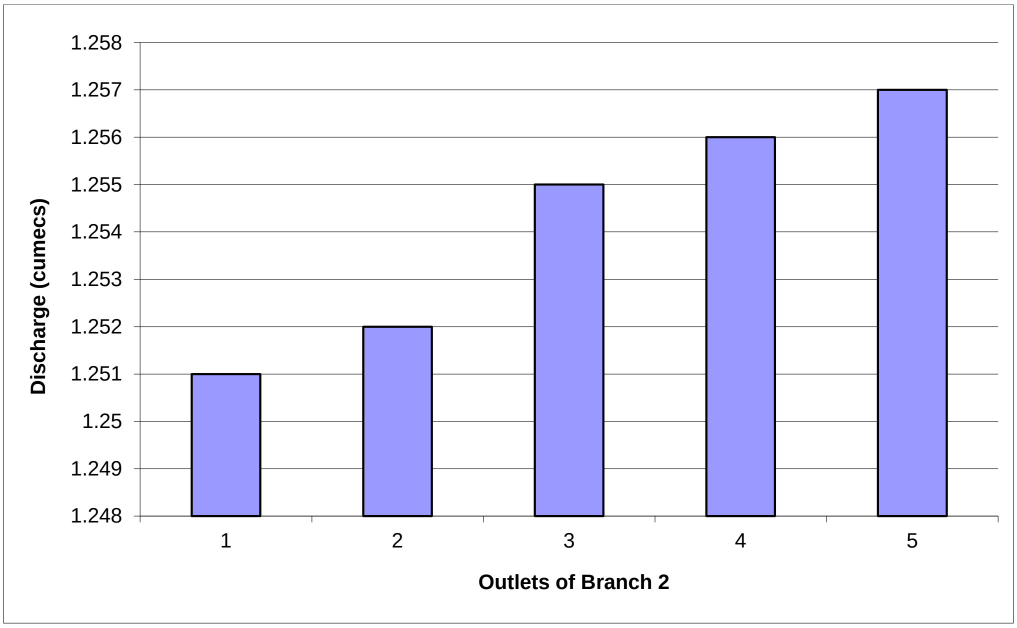


Figure 5.11: Distribution of flow through the outlets of Branch 2, Example 1

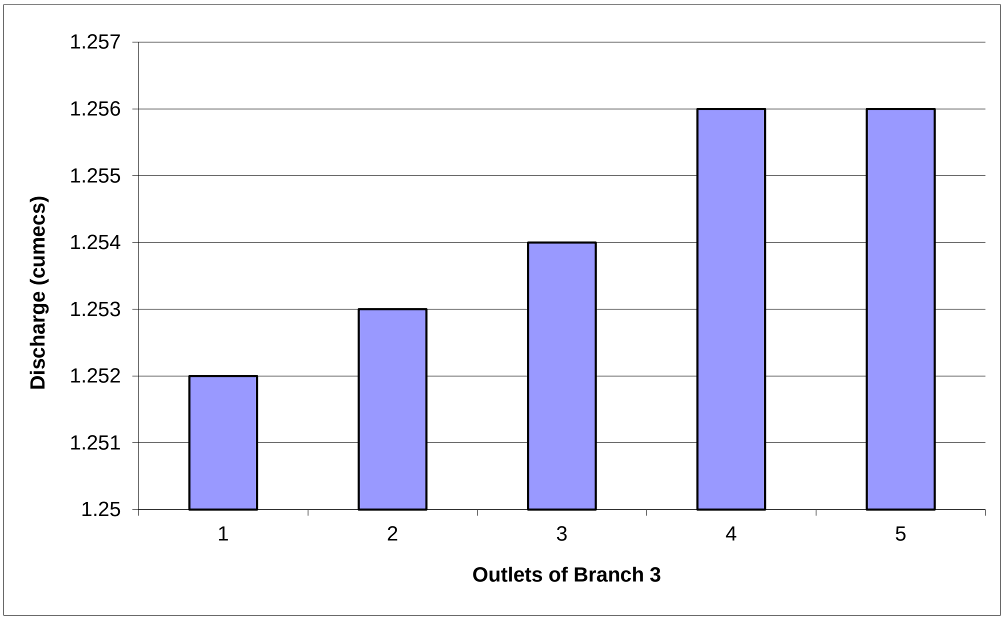


Figure 5.12: Distribution of flow through the outlets of Branch 3, Example 1

1. Smaller slopes in the channels result in nearly equal flows through the outlets of a watercourse branch or sub-branch.

2. Different widths of the two sub-branches of the watercourse do not make

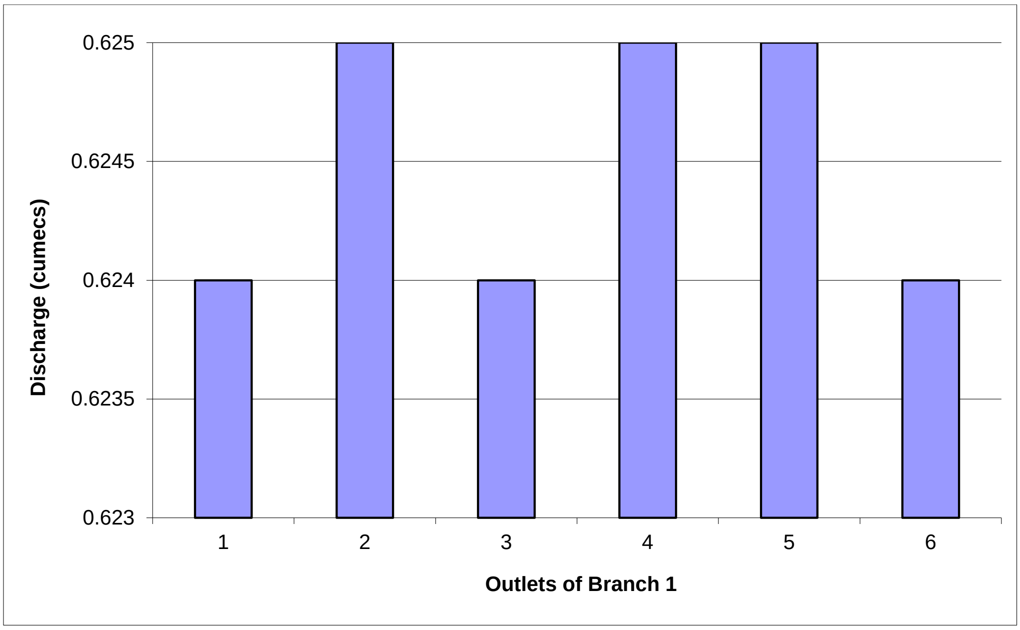


Figure 5.13: Distribution of flow through the outlets of Branch 1, Example 2

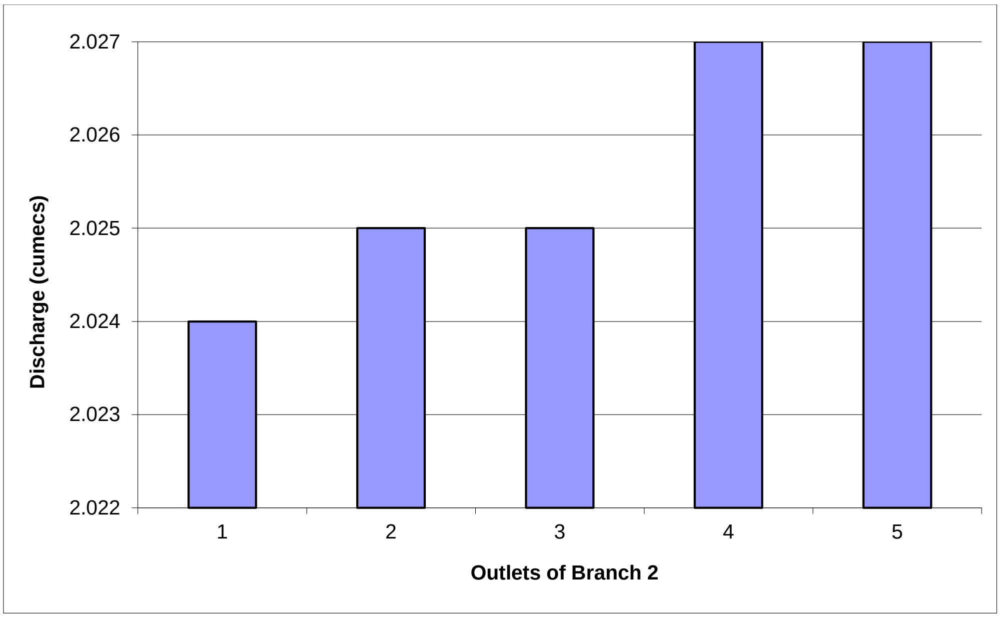


Figure 5.14: Distribution of flow through the outlets of Branch 2, Example 2

any significant difference to the out-flowing discharges through the outlets, provided the diameters of the outlets are similar.

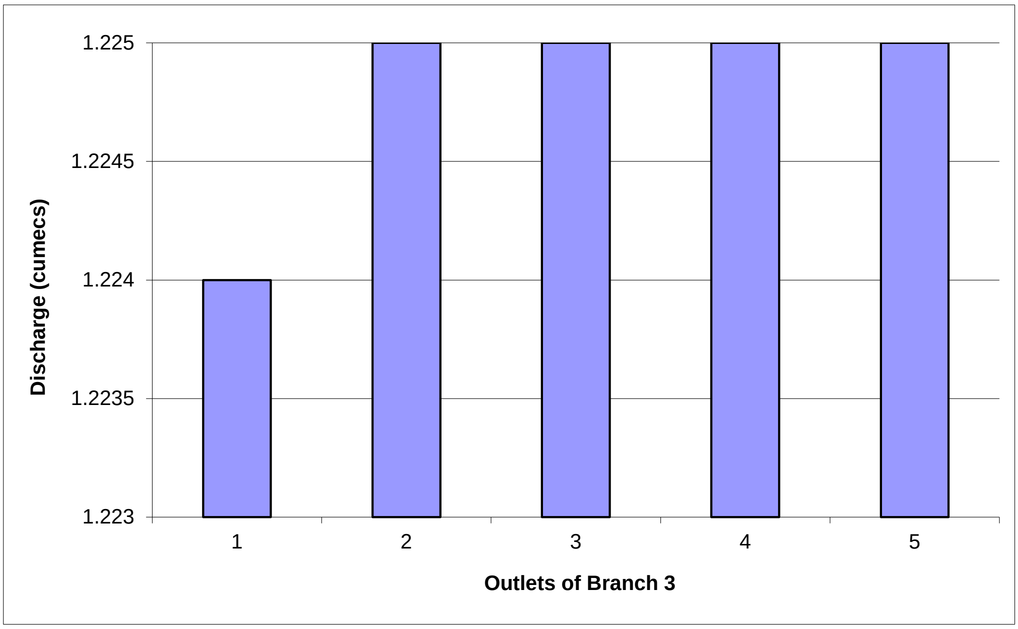


Figure 5.15: Distribution of flow through the outlets of Branch 3, Example 2

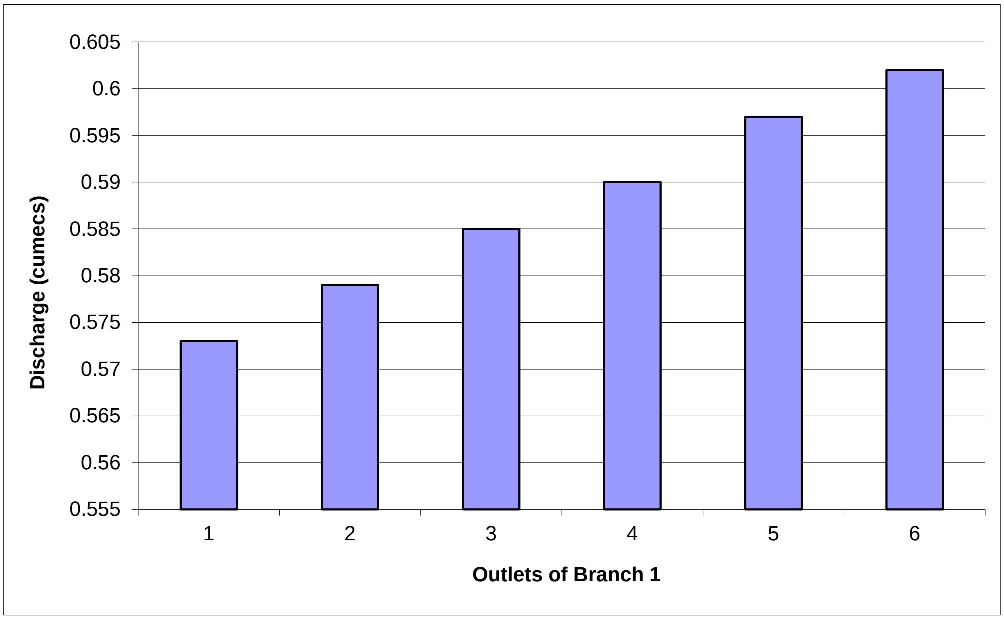


Figure 5.16: Distribution of flow through the outlets of Branch 1, Example 3

3. It is more apparent from the steeper channels that the flows through the outlets increase moving downstream. This occurs as the depth of flow increases

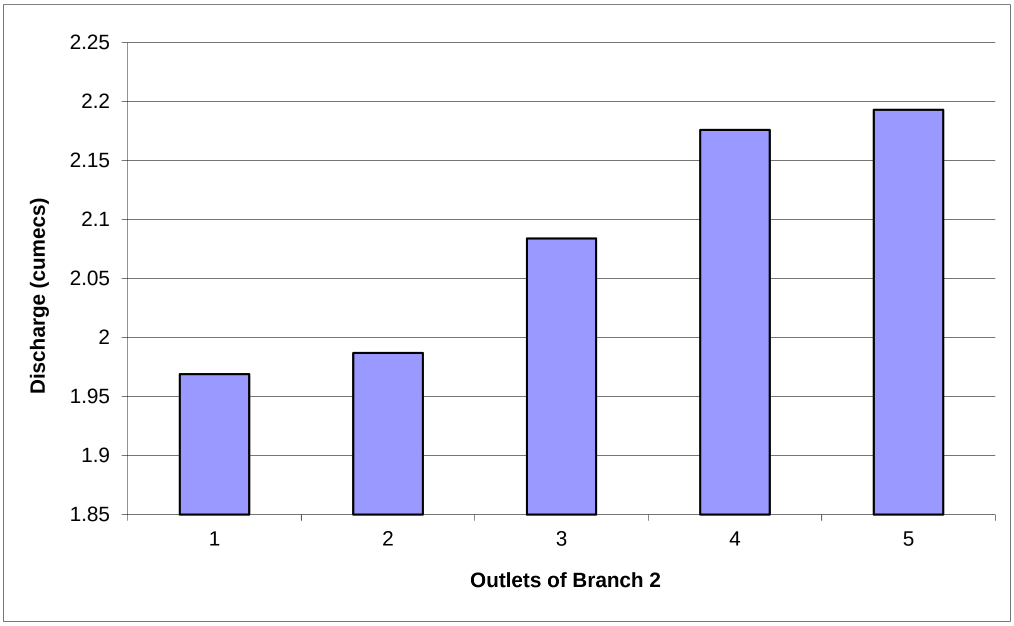


Figure 5.17: Distribution of flow through the outlets of Branch 2, Example 3

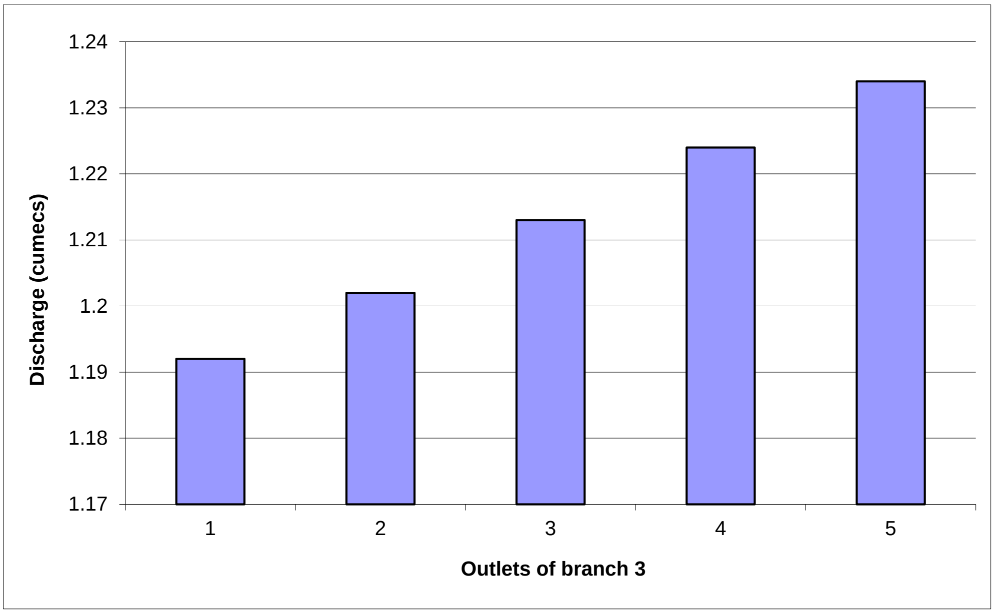


Figure 5.18: Distribution of flow through the outlets of Branch 3, Example 3

towards the downstream; a phenomenon that is similar to a backwater gradually varied profile of water surface encountered for channels with spillways at the downstream end.

From the results of the numerical experiments described in this chapter, it may be inferred that a steady flow in the main canal, its branches, distributaries, minors and watercourses would finally result in a steady outflow through the field outlets. Whatever unsteadiness that may occur during the changeover periods of discharges in the canal branches, is likely to die down rather quickly, and may not substantially influence the flow conditions of a ten-day constant discharge period in an irrigation canal schedule.

Chapter 6

Modelling of canal flow and evaluation of its efficiency

6.1 Survey of Canal Cross Section

The design cross section data of canals were collected from Office of Executive engineer Damodar head works division, Durgapur and Damodar irrigation circle, Bardhamann. A survery was also conducted to evaluate post construction cross section scenario in left bank main canal and Panagarh branch canal. The location of various hydraulic stuctures, outlets were also obtained during the survey. Figure 6.1 shows the location of regulatory structures, syphons, pipe outlets on left bank and right bank of left bank main canal(LBMC). Location of cross section data obtained during survey on left bank main canal(LBMC)is shown in Figure 6.2.Cross section data were plotted on those locations which are shown in Figure 6.3 to 6.21. Location of cross section data obtained during survey on Panagarh branch canal is shown in Figure 6.22.Corresponding cross section data were plotted which are shown in Figure 6.23 to 6.35. The degisn cross section data collected from Office of Executive engineer Damodar head works division, Durgapur and Damodar irrigation circle, Bardhamann are given in Table 6.1 to Table 6.191.

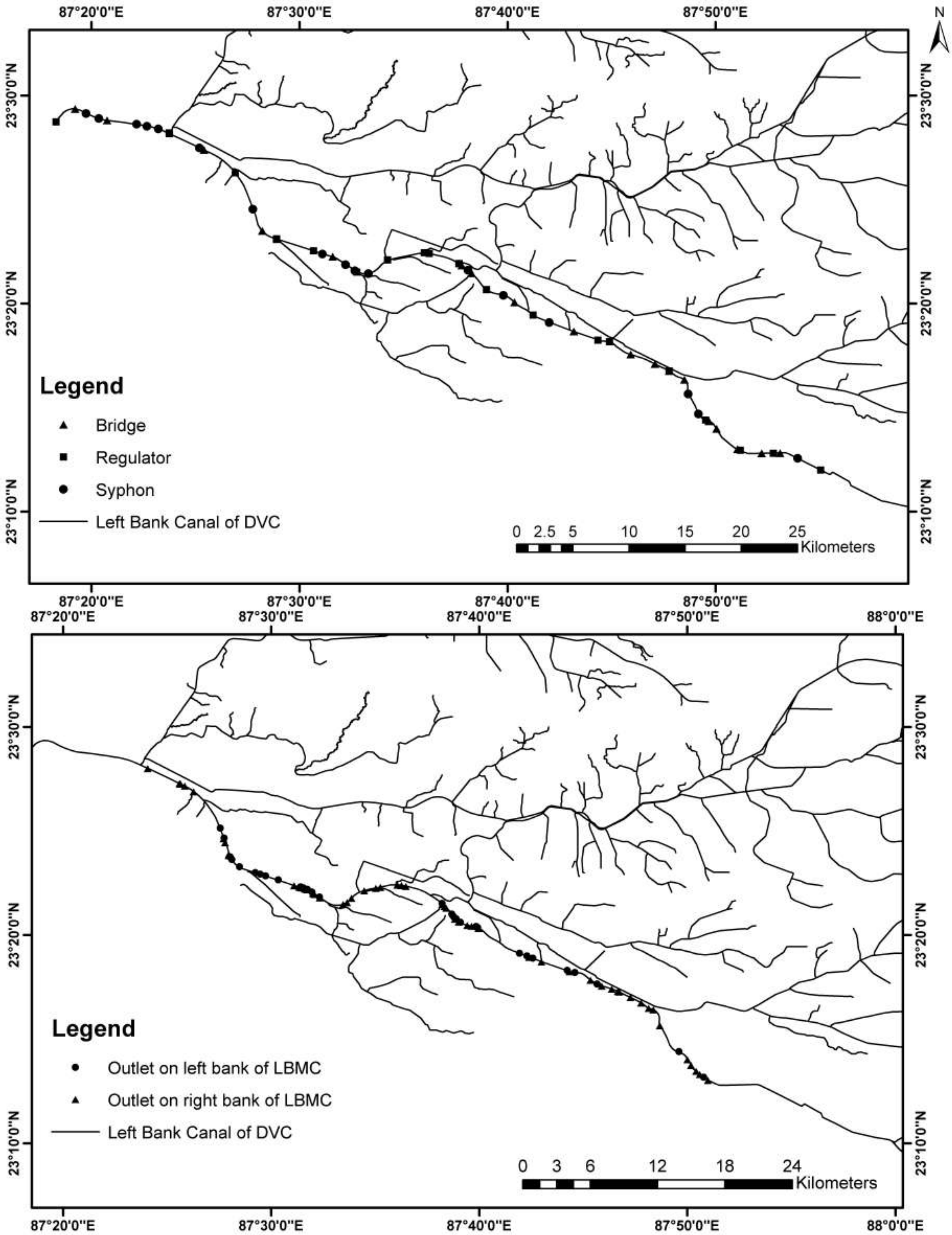


Figure 6.1: Location of Different Structures on Left Bank Main Canal

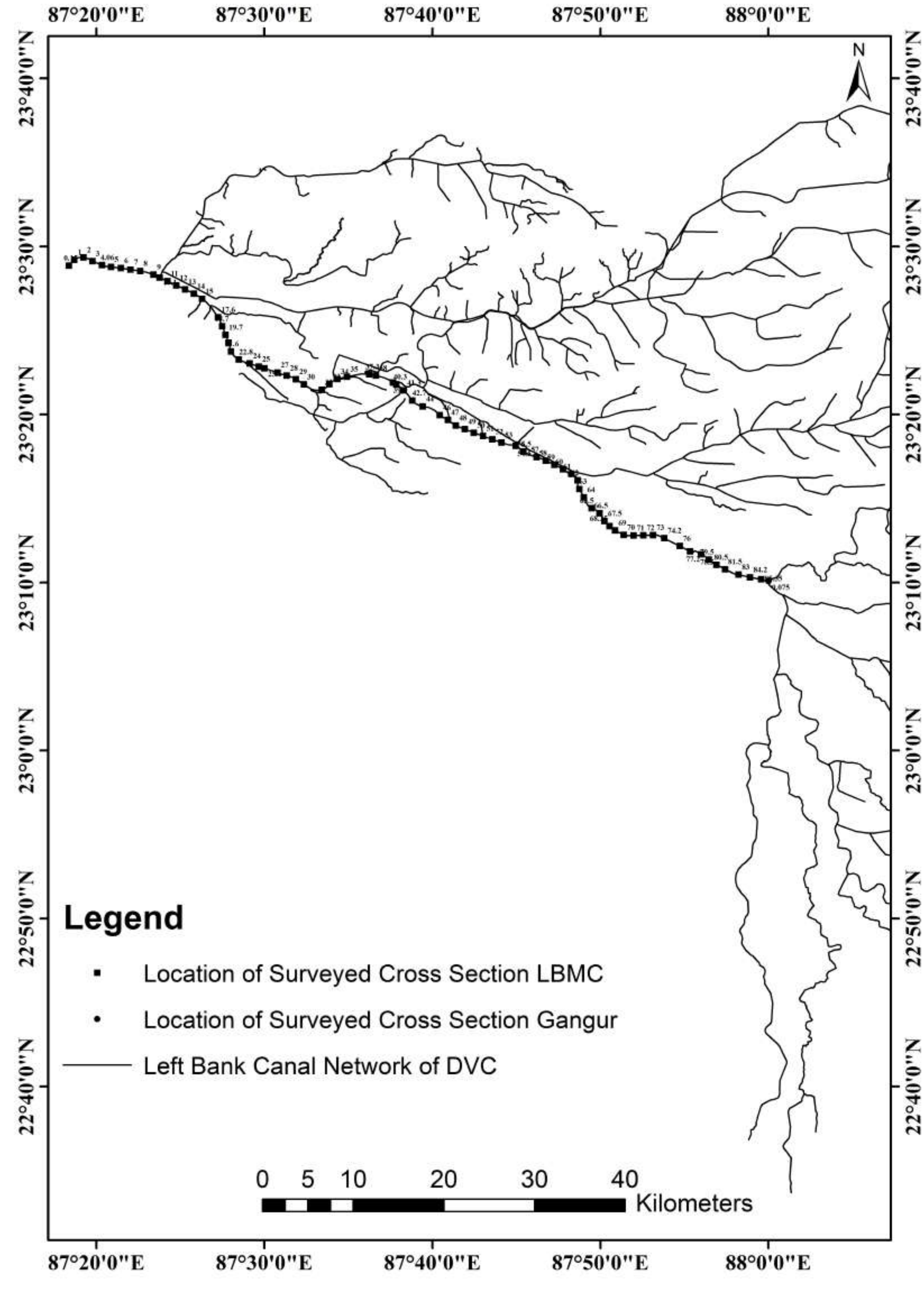


Figure 6.2: Location of surveyed cross section level on Left Bank Main Canal

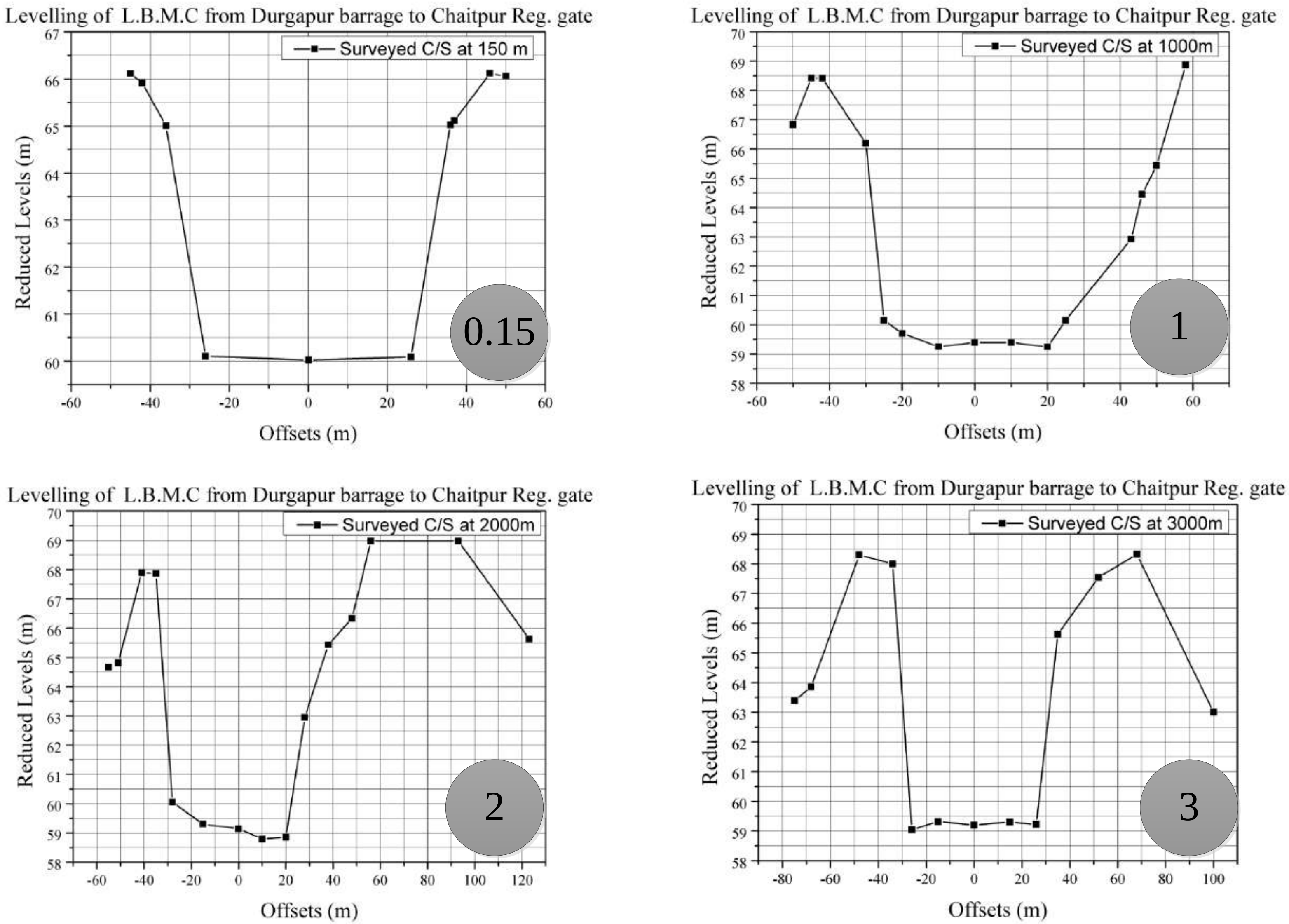


Figure 6.3: Canal cross section from 0.15 km to 3 km on Left Bank Main Canal

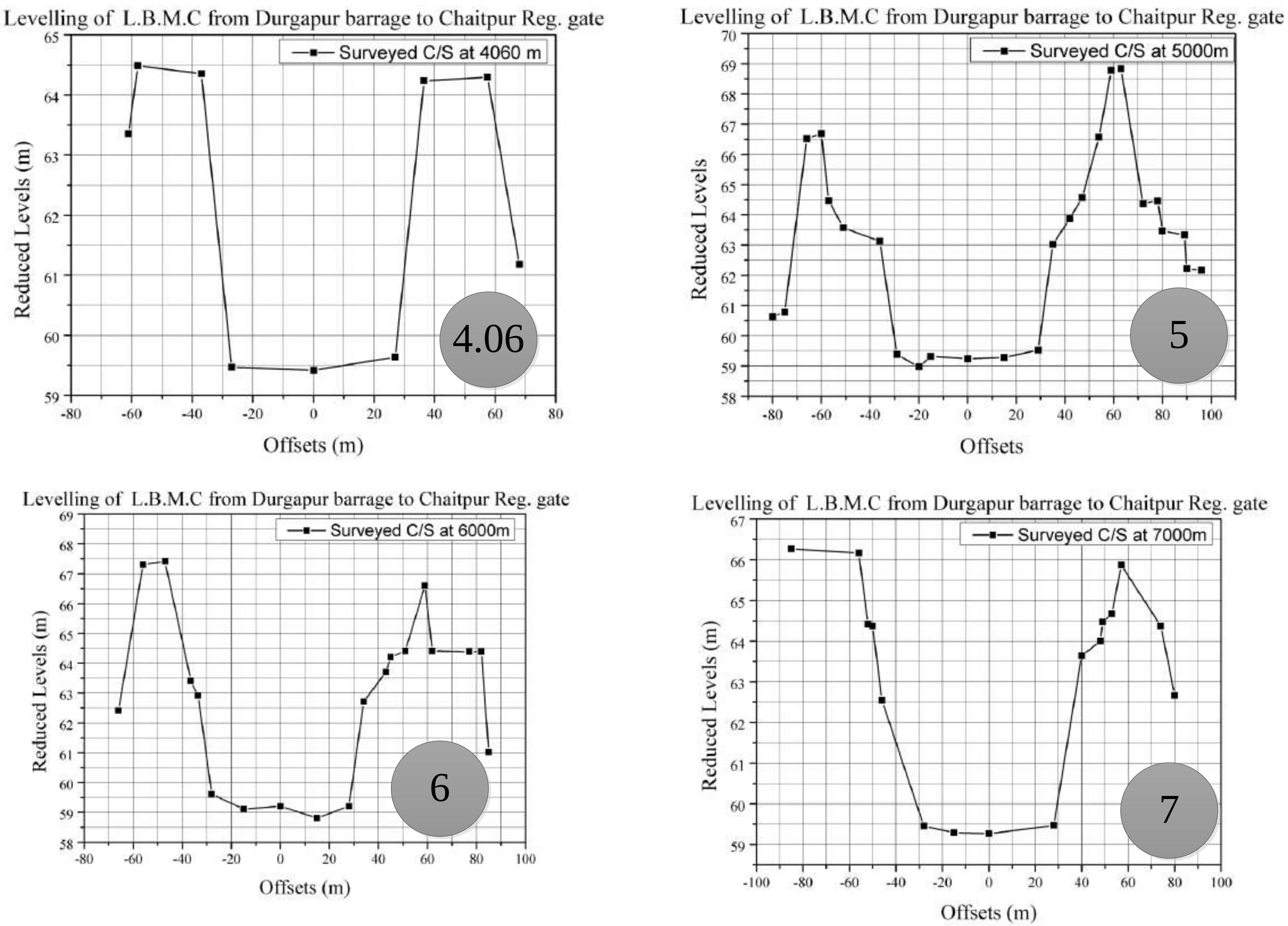


Figure 6.4: Canal cross section from 4.06 km to 7 km on Left Bank Main Canal

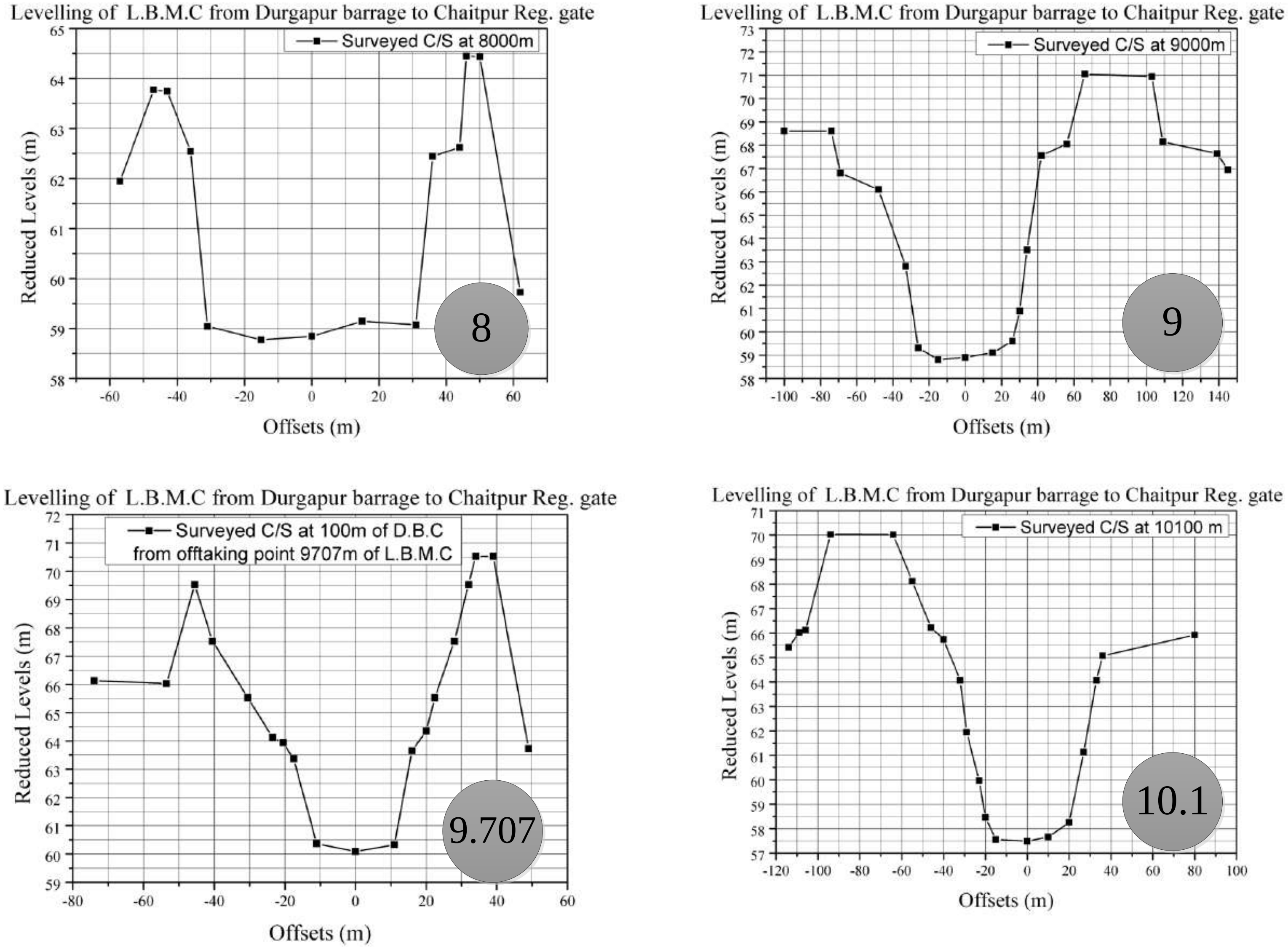


Figure 6.5: Canal cross section from 8 km to 10.1 km on Left Bank Main Canal

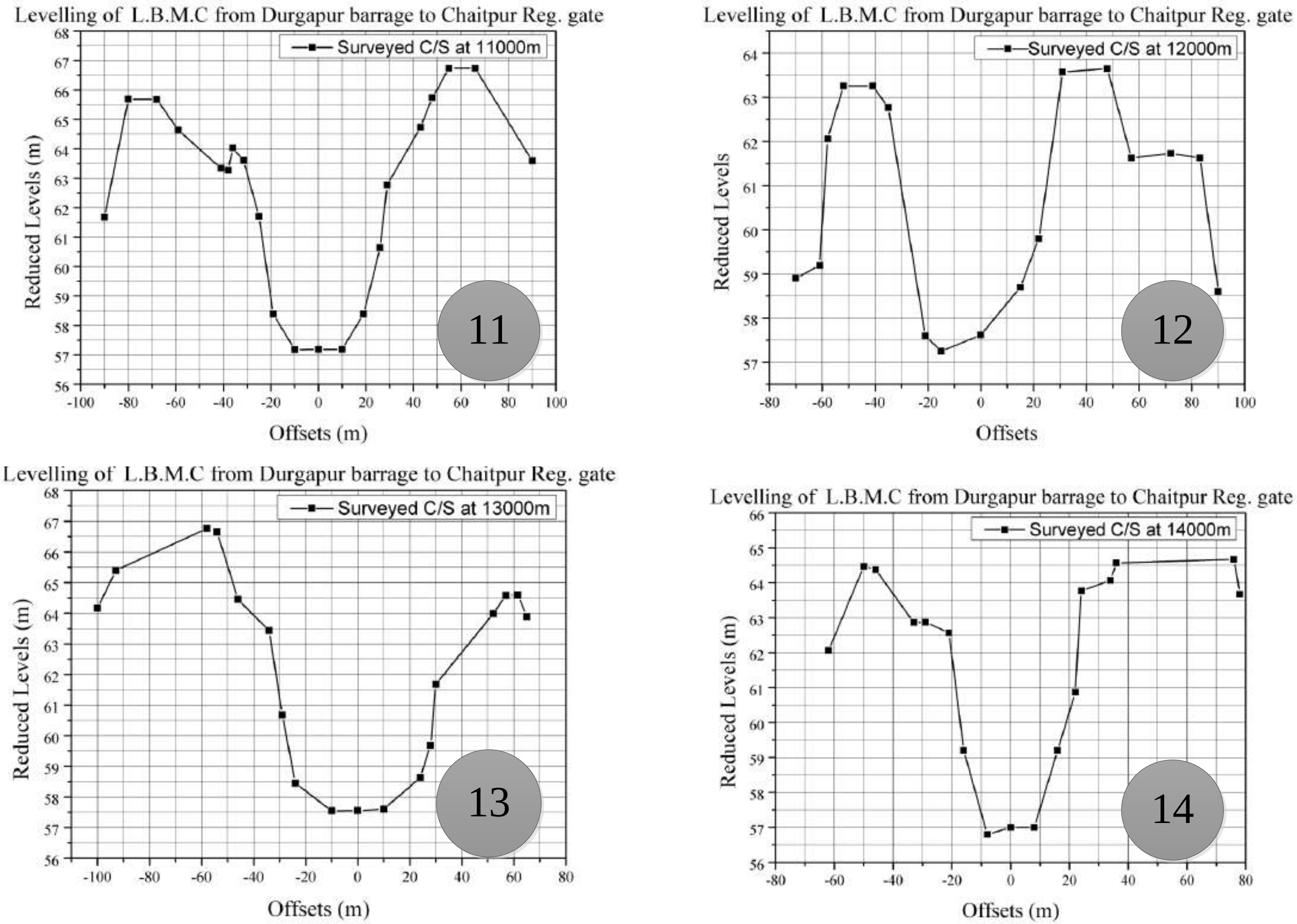


Figure 6.6: Canal cross section from 11 km to 14 km on Left Bank Main Canal

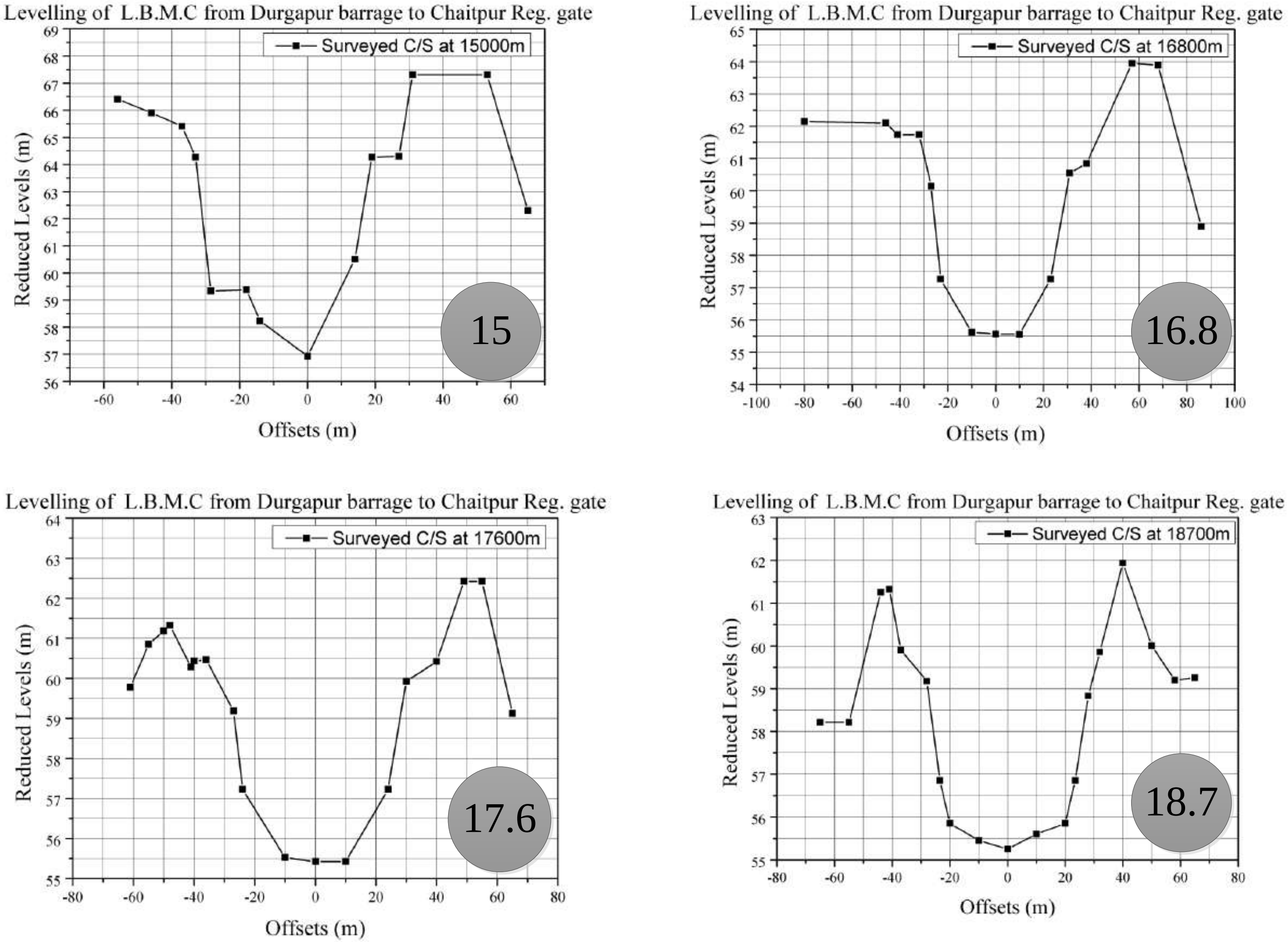


Figure 6.7: Canal cross section from 15 km to 18.7 km on Left Bank Main Canal

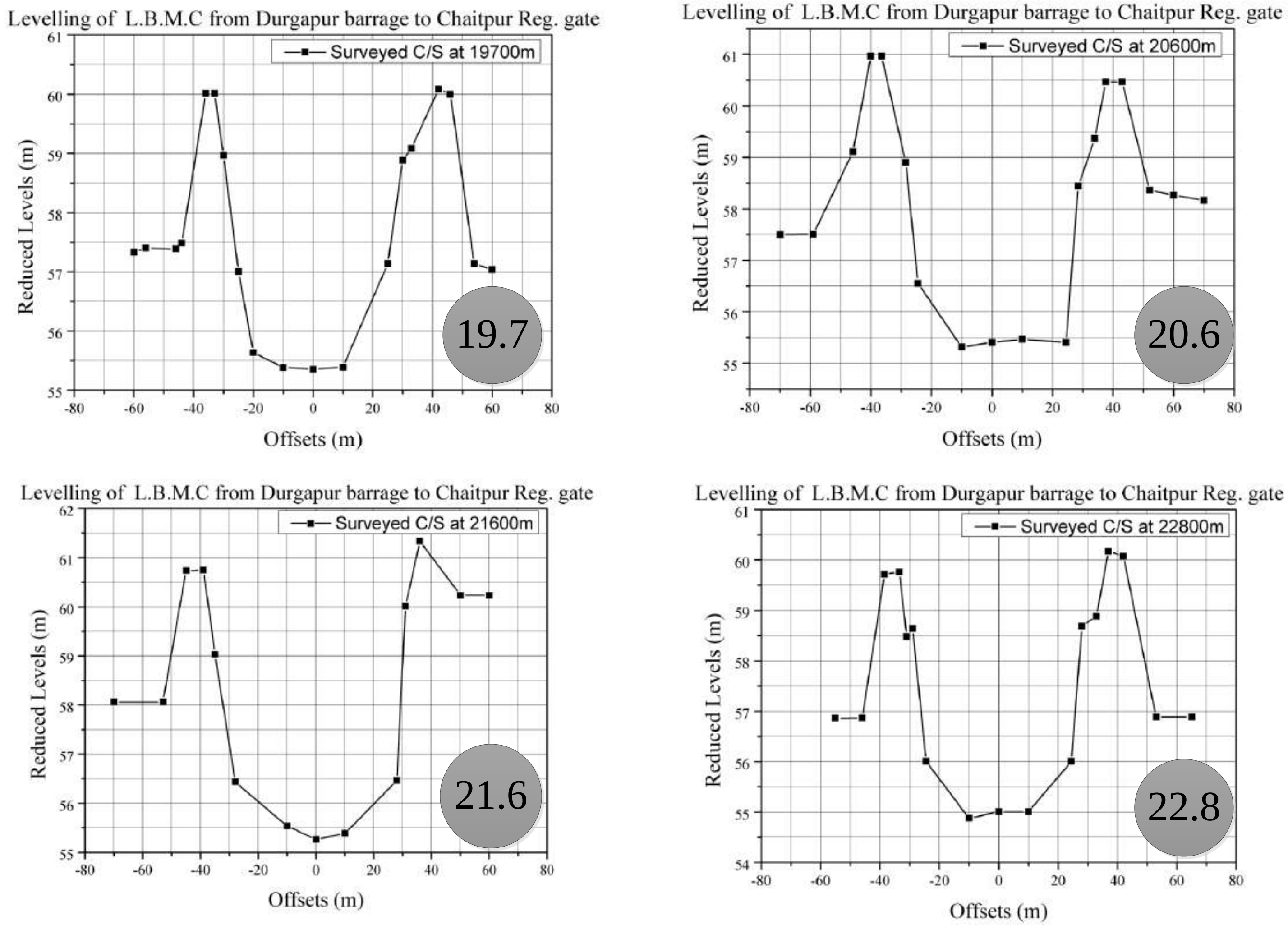


Figure 6.8: Canal cross section from 19.7 km to 22.8 km on Left Bank Main Canal

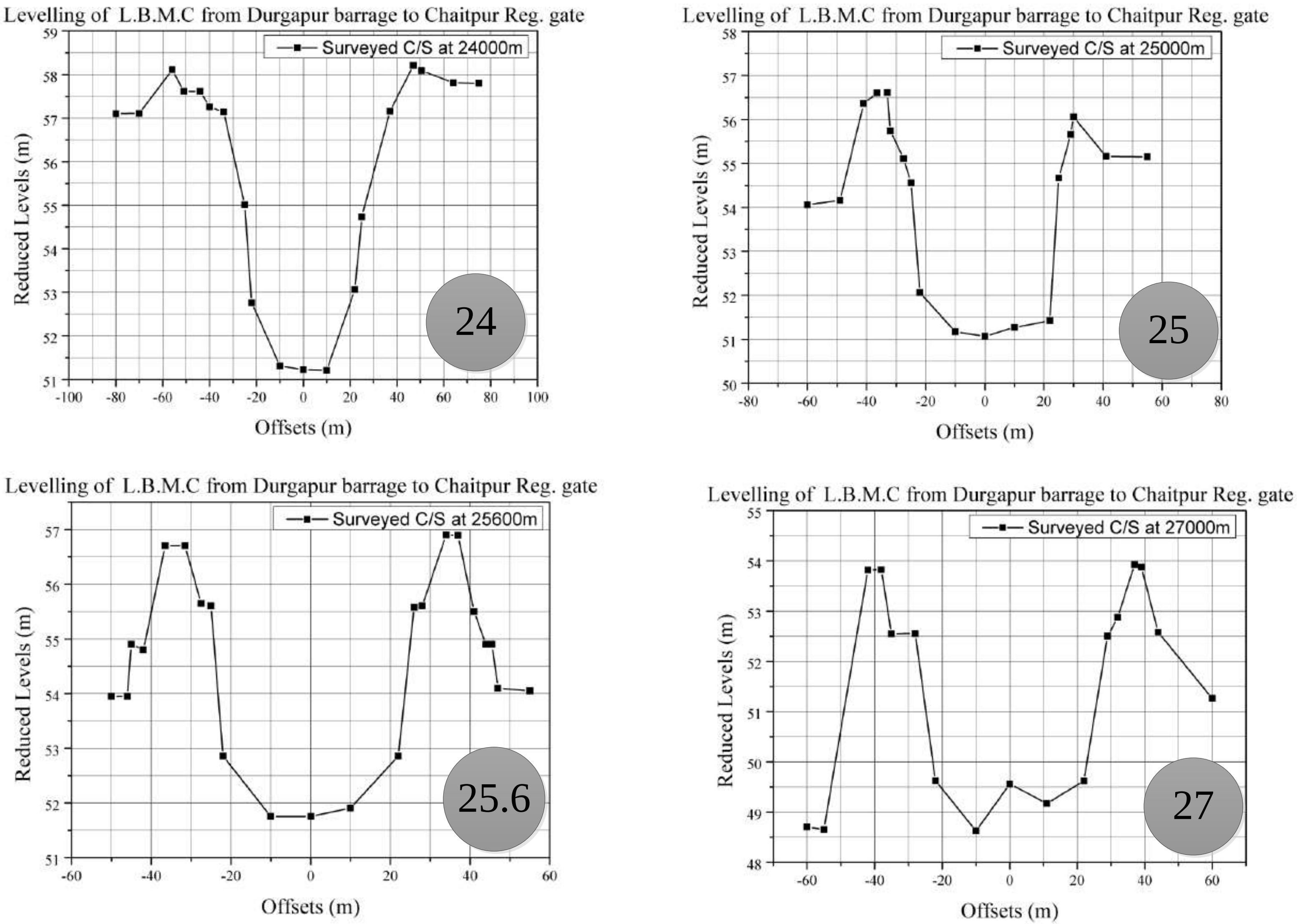


Figure 6.9: Canal cross section from 24 km to 27 km on Left Bank Main Canal

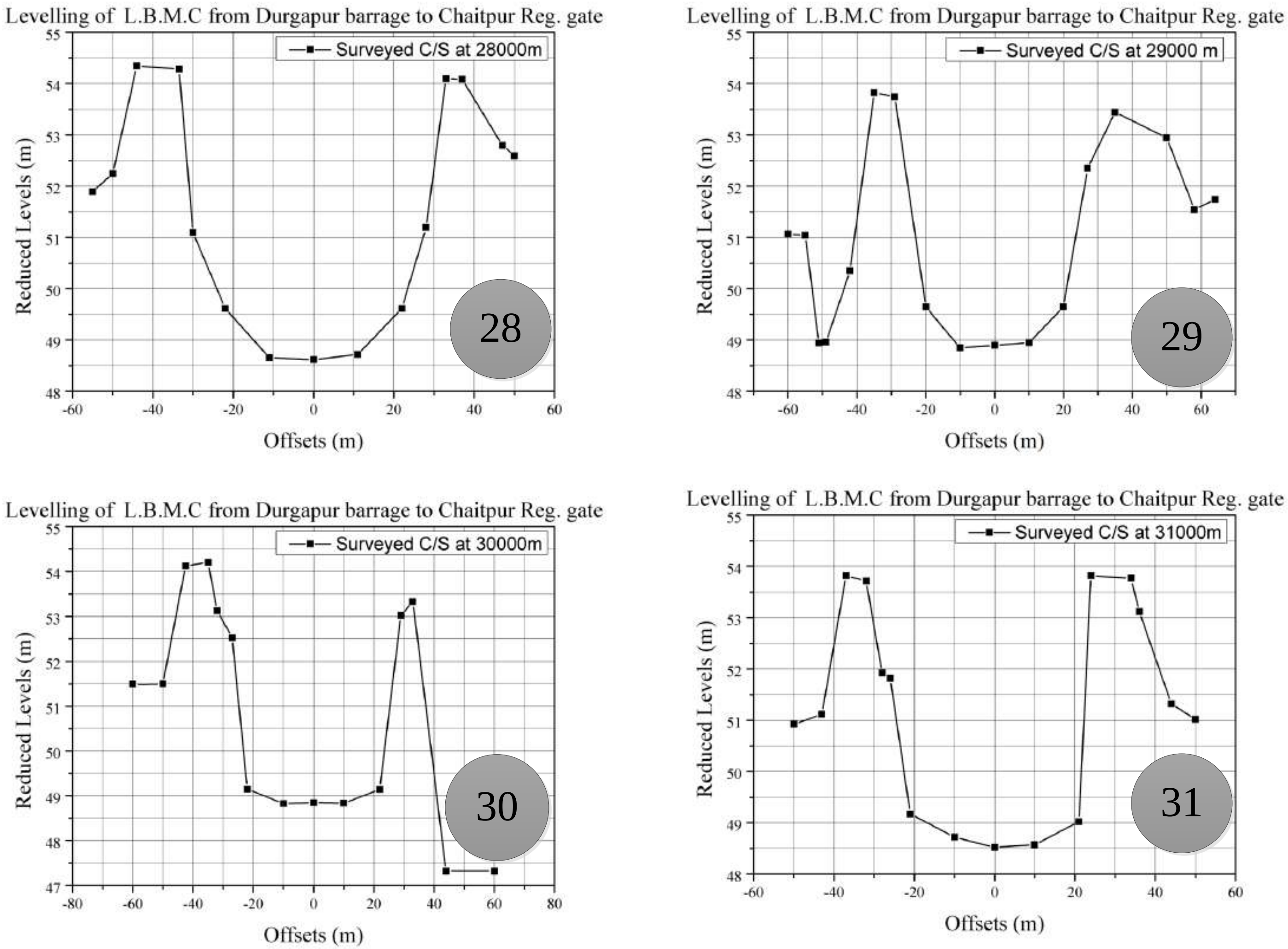


Figure 6.10: Canal cross section from 28 km to 31 km on Left Bank Main Canal

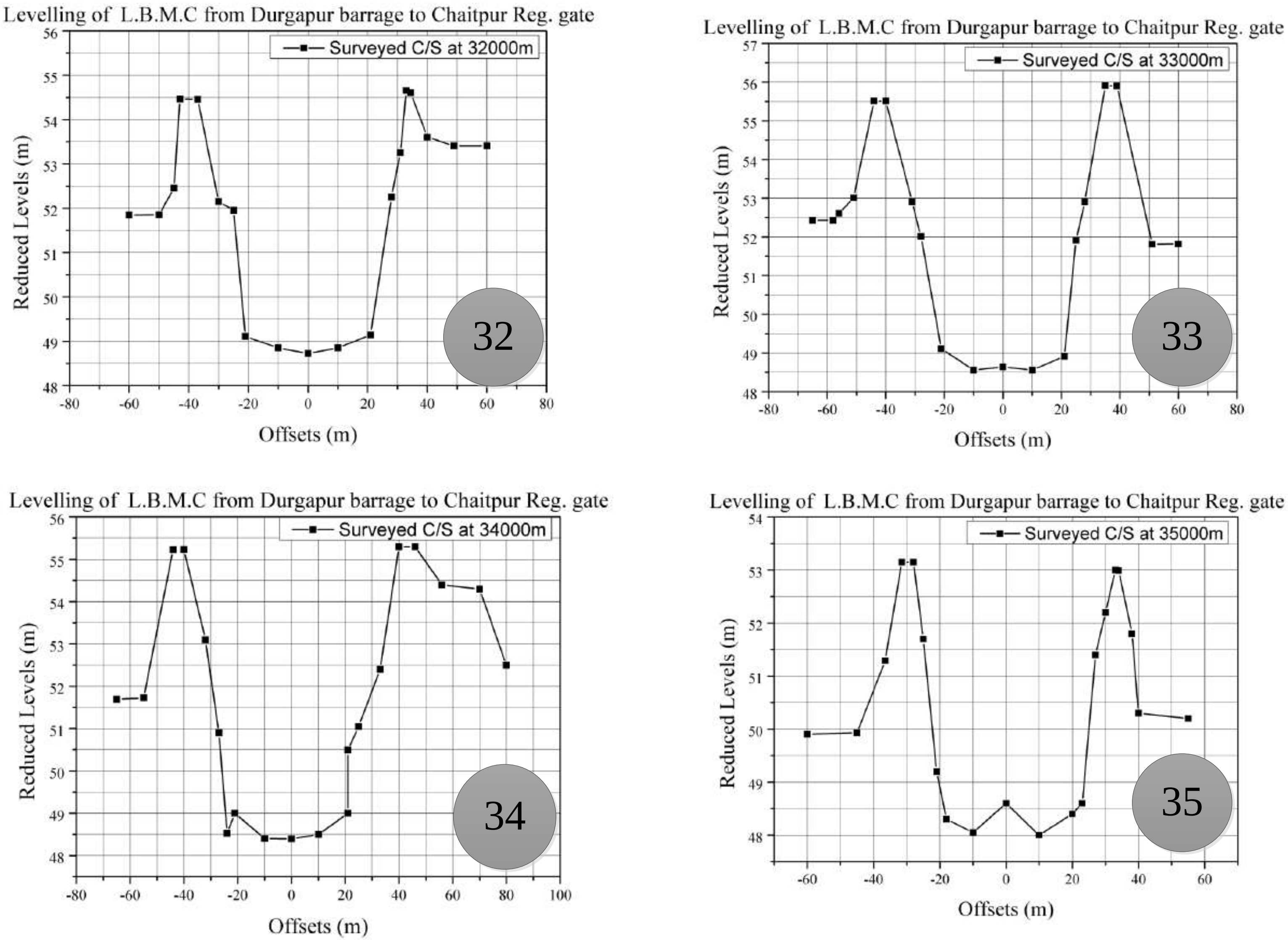


Figure 6.11: Canal cross section from 32 km to 35 km on Left Bank Main Canal

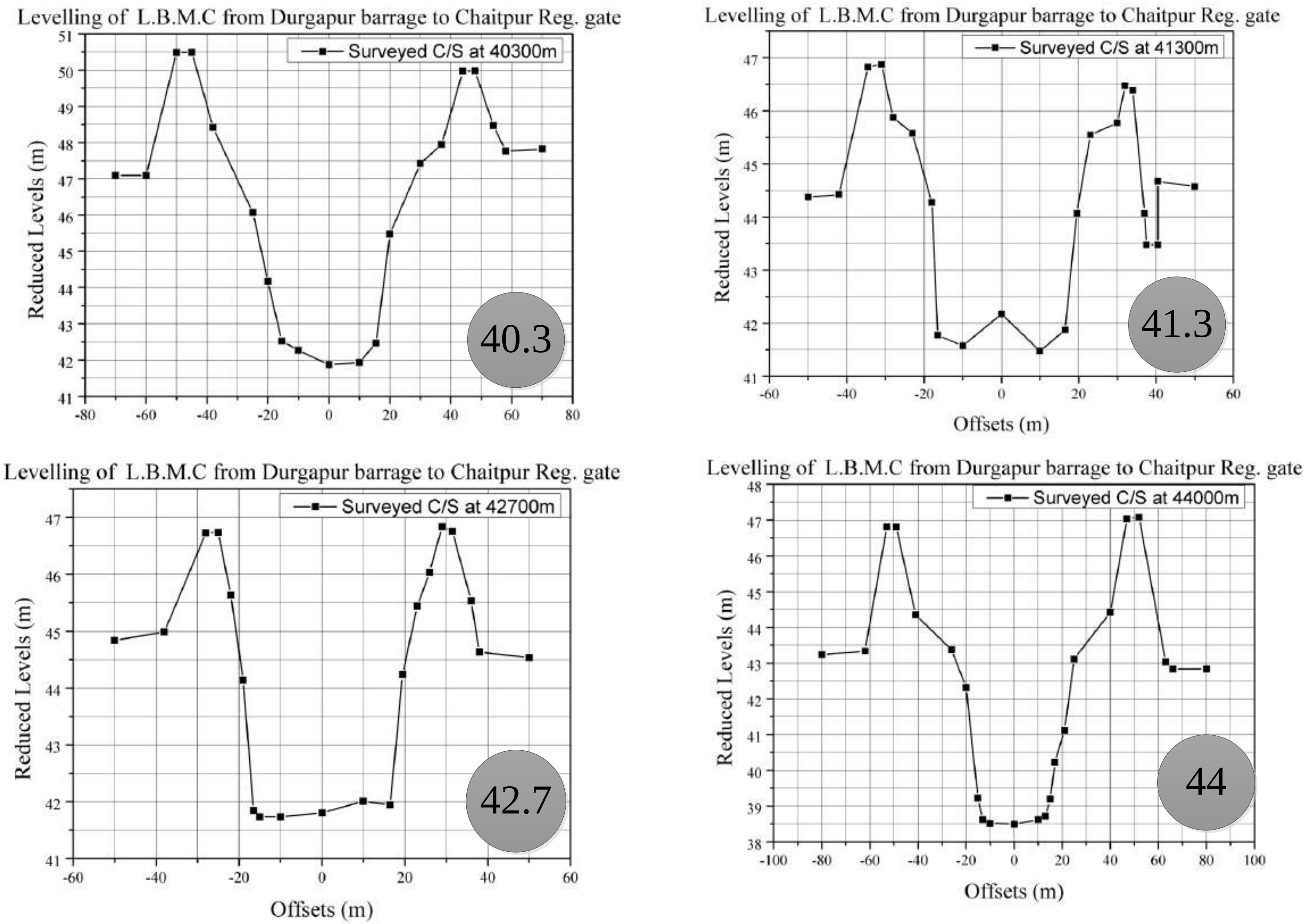


Figure 6.12: Canal cross section from 40.3 km to 44 km on Left Bank Main Canal

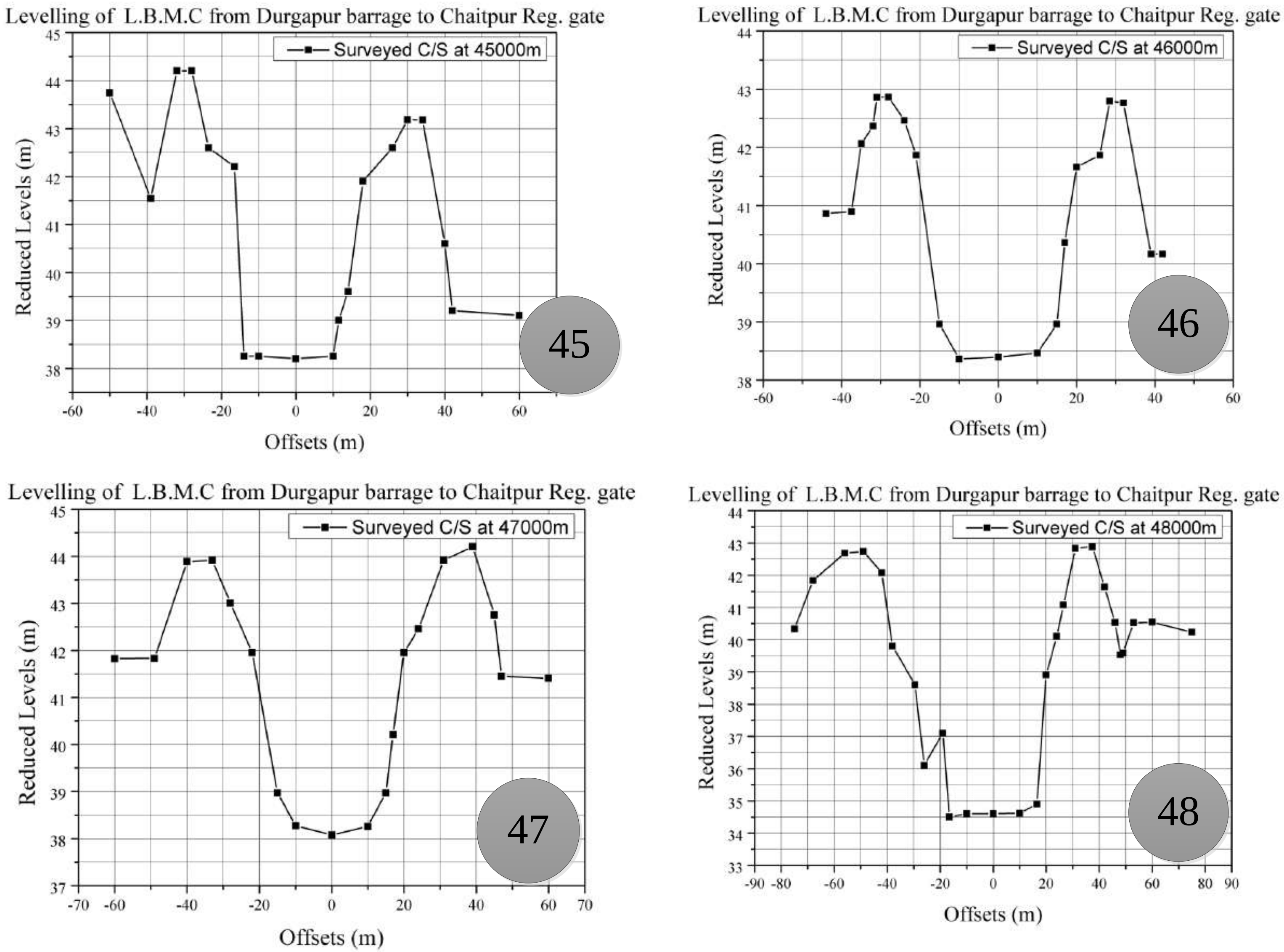


Figure 6.13: Canal cross section from 45 km to 48 km on Left Bank Main Canal

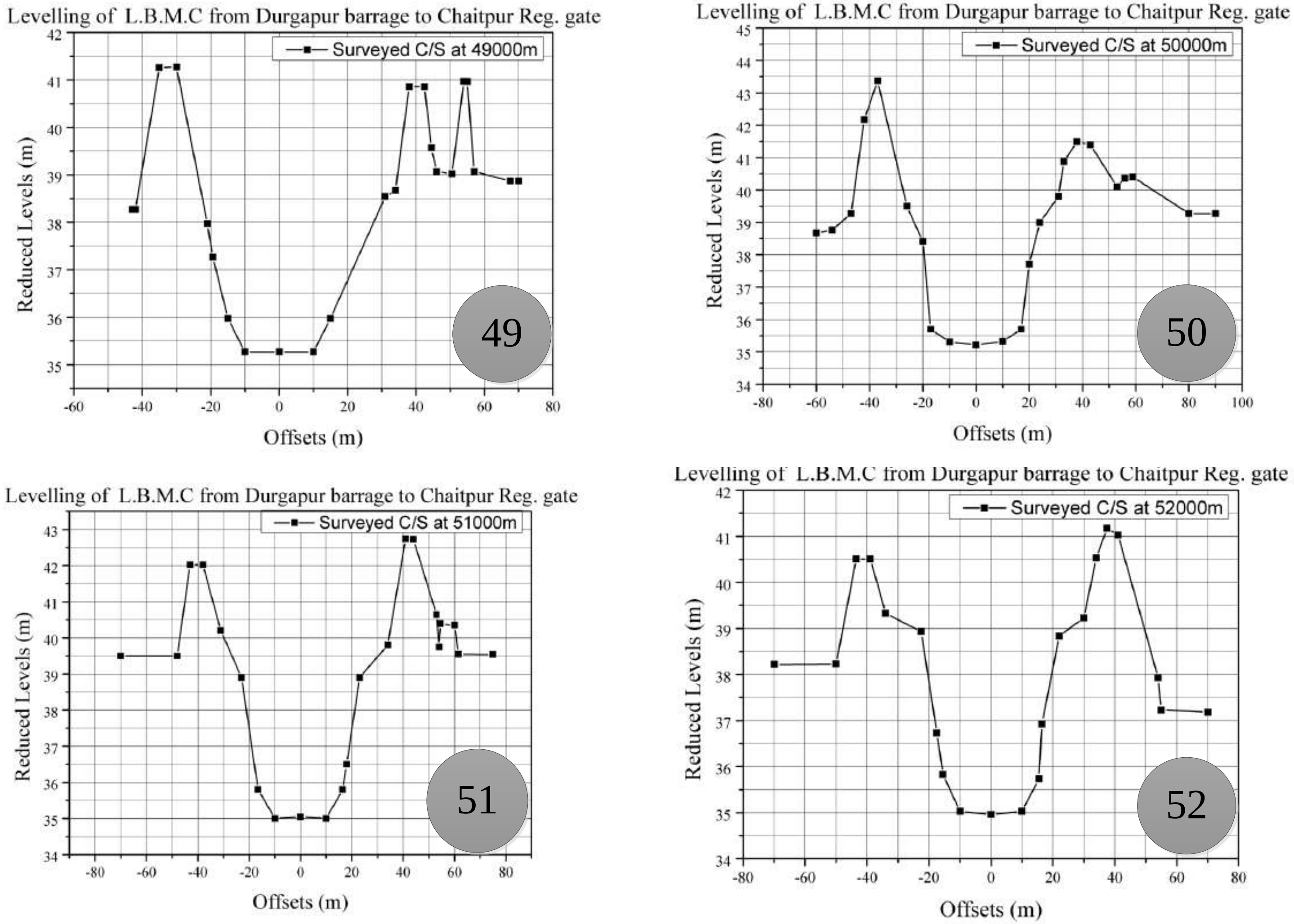


Figure 6.14: Canal cross section from 49 km to 52 km on Left Bank Main Canal

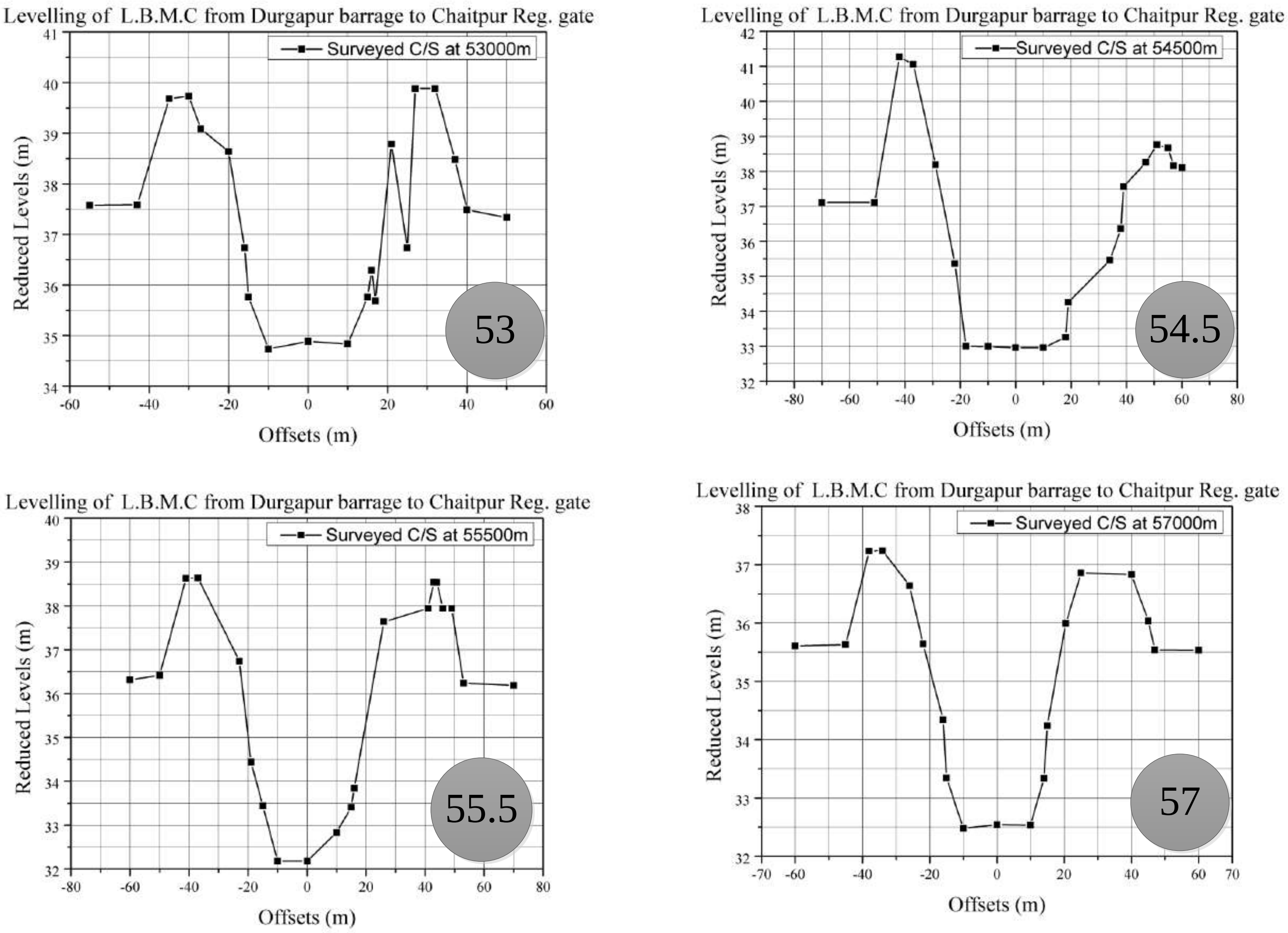


Figure 6.15: Canal cross section from 53 km to 57 km on Left Bank Main Canal

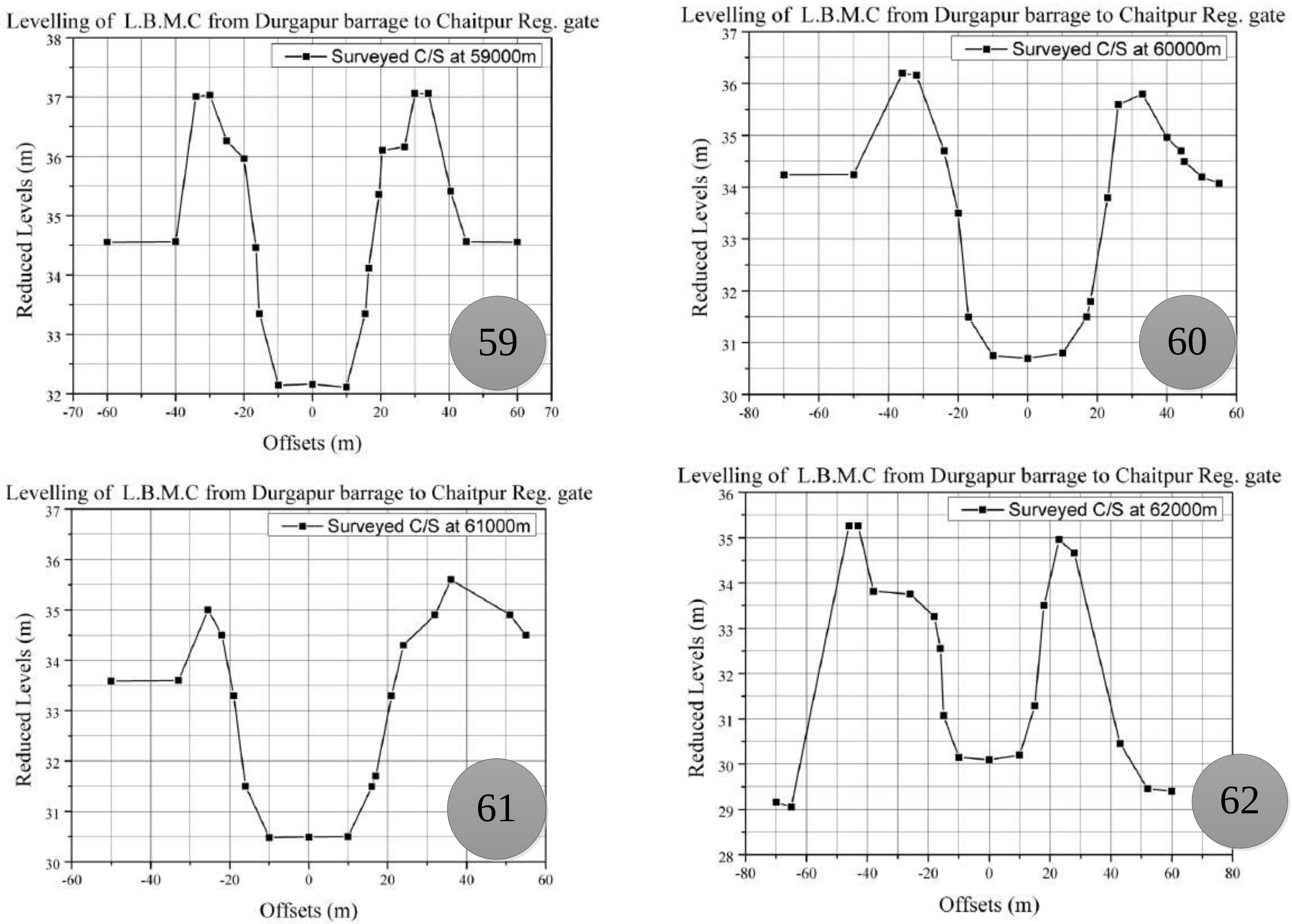


Figure 6.16: Canal cross section from 59 km to 62 km on Left Bank Main Canal

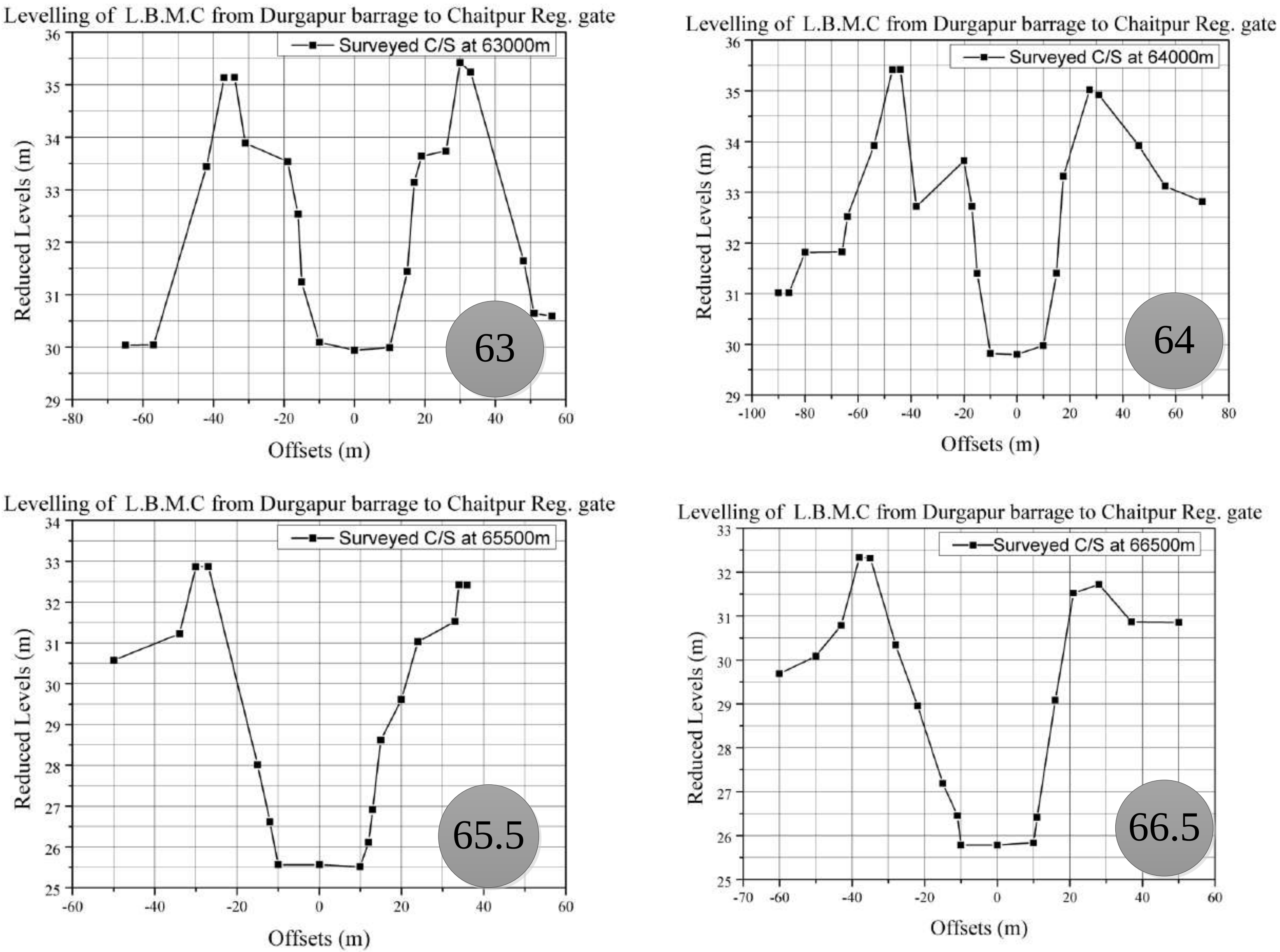


Figure 6.17: Canal cross section from 63 km to 66.5 km on Left Bank Main Canal

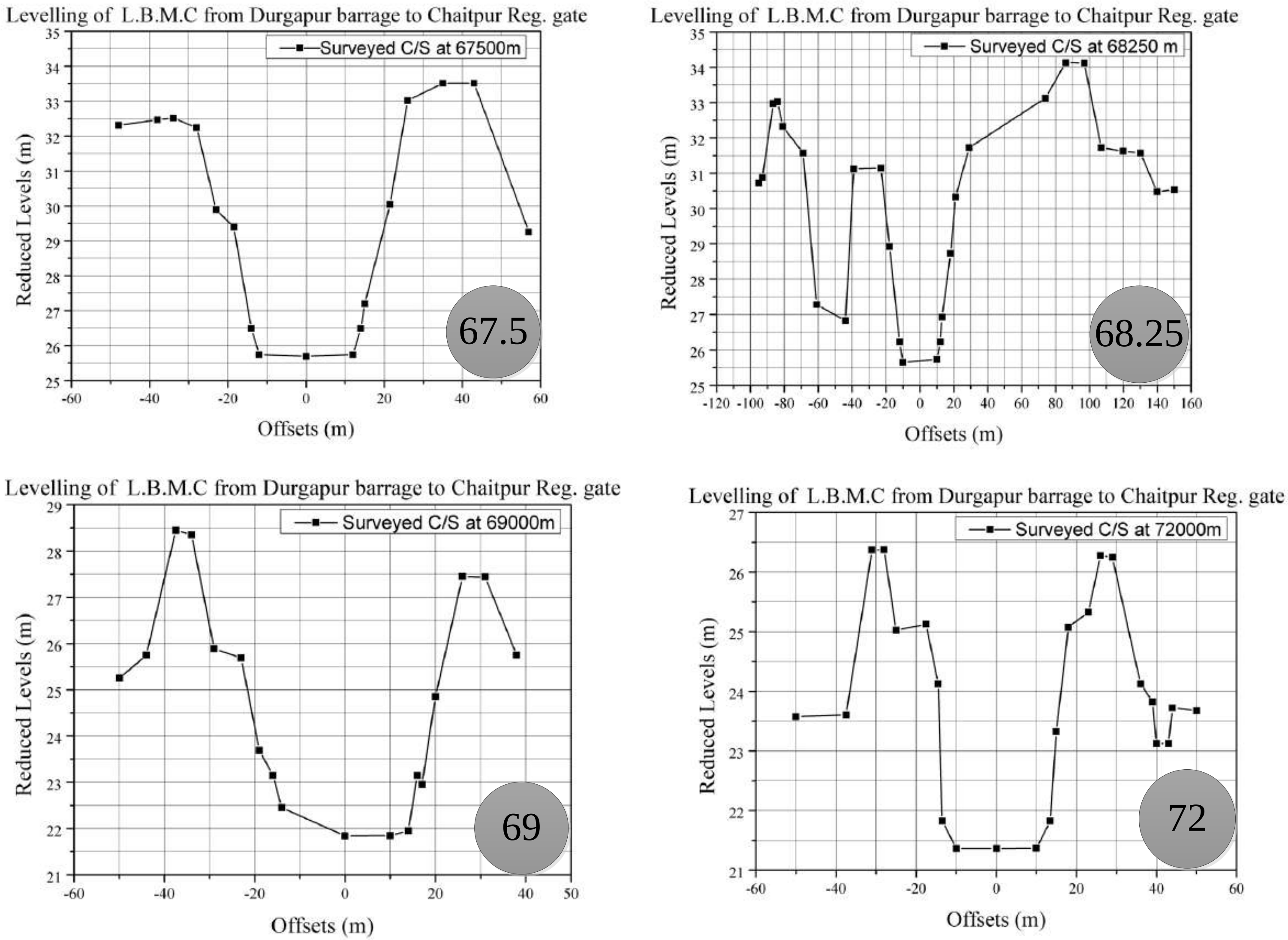


Figure 6.18: Canal cross section from 67.5 km to 72 km on Left Bank Main Canal

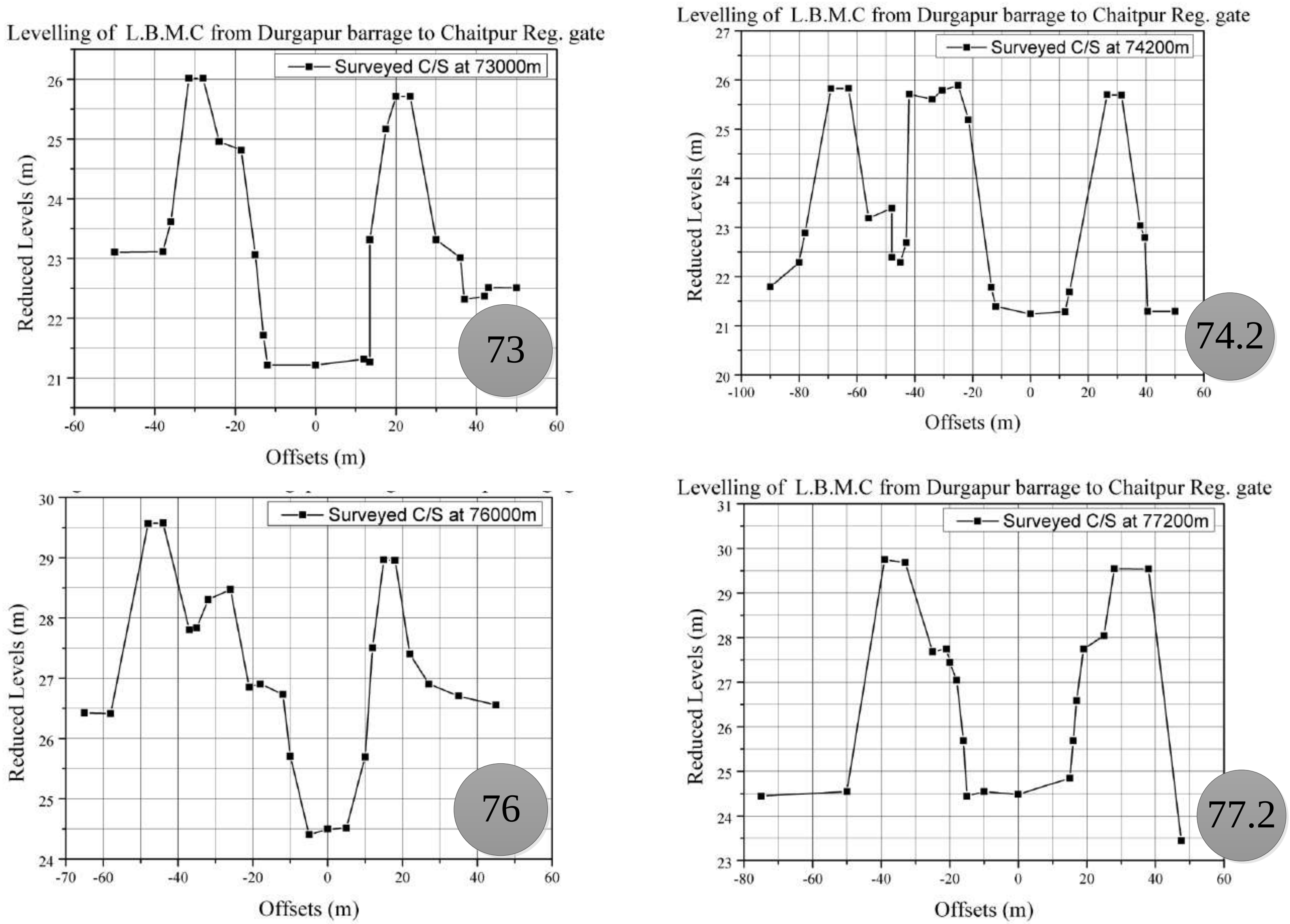


Figure 6.19: Canal cross section from 73 km to 77.2 km on Left Bank Main Canal

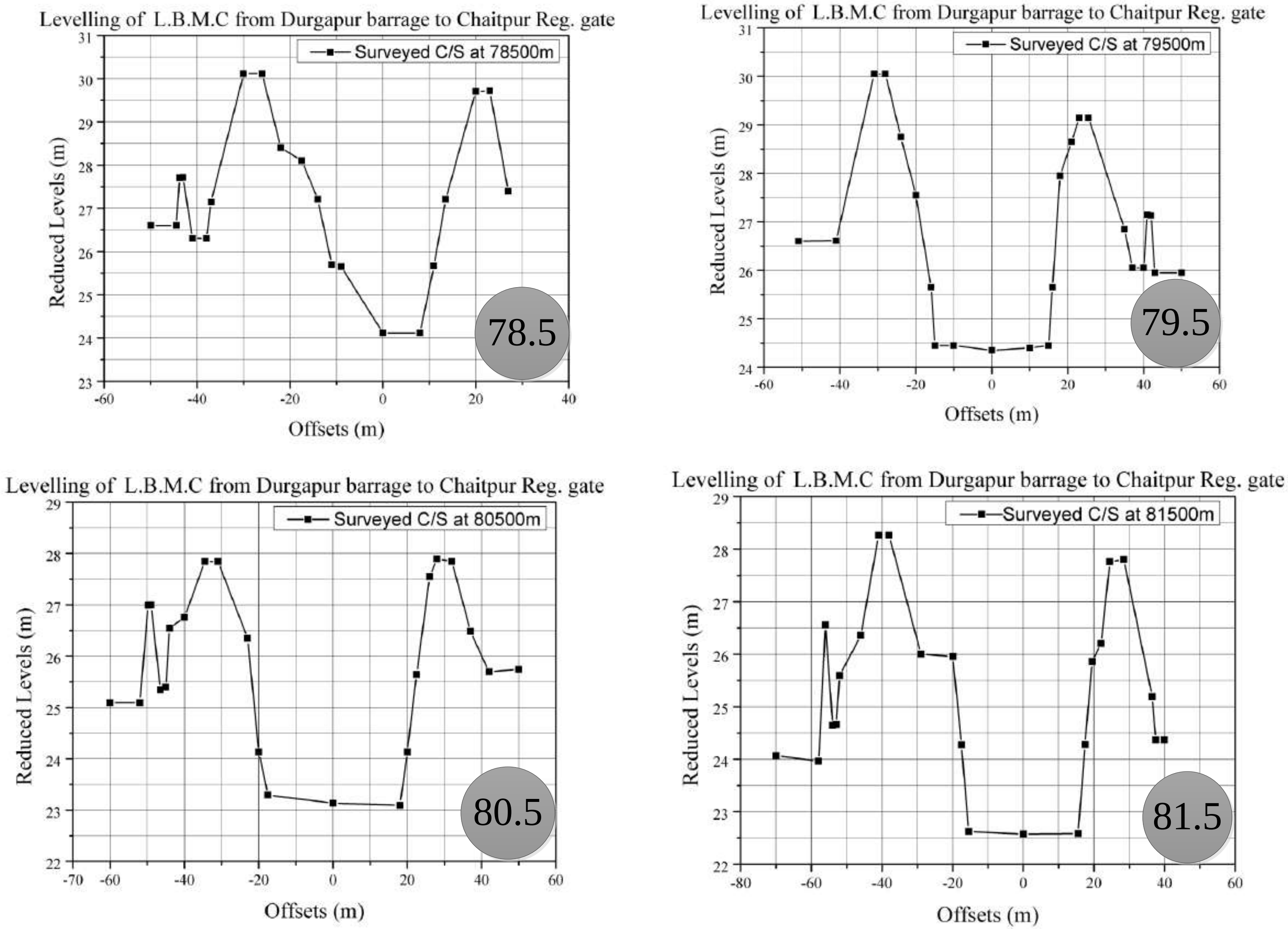


Figure 6.20: Canal cross section from 78.5 km to 81.5 km on Left Bank Main Canal

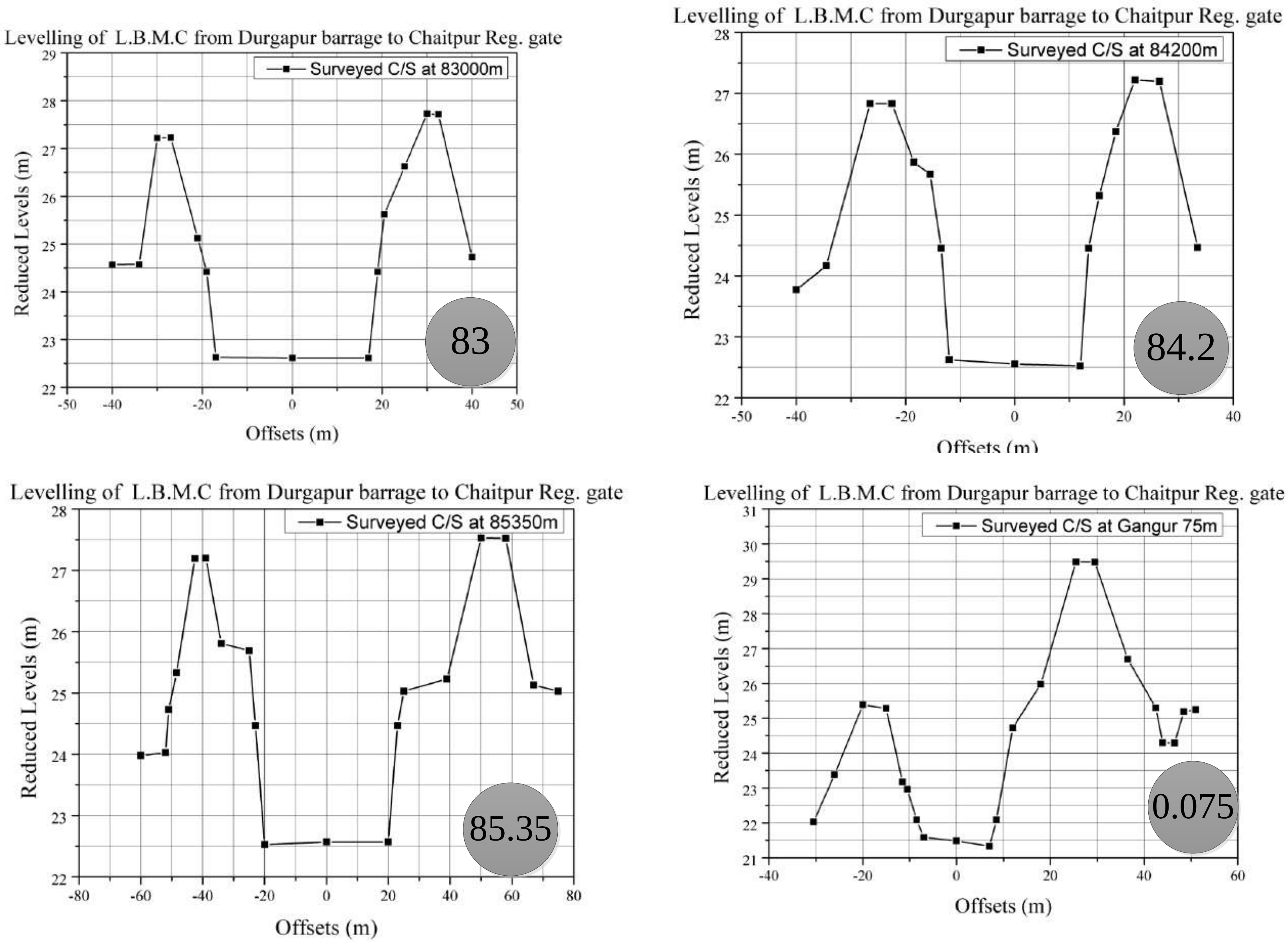


Figure 6.21: Canal cross section from 83 km on Left Bank Main Canal to 0.075 km on Gangur Canal

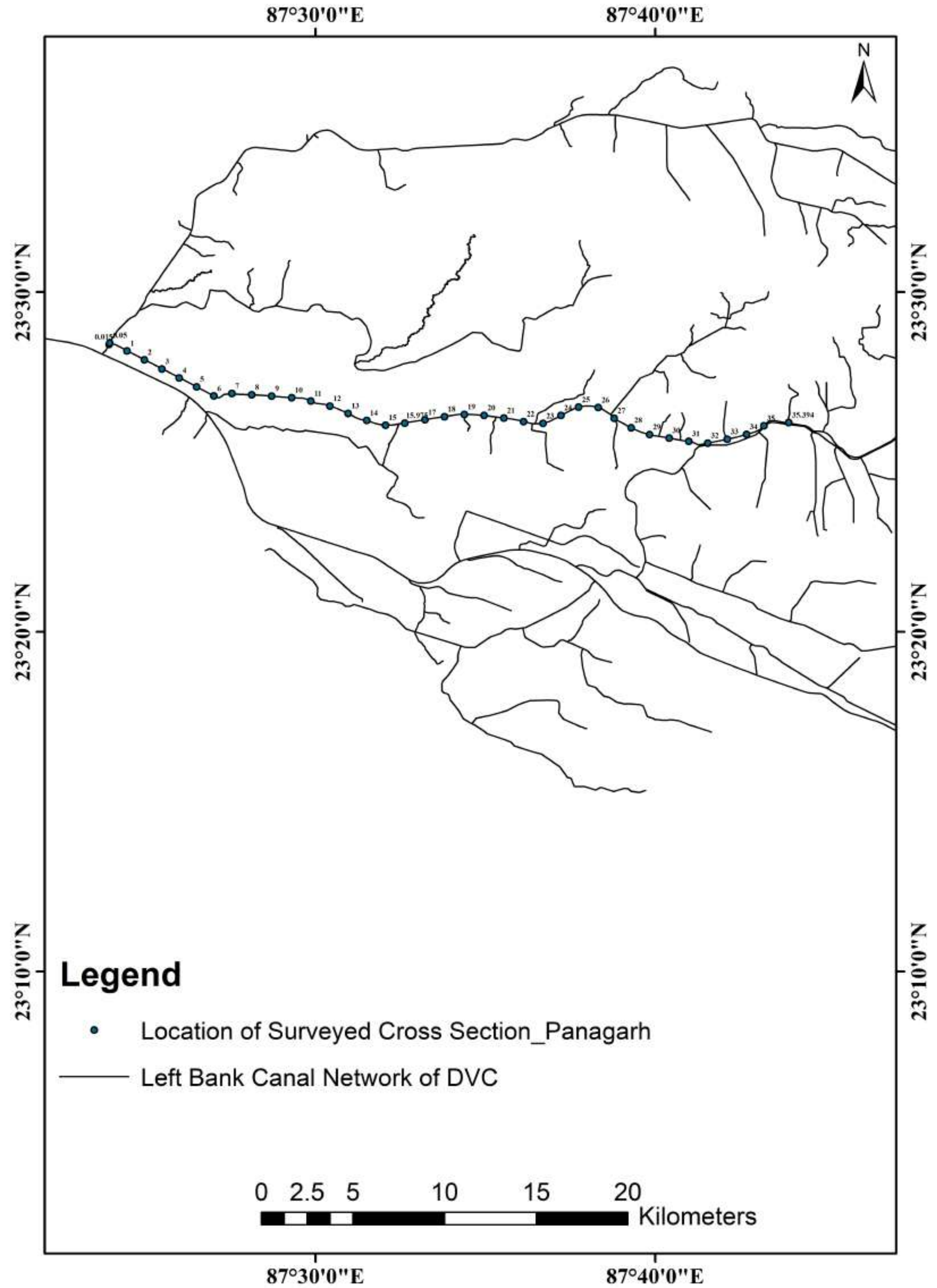


Figure 6.22: Location of surveyed cross section level on Panagarh Branch Canal

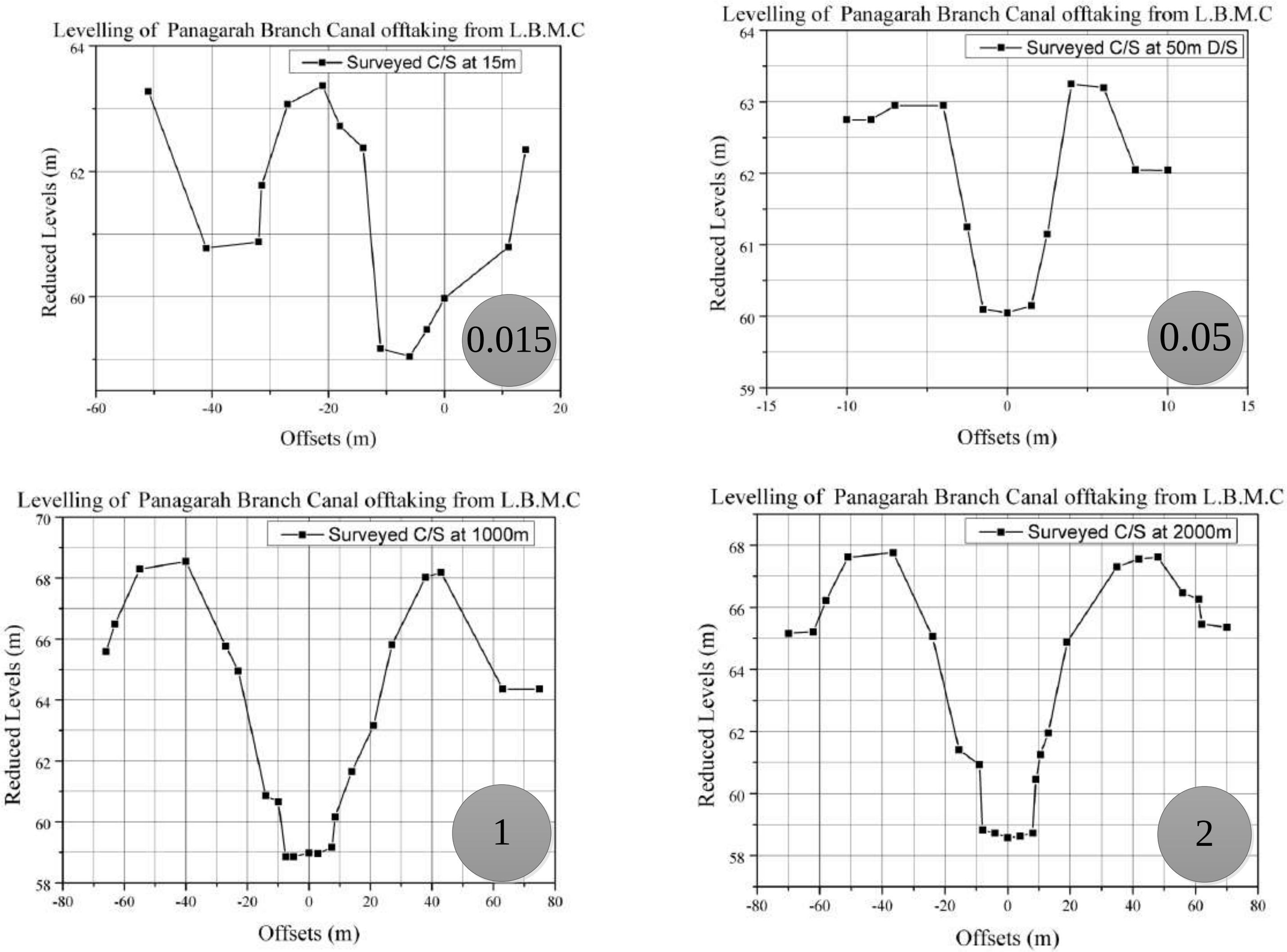


Figure 6.23: Canal cross section from 0.015 km to 2 km on Panagarh branch canal

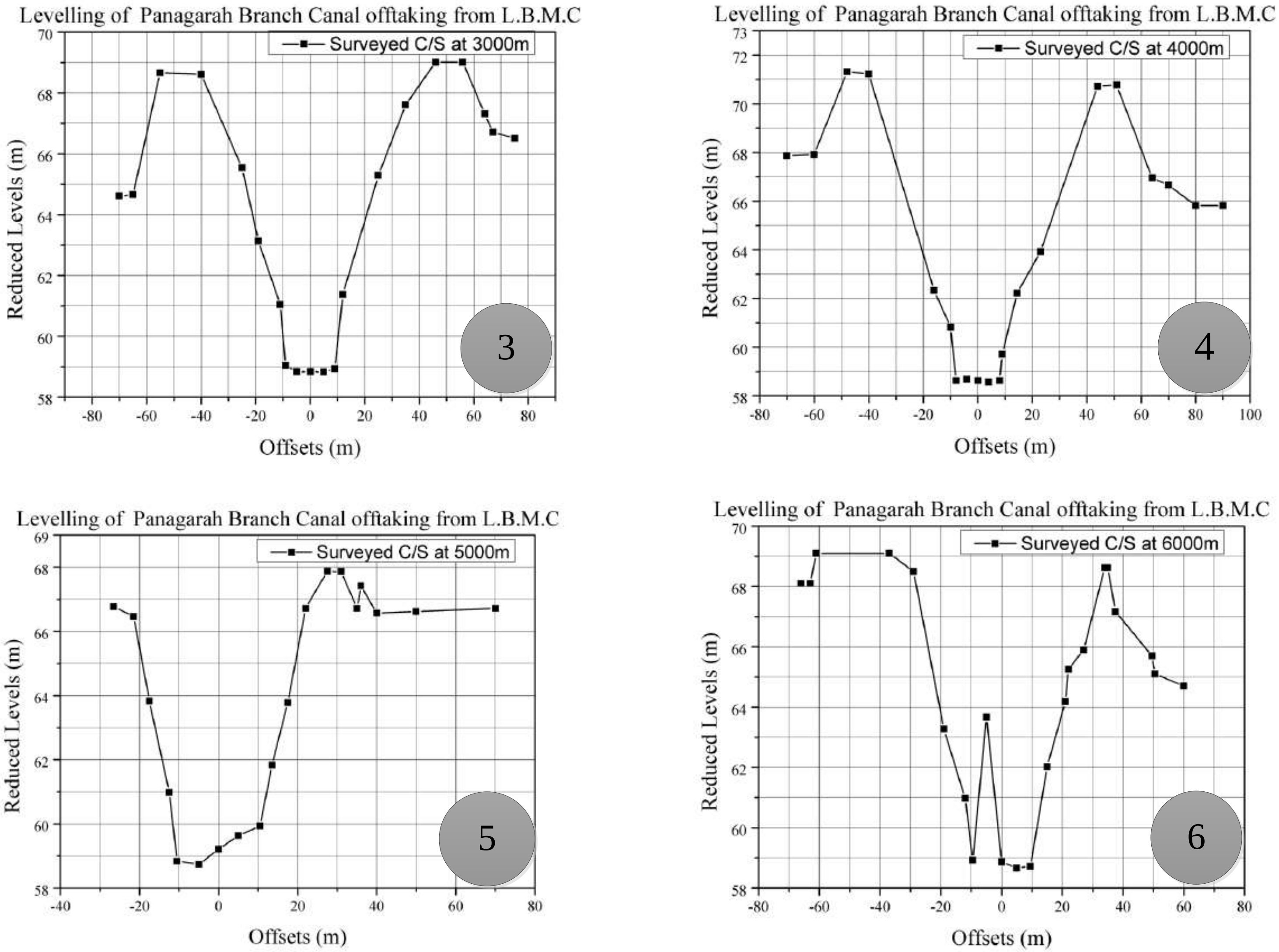


Figure 6.24: Canal cross section from 3 km to 6 km on Panagarh branch canal

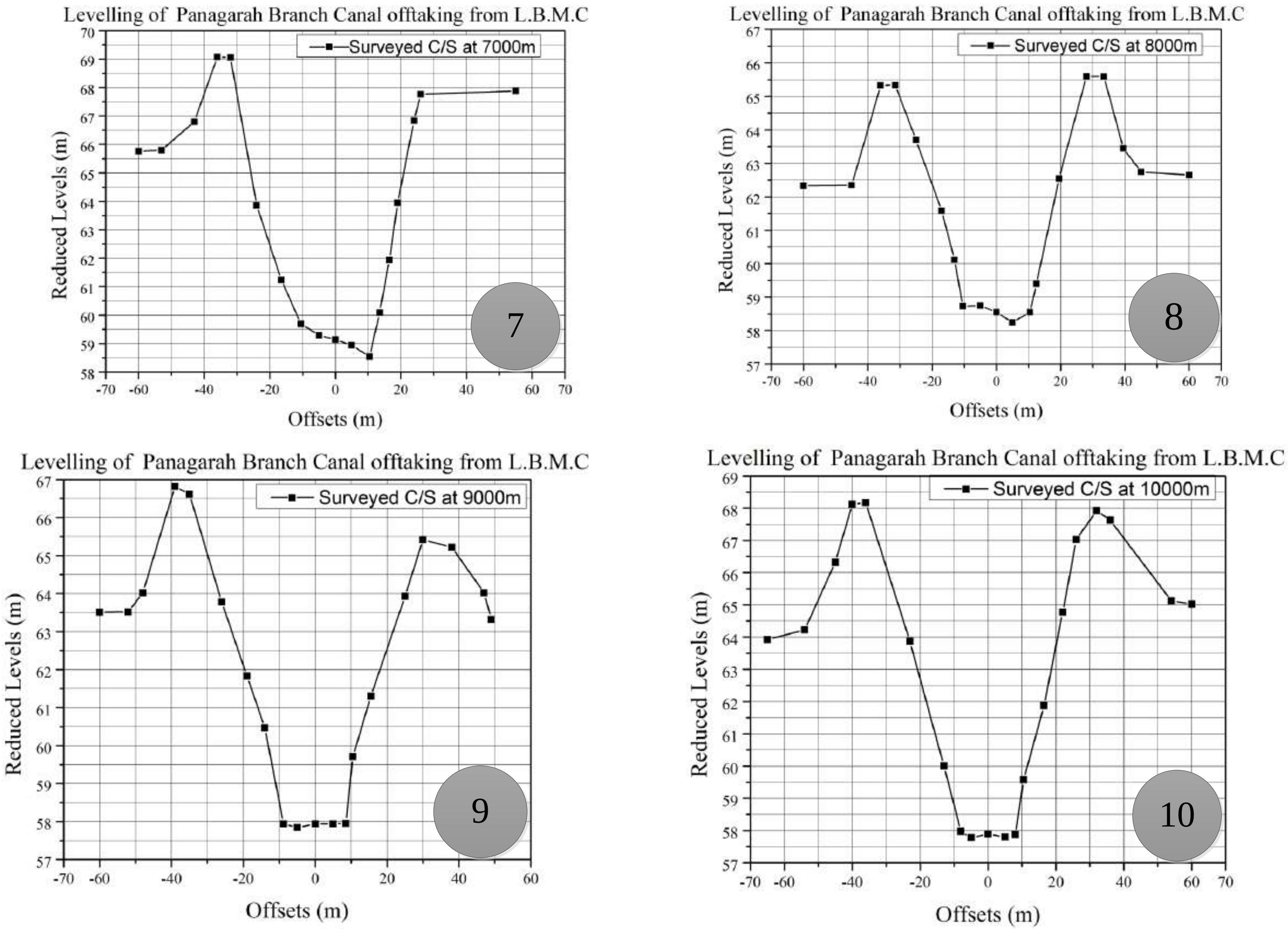


Figure 6.25: Canal cross section from 7 km to 10 km on Panagarh branch canal

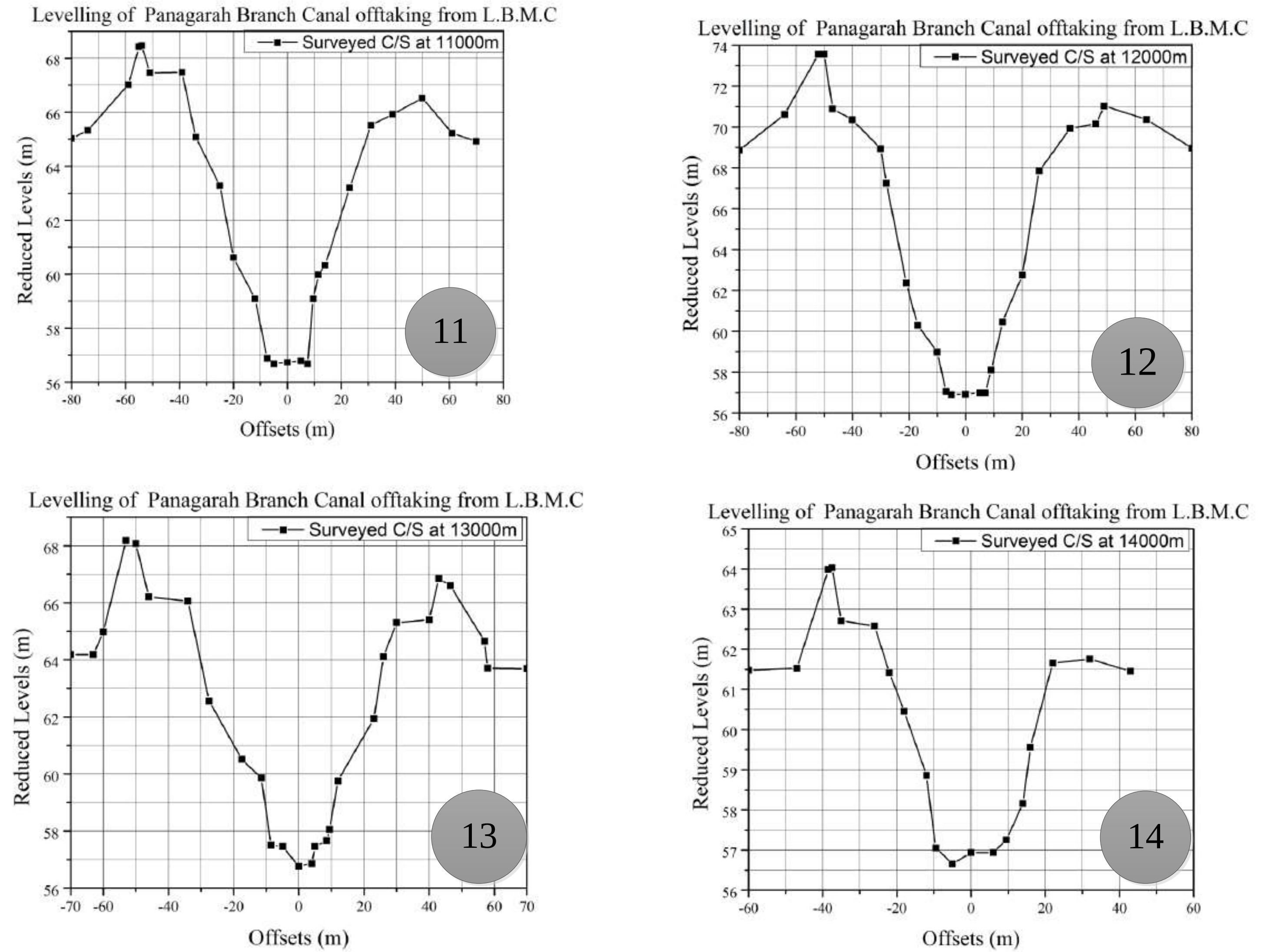


Figure 6.26: Canal cross section from 11 km to 14 km on Panagarh branch canal

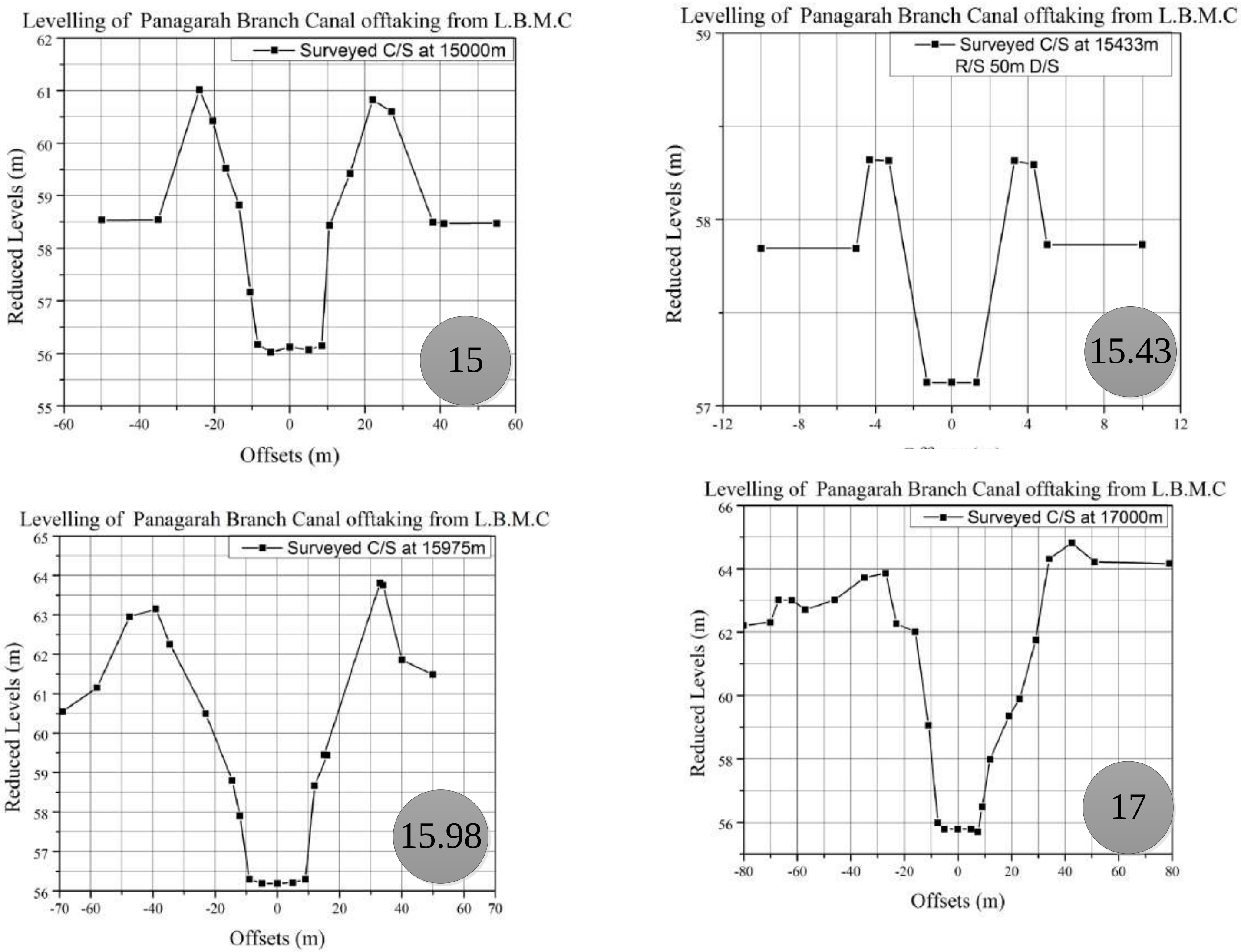


Figure 6.27: Canal cross section from 15 km to 17 km on Panagarh branch canal

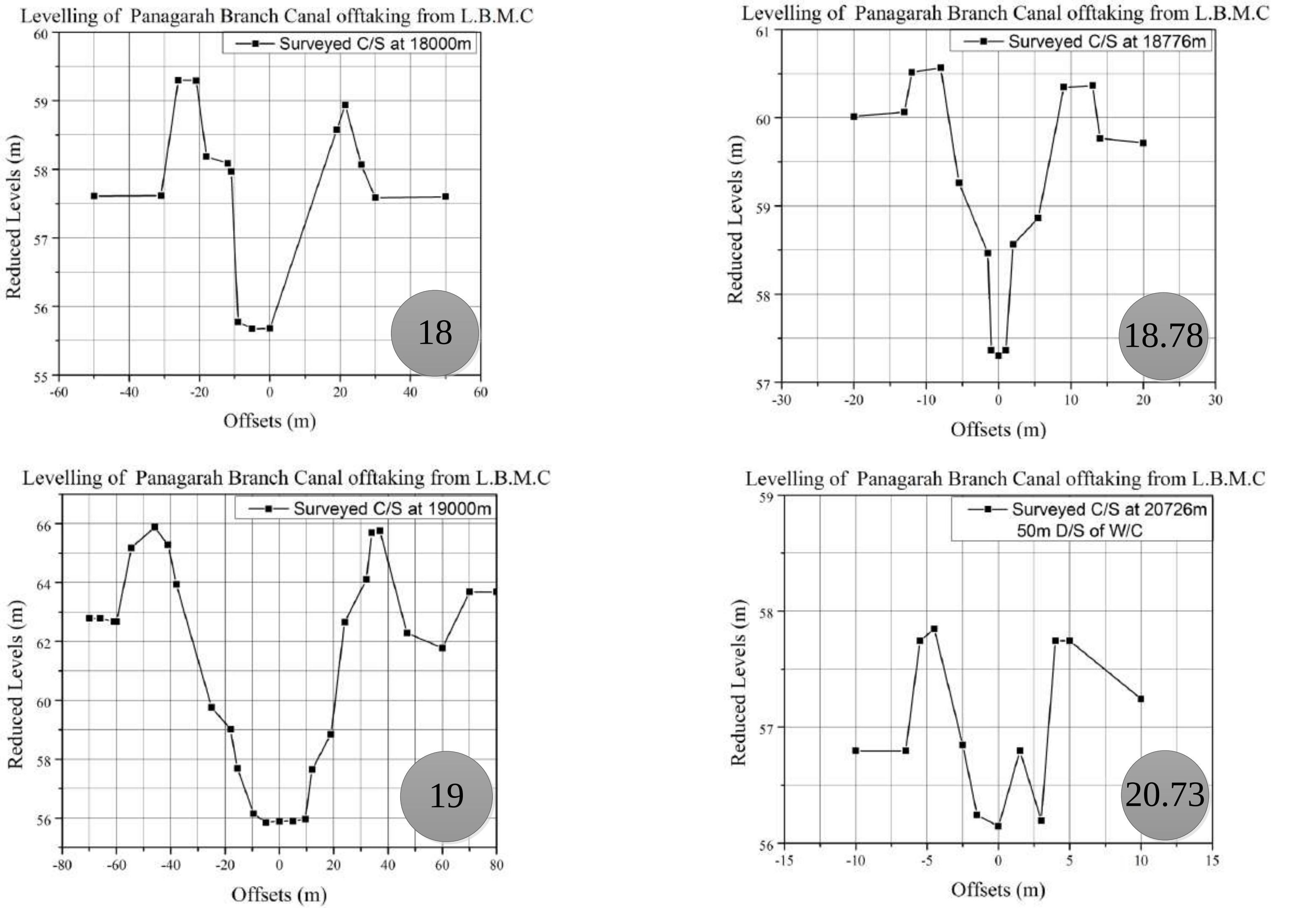


Figure 6.28: Canal cross section from 18 km to 20.73 km on Panagarh branch canal

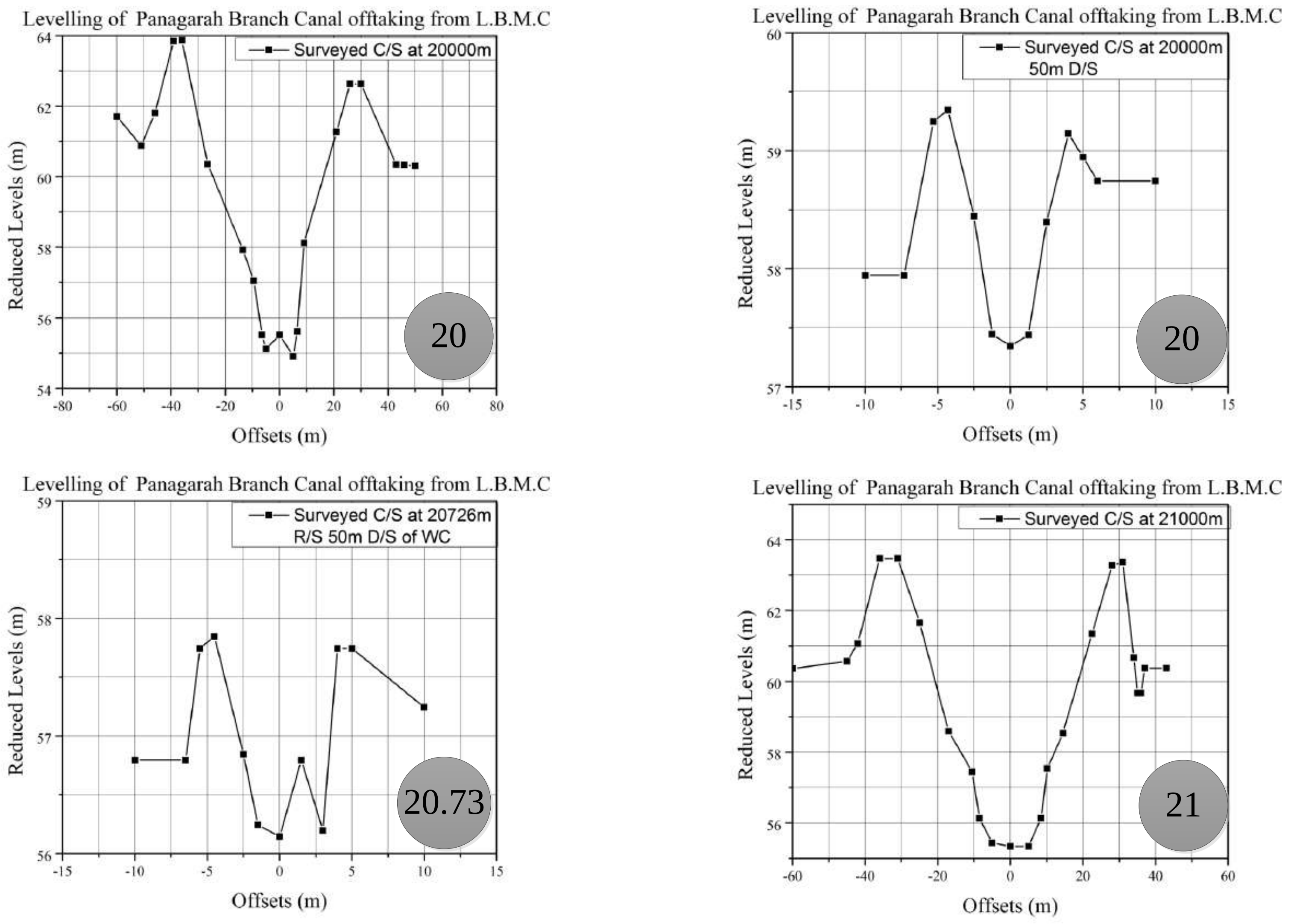


Figure 6.29: Canal cross section from 20 km to 21 km on Panagarh branch canal

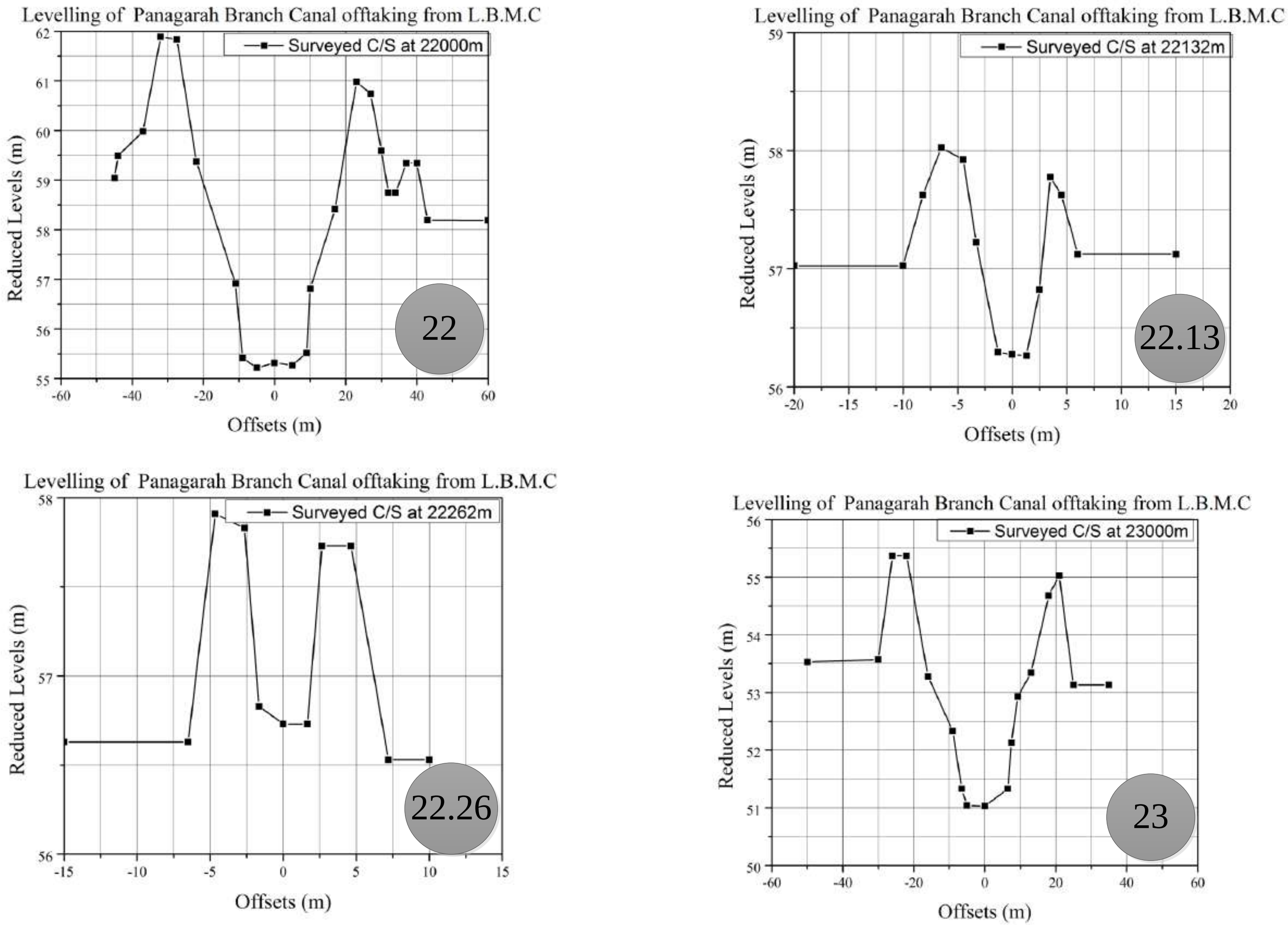


Figure 6.30: Canal cross section from 22 km to 23 km on Panagarh branch canal

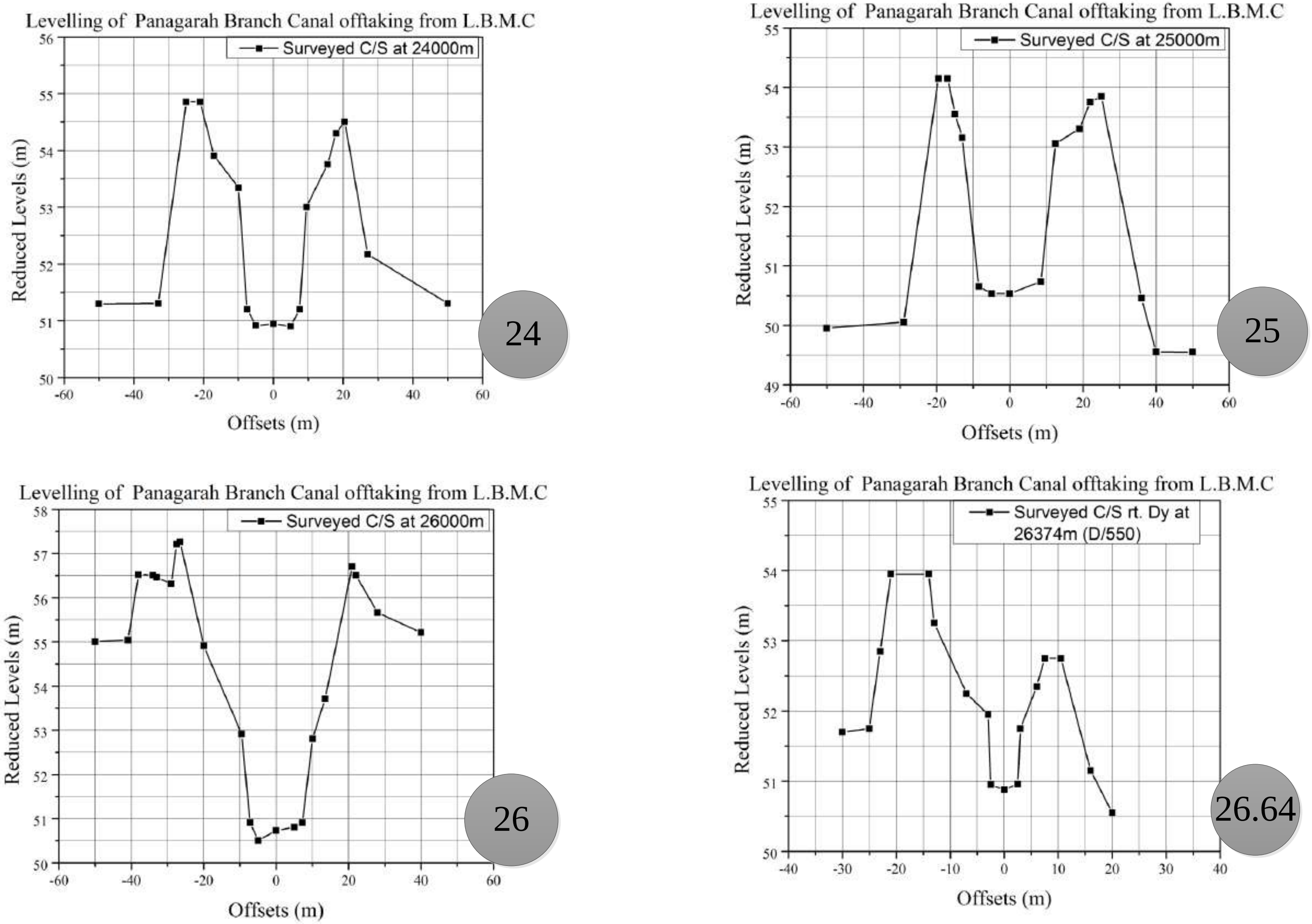


Figure 6.31: Canal cross section from 24 km to 26.64 km on Panagarh branch canal

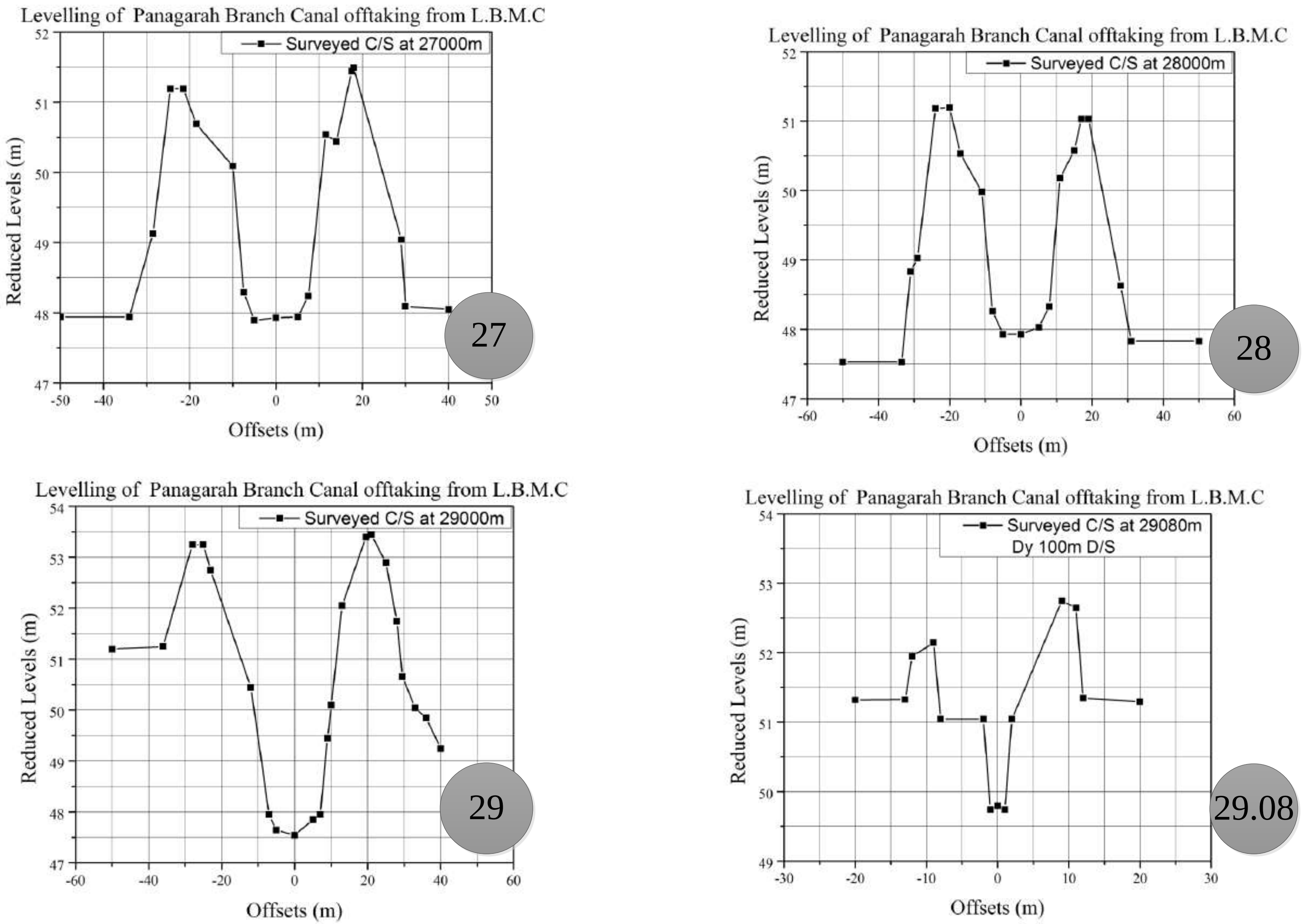


Figure 6.32: Canal cross section from 27 km to 29.08 km on Panagarh branch canal

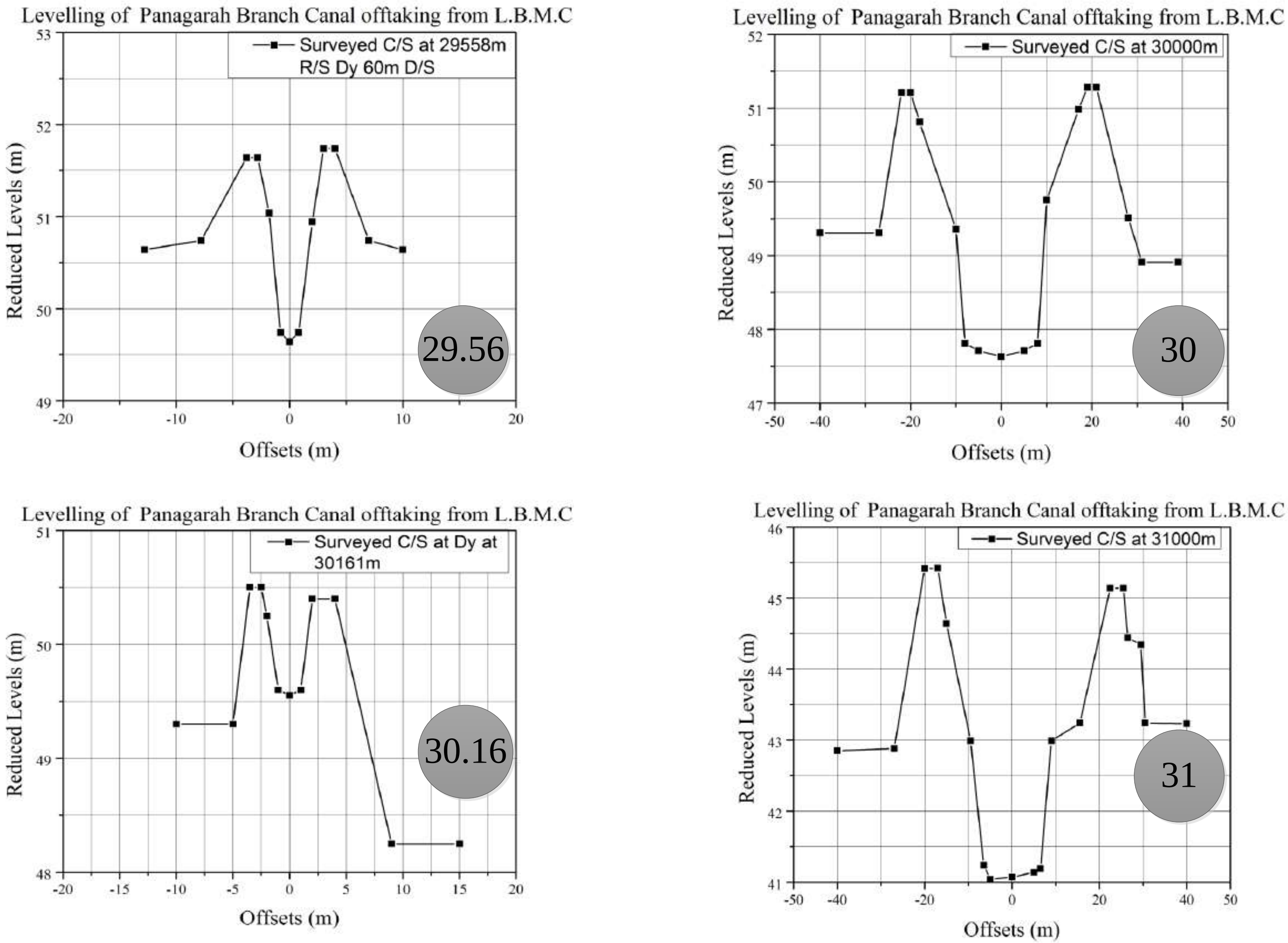


Figure 6.33: Canal cross section from 29.56 km to 31 km on Panagarh branch canal

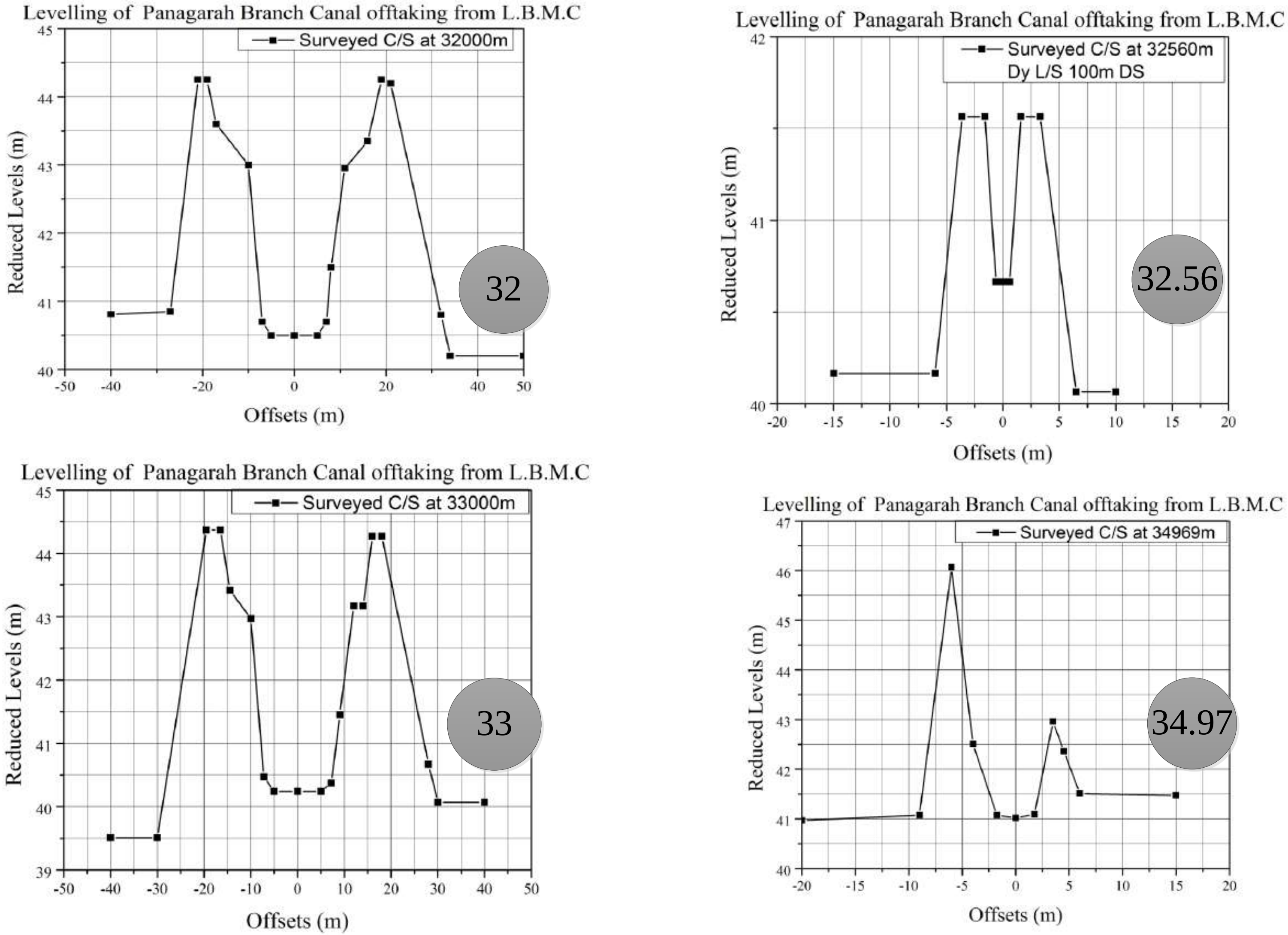
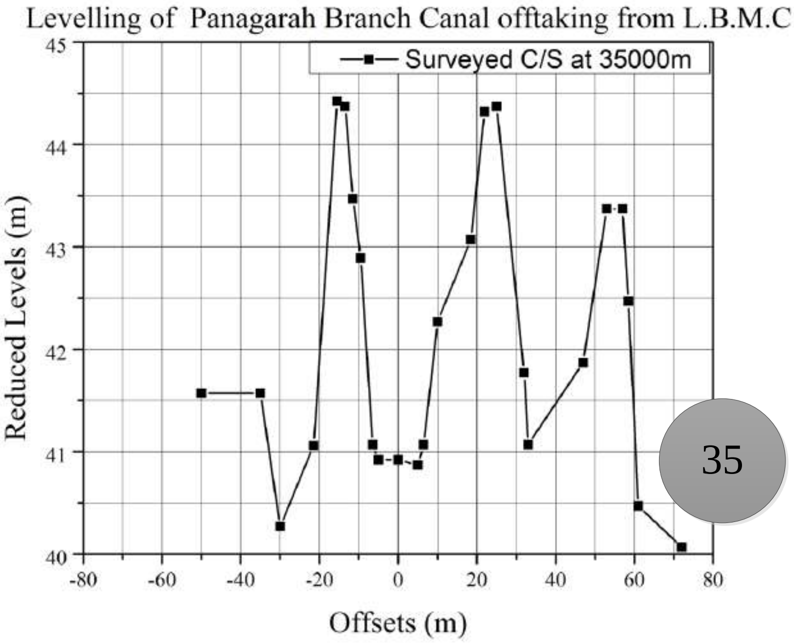


Figure 6.34: Canal cross section from 32 km to 34.97 km on Panagarh branch canal



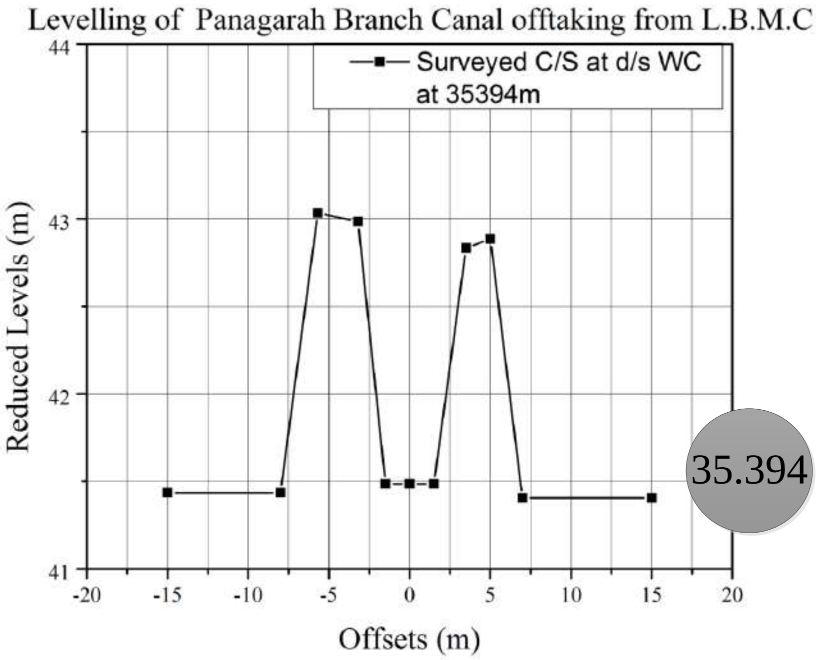


Figure 6.35: Canal cross section from 33 km to 35 km on Panagarh branch canal

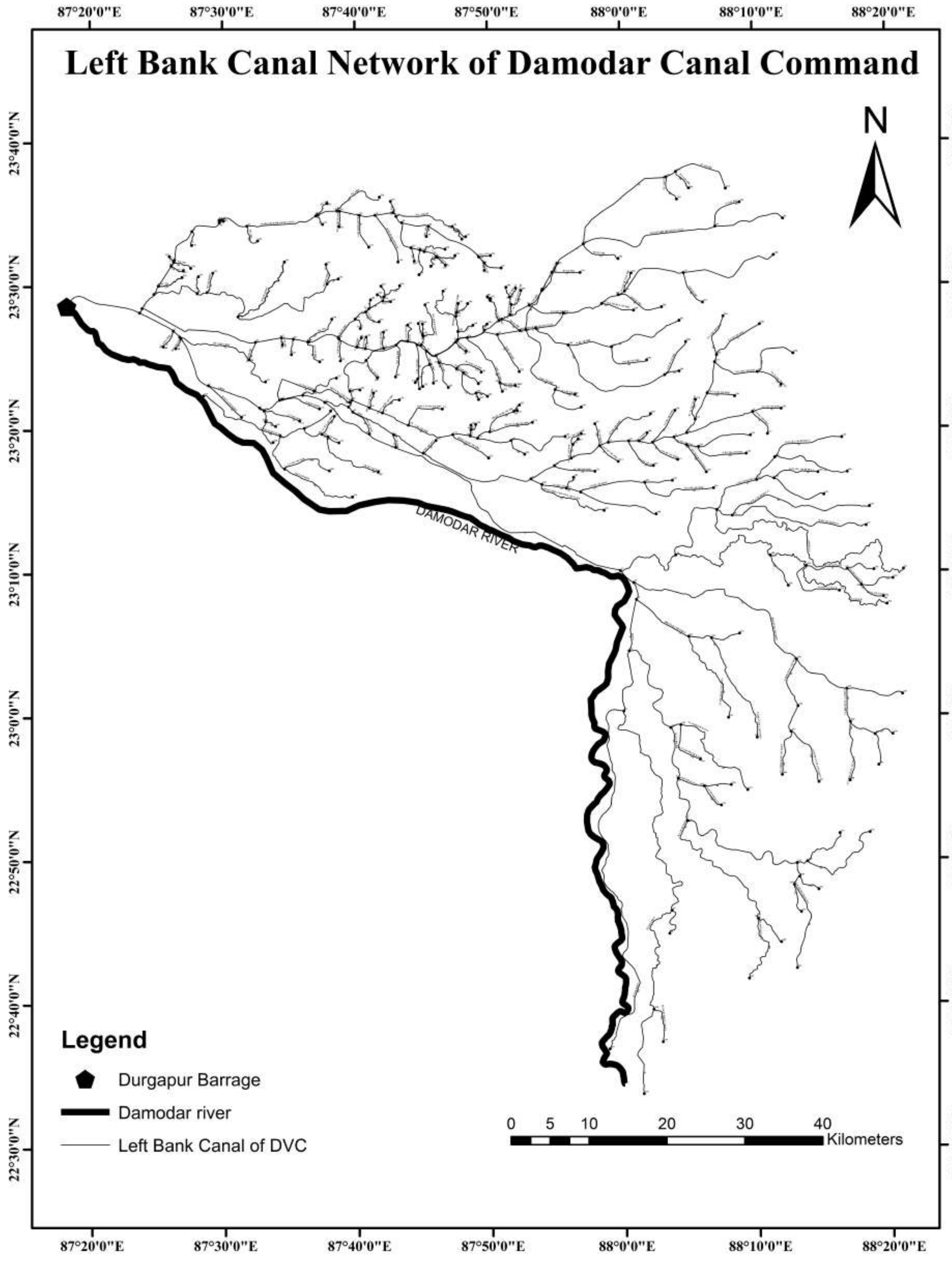


Figure 6.36: Left Bank Canal Network of DVC irrigation system

Table 6.1: Distributory 1 BC of Damodar Branch Canal (Id:49,Node No: 86-183)

Distance in feet	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000’	Discharge (cusec)	V (ft/sec)	V/V0	Hyd. grad	Distance in feet	Structure
0	142.45	NA	147.45	5	10	1	234.00	2.34	0.99	0.60	0.00	head sluice
5000	139.45	NA	144.45	5	10	1	234.00	2.34	0.99	0.60	44.30	syphon
8113	137.58	NA	142.58	5	10	1	234.00	2.34	0.99	0.60	58.76	cart bridge
8113	132.08	NA	137.58	5.5	8	1	234.00	2.34	0.99	0.60	85.50	off take disty no. 1/A
10000	130.95	NA	136.45	5.5	8	1	234.00	2.34	0.99	0.30	81.13	regulator 1 with bridge
NA	128.55	NA	134.05	5.5	8	1	234.00	2.34	0.99	0.30	138.79	off take disty no. 1/b
NA	125.80	NA	131.80	5.5	8	1	234.00	2.34	0.99	0.30	139.95	regulator 2 with bridge
15000	125.50	NA	131.50	6	10	1	234.00	2.34	0.99	0.30	179.27	cart bridge

Table 6.2: (continued) Distributory 1 BC of Damodar Branch Canal (Id:49,Node No: 86-183)

Distance in feet	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Discharge (cusec)	V (ft/sec)	V/V0	Hyd. grad	Distance in feet	Structure
20000	124.00	NA	130.00	6	10	1	234.00	2.34	0.99	0.50	191.17	cart bridge
25000	122.50	NA	128.50	6	10	1	234.00	2.34	0.99	0.50	201.34	syphon
26173	122.15	NA	128.15	6	10	1	234.00	2.34	0.99	0.50	259.73	off take of disty no. 1/C
30000	119.24	NA	124.24	5	8	1	234.00	2.34	0.99	0.40	262.00	regulator 3 with bridge
35000	116.74	NA	121.74	5	8	1	234.00	2.34	0.99	0.40	294.30	cart bridge
40000	114.24	NA	119.24	5	8	1	234.00	2.34	0.99	0.40	360.55	cart bridge
45000	111.74	NA	116.74	5	8	1	234.00	2.34	0.99	0.40	376.70	syphon
50000	109.73	NA	114.73	5	8	1	234.00	2.34	0.99	0.60	398.00	cart bridge
55000	107.73	NA	112.73	5	8	1	234.00	2.34	0.99	0.60	425.00	cart bridge
60000	105.65	NA	110.15	4.5	5	1	234.00	2.34	0.99	0.60	463.37	off take of disty no. 1/D

Table 6.3: (continued) Distributory 1 BC of Damodar Branch Canal (Id:49,Node No: 86-183)

Distance in feet	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Discharge (cusec)	V (ft/sec)	V/V0	Hyd. grad	Distance in feet	Structure
65000	103.14	NA	107.14	4	4	1	234.00	2.34	0.99	0.50	465.37	cart bridge
70000	100.43	NA	104.43	4	4	1	234.00	2.34	0.99	0.50	523.50	cart bridge
75000	98.43	NA	101.93	3.5	4	1	234.00	2.34	0.99	0.80	562.70	cart bridge
77126	97.37	NA	100.87	3.5	4	1	234.00	2.34	0.99	0.80	571.09	off take of disty no. 1/E
77126	98.37	NA	100.87	2.5	4	1	234.00	2.34	0.99	0.40	616.25	cart bridge
80000	96.07	NA	98.57	2.5	4	1	234.00	2.34	0.99	0.40	771.26	cart bridge
80626	95.59	NA	98.09	2.5	4	1	234.00	2.34	0.99	0.40	802.40	cart bridge
80626	95.09	NA	98.09	3	4	1	234.00	2.34	0.99	0.40	804.00	b.k. rly line
85000	93.32	NA	96.32	3	3	1	234.00	2.34	0.99	0.40	835.00	cart bridge

Table 6.4: 1A BC of Damodar Branch Canal

Distance in feet	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000’	Discharge (cusec)	V (ft/sec)	V/V0	Hyd. grad	Distance in feet	Structure
0	136.89	NA	138.89	2	3	1	18.00	1.6	0.77	1.00	0	head sluice
2876	134.02	NA	136.02	2	3	1	18.00	1.6	0.77	1.00	28.76	cart bridge with regulators
2876	132.73	NA	134.48	1.75	3	1	18.00	1.6	0.77	1.00		
5000	130.63	NA	132.38	1.75	3	1	18.00	1.6	0.77	1.00		
6584	123.06	NA	130.81	1.75	3	1	18.00	1.6	0.77	1.00		

Table 6.5: 1B BC of Damodar Branch Canal (Id:105,Node No: 177-270)

Distance in feet	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Discharge (cusec)	V (ft/sec)	V/V0	Hyd. grad	Distance in feet	Structure
0	131.11	NA	134.11	3	4	1	13.00	0.71	0.41	NA	0	head sluice
5	129.61	NA	132.61	3	4	1	13.00	0.71	0.41	NA	60	cart bridge
9	130.71	NA	132.21	3	4	1	13.00	0.71	0.41	NA		
10	130.21	NA	131.7	1.5	3	1	13.00	0.71	0.41	NA		

Table 6.6: 1C BC of Damodar Branch Canal (Id:106,Node No: 178-271)

Distance in feet	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Discharge (cusec)	V (ft/sec)	V/V0	Hyd. grad	Distance in feet	Structure
0	123.92	NA	127.32	4	6	1	40.00	1.0	0.50	0.10	0	head sluice
5000	123.42	NA	127.42	4	5	1	40.00	1.0	0.50	0.10	55.00	regulator
7532	123.17	NA	127.17	4	4	1	40.00	1.0	0.50	0.10	70.00	cart bridge
7532	123.42	NA	127.17	3.75	4	1	40.00	1.0	0.50	0.10	122.00	regulator
10000	123.17	NA	126.92	3.75	4	1	40.00	1.0	0.50	0.20	135.23	cart bridge
10000	123.42	NA	126.92	3.5	4	1	40.00	1.0	0.50	0.20		
15000	123.45	NA	125.43	2.5	4	1	40.00	1.0	0.50	0.20		
15946	123.24	NA	125.74	2.5	4	1	40.00	1.0	0.50	0.20		

Table 6.7: 1D BC of Damodar Branch Canal (Id:107,Node No: 179-272)

Distance in feet	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000’	Discharge (cusec)	V (ft/sec)	V/V0	Hyd. grad	Distance in feet	Structure
0	111.200	NA	116.200	3	3	1	26.00	1.44	0.84	0.70	20	head sluice
20	112.700	NA	115.700	3	3	1	26.00	1.44	0.84	0.70	32	cart bridge
4244	111.020	NA	114.020	3	3	1	26.00	1.44	0.84	0.70	97.25	cart bridge
4244	111.720	NA	113.970	2.25	3	1	26.00	1.44	0.84	0.70	120.79	cart bridge
5000	111.230	NA	113.480	2.25	3	1	26.00	1.44	0.84	0.70	133.5	regulator
10000	107.980	NA	109.980	2	3	1	26.00	1.44	0.84	0.70	150.36	cart bridge
15000	104.000	NA	106.000	2	3	1	26.00	1.44	0.84	1.00		
18436	99.080	NA	102.560	2	2	1	26.00	1.44	0.84	1.00		

Table 6.8: 1E BC of Damodar Branch Canal (Id:108,Node No: 181-274)

Distance in feet	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	formation level of embankment	Slope in 1000'	Discharge (cusec)	V (ft/sec)	V/V0	Hyd. grad	Distance in feet	Structure
0	106.89	na	111.89	5	01:01	1	50.00	1.44	0.69	0.20	0	head sluice
25	105.39	NA	110.39	5	01:01	1	50.00	1.44	0.69	0.20	45.43	cart bridge
5000	104.39	NA	109.39	5	01:01	1	50.00	1.44	0.69	0.20	63.00	off take disty no. 1F
6300	104.13	NA	109.13	5	01:01	1	50.00	1.44	0.69	0.20	86.16	cart bridge
6400	105.36	NA	109.06	3.7	01:01	1	50.00	1.44	0.69	0.80	127.16	cart bridge
6900	105.12	NA	108.82	3.7	01:01	1	50.00	1.44	0.69	0.80	175.23	cart bridge
7000	105.79	NA	108.79	3	01:01	1	50.00	1.44	0.69	0.80	211.43	
10000	103.47	NA	106.47	3	01:01	1	50.00	1.44	0.69	0.80		
15000	100.87	NA	103.37	2.5	01:01	1	50.00	1.44	0.69	0.70		
20000	95.01	NA	96.76	1.75	01:01	1	50.00	1.44	0.69	1.20		
21143	93.36	NA	95.11	1.75	01:01	1	50.00	1.44	0.69	1.20		

Table 6.9: 1F BC of Damodar Branch Canal (Id:109,Node No: 273-276)

Distance in feet	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Discharge (cusec)	V (ft/sec)	V/V0	Hyd. grad	Distance in feet	Structure
0	106.13	NA	108.13	2	9.5	1	31.00	1.35	1.35	0.20	0	head sluice
5000	105.13	NA	107.13	2	9.5	1	31.00	1.35	1.35	0.20	63.00	off take disty no. 1E
10000	102.18	NA	104.18	2	3.5	1	31.00	1.35	1.35	1.10	74.00	regulator
15000	96.14	NA	98.14	2	2	1	31.00	1.35	1.35	0.80	114.00	regulator
16000	95.34	NA	97.34	2	2	1	31.00	1.35	1.35	0.80	147.00	regulator

Table 6.10: 6 MC of DMC (Node: 17-27)

Chainage	Ground Level	Design Bed Level	Actual Bed level done	F.S.L (Existed)	F.S.L (Proposed)	F.S.D (ft)	Height of Bank	crest level of embankment(exist)	crest level of embankment(prop)	Bed width (ft)	Slope in 1000'	Discharge (cusec)	Velocity (ft/s)	V/V0
0	107.39	97.85	103.76	110.26	105.18	7.3	0.06	113.26	107.65	29	0.25	928	3.56	1.18
10	107.06	97.68	98.36	104.86	104.98	7.3	0.42	114.39	107.48	29	0.25	928	3.56	1.18
20	105.56	97.43	97.96	104.46	104.73	7.3	1.67	112.49	107.23	29	0.25	928	3.56	1.18
30	104.3	97.18	97.56	104.06	104.48	7.3	2.68	110.29	106.98	29	0.25	928	3.56	1.18
40	102.83	96.93	97.16	105.66	104.23	7.3	3.88	108.09	106.79	29	0.25	928	3.56	1.18
50	102.31	96.68	96.76	103.26	103.98	7.3	2.17	107.39	106.48	29	0.25	928	3.56	1.18
60.8	101.45	96.41	96.33	102.83	103.71	7.3	4.76	106.94	106.21	29	0.25	928	3.56	1.18
70.8	101.71	96.16	95.93	102.43	103.46	7.3	4.25	107.62	105.96	29	0.25	928	3.56	1.18
80.8	101.39	95.91	95.53	102.03	103.21	7.3	4.12	106.11	105.71	29	0.25	928	3.56	1.18
91	101.84	95.66	95.12	101.62	102.96	7.3	3.62	105.12	105.46	29	0.25	928	3.56	1.18
100	101.31	95.35	94.76	101.26	102.73	7.3	3.92	107.18	105.23	29	0.25	928	3.56	1.18
110	100.31	95.18	94.36	100.86	102.48	7.3	4.67	105.77	104.98	29	0.25	928	3.56	1.18
120	98.94	94.93	93.45	100.45	102.23	7.3	5.79	103.45	104.73	29	0.25	928	3.56	1.18
130	97.95	94.68	91.65	99.95	101.98	7.3	6.55	102.95	104.48	29	0.25	928	3.56	1.18
140	97.51	94.43	91.51	99.45	101.73	7.3	6.72	102.45	104.23	29	0.25	928	3.56	1.18
150	97.01	94.18	91.01	98.95	101.48	7.3	6.97	101.95	103.98	29	0.25	928	3.56	1.18

Table 6.11: (continued) 6 MC of DMC (Node: 17-27)

Chainage	Ground Level	Design Bed Level	Actual Bed level done	F.S.L (Existed)	F.S.L (Proposed)	F.S.D (ft)	Height of Bank	crest level of embankment(exist)	crest level of embankment(prop)	Bed width (ft)	Slope in 1000'	Discharge (cusec)	Velocity (ft/s)	V/V0
150	na	92.1	na	na	99.4	7.3	na	na	101.9	29	0.25	928	3.56	1.18
160	96.6	91.85	90.9	98.45	99.15	7.3	5.05	101.45	101.65	29	0.25	928	3.56	1.18
170	96.28	91.6	90.58	97.95	100	7.3	5.12	100.95	101.4	29	0.25	928	3.56	1.18
180	96.04	91.43	90.45	97.45	98.65	7.3	5.11	100.69	101.15	29	0.25	928	3.56	1.18
190	95.8	91.18	89.95	96.95	98.4	7.3	5.1	100.49	100.9	29	0.25	928	3.56	1.18
200	95.32	90.85	89.45	96.45	98.15	7.3	5.33	99.69	100.65	29	0.25	928	3.56	1.18
210	95.56	90.6	88.95	95.95	98.95	7.3	4.85	101.42	100.4	29	0.25	928	3.56	1.18
220	94.77	90.35	88.45	95.45	97.65	7.3	5.58	99.36	100.15	29	0.25	928	3.56	1.18
230	94.46	90.1	88.08	95.08	97.4	7.3	5.44	100.37	99.9	29	0.25	928	3.56	1.18
240	95.28	89.85	87.78	94.78	99.15	7.3	4.37	99.66	99.65	29	0.25	928	3.56	1.18
250	94.04	89.6	87.48	94.48	96.9	7.3	5.36	100.03	99.4	29	0.25	928	3.56	1.18
260	94.65	89.35	87.18	94.18	96.65	7.3	4.5	na	99.15	29	0.25	928	3.56	1.18
270	94.69	89.37	87.79	93.39	96.37	7	4.18	89.64	98.87	22	0.3	707	3.67	1.25
273	na	89.28	na	93.67	96.28	7	na		na	22	0.3	707	3.67	1.25
273	na	86.78	na	na	93.78	7	na		na	22	0.3	707	3.67	1.25
280	92.62	86.57	87.39	93.39	93.57	7	3.45	97.26	96.07	22	0.3	707	3.67	1.25

Table 6.12: (continued) 6 MC of DMC (Node: 17-27)

Chainage	Ground Level	Design Bed Level	Actual Bed level done	F.S.L (Existed)	F.S.L (Proposed)	F.S.D (ft)	Height of Bank	crest level of embankment(exist)	crest level of embankment(prop)	Bed width (ft)	Slope in 1000’	Discharge (cusec)	Velocity (ft/s)	V/V0
290	92.31	86.27	86.99	92.99	93.27	7	3.46	97.28	95.77	22	0.3	707	3.67	1.25
300	91.85	85.97	86.59	92.59	92.97	7	3.62	96.05	95.47	22	0.3	707	3.67	1.25
310	90.85	85.67	86.19	92.19	92.67	7	4.32	95.53	95.17	22	0.3	707	3.67	1.25
320	90.08	85.37	83.86	91.79	92.37	7	4.79	94.79	94.87	22	0.3	707	3.67	1.25
330	89.37	85.07	83.31	91.39	92.07	7	5.2	94.39	94.57	22	0.3	707	3.67	1.25
340	88.6	84.77	81.79	90.99	91.77	7	5.67	93.99	94.27	22	0.3	707	3.67	1.25
350	88.25	84.47	81.01	90.59	91.47	7	5.72	93.59	93.97	22	0.3	707	3.67	1.25
360	88.05	84.17	82.15	90.19	91.17	7	5.62	93.19	93.67	22	0.3	707	3.67	1.25
370	88.19	83.87	82.35	89.79	90.87	7	5.18	92.79	93.37	22	0.3	707	3.67	1.25
372.64	na	83.8	na	89.71	90.8	7	na	na	na	22	0.3	707	3.67	1.25
380	89.34	83.57	83.1	89.1	90.57	7	3.73	93.74	93.07	20	0.3	696	3.67	1.25
390	88.78	83.27	82.3	88.3	90.27	7	3.98	93.79	92.77	20	0.3	696	3.67	1.25
400	88.24	82.97	81.5	87.5	89.97	7	4.23	93.36	92.47	20	0.3	696	3.67	1.25
410	86.08	82.67	80.7	86.7	89.67	7	6.09	89.77	92.17	20	0.3	696	3.67	1.25
420	84.85	82.37	79.9	85.9	89.37	7	7.02	89.3	91.87	20	0.3	696	3.67	1.25
430	82.82	82.07	79.1	85.1	89.07	7	8.75	87.6	91.37	20	0.3	696	3.67	1.25
440	82.66	81.77	77.06	84.3	88.77	7	8.61	87.88	91.27	20	0.3	696	3.67	1.25

Table 6.13: (continued) 6 MC of DMC (Node: 17-27)

Chainage	Ground Level	Design Bed Level	Actual Bed level done	F.S.L (Existed)	F.S.L (Proposed)	F.S.D (ft)	Height of Bank	crest level of embankment(exist)	crest level of embankment(prop)	Bed width (ft)	Slope in 1000’	Discharge (cusec)	Velocity (ft/s)	V/V0
450	82.24	81.47	77.5	85.5	88.47	7	8.73	86	90.97	20	0.3	696	3.67	1.25
455.72	na	81.54	na	83.24	88.54	7	na	na	na	20	0.3	696	3.67	1.25
455.72	na	78.04	na	na	84.84	6.8	na	na	na	20	0.3	652	3.6	1.07
460.72	82.08	77.83	77.03	83.03	84.63	6.8	5.09	86.75	87.13	20	0.3	652	3.6	1.07
470.72	81.32	77.53	76.83	82.83	84.53	6.8	5.51	85.97	86.83	20	0.3	652	3.6	1.07
480.72	80.82	77.23	75.82	82.63	84.03	6.8	5.71	85.13	86.53	20	0.3	652	3.6	1.07
490	80.31	76.98	76.44	82.44	83.78	6.8	5.57	84.94	86.28	20	0.3	652	3.6	1.07
500	79.57	76.68	73.24	82.24	83.48	6.8	6.41	84.74	86.98	20	0.3	652	3.6	1.07
510	79.39	76.38	71.89	82.04	83.18	6.8	6.29	84.54	85.68	20	0.3	652	3.6	1.07
520	79.12	76.08	71.79	81.84	82.88	6.8	6.26	84.54	85.28	20	0.3	652	3.6	1.07
530	78.89	75.78	70.48	81.64	82.58	6.8	6.19	84.14	85.08	20	0.3	652	3.6	1.07
540	78.89	75.48	70.39	81.44	82.28	6.8	5.89	83.94	84.78	20	0.3	652	3.6	1.07
550	78.94	75.18	72.77	81.24	81.98	6.8	5.54	83.74	84.48	20	0.3	652	3.6	1.07
560	79.51	74.88	75.04	81.04	81.68	6.8	4.67	83.54	84.18	20	0.3	652	3.6	1.07
570	79.74	74.58	74.84	80.84	81.28	6.8	4.14	84.22	83.88	20	0.3	652	3.6	1.07
580	78.19	74.28	74.64	80.64	81.08	6.8	5.39	86.11	83.38	20	0.3	652	3.6	1.07

Table 6.14: (continued) 6 MC of DMC (Node: 17-27)

Chainage	Ground Level	Design Bed Level	Actual Bed level done	F.S.L (Existed)	F.S.L (Proposed)	F.S.D (ft)	Height of Bank	crest level of embankment(exist)	crest level of embankment(prop)	Bed width (ft)	Slope in 1000'	Discharge (cusec)	Velocity (ft/s)	V/V0
588	80.44	74.04	74.48	80.48	80.84	6.8	2.9	83.9	83.34	20	0.3	652	3.6	1.07
588	na	74.14	74.48	80.48	80.84	6.7	na	na	na	20	0.3	622	3.56	1.25
590.26	80.37	74.08	74.29	80.48	80.78	6.7	2.01	83.88	83.28	20	0.3	622	3.56	1.25
600	80.59	73.78	74.01	80.23	80.48	6.7	2.39	85.35	82.98	20	0.3	622	3.56	1.25
610.26	80.17	73.48	73.84	80.03	80.18	6.7	2.51	85.44	82.68	20	0.3	622	3.56	1.25
620.26	77.42	73.18	73.09	73.83	79.88	6.7	4.66	85.91	82.38	20	0.3	622	3.56	1.25
627.14	78.03	na	73.37	79.7	79.67	6.7	na	na	82.17	20	0.3	622	3.56	1.25
627.14	na	na	71.87	78.2	78.17	6.3	na	na	80.67	20	0.3	570	3.47	1.25
630	77.52	71.78	73.27	78.05	78.08	6.3	3.06	85.97	80.58	20	0.3	570	3.47	1.25
640	76.74	71.48	72.74	77.55	77.78	6.3	3.54	80.41	80.28	20	0.3	570	3.47	1.25
650	76.21	71.18	72.37	77.05	77.48	6.3	3.77	80.01	79.98	20	0.3	570	3.47	1.25
660	75.45	70.88	71.45	76.55	77.18	6.3	4.23	79.13	79.68	20	0.3	570	3.47	1.25
670	74.85	70.58	70.85	76.05	76.88	6.3	4.53	78.8	79.38	20	0.3	570	3.47	1.25
680.26	73.99	70.28	68.41	75.54	76.58	6.3	5.09	77.81	79.08	20	0.3	570	3.47	1.25
690.26	73.46	69.98	67.02	75.04	76.28	6.3	5.32	78.26	78.78	20	0.3	570	3.47	1.25
700.26	73.24	69.68	68.49	74.54	75.98	6.3	5.24	77.32	78.48	20	0.3	570	3.47	1.25
710.26	72.62	69.38	67.2	74.04	75.68	6.3	5.56	77.02	78.18	20	0.3	570	3.47	1.25

Table 6.15: (continued) 6 MC of DMC (Node: 17-27)

Chainage	Ground Level	Design Bed Level	Actual Bed level done	F.S.L (Existed)	F.S.L (Proposed)	F.S.D (ft)	Height of Bank	crest level of embankment(exist)	crest level of embankment(prop)	Bed width (ft)	Slope in 1000'	Discharge (cusec)	Velocity (ft/s)	V/V0
713.97	na	69.07	na	na	75.57	6.5	na	na	78.07	18.5	0.3	554	3.47	1.25
720	71.99	68.88	65.39	73.53	75.38	6.5	5.89	76.11	77.88	18.5	0.3	554	3.47	1.25
730	72.26	68.58	68.61	73.03	75.08	6.5	5.32	76.02	77.58	18.5	0.3	554	3.47	1.25
740	71.02	68.28	68.02	72.53	74.78	6.5	6.26	74.94	77.28	18.5	0.3	554	3.47	1.25
750	70.53	67.98	67.53	72.03	74.48	6.5	6.45	74.72	76.98	18.5	0.3	554	3.47	1.25
757.5	na	67.76	na	na	74.26	6.5	na	na	74.76	18.5	0.3	554	3.47	1.25
760	70.27	67.68	65.94	71.53	74.18	6.5	6.41	74.36	76.68	18.5	0.3	554	3.47	1.25
770.51	70.17	67.38	66.42	71.01	73.88	6.5	6.21	73.89	76.38	18.5	0.3	554	3.47	1.25
778.68	69.2	67.08	65.96	70.52	73.58	6.5	6.79	73.47	76.08	18.5	0.3	554	3.47	1.25
790.26	67.49	66.78	62.24	70.04	73.28	6.5	8.29	72.59	75.78	18.5	0.3	554	3.47	1.25
800.7	67.47	66.48	61.8	69.41	72.98	6.5	8.01	72.5	75.48	18.5	0.3	554	3.47	1.25
812.76	67.14	66.18	60.06	68.91	72.68	6.5	na	71.82	na	18.5	0.3	554	3.47	1.25
816.34	na	66	na	68.74	72.5	6.5	na	na	75	18.5	0.3	554	3.47	1.25
816.34	na	62.8	na	67.49	69.5	6.7	na	na	72	16	0.3	479	3.15	1.25
820	66.34	62.68	62.59	67.37	69.38	6.7	5.54	70.24	71.88	16	0.3	479	3.15	1.25

Table 6.16: (continued) 6 MC of DMC (Node: 17-27)

Chainage	Ground Level	Design Bed Level	Actual Bed level done	F.S.L (Existed)	F.S.L (Proposed)	F.S.D (ft)	Height of Bank	crest level of embankment(exist)	crest level of embankment(prop)	Bed width (ft)	Slope in 1000'	Discharge (cusec)	Velocity (ft/s)	V/V0
830	65.58	62.38	61.42	67.07	69.08	6.7	6	68.47	71.58	16	0.3	479	3.15	1.25
840.2	68.02	62.08	62.7	66.76	68.78	6.7	4.26	70.36	71.28	16	0.3	479	3.15	1.25
850.2	64.66	61.78	59.91	66.46	68.48	6.7	6.32	69.34	70.98	16	0.3	479	3.15	1.25
860	64.59	61.48	60.96	66.16	68.18	6.7	6.62	69.02	70.68	16	0.3	479	3.15	1.25
870.76	64.07	61.18	59.13	na	67.88	6.7	6.31	na	70.38	16	0.3	479	3.15	1.25
880.76	63.18	60.88	57.43	65.54	67.58	6.7	6.9	68.56	70.08	16	0.3	479	3.15	1.25
890.76	62.52	60.58	56.52	65.24	67.28	6.7	7.26	67.16	69.78	16	0.3	479	3.15	1.25
900.17	62.05	60.28	60.3	64.96	66.98	6.7	7.43	67.84	69.48	16	0.3	479	3.15	1.25
910.2	62.11	59.98	56.28	64.65	66.68	6.7	8.07	67.48	69.18	16	0.3	479	3.15	1.25
912.53	na	59.91	na	na	66.61	6.7	na	na	69.11	16	0.3	479	3.15	1.25
912.53	na	59.08	na	na	65.78	6.7	na	na	67.88	16	0.3	479	3.15	1.25

Table 6.17: Long section of 6 MC of DMC (Node: 17-27)

Chainage	Actual Bed level done	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Discharge (cusec)	Velocity (ft/s)	V/V0	Distance	Structure
0	97.85	105.18	7.3	29	0.25	928	3.56	1.18	0	head regulator
2	n.a	n.a	7.3	29	0.25	928	3.56	1.18	26.2	cart bridge
10	97.68	104.98	7.3	29	0.25	928	3.56	1.18	59.75	cart bridge on Burdwan suri road
20	97.43	104.73	7.3	29	0.25	928	3.56	1.18	90.9	bridge
30	97.18	104.48	7.3	29	0.25	928	3.56	1.18	92	regulator without fall
40	96.93	104.23	7.3	29	0.25	928	3.56	1.18	116	E.I.R at crossing
50	96.68	103.98	7.3	29	0.25	928	3.56	1.18	138.49	cart bridge
60.8	96.41	103.71	7.3	29	0.25	928	3.56	1.18	150.2	regulator (fall 2'1")
70.8	96.16	103.46	7.3	29	0.25	928	3.56	1.18	180	bridge
80.8	95.91	103.21	7.3	29	0.25	928	3.56	1.18	209.93	B.K RLY bridge
91	95.66	102.96	7.3	29	0.25	928	3.56	1.18	223.75	Burdwan Katwa road bridge
92	n.a	102.94	7.3	29	0.25	928	3.56	1.18	259.5	offtake of disty 6A (disch 221 cusec)
100	95.35	102.73	7.3	29	0.25	928	3.56	1.18	273	fall with regulator (prop fall=2.5' exist fall= 0,)

Table 6.18: (continued) Long section of 6 MC of DMC (Node: 17-27)

Chainage	Actual Bed level done	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Discharge (cusec)	Velocity (ft/s)	V/V0	Distance	Structure
110	95.18	102.48	7.3	29	0.25	928	3.56	1.18	285.14	bridge
119	n.a	n.a	7.3	29	0.25	928	3.56	1.18	345.39	bridge
120	94.93	102.23	7.3	29	0.25	928	3.56	1.18	372.64	offtake of disty 6C (disch= 11 cusecs)
130	94.68	101.98	7.3	29	0.25	928	3.56	1.18	373.35	V.C.D.B road bridge
140	94.43	101.73	7.3	29	0.25	928	3.56	1.18	416.48	bridge
150	94.18	101.48	7.3	29	0.25	928	3.56	1.18	451.7	offtake of disty 6D (disch= 44 cusecs)
150	92.1	99.4	7.3	29	0.25	928	3.56	1.18	455.72	fall with regulator (prop fall=3.5' exist fall= 0)
160	91.85	99.15	7.3	29	0.25	928	3.56	1.18	489.7	bridge
170	91.6	100	7.3	29	0.25	928	3.56	1.18	587.23	offtake of disty 6E (disch = 32 cusecs)
180	91.43	98.65	7.3	29	0.25	928	3.56	1.18	588	cart bridge with regulator
190	91.18	98.4	7.3	29	0.25	928	3.56	1.18	613	cart bridge
200	90.85	98.15	7.3	29	0.25	928	3.56	1.18	626.86	offtake of disty 6F (disch = 52 cusecs)

Table 6.19: (continued) Long section of 6 MC of DMC (Node: 17-27)

Chainage	Actual Bed level done	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Discharge (cusec)	Velocity (ft/s)	V/V0	Distance	Structure
210	90.6	98.95	7.3	29	0.25	928	3.56	1.18	627.14	fall with regulator (prop fall=1.5' exist fall= 0)
220	90.35	97.65	7.3	29	0.25	928	3.56	1.18	763.26	regulator
223	n.a	n.a	7.3	29	0.25	928	3.56	1.18	779.2	cart bridge
230	90.1	97.4	7.3	29	0.25	928	3.56	1.18	815.34	offtake of disty 6N (6H) and 6J (disch = 75 cusecs)
240	89.85	99.15	7.3	29	0.25	928	3.56	1.18	816.34	bridge with regulator (prop fall=3.0' exist fall= 1.25')
250	89.6	96.9	7.3	29	0.25	928	3.56	1.18	911.53	offtake of disty 6K (disch = 70 cusecs)
260	89.35	96.65	7.3	29	0.25	928	3.56	1.18	912.53	bridge with regulator (prop fall=1.23')
260.8	89.35	96.65	7	22	0.3	707	3.67	1.25		
270	89.37	96.37	7	22	0.3	707	3.67	1.25		
273	89.28	96.28	7	22	0.3	707	3.67	1.25		
273	86.78	93.78	7	22	0.3	707	3.67	1.25		
280	86.57	93.57	7	22	0.3	707	3.67	1.25		

Table 6.20: ddddd

Chainage	Actual Bed level done	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Discharge (cusec)	Velocity (ft/s)	V/V0
285.14	n.a	n.a	7	22	0.3	707	3.67	1.25
290	86.27	93.27	7	22	0.3	707	3.67	1.25
300	85.97	92.97	7	22	0.3	707	3.67	1.25
310	85.67	92.67	7	22	0.3	707	3.67	1.25
320	85.37	92.37	7	22	0.3	707	3.67	1.25
330	85.07	92.07	7	22	0.3	707	3.67	1.25
340	84.77	91.77	7	22	0.3	707	3.67	1.25
350	84.47	91.47	7	22	0.3	707	3.67	1.25
360	84.17	91.17	7	22	0.3	707	3.67	1.25
370	83.87	90.87	7	22	0.3	707	3.67	1.25
372.64	83.8	90.8	7	22	0.3	707	3.67	1.25
380	83.57	90.57	7	20	0.3	696	3.67	1.25
390	83.27	90.27	7	20	0.3	696	3.67	1.25
400	82.97	89.97	7	20	0.3	696	3.67	1.25
410	82.67	89.67	7	20	0.3	696	3.67	1.25
420	82.37	89.37	7	20	0.3	696	3.67	1.25
430	82.07	89.07	7	20	0.3	696	3.67	1.25
440	81.77	88.77	7	20	0.3	696	3.67	1.25
450	81.47	88.47	7	20	0.3	696	3.67	1.25
455.72	81.54	88.34	7	20	0.3	696	3.67	1.25
455.72	78.04	84.84	7	20	0.3	696	3.67	1.25
460.72	77.83	84.63	6.8	20	0.3	652	3.6	1.07
470.72	77.53	84.53	6.8	20	0.3	652	3.6	1.07
480.72	77.23	84.03	6.8	20	0.3	652	3.6	1.07
490	76.98	83.78	6.8	20	0.3	652	3.6	1.07
500	76.68	83.48	6.8	20	0.3	652	3.6	1.07
510	76.38	83.18	6.8	20	0.3	652	3.6	1.07
520	76.08	82.88	6.8	20	0.3	652	3.6	1.07

Table 6.21: ddddd

Chainage	Actual Bed level done	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000’	Discharge (cusec)	Velocity (ft/s)	V/V0
530	75.78	82.58	6.8	20	0.3	652	3.6	1.07
540	75.48	82.28	6.8	20	0.3	652	3.6	1.07
550	75.18	81.98	6.8	20	0.3	652	3.6	1.07
560	74.88	81.68	6.8	20	0.3	652	3.6	1.07
570	74.58	81.28	6.8	20	0.3	652	3.6	1.07
580	74.28	81.08	6.8	20	0.3	652	3.6	1.07
588	74.04	80.84	6.8	20	0.3	652	3.6	1.07
590.26	74.08	80.78	6.7	20	0.3	622	3.56	1.25
600	73.78	80.48	6.7	20	0.3	622	3.56	1.25
610.26	73.48	80.18	6.7	20	0.3	622	3.56	1.25
620.26	73.18	79.88	6.7	20	0.3	622	3.56	1.25
627.14	72.97	79.67	6.7	20	0.3	622	3.56	1.25
627.14	71.87	78.17	6.7	20	0.3	622	3.56	1.25
630	71.78	78.08	6.3	20	0.3	570	3.47	1.25
640	71.48	77.78	6.3	20	0.3	570	3.47	1.25
650	71.18	77.48	6.3	20	0.3	570	3.47	1.25
660	70.88	77.18	6.3	20	0.3	570	3.47	1.25
670	70.58	76.88	6.3	20	0.3	570	3.47	1.25
680.26	70.28	76.58	6.3	20	0.3	570	3.47	1.25
690.26	69.98	76.28	6.3	20	0.3	570	3.47	1.25
700.26	69.68	75.98	6.3	20	0.3	570	3.47	1.25
710.26	69.38	75.68	6.3	20	0.3	570	3.47	1.25
712.97	69.07	75.37	6.3	20	0.3	570	3.47	1.25
713.97	69.27	75.57	6.3	20	0.3	570	3.47	1.25
720	68.88	75.38	6.5	18.5	0.3	554	3.47	1.25
730	68.58	75.08	6.5	18.5	0.3	554	3.47	1.25
740	68.28	74.78	6.5	18.5	0.3	554	3.47	1.25
750	67.98	74.48	6.5	18.5	0.3	554	3.47	1.25

Table 6.22: ddddd

Chainage	Actual Bed level done	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Discharge (cusec)	Velocity (ft/s)	V/V0
757.5	67.76	74.26	6.5	18.5	0.3	554	3.47	1.25
760	67.68	74.18	6.5	18.5	0.3	554	3.47	1.25
763.26	n.a	n.a	6.5	18.5	0.3	554	3.47	1.25
770.51	67.38	73.88	6.5	18.5	0.3	554	3.47	1.25
778.68	67.08	73.58	6.5	18.5	0.3	554	3.47	1.25
790.26	66.78	73.28	6.5	18.5	0.3	554	3.47	1.25
800.7	66.48	72.98	6.5	18.5	0.3	554	3.47	1.25
812.76	66.18	72.68	6.5	18.5	0.3	554	3.47	1.25
815.34	66	72.5	6.5	18.5	0.3	554	3.47	1.25
816.34	62.8	69.5	6.5	18.5	0.3	554	3.47	1.25
820	62.68		6.7	16	0.3	479	3.15	1.25
830	62.38		6.7	16	0.3	479	3.15	1.25
840.3	62.08		6.7	16	0.3	479	3.15	1.25
850.3	61.78		6.7	16	0.3	479	3.15	1.25
860	61.48		6.7	16	0.3	479	3.15	1.25
870.76	61.18		6.7	16	0.3	479	3.15	1.25
880.76	60.88		6.7	16	0.3	479	3.15	1.25
890.76	60.58		6.7	16	0.3	479	3.15	1.25
900.17	60.28		6.7	16	0.3	479	3.15	1.25
910.2	59.98		6.7	16	0.3	479	3.15	1.25
912.53	59.91	66.61	6.7	16	0.3	479	3.15	1.25
913.53	59.08	65.39	6.7	16	0.3	479	3.15	1.25

Table 6.23: 6A MC of DMC (Id:63, Node No:17-208)

Chainage	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Discharge (cusec)	V (ft/sec)	V/V0	Free board	Distance in chainage	Structure
0	89.09	88.49	93.49	4.4	17.75	0.2	193	2.05	NA	2	54.34	existing bridge and prop fall=2'
10	88.89	87.89	93.29	4.4	17.75	0.2	193	2.05	NA	2	98	existing regulator and prop fall=3'
20	88.69	87.29	93.09	4.4	17.75	0.2	193	2.05	NA	2	125.54	bridge
30	88.49	86.69	92.89	4.4	17.75	0.2	193	2.05	NA	2	163	existing regulator and prop fall=3'
40	88.29	86.09	92.69	4.4	17.75	0.2	193	2.05	NA	2	176.89	bridge
50	88.09	85.49	92.49	4.4	17.75	0.2	193	2.05	NA	2	217.38	bridge
54.34	88	na	92.4	4.4	17.75	0.2	193	2.05	NA	2	219	offtake of disty 6B MC
54.34	86	na	90.4	4.4	17.75	0.2	193	2.05	NA	2	249.28	bridge with regul;ator

Table 6.24: (continued) 6A MC of DMC (Id:63, Node No:17-208)

Chainage	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Discharge (cusec)	V (ft/sec)	V/V0	Free board
60	85.89	84.89	90.29	4.4	17.75	0.2	193	2.05	NA	2
70	85.69	84.29	90.09	4.4	17.75	0.2	193	2.05	NA	2
80	85.49	83.69	89.89	4.4	17.75	0.2	193	2.05	NA	2
90	85.29	83.09	89.69	4.4	17.75	0.2	193	2.05	NA	2
98	85.13	na	89.53	4.4	17.75	0.2	193	2.05	NA	2
98	82.13	na	86.53	4.4	17.75	0.2	193	2.05	NA	2
100	82.09	82.49	86.49	4.4	17.75	0.2	193	2.05	NA	2
110	81.89	81.89	86.29	4.4	17.75	0.2	193	2.05	NA	2
120	81.69	81.29	86.09	4.4	17.75	0.2	193	2.05	NA	2
130	81.49	80.69	85.89	4.4	17.75	0.2	193	2.05	NA	2
140	81.29	80.09	85.69	4.4	17.75	0.2	193	2.05	NA	2
150	81.09	79.49	85.49	4.4	17.75	0.2	193	2.05	NA	2
160	80.89	78.49	85.29	4.4	17.75	0.2	193	2.05	NA	2
163	80.98	na	85.23	4.25	16.75	0.2	173	1.9	NA	2

Table 6.25: (continued) 6A MC of DMC (Id:63, Node No:17-208)

Chainage	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Discharge (cusec)	V (ft/sec)	V/V0	Free board
163	77.98	na	82.23	4.25	16.75	0.2	173	1.9	NA	2
170	77.84	78.29	82.09	4.25	16.75	0.2	173	1.9	NA	2
180	77.64	77.69	81.89	4.25	16.75	0.2	173	1.9	NA	2
190	77.44	77.09	81.69	4.25	16.75	0.2	173	1.9	NA	2
200	77.24	75.49	81.49	4.25	16.75	0.2	173	1.9	NA	2
210	77.04	75.89	81.29	4.25	16.75	0.2	173	1.9	NA	2
220	76.84	76.29	81.09	4.25	16.75	0.2	173	1.9	NA	2
230	76.64	75.99	80.89	4.25	16.75	0.2	173	1.9	NA	2
240	76.44	75.69	80.69	4.25	16.75	0.2	173	1.9	NA	2
250	76.24	75.39	80.49	4.25	16.75	0.2	173	1.9	NA	2

Table 6.26: 6 B MC of DMC(Id:64, Node No:207-210)

Chainage	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000’	Discharge (cusec)	V (ft/sec)	V/V0	Free board	Distance in chainage	Structure
0	76.35	76.32	87.07	3.5	10.75	0.25	92.5	1.85	0.98	2	44.21	cart bridge
10	76.1	74.65	79.45	3.5	10.75	0.25	92.5	1.85	0.98	2	99.4	syphon aqueduct with bridge (prop fall=3’ exist fall= 0.98)
20	75.85	75.1	79.05	3.5	10.75	0.25	92.5	1.85	0.98	2	140.06	cart bridge
30.88	75.58	74.41	78.61	3.5	10.75	0.25	92.5	1.85	0.98	2	144.88	regulator
40.88	75.33	73.13	78.21	3.5	10.75	0.25	92.5	1.85	0.98	2		
50.88	75.08	71.26	77.81	3.5	10.75	0.25	92.5	1.85	0.98	2		
60.88	74.83	70.46	77.41	3.5	10.75	0.25	92.5	1.85	0.98	2		
70.88	74.58	69.71	77.01	3.5	10.75	0.25	92.5	1.85	0.98	2		
80.88	74.33	67.99	76.61	3.5	10.75	0.25	92.5	1.85	0.98	2		
90.88	74.08	68.27	76.21	3.5	10.75	0.25	92.5	1.85	0.98	2		
99.4	73.97	na	75.87	3.5	10.75	0.25	92.5	1.85	0.98	2		
99.4	70.97	na	74.89	3.4	10	0.25	76.75	1.79	0.98	2		

Table 6.27: (continued) 6 B MC of DMC(Id:64, Node No:207-210)

Chainage	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Discharge (cusec)	V (ft/sec)	V/V0	Free board
100.88	70.93	72.3	74.81	3.4	10	0.25	76.75	1.79	0.98	2
110.88	70.68	70.22	74.41	3.4	10	0.25	76.75	1.79	0.98	2
120.88	70.43	69.92	74.01	3.4	10	0.25	76.75	1.79	0.98	2
130.88	70.18	69.1	73.61	3.4	10	0.25	76.75	1.79	0.98	2
140.06	69.93	70.71	73.21	3.4	10	0.25	76.75	1.79	0.98	2
144.88	69.83	na	na	3.4	10	0.25	76.75	1.79	0.98	2
144.88	69.98	na	na	3.25	9.75	0.25	76.75	1.74	0.98	3
150.88	69.83	68.76		3.25	9.75	0.25	76.75	1.74	0.98	2
160.7	69.58	67.98		3.25	9.75	0.25	76.75	1.74	0.98	2
167.7	69.4	na	72.14	3.25	9.75	0.25	76.75	1.74	0.98	2
167.7	69.65	na	na	3	9	0.25	76.75	1.66	0.98	2
170.7	69.58	65.79	72	3	9	0.25	76.75	1.66	0.98	2
180.7	69.33	65.52	71.55	3	9	0.25	76.75	1.66	0.98	2

Table 6.28: 6 B1 MC of DMC (Id:123, Node No:209-293)

Distance in ft	Design Bed Level	F.S.L	F.S.D (ft)	Ground level	Height of embankment	Crest level	Bed width (ft)	Slope in 1000'	Discharge (cusec)	V (ft/sec)	V/V0	Distance in chainage	Structure
0	65.05	66.95	1.9	66.75	1.7	68.45	18.5	0.15	39.83	1.041	0.834	20' of start	regulator
500	64.98	66.88	1.9	66.23	2.15	68.38	18.5	0.15	39.83	1.041	0.834	5580	pipe syphon
1000	64.9	66.8	1.9	66.16	2.14	68.3	18.5	0.15	39.83	1.041	0.834	6060	Village road bridge (fall= 0.2')
1500	64.83	66.73	1.9	65.95	2.28	68.23	18.5	0.15	39.83	1.041	0.834	7120	water course 1L
2000	64.75	66.65	1.9	65.91	2.24	68.15	18.5	0.15	39.83	1.041	0.834	8540	Village road bridge (fall= 0.2') and pipe syphon
2500	64.68	66.58	1.9	65.61	2.47	68.08	18.5	0.15	39.83	1.041	0.834	10000	water course 2L
3000	64.6	66.5	1.9	65.45	2.55	68	18.5	0.15	39.83	1.041	0.834	11000	water course 1R
3500	64.53	66.43	1.9	65.3	2.65	67.95	18.5	0.15	39.83	1.041	0.834	11500	Village road bridge (fall= 0.2')

Table 6.29: (continued) 6 B1 MC of DMC (Id:123, Node No:209-293)

Distance in ft	Design Bed Level	F.S.L	F.S.D (ft)	Ground level	Height of embankment	Crest level	Bed width (ft)	Slope in 1000'	Discharge (cusec)	V (ft/sec)	V/V0	Distance in chainage	Structure
4000	64.45	66.35	1.9	65.38	2.47	67.85	18.5	0.15	39.83	1.041	0.834	12500	Road bridge
4500	64.38	66.28	1.9	65.21	2.57	67.78	18.5	0.15	39.83	1.041	0.834	19195	district road bridge (fall= 0.2')
5000	64.3	66.2	1.9	65.1	2.6	67.7	18.5	0.15	39.83	1.041	0.834	21500	prop. Village road bridge (fall= 0.2')
5500	64.23	66.13	1.9	65	2.68	67.68	18.5	0.15	39.83	1.041	0.834	24000	prop. Village road bridge (fall= 0.2')
6000	64.15	66.05	1.9	65.1	2.45	67.55	18.5	0.15	39.83	1.041	0.834	25400	prop. Village road bridge (fall= 0.2')
6060	64.14	66.04	1.9	66.62	0.92	67.54	18.5	0.15	39.83	1.041	0.834	27600	water course 9L (fall= 2.0')
6060	63.94	65.84	1.9	na	na	67.34	18.5	0.15	39.83	1.041	0.834	29600	prop. Village road bridge (fall= 0.2')
6500	63.88	65.78	1.9	64.28	3	67.28	18.5	0.15	39.83	1.041	0.834	31000	prop. Village road bridge (fall= 0.2')

Table 6.30: (continued) 6 B1 MC of DMC (Id:123, Node No:209-293)

Distance in ft	Design Bed Level	F.S.L	F.S.D (ft)	Ground level	Height of em-bank-ment	Crest level	Bed width (ft)	Slope in 1000'	Discharge (cusec)	V (ft/sec)	V/V0
7000	63.8	65.7	1.9	64.07	3.13	67.2	18.5	0.15	39.83	1.041	0.834
7120	63.78	65.68	1.9	64.14	3.04	67.18	18.5	0.15	39.83	1.041	0.834
7500	63.73	65.63	1.9	64.58	2.55	67.13	18	0.15	39.37	1.049	0.835
8000	63.65	65.55	1.9	65.09	1.96	67.05	18	0.15	39.37	1.049	0.835
8500	63.58	65.48	1.9	65.12	1.86	66.98	18	0.15	39.37	1.049	0.835
8540	63.57	65.47	1.9	66.52	0.45	66.97	18	0.15	39.37	1.049	0.835
8540	63.31	65.21	1.9	65.13	1.64	66.77	18	0.15	39.37	1.049	0.835
9000	63.3	65.2	1.9	65.51	1.19	66.7	18	0.15	39.37	1.049	0.835
9500	63.23	65.13	1.9	63.15	3.5	66.65	18	0.15	39.37	1.049	0.835
10000	63.15	65.05	1.9	63.54	3.01	66.55	18	0.15	39.37	1.049	0.835
10500	63.08	64.98	1.9	65.2	1.28	66.48	17.5	0.15	38.7	1.04	0.83
11000	63	64.9	1.9	66.84	-0.44	66.4	17.5	0.15	38.7	1.04	0.83
11500	62.93	64.83	1.9	68.45	-2.12	66.33	17	0.15	37.3	1.039	0.825
11500	62.73	64.63	1.9	na	na	66.13	17	0.15	37.3	1.039	0.825
12000	62.65	64.55	1.9	66.74	-0.69	66.05	17	0.15	37.3	1.039	0.825

Table 6.31: (continued) 6 B1 MC of DMC (Id:123, Node No:209-293)

Distance in ft	Design Bed Level	F.S.L	F.S.D (ft)	Ground level	Height of em-bank-ment	Crest level	Bed width (ft)	Slope in 1000'	Discharge (cusec)	V (ft/sec)	V/V0
12500	62.58	64.48	1.9	66.18	-0.2	65.98	17	0.15	37.3	1.039	0.825
12500	62.38	64.28	1.9	na	na	65.78	17	0.15	37.3	1.039	0.825
13000	62.3	64.2	1.9	65.68	0.02	65.7	17	0.15	37.3	1.039	0.825
13500	62.23	64.13	1.9	65.04	0.59	65.63	17	0.15	37.3	1.039	0.825
14000	62.15	64.05	1.9	63.85	1.7	65.55	16	0.15	34.53	1.039	0.825
13500	62.23	64.13	1.9	65.04	0.59	65.63	17	0.15	37.3	1.039	0.825
14000	62.15	64.05	1.9	63.85	1.7	65.55	16	0.15	34.53	1.039	0.825
14500	62.08	63.98	1.9	64.03	1.45	65.48	16	0.15	34.53	1.039	0.825
15000	62	63.9	1.9	64.14	1.26	65.4	16	0.15	34.53	1.039	0.825
15500	61.95	63.85	1.9	63.88	1.45	65.33	16	0.15	34.53	1.039	0.825
16000	61.85	63.75	1.9	62.78	2.47	65.25	16	0.15	34.53	1.039	0.825
16500	61.78	63.68	1.9	62.76	2.42	65.18	15.5	0.15	33.77	1.03	0.82
17000	61.7	63.6	1.9	64.38	0.72	65.1	15.5	0.15	33.77	1.03	0.82
17500	61.63	63.53	1.9	64.34	0.69	65.03	15	0.15	32.47	1.02	0.81
18000	61.55	63.45	1.9	64.03	0.92	64.95	15	0.15	32.47	1.02	0.81

Table 6.32: (continued) 6 B1 MC of DMC (Id:123, Node No:209-293)

Distance in ft	Design Bed Level	F.S.L	F.S.D (ft)	Ground level	Height of em-bank-ment	Crest level	Bed width (ft)	Slope in 1000'	Discharge (cusec)	V (ft/sec)	V/V0
18200	61.52	63.42	1.9	63.78	1.14	64.92	15	0.15	32.47	1.02	0.81
18200	61.62	63.42	1.8	na	na	64.92	14.5	0.15	28.14	0.985	0.81
18500	61.58	63.38	1.8	62.67	2.21	64.88	14.5	0.15	28.14	0.985	0.81
19000	61.5	63.3	1.8	62.03	2.77	64.8	14.5	0.15	28.14	0.985	0.81
19195	61.47	63.27	1.8	62.18	2.59	64.77	14.5	0.15	28.14	0.985	0.81
19195	61.37	63.07	1.7	na	na	64.57	14	0.2	28.14	1.12	0.96
19500	61.31	63.01	1.7	60.02	4.49	64.51	14	0.2	28.14	1.12	0.96
20000	61.21	62.91	1.7	60.09	4.32	64.41	14	0.2	28.14	1.12	0.96
20500	61.11	62.81	1.7	62.58	1.73	64.31	11.5	0.2	22.67	1.09	0.95
19500	61.31	63.01	1.7	60.02	4.49	64.51	14	0.2	28.14	1.12	0.96
20000	61.21	62.91	1.7	60.09	4.32	64.41	14	0.2	28.14	1.12	0.96
20500	61.11	62.81	1.7	62.58	1.73	64.31	11.5	0.2	22.67	1.09	0.95
21000	61.01	62.71	1.7	61.38	2.83	64.21	11.5	0.2	22.67	1.09	0.95
21500	60.91	62.61	1.7	58.76	5.35	64.11	11.5	0.2	22.67	1.09	0.95
21500	60.71	62.41	1.7	na	na	63.91	11.5	0.2	22.67	1.09	0.95
22000	60.61	62.31	1.7	59.56	4.25	63.81	11.5	0.2	22.67	1.09	0.95
22500	60.51	62.21	1.7	58.85	4.86	63.71	11.5	0.2	22.67	1.09	0.95

Table 6.33: (continued) 6 B1 MC of DMC (Id:123, Node No:209-293)

Distance in ft	Design Bed Level	F.S.L	F.S.D (ft)	Ground level	Height of em-bank-ment	Crest level	Bed width (ft)	Slope in 1000'	Discharge (cusec)	V (ft/sec)	V/V0
23000	60.41	62.11	1.7	58.85	4.76	63.61	11.5	0.2	22.67	1.09	0.95
23500	60.31	62.01	1.7	59.56	3.95	63.51	11.5	0.2	22.67	1.09	0.95
24000	60.21	61.91	1.7	59.14	4.27	63.41	11.5	0.2	22.67	1.09	0.95
24000	60.21	61.71	1.5	na	na	63.21	7	0.225	13.11	1.003	0.92
24500	60.1	61.6	1.5	59.11	3.9	63.01	7	0.225	13.11	1.003	0.92
25000	59.98	61.48	1.5	59.05	3.93	62.98	7	0.225	13.11	1.003	0.92
25400	59.89	61.39	1.5	58.74	4.15	62.89	7	0.225	13.11	1.003	0.92
25400	59.69	61.19	1.5	na	na	62.69	7	0.225	13.11	1.003	0.92
26000	59.56	61.06	1.5	58.14	4.42	62.56	7	0.225	13.11	1.003	0.92
25400	59.69	61.19	1.5	na	na	62.69	7	0.225	13.11	1.003	0.92
26000	59.56	61.06	1.5	58.14	4.42	62.56	7	0.225	13.11	1.003	0.92
25400	59.69	61.19	1.5	na	na	62.69	7	0.225	13.11	1.003	0.92
26000	59.56	61.06	1.5	58.14	4.42	62.56	7	0.225	13.11	1.003	0.92
26500	59.44	60.94	1.5	57.69	4.75	62.44	7	0.225	13.11	1.003	0.92
27000	59.33	60.83	1.5	57.89	4.44	62.33	7	0.225	13.11	1.003	0.92
27600	59.19	60.69	1.5	59.19	3	62.19	7	0.225	13.11	1.003	0.92

Table 6.34: (continued) 6 B1 MC of DMC (Id:123, Node No:209-293)

Distance in ft	Design Bed Level	F.S.L	F.S.D (ft)	Ground level	Height of embankment	Crest level	Bed width (ft)	Slope in 1000'	Discharge (cusec)	V (ft/sec)	V/V0
27600	57.19	58.69	1.5	na	na	60.19	5.5	0.3	11.41	1.129	1.021
28000	57.07	58.57	1.5	57.59	2.48	60.07	5.5	0.3	11.41	1.129	1.021
28500	56.92	58.42	1.5	55.08	4.84	59.92	5.5	0.3	11.41	1.129	1.021
29200	56.71	58.21	1.5	58.22	1.49	59.71	5.5	0.3	11.41	1.129	1.021
29600	56.59	58.09	1.5	59.85	-0.26	59.59	4.5	0.3	8.76	1.085	1
29600	56.39	57.89	1.5	na	na	59.39	4.5	0.3	8.76	1.085	1
30000	56.27	57.77	1.5	55.92	3.35	59.27	4.5	0.3	8.76	1.085	1
30500	56.32	57.52	1.2	56.71	2.31	59.02	1.25	0.5	2.34	0.98	1.04
31000	56.02	57.22	1.2	na	na	58.72	1.25	0.5	2.34	0.98	1.04
31000	55.82	57.02	1.2	na	na	58.52	1.25	0.5	2.34	0.98	1.04
31500	55.62	56.82	1.2	56.39	1.93	58.32	1.25	0.5	2.34	0.98	1.04
32000	55.37	56.57	1.2	55.02	3.03	58.05	1.25	0.5	2.34	0.98	1.04
32500	55.12	56.32	1.2	56.04	1.78	57.82	1.25	0.5	2.34	0.98	1.04
32970	54.88	56.08	1.2	55.94	1.64	57.58	1.25	0.5	2.34	0.98	1.04

Table 6.35: 6 C MC (Id:65, Node No:18-211)

Distance in ft	Design Bed Level	Ground Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width of bank	Free board	Inside Berm
0	86.65	86.65	89.4	2.75	90.45	91.5	3	0.7	2	0.75	3	89.9
100	86.58	86.58	89.33	2.75	90.08	91	3	0.7	2	0.75	3	89.74
200	86.51	86.51	89.26	2.75	90.01	90.58	3	0.7	2	0.75	3	89.6
300	86.44	86.44	89.19	2.75	89.94	90.84	3	0.7	2	0.75	3	88.8
400	86.37	86.37	89.12	2.75	89.87	90.77	3	0.7	2	0.75	3	88.96
500	86.3	86.3	89.05	2.75	89.8	90.63	3	0.7	2	0.75	3	89.06
600	86.23	86.23	88.98	2.75	89.73	90.65	3	0.7	2	0.75	3	88.94
700	86.16	86.16	88.91	2.75	89.66	90.42	3	0.7	2	0.75	3	88.78
800	86.09	86.09	88.84	2.75	89.59	90.21	3	0.7	2	0.75	3	88.84
900	86.02	86.02	88.77	2.75	89.52	90.03	3	0.7	2	0.75	3	88.65
1000	85.95	85.95	88.7	2.75	89.45	90.08	3	0.7	2	0.75	3	88.5
1100	85.88	85.88	88.63	2.75	89.38	90.12	3	0.7	2	0.75	3	88.42
1200	85.81	85.81	88.56	2.75	89.31	89.86	3	0.7	2	0.75	3	88.32
1300	85.74	85.74	88.49	2.75	89.24	89.67	3	0.7	2	0.75	3	88.34
1400	85.67	85.67	88.42	2.75	89.17	89.83	3	0.7	2	0.75	3	87.9

Table 6.36: (continued) 6 C MC (Id:65, Node No:18-211)

Distance in ft	Design Bed Level	Ground Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width of bank	Free board	Inside Berm
1500	85.6	85.6	88.35	2.75	89.1	89.16	3	0.7	2	0.75	3	88.01
1600	85.56	85.56	88.31	2.75	89.03	89.27	3	0.7	2	0.75	3	88.01
1700	85.43	85.43	88.18	2.75	88.96	89.78	3	0.7	2	0.75	3	87.76
1800	85.39	85.39	88.14	2.75	88.89	89.12	3	0.7	2	0.75	3	87.79
1900	85.32	85.32	88.07	2.75	88.82	88.98	3	0.7	2	0.75	3	87.44
2000	85.25	85.25	88	2.75	88.75	89.01	3	0.7	2	0.75	3	87.47
2100	85.18	85.18	87.93	2.75	88.68	89.02	3	0.7	2	0.75	3	87.46
2200	85.11	85.11	87.86	2.75	88.61	88.98	3	0.7	2	0.75	3	87.37
2300	85.04	85.04	87.79	2.75	88.54	89.03	3	0.7	2	0.75	3	87.36
2400	84.97	84.97	87.72	2.75	88.47	88.93	3	0.7	2	0.75	3	87.22
2500	84.9	84.9	87.65	2.75	88.4	88.93	3	0.7	2	0.75	3	87.26
2600	84.83	84.83	87.58	2.75	88.33	88.54	3	0.7	2	0.75	3	87.11
2700	84.72	84.72	87.47	2.75	88.26	88.59	3	0.7	2	0.75	3	87.05
2800	84.69	84.69	87.44	2.75	88.19	88.61	3	0.7	2	0.75	3	86.96
2900	84.62	84.62	87.37	2.75	88.12	88.36	3	0.7	2	0.75	3	86.88
3000	84.55	84.55	87.3	2.75	88.05	88.33	3	0.7	2	0.75	3	86.8
3100	84.48	84.48	87.23	2.75	87.98	88.19	3	0.7	2	0.75	3	86.84

Table 6.37: (continued) 6 C MC (Id:65, Node No:18-211)

Distance in ft	Design Bed Level	Ground Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width of bank	Free board	Inside Berm
3200	84.41	84.41	87.16	2.75	87.91	88.38	3	0.7	2	0.75	3	86.78
3300	84.34	84.34	87.09	2.75	87.84	88.11	3	0.7	2	0.75	3	86.7
3400	84.27	84.27	87.02	2.75	87.77	88.71	3	0.7	2	0.75	3	86.69
3500	84.2	84.2	86.95	2.75	87.7	87.96	3	0.7	2	0.75	3	86.58
3600	84.13	84.13	86.88	2.75	87.63	88.06	3	0.7	2	0.75	3	86.63
3700	84.06	84.06	86.81	2.75	87.56	87.95	3	0.7	2	0.75	3	86.44
3800	83.99	83.99	86.74	2.75	87.49	87.8	3	0.7	2	0.75	3	86.37
3900	83.92	83.92	86.67	2.75	87.42	87.82	3	0.7	2	0.75	3	86.34
4000	83.85	83.85	86.6	2.75	87.35	87.65	3	0.7	2	0.75	3	86.14
4100	83.78	83.78	86.53	2.75	87.28	87.62	3	0.7	2	0.75	3	85.99
4200	83.71	83.71	86.46	2.75	87.21	87.45	3	0.7	2	0.75	3	86.08
4300	83.64	83.64	86.39	2.75	87.14	87.57	3	0.7	2	0.75	3	85.91
4400	83.57	83.57	86.32	2.75	87.07	87.52	3	0.7	2	0.75	3	85.93
4500	83.5	83.5	86.25	2.75	87	87.05	3	0.7	2	0.75	3	85.83
4600	83.43	83.43	86.18	2.75	86.93	87.41	3	0.7	2	0.75	3	85.92

Table 6.38: (continued) 6 C MC (Id:65, Node No:18-211)

Distance in ft	Design Bed Level	Ground Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width of bank	Free board	Inside Berm
4700	83.36	83.36	86.11	2.75	86.86	86.9	3	0.7	2	0.75	3	85.49
4800	83.29	83.29	86.04	2.75	86.79	86.88	3	0.7	2	0.75	3	85.64
4900	83.22	83.22	85.97	2.75	86.72	86.75	3	0.7	2	0.75	3	85.33
5000	83.15	83.15	85.9	2.75	86.65	86.7	3	0.7	2	0.75	3	85.39
5100	83.08	83.08	85.83	2.75	86.58	86.89	3	0.7	2	0.75	3	85.23
5200	83.01	83.01	85.76	2.75	86.51	86.54	3	0.7	2	0.75	3	85.01
5300	82.94	82.94	85.69	2.75	86.44	na	3	0.7	2	0.75	3	85.03
5400	82.87	82.87	85.62	2.75	86.37	86.5	3	0.7	2	0.75	3	84.98
5500	82.8	82.8	85.55	2.75	86.3	86.67	3	0.7	2	0.75	3	85
5600	82.73	82.73	85.48	2.75	86.23	86.48	3	0.7	2	0.75	3	84.98
5700	82.66	82.66	85.41	2.75	86.16	86.36	3	0.7	2	0.75	3	84.95
5800	82.59	82.59	85.34	2.75	86.09	86.86	3	0.7	2	0.75	3	85.06
5900	82.52	82.52	85.27	2.75	86.02	na	3	0.7	2	0.75	3	86.09
6000	82.45	82.45	85.2	2.75	85.95	89.06	3	0.7	2	0.75	3	86.66
6100	82.38	82.38	85.13	2.75	85.88	87.32	3	0.7	2	0.75	3	85.52
6200	82.31	82.31	85.06	2.75	85.81	85.94	3	0.7	2	0.75	3	84.51
6300	82.24	82.24	84.99	2.75	85.74	86.06	3	0.7	2	0.75	3	84.38

Table 6.39: (continued) 6 C MC (Id:65, Node No:18-211)

Distance in ft	Design Bed Level	Ground Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width of bank	Free board	Inside Berm
6400	82.17	82.17	84.92	2.75	85.67	85.98	3	0.7	2	0.75	3	84.44
6500	82.1	82.1	84.85	2.75	85.6	86.04	3	0.7	2	0.75	3	84.47
6600	82.03	82.03	84.78	2.75	85.53	85.96	3	0.7	2	0.75	3	84.43
6700	81.96	81.96	84.71	2.75	85.46	na	3	0.7	2	0.75	3	84.39
6800	81.89	81.89	84.64	2.75	85.39	85.96	3	0.7	2	0.75	3	85.19
6900	81.82	81.82	84.57	2.75	85.32	86.38	3	0.7	2	0.75	3	84.31
7000	81.75	81.75	84.5	2.75	85.25	85.58	3	0.7	2	0.75	3	84.51
7100	81.68	81.68	84.43	2.75	85.18	85.5	3	0.7	2	0.75	3	83.95
7200	81.61	81.61	84.36	2.75	85.11	85.4	3	0.7	2	0.75	3	83.9
7300	81.54	81.54	84.29	2.75	85.04	85.12	3	0.7	2	0.75	3	83.88
7400	81.47	81.47	84.22	2.75	84.97	85.02	3	0.7	2	0.75	3	83.78
7500	81.4	81.4	84.15	2.75	84.9	85.14	3	0.7	2	0.75	3	83.51
7600	81.33	81.33	84.08	2.75	84.83	85.44	3	0.7	2	0.75	3	83.64
7700	81.26	81.26	84.01	2.75	84.76	85.04	3	0.7	2	0.75	3	83.65
7800	81.19	81.19	83.94	2.75	84.69	84.86	3	0.7	2	0.75	3	83.46
7900	81.12	81.12	83.87	2.75	84.62	85.24	3	0.7	2	0.75	3	83.48

Table 6.40: (continued) 6 C MC (Id:65, Node No:18-211)

Distance in ft	Design Bed Level	Ground Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width of bank	Free board	Inside Berm
8000	81.05	81.05	83.8	2.75	84.55	84.78	3	0.7	2	0.75	3	83.44
8100	80.98	80.98	83.73	2.75	84.48	84.58	3	0.7	2	0.75	3	83.14
8200	80.91	80.91	83.66	2.75	84.41	84.74	3	0.7	2	0.75	3	83.02
8300	80.84	80.84	83.59	2.75	84.34	84.53	3	0.7	2	0.75	3	83.15
8400	80.77	80.77	83.52	2.75	84.27	84.62	3	0.7	2	0.75	3	83.02
8500	80.7	80.7	83.45	2.75	84.2	na	3	0.7	2	0.75	3	83.09
8600	80.63	80.63	83.38	2.75	84.13	84.77	3	0.7	2	0.75	3	83.1
8700	80.56	80.56	83.31	2.75	84.06	84.71	3	0.7	2	0.75	3	82.82
8800	80.49	80.49	83.24	2.75	83.99	84.07	3	0.7	2	0.75	3	82.89
8900	80.42	80.42	83.17	2.75	83.92	84.12	3	0.7	2	0.75	3	82.63
9000	80.35	80.35	83.1	2.75	83.85	na	3	0.7	2	0.75	3	82.68
9100	80.28	80.28	83.03	2.75	83.78	84.13	3	0.7	2	0.75	3	82.61
9200	80.21	80.21	82.96	2.75	83.71	84.03	3	0.7	2	0.75	3	82.47
9300	80.14	80.14	82.89	2.75	83.64	84.26	3	0.7	2	0.75	3	82.61
9400	80.07	80.07	82.82	2.75	83.57	84.11	3	0.7	2	0.75	3	82.46
9500	80	80	82.75	2.75	83.5	84.11	3	0.7	2	0.75	3	82.19
9600	79.93	79.93	82.68	2.75	83.43	83.97	3	0.7	2	0.75	3	82.46

Table 6.41: (continued) 6 C MC (Id:65, Node No:18-211)

Distance in ft	Design Bed Level	Ground Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width of bank	Free board	Inside Berm
9700	79.86	79.86	82.61	2.75	83.36	83.85	3	0.7	2	0.75	3	82.26
9800	79.79	79.79	82.54	2.75	83.29	83.87	3	0.7	2	0.75	3	82.14
9900	79.72	79.72	82.47	2.75	83.22	83.87	3	0.7	2	0.75	3	82.15
10000	80.4	80.4	82.4	2	83.15	83.7	3	0.7	2	0.75	3	82.17
10100	80.32	80.32	82.32	2	83.07	83.16	3	0.7	2	0.75	3	82.06
10200	80.24	80.24	82.24	2	82.99	83.26	3	0.7	2	0.75	3	81.97
10300	80.16	80.16	82.16	2	82.91	83.06	3	0.7	2	0.75	3	81.94
10400	80.08	80.08	82.08	2	82.83	83.12	3	0.7	2	0.75	3	82
10500	80	80	82	2	82.75	83.2	3	0.8	2	0.75	3	81.98
10600	79.92	79.92	81.92	2	82.67	82.96	3	0.8	2	0.75	3	81.86
10700	79.84	79.84	81.84	2	82.59	82.91	3	0.8	2	0.75	3	81.67
10800	79.76	79.76	81.76	2	82.51	82.59	3	0.8	2	0.75	3	81.52
10900	79.68	79.68	81.68	2	82.43	82.63	3	0.8	2	0.75	3	81.51
11000	79.6	79.6	81.6	2	82.35	82.35	3	0.8	2	0.75	3	81.41
11100	79.52	79.52	81.52	2	82.27	82.41	3	0.8	2	0.75	3	81.21
11200	79.44	79.44	81.44	2	82.19	82.41	3	1	1	0.75	2	81.25

Table 6.42: (continued) 6 C MC (Id:65, Node No:18-211)

Distance in ft	Design Bed Level	Ground Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width of bank	Free board	Inside Berm
11300	79.34	79.34	81.34	2	82.09	82.21	3	1	1	0.75	2	81.11
11400	79.24	78.47	81.24	2	81.99	81.99	3	1	1	0.75	2	80.47
11500	79.14	78.84	81.14	2	81.89	81.89	3	1	1	0.75	2	80.84
11600	79.04	79.04	81.04	2	81.79	81.82	3	1	1	0.75	2	80.72
11700	78.94	78.94	80.94	2	81.69	81.8	3	1	1	0.75	2	80.7
11800	78.84	78.84	80.84	2	81.59	81.61	3	1	1	0.75	2	80.51
11900	78.74	78.74	80.74	2	81.49	81.64	3	1	1	0.75	2	80.54
12000	78.64	78.64	80.64	2	81.39	81.56	3	1	1	0.75	2	80.36
12100	78.54	78.54	80.54	2	81.29	81.28	3	1	1	0.75	2	80.18
12200	78.44	78.44	80.44	2	81.19	81.34	3	1	1	0.75	2	80.24
12300	78.34	78.14	80.34	2	81.09	81.09	3	1	1	0.75	2	79.84
12400	78.24	77.76	80.24	2	80.99	80.99	3	1	1	0.75	2	79.76
12500	78.14	78.14	80.14	2	80.89	80.89	3	1	1	0.75	2	79.86
12600	78.04	77.68	80.04	2	80.79	80.79	3	1	1	0.75	2	79.48
12700	77.94	77.36	79.94	2	80.69	80.69	3	1	1	0.75	2	79.36
12800	77.84	77.58	79.84	2	80.59	80.59	3	1	1	0.75	2	79.38

Table 6.43: (continued) 6 C MC (Id:65, Node No:18-211)

Distance in ft	Design Bed Level	Ground Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000’	Crest width of bank	Free board	Inside Berm
12900	77.74	77.42	79.74	2	80.49	80.49	3	1	1	0.75	2	79.22
13000	77.64	76.59	79.64	2	80.39	80.39	3	1	1	0.75	2	78.89
13100	77.54	77.73	79.54	2	80.29	80.29	3	1	1	0.75	2	79.03
13200	77.44	76.87	79.44	2	80.19	80.19	3	1	1	0.75	2	78.87
13300	77.34	76.89	79.34	2	80.09	80.09	3	1	1	0.75	2	78.79
13400	77.24	77.24	79.24	2	79.99	80.45	3	1	1	0.75	2	79.15
13500	77.14	77.14	79.14	2	79.89	80.48	3	1	1	0.75	2	79.18
13600	77.04	77.04	79.04	2	79.79	79.79	3	1	1	0.75	2	78.46
13700	76.94	76.94	78.94	2	79.69	79.69	3	1	1	0.75	2	78.65
13700	77.32	77.32	78.82	1.5	na	na	2	0.7	1	0.5	1	na
13800	77.25	77.25	78.75	1.5	79.25	79.38	2	0.7	1	0.5	1	78.48
13900	77.18	77.18	78.68	1.5	79.18	79.67	2	0.7	1	0.5	1	78.67
14000	77.11	77.11	78.61	1.5	79.11	79.12	2	0.7	1	0.5	1	78.22
14100	77.04	77.04	78.54	1.5	79.04	79.42	2	0.7	1	0.5	1	78.52
14200	76.97	76.97	78.47	1.5	78.97	79.44	2	0.7	1	0.5	1	78.44
14300	76.9	76.9	78.4	1.5	78.9	79.16	2	0.7	1	0.5	1	78.16

Table 6.44: (continued) 6 C MC (Id:65, Node No:18-211)

Distance in ft	Design Bed Level	Ground Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width of bank	Free board	Inside Berm
14400	76.83	76.83	78.33	1.5	78.83	79.12	2	0.7	1	0.5	1	78.22
14500	76.76	76.76	78.26	1.5	78.76	79.08	2	0.7	1	0.5	1	78.08
14600	76.69	76.69	78.19	1.5	78.69	78.85	2	0.7	1	0.5	1	77.98
14700	76.62	76.62	78.12	1.5	78.62	79.04	2	0.7	1	0.5	1	78.04
14800	76.55	76.55	78.05	1.5	78.55	78.5	2	0.7	1	0.5	1	77.6
14900	76.48	76.48	77.98	1.5	78.48	78.76	2	0.7	1	0.5	1	77.86
15000	76.41	76.41	77.91	1.5	78.41	78.91	2	0.7	1	0.5	1	77.91
15100	76.34	76.34	77.84	1.5	78.34	78.69	2	0.7	1	0.5	1	77.69
15200	76.27	76.27	77.77	1.5	78.27	78.33	2	0.7	1	0.5	1	77.43
15300	76.2	76.2	77.7	1.5	78.2	78.41	2	0.7	1	0.5	1	77.51
15400	76.13	76.13	77.63	1.5	78.13	78.41	2	0.7	1	0.5	1	77.51
15500	76.06	76.06	77.56	1.5	78.06	78.47	2	0.7	1	0.5	1	77.47
15600	75.99	75.99	77.49	1.5	77.99	78.29	2	0.7	1	0.5	1	77.29
15700	75.92	75.92	77.42	1.5	77.92	78.12	2	0.7	1	0.5	1	77.22
15800	75.85	75.85	77.35	1.5	77.85	78.02	2	0.7	1	0.5	1	77.12
15900	75.78	75.78	77.28	1.5	77.78	78.99	2	0.7	1	0.5	1	77.09
16000	75.71	75.71	77.21	1.5	77.71	78.23	2	0.7	1	0.5	1	77.23

Table 6.45: (continued) 6 C MC (Id:65, Node No:18-211)

Table 6.46: 6 D MC (Id:66, Node No:19-213)

Distance in ft	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Ground Level	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width of bank	Free board	Inside Berm	Distance	Structure
0	82.58	82.58	84.58	2	86.58	83.58	87.87	4.25	0.4	2	1.5	3	0	head sluice
100	82.54	82.04	84.54	2	86.04	83.54	86.14	4.25	0.4	2	1.5	3	3433	bridge
200	82.5	80.22	84.5	2	86	83.72	86.04	4.25	0.4	2	1.5	3	3583	drainage syphon
300	82.46	79.93	84.46	2	85.96	83.43	86.04	4.25	0.4	2	1.5	3	5263	bridge
400	82.42	80.12	84.42	2	85.92	83.62	86.04	4.25	0.4	2	1.5	3	5983	offtake of disty no 6D/1 MC
500	82.38	80.45	84.38	2	85.88	83.7	85.88	4.25	0.4	2	1.5	3	6383	regulator
600	82.34	80.14	84.34	2	85.84	83.47	85.91	4.25	0.4	2	1.5	3		
700	82.3	80.28	84.3	2	85.8	83.61	85.88	4.25	0.4	2	1.5	3		
800	82.26	79.63	84.26	2	85.76	83.23	85.78	4.25	0.4	2	1.5	3		

Table 6.47: (continued) 6 C MC (Id:65, Node No:18-211)

Distance in ft	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Ground Level	Crest level of embankment	Bed width (ft)	Slope in 1000’	Crest width of bank	Free board	Inside Berm
900	82.22	79.68	84.22	2	85.72	83.28	86.77	4.25	0.4	2	1.5	3
996	82.18	79.87	84.18	2	85.68	83.29	85.68	4.25	0.4	2	1.5	3
1096	82.14	79.85	84.14	2	85.64	83.35	85.68	4.25	0.4	2	1.5	3
1196	82.1	79.88	84.1	2	85.6	83.38	85.84	4.25	0.4	2	1.5	3
1296	82.06	80	84.06	2	85.56	83.4	85.68	4.25	0.4	2	1.5	3
1396	82.02	79.94	84.02	2	85.52	83.36	85.58	4.25	0.4	2	1.5	3
1496	81.98	80.17	83.98	2	85.48	83.33	85.45	4.25	0.4	2	1.5	3
1596	81.94	81.94	83.94	2	85.44	83.18	85.55	4.25	0.4	2	1.5	3
1696	81.9	80.13	83.9	2	85.4	83.29	85.55	4.25	0.4	2	1.5	3
1796	81.86	84.86	83.86	2	85.36	84.14	85.65	4.25	0.4	2	1.5	3
1896	81.82	81.82	83.82	2	85.32	83.32	85.35	4.25	0.4	2	1.5	3
1996	81.78	79.9	83.78	2	85.28	82.81	85.36	4.25	0.4	2	1.5	3
2085	81.74	80.19	83.74	2	85.24	82.61	85.26	4.25	0.4	2	1.5	3
2185	81.7	81.7	83.7	2	85.2	82.84	85.26	4.25	0.4	2	1.5	3
2285	81.66	79.18	83.66	2	85.16	82.88	85.96	4.25	0.4	2	1.5	3

Table 6.48: (continued) 6 C MC (Id:65, Node No:18-211)

Distance in ft	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Ground Level	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width of bank	Free board	Inside Berm
2385	81.62	79.18	83.62	2	85.12	82.88	85.16	4.25	0.4	2	1.5	3
2485	81.58	79.18	83.58	2	85.08	82.68	85.07	4.25	0.4	2	1.5	3
2585	81.54	78.83	83.54	2	85.04	82.58	85.17	4.25	0.4	2	1.5	3
2685	81.5	78.95	83.5	2	85	82.65	85.21	4.25	0.4	2	1.5	3
2785	81.46	78.86	83.46	2	84.96	82.61	85.47	4.25	0.4	2	1.5	3
2885	81.42	79.03	83.42	2	84.92	82.63	85.07	4.25	0.4	2	1.5	3
2985	81.38	78.68	83.38	2	84.88	82.38	85.05	4.25	0.4	2	1.5	3
3085	81.34	78.88	83.34	2	84.84	82.48	84.95	4.25	0.4	2	1.5	3
3183	81.3	78.67	83.3	2	84.8	82.39	85.25	4.25	0.4	2	1.5	3
3283	81.26	78.93	83.26	2	84.76	83.68	85.05	4.25	0.4	2	1.5	3
3383	81.22	81.22	83.22	2	84.72	84.06	85.05	4.25	0.4	2	1.5	3
3483	81.18	81.18	83.18	2	84.68	80.76	84.68	4.25	0.4	2	1.5	3
3583	81.14	81.14	83.14	2	84.64	80.04	84.71	4.25	0.4	2	1.5	3
3683	81.1	78.93	83.1	2	84.6	82.35	84.87	4.25	0.4	2	1.5	3
3783	81.06	78.91	83.06	2	84.56	82.25	84.87	4.25	0.4	2	1.5	3

Table 6.49: (continued) 6 C MC (Id:65, Node No:18-211)

Distance in ft	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Ground Level	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width of bank	Free board	Inside Berm
3883	81.02	79.05	83.02	2	84.52	82.39	84.91	4.25	0.4	2	1.5	3
3983	80.98	78.75	82.98	2	84.48	82.09	84.56	4.25	0.4	2	1.5	3
4083	80.94	77.8	82.94	2	84.44	82.13	84.66	4.25	0.4	2	1.5	3
4183	80.9	77.6	82.9	2	84.4	81.93	84.56	4.25	0.4	2	1.5	3
4283	80.86	78.11	82.86	2	84.36	81.81	84.86	4.25	0.4	2	1.5	3
4383	80.82	78.22	82.82	2	84.32	82.04	84.36	4.25	0.4	2	1.5	3
4483	80.78	78.19	82.78	2	84.28	81.89	84.51	4.25	0.4	2	1.5	3
4583	80.74	77	82.74	2	84.24	81.83	84.61	4.25	0.4	2	1.5	3
4683	80.7	76.77	82.7	2	84.2	81.87	84.31	4.25	0.4	2	1.5	3
4783	80.66	77.75	82.66	2	84.16	81.67	84.51	4.25	0.4	2	1.5	3
4883	80.62	77.77	82.62	2	84.12	81.67	84.61	4.25	0.4	2	1.5	3
4983	80.58	77.83	82.58	2	84.08	81.73	84.16	4.25	0.4	2	1.5	3
5083	80.54	78.12	82.54	2	84.04	81.74	84.76	4.25	0.4	2	1.5	3
5183	80.5	80.5	82.5	2	84	81.5	84.06	4.25	0.4	2	1.5	3
5283	80.46	77.5	82.46	2	83.96	81.5	84.36	4.25	0.4	2	1.5	3
5383	80.42	77.34	82.42	2	83.92	81.34	84.16	4.25	0.4	2	1.5	3

Table 6.50: (continued) 6 C MC (Id:65, Node No:18-211)

Distance in ft	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Ground Level	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width of bank	Free board	Inside Berm
5483	80.38	77.33	82.38	2	83.88	81.25	84.2	4.25	0.4	2	1.5	3
5583	80.34	77.3	82.34	2	83.84	81.3	84.1	4.25	0.4	2	1.5	3
5683	80.3	77.3	82.3	2	83.8	81.22	84.1	4.25	0.4	2	1.5	3
5783	80.26	75.93	82.26	2	83.76	81.18	83.8	4.25	0.4	2	1.5	3
5883	80.22	77.3	82.22	2	83.72	81.22	84	4.25	0.4	2	1.5	3
5983	80.18	77.42	82.18	2	83.68	81.22	83.79	4.25	0.4	2	1.5	3
5983	80.88	na	82.18	1.3	na	81.22	na	3	0.4	2	1.5	3
6083	80.84	76.91	82.14	1.3	83.64	81.16	83.79	3	0.4	2	1.5	3
6183	80.8	77.05	82.1	1.3	83.6	81.3	84.69	3	0.4	2	1.5	3
6283	80.76	76.26	82.06	1.3	83.56	81.26	83.69	3	0.4	2	1.5	3
6383	80.72	77.18	82.02	1.3	83.52	81.18	83.83	3	0.4	2	1.5	3
6483	80.68	77.13	81.98	1.3	83.48	81.13	83.95	3	0.4	2	1.5	3
6583	80.64	76.89	81.94	1.3	83.44	81.14	83.75	3	0.4	2	1.5	3
6683	80.6	76.77	81.9	1.3	83.4	81.09	83.45	3	0.4	2	1.5	3
6783	80.56	76.01	81.86	1.3	83.36	81.01	83.55	3	0.4	2	1.5	3

Table 6.51: (continued) 6 C MC (Id:65, Node No:18-211)

Distance in ft	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of em-bank-ment	Ground Level	Crest level of em-bank-ment	Bed width (ft)	Slope in 1000’	Crest width of bank	Free board	Inside Berm
6883	80.52	76.79	81.82	1.3	83.32	80.79	83.35	3	0.4	2	1.5	3
6983	80.48	76.73	81.78	1.3	83.28	80.73	83.77	3	0.4	2	1.5	3
6983	80.68	na	81.78	1.1	na	80.73	na	2	1.3	2	1	2
7083	80.55	77.1	81.85	1.1	82.65	80.75	83.07	2	1.3	2	1	2
7183	80.42	77.47	81.52	1.1	82.52	80.79	82.77	2	1.3	2	1	2
7283	80.29	78.87	81.39	1.1	82.39	81.69	82.47	2	1.3	2	1	2
7383	80.16	79.02	81.26	1.1	82.26	79.02	82.27	2	1.3	2	1	2
7483	80.03	78.93	81.13	1.1	82.13	78.93	82.48	2	1.3	2	1	2
7583	79.9	77.48	81	1.1	82	80.38	82.48	2	1.3	2	1	2
7683	79.77	77.4	80.87	1.1	81.87	80.4	82.18	2	1.3	2	1	2
7783	79.64	77.55	80.74	1.1	81.74	80.2	81.98	2	1.3	2	1	2
7883	79.51	77.67	80.61	1.1	81.61	80.27	82.18	2	1.3	2	1	2
7983	79.38	77.43	80.48	1.1	81.48	80.08	81.84	2	1.3	2	1	2
8083	79.25	78.52	80.35	1.1	81.35	81.42	83.94	2	1.3	2	1	2
8183	79.12	77.04	80.22	1.1	81.22	79.79	81.64	2	1.3	2	1	2

Table 6.52: (continued) 6 C MC (Id:65, Node No:18-211)

Distance in ft	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Ground Level	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width of bank	Free board	Inside Berm
8283	78.99	76.91	80.09	1.1	81.09	79.66	81.54	2	1.3	2	1	2
8383	78.86	76.58	79.96	1.1	80.96	79.58	81.54	2	1.3	2	1	2
8483	78.73	76.84	79.83	1.1	80.83	79.34	81.61	2	1.3	2	1	2
8583	78.6	75.9	79.7	1.1	80.7	79.32	81.71	2	1.3	2	1	2
8683	78.47	75.77	79.57	1.1	80.57	79.19	81.41	2	1.3	2	1	2
8783	78.34	77.17	79.44	1.1	80.44	79.34	81.21	2	1.3	2	1	2
8883	78.21	76.97	79.31	1.1	80.31	79.05	80.81	2	1.3	2	1	2
8983	78.08	76.77	79.18	1.1	80.18	79.02	80.91	2	1.3	2	1	2
9083	77.95	76.24	79.05	1.1	80.05	78.66	80.41	2	1.3	2	1	2
9183	77.82	76.12	78.92	1.1	79.92	78.62	80.41	2	1.3	2	1	2

Table 6.53: 6 D1 MC (Id:124, Node No:212-294)

Distance in ft	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Ground Level	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width of bank	Free board	Inside Berm	Distance	Structure
0	80.74	80.74	81.94	1.2	83.44	81.52	83.44	5	0.3	2	1.5	3	0	head sluice
100	80.71	79.01	81.91	1.2	83.41	81.51	83.41	5	0.3	2	1.5	3	2813	D.B road bridge
200	80.68	79.08	81.88	1.2	83.38	81.58	83.38	5	0.3	2	1.5	3	3270	regulator
300	80.65	78.96	81.85	1.2	83.35	81.46	83.35	5	0.3	2	1.5	3		
400	80.62	79.06	81.82	1.2	83.32	81.46	83.32	5	0.3	2	1.5	3		
500	80.59	79.25	81.79	1.2	83.29	81.49	83.29	5	0.3	2	1.5	3		
600	80.56	79.64	81.76	1.2	83.26	81.64	83.26	5	0.3	2	1.5	3		
700	80.53	80.53	81.73	1.2	83.23	81.76	83.23	5	0.3	2	1.5	3		
800	80.5	80.5	81.7	1.2	83.2	83.95	83.2	5	0.3	2	1.5	3		
900	80.47	80.47	81.67	1.2	83.17	83.52	83.17	5	0.3	2	1.5	3		
1000	80.44	80.44	81.64	1.2	83.14	81.79	83.14	5	0.3	2	1.5	3		

Table 6.54: (continued) 6 D1 MC (Id:124, Node No:212-294)

Distance in ft	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Ground Level	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width of bank	Free board	Inside Berm
1100	80.41	80.22	81.61	1.2	83.11	81.8	83.11	5	0.3	2	1.5	3
1200	80.38	80.17	81.58	1.2	83.08	81.75	83.08	5	0.3	2	1.5	3
1300	80.35	80.17	81.55	1.2	83.05	81.75	83.05	5	0.3	2	1.5	3
1400	80.32	80.22	81.52	1.2	83.02	81.8	83.02	5	0.3	2	1.5	3
1500	80.29	80.29	81.49	1.2	82.99	81.75	82.99	5	0.3	2	1.5	3
1600	80.26	80.2	81.46	1.2	82.96	81.7	82.96	5	0.3	2	1.5	3
1643	80.25	na	81.45	1.2	82.95	81.71	82.95	5	0.3	2	1.5	3
1743	80.22	80.13	81.42	1.2	82.92	81.63	82.92	5	0.3	2	1.5	3
1852	80.19	80.07	81.39	1.2	82.89	81.65	82.89	5	0.3	2	1.5	3
1952	80.16	80.04	81.36	1.2	82.86	81.62	82.86	5	0.3	2	1.5	3
2052	80.13	79.81	81.33	1.2	82.83	81.39	82.83	5	0.3	2	1.5	3
2152	80.1	79.69	81.3	1.2	82.8	81.37	82.8	5	0.3	2	1.5	3
2252	80.07	79.47	81.27	1.2	82.77	81.3	82.77	5	0.3	2	1.5	3
2352	80.04	79.21	81.24	1.2	82.74	81.13	82.74	5	0.3	2	1.5	3
2452	80.01	79.29	81.21	1.2	82.71	81.21	82.71	5	0.3	2	1.5	3

Table 6.55: (continued) 6 D1 MC (Id:124, Node No:212-294)

Distance in ft	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Ground Level	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width of bank	Free board	Inside Berm
2552	79.98	79.27	81.18	1.2	82.68	81.17	82.68	5	0.3	2	1.5	3
2652	79.95	79.16	81.15	1.2	82.65	81.08	82.65	5	0.3	2	1.5	3
2752	79.92	79.24	81.12	1.2	82.62	81.16	82.62	5	0.3	2	1.5	3
2852	79.89	97.89	81.09	1.2	82.59	79.85	82.59	5	0.3	2	1.5	3
2952	79.86	79.86	81.06	1.2	82.56	82.42	82.56	5	0.3	2	1.5	3
3052	79.83	79.83	81.03	1.2	82.53	81.16	82.53	5	0.3	2	1.5	3
3152	79.8	na	81	1.2	82.5	78.86	82.5	5	0.3	2	1.5	3
3252	79.77	79.77	80.97	1.2	82.47	81.47	82.47	5	0.3	2	1.5	3
3352	79.74	79.74	80.94	1.2	82.44	80.5	82.44	5	0.3	2	1.5	3
3452	79.71	na	80.91	1.2	82.41	80.29	82.41	5	0.3	2	1.5	3
3552	79.68	78.23	80.88	1.2	82.38	80.73	82.38	5	0.3	2	1.5	3
3652	79.65	78.17	80.85	1.2	82.35	80.99	82.35	5	0.3	2	1.5	3
3752	79.62	77.73	80.82	1.2	82.32	80.23	82.32	5	0.3	2	1.5	3
3852	79.59	77.36	80.79	1.2	82.29	80.03	82.29	5	0.3	2	1.5	3

Table 6.56: (continued) 6 D1 MC (Id:124, Node No:212-294)

Distance in ft	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Ground Level	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width of bank	Free board	Inside Berm
3952	79.56	77.28	80.76	1.2	82.26	80.2	82.26	5	0.3	2	1.5	3
4052	79.53	77.07	80.73	1.2	82.23	79.99	82.23	5	0.3	2	1.5	3
4152	79.5	77.06	80.7	1.2	82.2	79.98	82.2	5	0.3	2	1.5	3
4252	79.47	76.96	80.67	1.2	82.17	79.96	82.17	5	0.3	2	1.5	3
4352	79.44	76.55	80.64	1.2	82.14	79.8	82.14	5	0.3	2	1.5	3
4452	79.41	76.24	80.61	1.2	82.11	79.49	82.11	5	0.3	2	1.5	3
4552	79.38	79.38	80.58	1.2	82.08	79.35	82.08	5	0.3	2	1.5	3
4552	79.58	79.58	80.58	1	na	na	na	2	1.1	2	1	2
4652	79.47	76.69	80.47	1	81.47	79.24	81.47	2	1.1	2	1	2
4752	79.36	76.35	80.36	1	81.36	79.93	81.36	2	1.1	2	1	2
4852	79.25	76.2	80.25	1	81.25	76.23	81.25	2	1.1	2	1	2
4952	79.14	na	80.14	1	81.14	76.07	81.14	2	1.1	2	1	2
5052	79.03	na	80.03	1	81.03	79.28	81.03	2	1.1	2	1	2
5087	78.99	na	79.99	1	80.99	80.25	80.99	2	1.1	2	1	2

Table 6.57: 6 E MC (Id:67, Node No:20-214)

Distance in ft	Design Bed Level	Actual Bed Level	Ground level	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm	Distance	Structure
0	79.56	79.56	81.89	81.76	2.2	82.76	84.71	4	0.3	3	1	3	0	head sluice (6E MC takes off from 6MC at 58723)
100		79.84	82.09		2.2		83.85	4	0.3	3	1	3	1500	regulator
200		79.31	81.89		2.2		83.57	4	0.3	3	1	3	3835	cart bridge
300		79.31	81.89		2.2		83.81	4	0.3	3	1	3	6000	regulator (fall = 1.5')
400		79.46	81.86		2.2		83.65	4	0.3	3	1	3		
500		79.36	81.76		2.2		83.81	4	0.3	3	1	3		
600		79.33	81.83		2.2		83.67	4	0.3	3	1	3		
700		79.37	81.87		2.2		84.01	4	0.3	3	1	3		
800		79.36	81.86		2.2		83.82	4	0.3	3	1	3		
900		79.14	81.72		2.2		83.89	4	0.3	3	1	3		
1000	79.26	79.35	81.85	81.46	2.2	82.46	83.77	4	0.3	3	1	3		

Table 6.58: (continued) 6 E MC (Id:67, Node No:20-214)

Distance in ft	Design Bed Level	Actual Bed Level	Ground level	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
1100		79.03	81.61		2.2		84.91	4	0.3	3	1	3
1200		79.14	81.54		2.2		83.51	4	0.3	3	1	3
1300		78.94	81.19		2.2		82.93	4	0.3	3	1	3
1400		79.18	81.26		2.2		83.23	4	0.3	3	1	3
1500		77.53	81.31		2.2		83.01	4	0.3	3	1	3
1600		78.97	81.22		2.2		83.21	4	0.3	3	1	3
1700		79	81.08		2.2		83.03	4	0.3	3	1	3
1800		79.03	81.08		2.2		82.81	4	0.3	3	1	3
1900		78.88	80.8		2.2		82.96	4	0.3	3	1	3
2000	78.96	78.65	80.71	81.16	2.2	82.16	82.29	4	0.3	3	1	3
2100		78.43	80.68		2.2		82.52	4	0.3	3	1	3
2200		78.44	80.52		2.2		82.64	4	0.3	3	1	3
2300		77.94	80.52		2.2		82.64	4	0.3	3	1	3
2400		77.91	80.49		2.2		82.38	4	0.3	3	1	3
2500		77.96	80.54		2.2		82.56	4	0.3	3	1	3
2600		77.78	80.36		2.2		82.29	4	0.3	3	1	3
2700		77.48	80.06		2.2		82.14	4	0.3	3	1	3

Table 6.59: (continued) 6 E MC (Id:67, Node No:20-214)

Distance in ft	Design Bed Level	Actual Bed Level	Ground level	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
2800		77.2	80.2		2.2		83.27	4	0.3	3	1	3
2900		77.11	80.11		2.2		82.57	4	0.3	3	1	3
3000	78.66	77.09	80.17	80.86	2.2	81.86	82.39	4	0.3	3	1	3
3100		77.01	80.09		2.2		82.52	3	0.5	3	1	3
3200		77	80.08		2.2		82.39	3	0.5	3	1	3
3300		77.12	80.12		2.2		82.63	3	0.5	3	1	3
3400		76.82	79.9		2.2		82.11	3	0.5	3	1	3
3500		76.5	79.82		2.2		81.97	3	0.5	3	1	3
3600		76.77	79.93		2.2		82.19	3	0.5	3	1	3
3700		77.67	79.83		2.2		82.13	3	0.5	3	1	3
3800		76.43	79.59		2.2		81.7	3	0.5	3	1	3
3900		78.21	79.73		2.2		81.71	3	0.5	3	1	3
4000	78.16	76.53	79.84	80.36	2.2	81.36	81.91	3	0.5	3	1	3
4100		76.58	79.58		2.2		81.91	3	0.5	3	1	3
4200		76.53	79.53		2.2		81.79	3	0.5	3	1	3
4300		76.67	79.67		2.2		81.62	3	0.5	3	1	3

Table 6.60: (continued) 6 E MC (Id:67, Node No:20-214)

Distance in ft	Design Bed Level	Actual Bed Level	Ground level	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
4400		76.91	79.39		2.2		81.37	3	0.5	3	1	3
4500		76.32	79.4		2.2		81.52	3	0.5	3	1	3
4600		76.04	79.2		2.2		81.63	3	0.5	3	1	3
4700		75.72	79.04		2.2		81.44	3	0.5	3	1	3
4800		76.42	78.92		2.2		80.89	3	0.5	3	1	3
4900		75.56	78.98		2.2		81.77	3	0.5	3	1	3
5000	77.66	75.12	78.78	79.86	2.2	80.86	81.04	3	0.5	3	1	3
5100		75.11	78.77		2.2		81.51	3	0.5	3	1	3
5200		74.95	78.7		2.2		81.13	3	0.5	3	1	3
5300		75.27	78.83		2.2		81.17	3	0.5	3	1	3
5400		74.22	78.3		2.2		80.87	3	0.5	3	1	3
5500		74.55	78.55		2.2		81.32	3	0.5	3	1	3
5600		74.5	78.32		2.2		81.1	3	0.5	3	1	3
5700		74.4	78.22		2.2		80.72	3	0.5	3	1	3
5800		74.41	78.23		2.2		80.68	3	0.5	3	1	3
5900		74.28	78.1		2.2		80.49	3	0.5	3	1	3
6000	77.16	na	77.91	79.36	2.2	80.36	80.36	3.5	1	3	1	3

Table 6.61: (continued) 6 E MC (Id:67, Node No:20-214)

Distance in ft	Design Bed Level	Actual Bed Level	Ground level	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
6000	76.66	na	na	77.86	1.2	78.86	na	3.5	1	3	1	3
6100		na	77.97		1.2		79.07	3.5	1	3	1	3
6200		76.08	77.74		1.2		78.86	3.5	1	3	1	3
6300		76.06	77.64		1.2		78.72	3.5	1	3	1	3
6400		75.63	77.38		1.2		78.68	3.5	1	3	1	3
6500		75.19	77.01		1.2		78.56	3.5	1	3	1	3
6600		74.65	76.9		1.2		78.42	3.5	1	3	1	3
6700		74.77	76.93		1.2		78.4	3.5	1	3	1	3
6800		75	77		1.2		78.71	3.5	1	3	1	3
6900		74.65	76.65		1.2		78.09	3.5	1	3	1	3
7000	75.66	73.81	76.06	76.86	1.2	77.86	77.86	3.5	1	3	1	3
7100		73.39	76.14		1.2		78.02	3.5	1	3	1	3
7200		73.25	76		1.2		77.96	3.5	1	3	1	3
7300		72.93	75.75		1.2		77.84	3.5	1	3	1	3
7400		72.77	75.69		1.2		77.76	3.5	1	3	1	3
7500		72.54	75.54		1.2		77.72	3.5	1	3	1	3

Table 6.62: (continued) 6 E MC (Id:67, Node No:20-214)

Distance in ft	Design Bed Level	Actual Bed Level	Ground level	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
7600		72.61	75.53		1.2		77.48	3.5	1	3	1	3
7700		72.37	75.45		1.2		77.68	3.5	1	3	1	3
7800		72.59	75.41		1.2		77.64	3.5	1	3	1	3
7900		72.69	75.44		1.2		77.38	3.5	1	3	1	3
8000	74.66	72.26	75.01	75.86	1.2	76.86	76.88	3.5	1	3	1	3
8100		71.2	74.7		1.2		77.02	3.5	1	3	1	3
8200		71.22	74.72		1.2		77.58	3.5	1	3	1	3
8300		70.65	74.47		1.2		77.14	3	1	3	1	3
8400		70.5	74.5		1.2		77.02	3	1	3	1	3
8500		70.52	74.52		1.2		76.57	3	1	3	1	3
8600		70.93	74.43		1.2		76.53	3	1	3	1	3
8700		70.91	74.41		1.2		76.84	3	1	3	1	3
8800		71.05	74.38		1.2		76.18	3	1	3	1	3
8900		71.16	74.41		1.2		76.47	3	1	3	1	3
9000	73.66	70.84	74.09	74.86	1.2	75.86	76.03	3	1	3	1	3
9100		70.98	74.06		1.2		76.04	3	1	3	1	3
9200		70.99	74.07		1.2		76.47	3	1	3	1	3

Table 6.63: (continued) 6 E MC (Id:67, Node No:20-214)

Distance in ft	Design Bed Level	Actual Bed Level	Ground level	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
9300		70.72	73.88		1.2		76.34	3	1	3	1	3
9400		70.71	73.87		1.2		76.16	3	1	3	1	3
9500		70.79	73.79		1.2		75.54	3	1	3	1	3
9600		70.79	73.79		1.2		75.65	3	1	3	1	3
9700		70.52	73.52		1.2		75.63	3	1	3	1	3
9800		70.43	73.51		1.2		75.56	3	1	3	1	3
9900		70.55	73.47		1.2		75.43	3	1	3	1	3
10000	72.66	70.46	73.46	73.86	1.2	74.86	75.23	3	1	3	1	3
10100		70.5	73.16		1.2		75.06	3	1	3	1	3
10200		70.29	73.19		1.2		75.32	3	1	3	1	3
10300		70.15	73.15		1.2		75.12	3	1	3	1	3
10400		70.45	73.11		1.2		75.07	3	1	3	1	3
10500	72.16	69.73	72.81	73.36	1.2	74.36	75	3	1	3	1	3

Table 6.64: 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm	Distance	Structure
0	79.75	78.9	78.9	81.3	2.4	81.6	83.7	4	0.5	3	1.5	3	0	head sluice
26	na	78.9	77.7	81.3	2.4		na	4	0.5	3	1.5	3	4950	syphon
53	na	77.7	77.65	80.1	2.4		81.82	4	0.5	3	1.5	3	6100	regulator
100	79.57		77.07		2.4		81.82	4	0.5	3	1.5	3	7722	cart bridge
200	79.52		76.85		2.4		82.02	4	0.5	3	1.5	3	14015	Bridge with fall= 1.3
300	79.85		76.85		2.4		82.34	4	0.5	3	1.5	3		
400	79.44		76.11		2.4		81.66	4	0.5	3	1.5	3		
475	na		76.11		2.4		na	4	0.5	3	1.5	3		
490	na		77.4		2.4		na	4	0.5	3	1.5	3		
500	79.48		77.4		2.4		81.93	4	0.5	3	1.5	3		
510	na		77.4		2.4		na	4	0.5	3	1.5	3		

Table 6.65: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
525	na		76.21		2.4		na	4	0.5	3	1.5	3
600	79.21		76.21		2.4		81.4	4	0.5	3	1.5	3
700	79.17		76.17		2.4		81.55	4	0.5	3	1.5	3
800	79.06		76.06		2.4		81.4	4	0.5	3	1.5	3
900	78.99		75.99		2.4		81.74	4	0.5	3	1.5	3
975	na		75.99		2.4		81.4	4	0.5	3	1.5	3
990	na		76.85		2.4		81.4	4	0.5	3	1.5	3
1000	79.03	77.2	76.85	79.6	2.4	81.1	81.15	4	0.5	3	1.5	3
1010			76.85		2.4		81.4	4	0.5	3	1.5	3
1025			75.79		2.4		81.4	4	0.5	3	1.5	3
1100	78.97		75.79		2.4		81.53	4	0.5	3	1.5	3
1200	78.7		75.52		2.4		81.6	4	0.5	3	1.5	3
1300	78.95		75.77		2.4		81.2	4	0.5	3	1.5	3
1400	79.07		75.99		2.4		81.07	4	0.5	3	1.5	3
1475	na		75.99		2.4		na	4	0.5	3	1.5	3
1490	na		76.56		2.4		na	4	0.5	3	1.5	3

Table 6.66: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
1500	78.74		76.56		2.4		81.04	4	0.5	3	1.5	3
1510	na		76.56		2.4		81.4	4	0.5	3	1.5	3
1525	na		75.34		2.4		81.4	4	0.5	3	1.5	3
1600	78.53		75.34		2.4		81.2	4	0.5	3	1.5	3
1700	78.14		74.64		2.4		81.17	4	0.5	3	1.5	3
1800	77.97		73.55		2.4		81.08	4	0.5	3	1.5	3
1900	77.87		72.69		2.4		81.2	4	0.5	3	1.5	3
1975	na		72.69		2.4		na	4	0.5	3	1.5	3
1990	na		76.56		2.4		na	4	0.5	3	1.5	3
2000	78.06	76.7	76.56	79.1	2.4	80.6	81	4	0.5	3	1.5	3
2010	na		72.56		2.4		na	4	0.5	3	1.5	3
2025	na		73.93		2.4		na	4	0.5	3	1.5	3
2100	78.01		73.93		2.4		80.93	4	0.5	3	1.5	3
2200	78.09		73.76		2.4		80.86	4	0.5	3	1.5	3
2300	77.96		73.29		2.4		81.07	4	0.5	3	1.5	3

Table 6.67: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
2400	77.82		73.32		2.4		80.83	4	0.5	3	1.5	3
2475	na		73.32		2.4		na	4	0.5	3	1.5	3
2490	na		76.3		2.4		na	4	0.5	3	1.5	3
2500	77.8		76.3		2.4		80.78	4	0.5	3	1.5	3
2510	na		76.3		2.4		na	4	0.5	3	1.5	3
2525	na		73.26		2.4		na	4	0.5	3	1.5	3
2600	77.76		73.26		2.4		80.76	4	0.5	3	1.5	3
2700	77.57		73.07		2.4		81.41	4	0.5	3	1.5	3
2800	77.55		72.97		2.4		80.81	4	0.5	3	1.5	3
2900	77.37		72.87		2.4		80.43	4	0.5	3	1.5	3
2975	na		72.87		2.4		na	4	0.5	3	1.5	3
2990	na		76.13		2.4		na	4	0.5	3	1.5	3
3000	77.31	76.2	76.13	78.6	2.4	80.1	80.63	4	0.5	3	1.5	3
3010	na		76.13		2.4		na	4	0.5	3	1.5	3
3025	na		72.12		2.4		na	4	0.5	3	1.5	3
3100	77.3		72.12		2.4		80.38	4	0.5	3	1.5	3

Table 6.68: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000’	Crest width	Free board	Inside berm
3200	77.11		72.53		2.4		80.39	4	0.5	3	1.5	3
3300	77.2		73.12		2.4		80.37	4	0.5	3	1.5	3
3400	77.19		73.11		2.4		79.99	4	0.5	3	1.5	3
3500	77.16		73.16		2.4		79.99	4	0.5	3	1.5	3
3575	na		73.16		2.4		na	4	0.5	3	1.5	3
3590	na		75.51		2.4		na	4	0.5	3	1.5	3
3600	77.09		75.51		2.4		80.09	4	0.5	3	1.5	3
3610	na		75.51		2.4		na	4	0.5	3	1.5	3
3625	na		73.06		2.4		na	4	0.5	3	1.5	3
3700	77.06		73.06		2.4		80.2	4	0.5	3	1.5	3
3800	76.98		72.8		2.4		80.08	4	0.5	3	1.5	3
3900	76.98		72.8		2.4		79.73	4	0.5	3	1.5	3
3975	na		72.8		2.4		na	4	0.5	3	1.5	3
3990	na		75.35		2.4		na	4	0.5	3	1.5	3

Table 6.69: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
4000	76.85	75.7	75.35	78.1	2.4	79.6	79.96	4	0.5	3	1.5	3
4010	na		75.35		2.4		na	4	0.5	3	1.5	3
4025	na		72.47		2.4		na	4	0.5	3	1.5	3
4100	76.8		72.47		2.4		80.18	4	0.5	3	1.5	3
4200	76.64		72.39		2.4		80.02	4	0.5	3	1.5	3
4300	76.58		72.25		2.4		79.84	4	0.5	3	1.5	3
4400	76.5		72.17		2.4		79.68	4	0.5	3	1.5	3
4475	na		72.17		2.4		na	4	0.5	3	1.5	3
4490	na		75.25		2.4		na	4	0.5	3	1.5	3
4500	76.43		75.25		2.4		79.85	4	0.5	3	1.5	3
4510	na		75.25		2.4		na	4	0.5	3	1.5	3
4525	na		71.96		2.4		na	4	0.5	3	1.5	3
4600	76.38		71.96		2.4		79.35	4	0.5	3	1.5	3
4700	76.41		71.08		2.4		79.36	4	0.5	3	1.5	3

Table 6.70: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
4800	76.39		71.14		2.4		79.19	4	0.5	3	1.5	3
4900	76.65		72.73		2.4		79.18	4	0.5	3	1.5	3
4950	76.68		75.23		2.4		79.13	4	0.5	3	1.5	3
5000	76.59	75.2	75.2	77.6	2.4	79.1	79.2	4	0.5	3	1.5	3
5100	76.34		72.76		2.4		79.05	4	0.5	3	1.5	3
5200	76.33		72.58		2.4		79.21	4	0.5	3	1.5	3
5300	76.27		72.27		2.4		79.59	4	0.5	3	1.5	3
5400	76.31		71.98		2.4		79.46	4	0.5	3	1.5	3
5475	na		71.98		2.4		na	4	0.5	3	1.5	3
5490	na		74.65		2.4		na	4	0.5	3	1.5	3
5500	75.95		74.65		2.4		79.41	4	0.5	3	1.5	3
5510	na		74.65		2.4		na	4	0.5	3	1.5	3
5525	na		71.53		2.4		na	4	0.5	3	1.5	3
5600	75.86		71.53		2.4		79.01	4	0.5	3	1.5	3
5700	74.21		71.63		2.4		80.39	4	0.5	3	1.5	3
5720	na		73.38		2.4		na	4	0.5	3	1.5	3

Table 6.71: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
5800	73.8		73.38		2.4		80.4	4	0.5	3	1.5	3
5850	na		72.92		2.4		na	4	0.5	3	1.5	3
5900	73.87		72.11		2.4		80.31	4	0.5	3	1.5	3
6000	76.47	74.7	73.28	77.1	2.4	78.6	79.18	4	0.5	3	1.5	3
6100	76.38		72.88		2.4		79.36	4	0.5	3	1.5	3
6200	76.28		72.78		2.4		79.3	4	0.5	3	1.5	3
6300	76.13		72.55		2.4		79.24	4	0.5	3	1.5	3
6347	76.22		72.72		2.4		79.12	4	0.5	3	1.5	3
6447	76.21	74.48	72.54	76.88	2.4	78.38	79.54	4	0.5	3	1.5	3
6522	na		72.54		2.4		na	6	0.2	3	1	3
6537	na		74.35		2.4		na	6	0.2	3	1	3
6547	76.1		74.35		2.4		78.4	6	0.2	3	1	3
6557	na		74.35		2.4		na	6	0.2	3	1	3
6572	na		73.39		2.4		na	6	0.2	3	1	3
6647	76.06		73.39		2.4		78.83	6	0.2	3	1	3
6747	76.02		73.27		2.4		78.57	6	0.2	3	1	3
6847	75.91		73.24		2.4		78.69	6	0.2	3	1	3

Table 6.72: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
6947	75.97		73.39		2.4		78.63	6	0.2	3	1	3
7022	na		73.39		2.4		na	6	0.2	3	1	3
7037	na		74.41		2.4		na	6	0.2	3	1	3
7047	75.91	74.36	74.41	76.76	2.4	77.76	78.45	6	0.2	3	1	3
7057	na		74.41		2.4		na	6	0.2	3	1	3
7072	na		73.1		2.4		na	6	0.2	3	1	3
7147	75.85		73.1		2.4		78.51	6	0.2	3	1	3
7247	75.71		72.79		2.4		78.75	6	0.2	3	1	3
7347	75.67		72.75		2.4		78.39	6	0.2	3	1	3
7447	75.7		72.52		2.4		78.75	6	0.2	3	1	3
7522	na		72.52		2.4		na	6	0.2	3	1	3
7537	na		74.22		2.4		na	6	0.2	3	1	3
7547	75.72		74.22		2.4		78.47	6	0.2	3	1	3
7557	na		74.22		2.4		na	6	0.2	3	1	3
7572	na		73.19		2.4		na	6	0.2	3	1	3
7647	75.86		73.19		2.4		78.36	6	0.2	3	1	3
7747	75.87		73.12		2.4		78.71	6	0.2	3	1	3

Table 6.73: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
7847	75.77		72.85		2.4		78.79	6	0.2	3	1	3
7947	75.36		73.61		2.4		78.69	6	0.2	3	1	3
8022	na		73.61		2.4		na	6	0.2	3	1	3
8037	na		74.21		2.4		na	6	0.2	3	1	3
8047	75.71	74.16	74.21	76.56	2.4	77.56	79.27	6	0.2	3	1	3
8057	na		74.21		2.4		na	6	0.2	3	1	3
8072	na		72.65		2.4		na	6	0.2	3	1	3
8147	75.57		72.65		2.4		78.37	6	0.2	3	1	3
8247	75.69		73.11		2.4		78.31	6	0.2	3	1	3
8347	75.66		73.08		2.4		78.24	6	0.2	3	1	3
8447	75.71		72.96		2.4		78.09	6	0.2	3	1	3
8522	na		72.96		2.4		na	6	0.2	3	1	3
8537	na		74.08		2.4		na	6	0.2	3	1	3
8547	75.75		74.08		2.4		78.14	6	0.2	3	1	3
8557	na		74.08		2.4		na	6	0.2	3	1	3
8572	na		73.04		2.4		na	6	0.2	3	1	3
8647	75.71		73.04		2.4		78.16	6	0.2	3	1	3

Table 6.74: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
8747	75.65		72.98		2.4		78.33	6	0.2	3	1	3
8847	75.71		73.04		2.4		78.27	6	0.2	3	1	3
8947	75.72		73.05		2.4		78.32	6	0.2	3	1	3
9022	na		73.05		2.4		na	6	0.2	3	1	3
9037	na		73.96		2.4		na	6	0.2	3	1	3
9047	75.63	73.96	73.96	76.36	2.4	77.36	78.22	6	0.2	3	1	3
9057	na		73.96		2.4		na	6	0.2	3	1	3
9072	na		73.2		2.4		na	6	0.2	3	1	3
9147	75.78		73.2		2.4		78.23	6	0.2	3	1	3
9247	75.72		73.14		2.4		78.21	6	0.2	3	1	3
9347	76.35		73.77		2.4		78.39	6	0.2	3	1	3
9447	75.48		73.15		2.4		78.15	6	0.2	3	1	3
9522	na		73.15		2.4		na	6	0.2	3	1	3
9537	na		73.87		2.4		na	6	0.2	3	1	3
9547	75.37		73.87		2.4		77.82	6	0.2	3	1	3
9557	na		73.87		2.4			6	0.2	3	1	3
9572	na		73.12		2.4			6	0.2	3	1	3

Table 6.75: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
9647	75.62		73.12		2.4		78.33	6	0.2	3	1	3
9747	75.85		73.27		2.4		78.55	6	0.2	3	1	3
9847	75.77		73.27		2.4		78.3	6	0.2	3	1	3
9947	75.85		73.6		2.4		78.05	6	0.2	3	1	3
10047	75.72	73.76	73.05	76.16	2.4	77.16	77.67	6	0.2	3	1	3
10147	75.48		73.75		2.4		77.73	4	0.2	3	1	3
10247	75.47		73.72		2.4		77.67	4	0.2	3	1	3
10347	75.74		73.49		2.4		77.93	4	0.2	3	1	3
10447	75.78		73.28		2.4		77.74	4	0.2	3	1	3
10522	na		73.28		2.4			4	0.2	3	1	3
10537	na		73.65		2.4			4	0.2	3	1	3
10547	75.4		73.65		2.4		77.75	4	0.2	3	1	3
10557	na		73.65		2.4			4	0.2	3	1	3
10572	na		73.19		2.4			4	0.2	3	1	3
10647	75.86		73.19		2.4		78.16	4	0.2	3	1	3
10747	74.27		72.27		2.4		78.58	4	0.2	3	1	3
10847	75.89		72.71		2.4		78.91	4	0.2	3	1	3
10947	75.88		72.71		2.4		78.12	4	0.2	3	1	3

Table 6.76: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
11047	75.81	73.56	73.48	75.96	2.4	76.96	77.66	4	0.2	3	1	3
11147	75.68		73.35		2.4		77.41	4	0.2	3	1	3
11247	75.59		73.26		2.4		77.32	4	0.2	3	1	3
11347	75.62		73.29		2.4		77.43	4	0.2	3	1	3
11447	75.53		73.2		2.4		77.49	4	0.2	3	1	3
11547	75.37		72.7		2.4		77.49	4	0.2	3	1	3
11647	75.38		72.63		2.4		77.62	4	0.2	3	1	3
11747	75.29		72.29		2.4		77.75	4	0.2	3	1	3
11847	75.33		72.41		2.4		77.63	4	0.2	3	1	3
11915	75.23		72.56		2.4		77.18	4	0.2	3	1	3
12015	75.22	73.37	72.64	75.77	2.4	76.77	77.17	4	0.2	3	1	3
12115	75.3		72.63		2.4		77.53	4	0.2	3	1	3
12215	75.15		72.4		2.4		77.36	4	0.2	3	1	3
12315	75.03		72.11		2.4		77.23	4	0.2	3	1	3
12415	75.15		72.23		2.4		77.48	4	0.2	3	1	3
12515	74.89		71.71		2.4		77.28	4	0.2	3	1	3
12615	74.89		71.71		2.4		77.05	4	0.2	3	1	3

Table 6.77: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
12715	74.88		71.8		2.4		77.14	4	0.2	3	1	3
12815	74.86		71.78		2.4		77.68	4	0.2	3	1	3
12915	74.77		71.52		2.4		77.2	4	0.2	3	1	3
12990	na		71.52		2.4		na	4	0.2	3	1	3
13005	na		73.15		2.4		na	4	0.2	3	1	3
13015	74.9		73.15		2.4		76.98	4	0.2	3	1	3
13025	na		73.15		2.4		na	4	0.2	3	1	3
13040	na		71.34		2.4		na	4	0.2	3	1	3
13115	74.67	73.17	71.34	75.57	2.4	76.57	77.03	4	0.2	3	1	3
13215	74.73		71.48		2.4		77.38	4	0.2	3	1	3
13315	74.83		71.65		2.4		77.27	4	0.2	3	1	3
13415	74.53		71.35		2.4		77.18	4	0.2	3	1	3
13490	na		71.35		2.4			4	0.2	3	1	3
13505	na		72.8		2.4			4	0.2	3	1	3
13515	74.53		72.8		2.4		76.98	4	0.2	3	1	3
13525	na		72.8		2.4			4	0.2	3	1	3
13540	na		70.92		2.4			4	0.2	3	1	3
13615	74.42		70.92		2.4		76.88	4	0.2	3	1	3

Table 6.78: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
13815	74.46		70.71		2.4		77.49	4	0.2	3	1	3
13915	74.37		70.62		2.4		77.65	4	0.2	3	1	3
13965	74.36		71.11		2.4			4	0.2	3	1	3
14015	74.67	72.97	72.97	75.37	2.4	76.37	76.79	4	0.2	3	1	3
14015	74.67	72.47		74.07	1.6	75.07	76.79	4	0.2	3	1	3
14115	74.09		72.42		1.6		75.31	4	0.5	3	1	3
14215	74.03		72.36		1.6		75.45	4	0.5	3	1	3
14315	74.03		72.28		1.6		75.35	4	0.5	3	1	3
14415	73.93		72.26		1.6		75.35	4	0.5	3	1	3
14515	73.88		72.21		1.6		75.28	4	0.5	3	1	3
14615	73.78		72.03		1.6		75.38	4	0.5	3	1	3
14715	73.7		72.12		1.6		75.36	4	0.5	3	1	3
14815	73.63		72.05		1.6		75.45	4	0.5	3	1	3
14915	73.51		71.59		1.6		74.83	4	0.5	3	1	3
15015	73.57	71.97	71.82	73.57	1.6	74.57	75.01	4	0.5	3	1	3
15115	73.6		71.77		1.6		74.87	4	0.5	3	1	3
15215	73.52		71.77		1.6		74.85	4	0.5	3	1	3

Table 6.79: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
15315	73.41		71.58		1.6		74.91	4	0.5	3	1	3
15415	73.49		71.62		1.6		74.92	4	0.5	3	1	3
15515	73.27	71.72	71.44	73.32	1.6	74.32	74.81	4	0.5	3	1	3
15590	na		71.44		1.6		na	3	0.5	3	1	3
15605	na		71.64		1.6		na	3	0.5	3	1	3
15615	72.82		71.64		1.6		74.63	3	0.5	3	1	3
15625	na		71.64		1.6		na	3	0.5	3	1	3
15640	na		70.45		1.6		na	3	0.5	3	1	3
15715	72.87		70.45		1.6		74.77	3	0.5	3	1	3
15815	72.84		70.17		1.6		74.97	3	0.5	3	1	3
15915	72.73		69.81		1.6		74.6	3	0.5	3	1	3
15990	na		69.81		1.6		na	3	0.5	3	1	3
16005	na		71.62		1.6		na	3	0.5	3	1	3
16015	72.45	71.47	71.62	73.07	1.6	74.07	74.17	3	0.5	3	1	3
16025	na		71.62		1.6		na	3	0.5	3	1	3
16040	na		69.06		1.6		na	3	0.5	3	1	3
16115	72.31		69.06		1.6		74.34	3	0.5	3	1	3
16215	71.97		68.39		1.6		74.82	3	0.5	3	1	3

Table 6.80: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
16315	71.82		68.24		1.6		74.72	3	0.5	3	1	3
16415	72.2		68.78		1.6		74.56	3	0.5	3	1	3
16490	na		68.78		1.6		na	3	0.5	3	1	3
16505	na		71.31		1.6		na	3	0.5	3	1	3
16515	72.23		71.31		1.6		73.89	3	0.5	3	1	3
16525	na		71.31		1.6		na	3	0.5	3	1	3
16540	na		69.17		1.6		na	3	0.5	3	1	3
16615	72.17		69.17		1.6		74.15	3	0.5	3	1	3
16715	72.11		69.11		1.6		74.36	3	0.5	3	1	3
16815	72.06		69.06		1.6		74.21	3	0.5	3	1	3
16915	71.82		69.82		1.6		74.19	3	0.5	3	1	3
16990	na		69.82		1.6		na	3	0.5	3	1	3
17005	na		70.89		1.6		na	3	0.5	3	1	3
17015	71.81	70.97	70.89	72.57	1.6	73.57	74.3	3	0.5	3	1	3
17025	na		70.89		1.6		na	3	0.5	3	1	3
17040	na		68.83		1.6		na	3	0.5	3	1	3
17115	71.75		68.83		1.6		74.09	3	0.5	3	1	3

Table 6.81: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
17215	71.72		68.72		1.6		74.03	3	0.5	3	1	3
17315	71.73		68.81		1.6		73.98	3	0.5	3	1	3
17415	71.7		68.95		1.6		73.97	3	0.5	3	1	3
17490	na		68.95		1.6		na	3	0.5	3	1	3
17505	na		68.83		1.6		na	3	0.5	3	1	3
17515	71.83		68.83		1.6		73.81	3	0.5	3	1	3
17525	na		68.83		1.6		na	3	0.5	3	1	3
17540	na		68.68		1.6		na	3	0.5	3	1	3
17615	71.68		68.68		1.6		73.8	3	0.5	3	1	3
17715	71.63		69.38		1.6		73.6	3	0.5	3	1	3
17815	71.65		69.32		1.6		73.82	3	0.5	3	1	3
17915	71.61		69.11		1.6		73.65	3	0.5	3	1	3
17990	na		69.11		1.6		na	3	0.5	3	1	3
18005	na		70.4		1.6		na	3	0.5	3	1	3
18015	71.58	70.47	70.4	72.07	1.6	73.07	73.61	3	0.5	3	1	3
18025	na		70.4		1.6		na	3	0.5	3	1	3

Table 6.82: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
18040	na		68.92		1.6		na	3	0.5	3	1	3
18115	71.5		68.92		1.6		73.48	3	0.5	3	1	3
18215	71.47		68.89		1.6		73.61	3	0.5	3	1	3
18315	71.45		68.95		1.6		73.58	3	0.5	3	1	3
18415	71.4		68.65		1.6		73.41	3	0.5	3	1	3
18490	na		68.65		1.6		na	3	0.5	3	1	3
18505	na		70.19		1.6		na	3	0.5	3	1	3
18515	71.37		70.19		1.6		73.44	3	0.5	3	1	3
18525	na		70.19		1.6		na	3	0.5	3	1	3
18540	na		68.79		1.6		na	3	0.5	3	1	3
18615	71.29		68.79		1.6		73.42	3	0.5	3	1	3
18715	71.28		68.45		1.6		73.42	3	0.5	3	1	3
18815	71.22		68.8		1.6		73.39	3	0.5	3	1	3
18915	71.17		68.84		1.6		73.28	3	0.5	3	1	3
19002	71.09	69.97	68.59	71.57	1.6	72.57	73.35	3	0.5	3	1	3

Table 6.83: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Table 6.84: 6 G MC of DMC (Id:67, Node No:20-214)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000’	Crest width	Free board	Inside berm
0	73.89	70.91	72.91	74.91	2	75.91	77.52	4.5	0.4	3	3	1
100	74.04		71.76		2		76.49	4.5	0.4	3	3	1
200	74.04		70.79		2		76.47	4.5	0.4	3	3	1
300	73.79		70.97		2		76.44	4.5	0.4	3	3	1
400	73.94		71.02		2		76.24	4.5	0.4	3	3	1
500	73.91		72.45		2		76.19	4.5	0.4	3	3	1
600	74.26		71.51		2		76.24	4.5	0.4	3	3	1
700	74.04		71.54		2		76.23	4.5	0.4	3	3	1
800	74.11		72.03		2		76.63	4.5	0.4	3	3	1
900	73.99		71.82		2		76.98	4.5	0.4	3	3	1
1000	74.03	72.51	72.36	74.51	2	75.51	75.84	4.5	0.4	3	3	1
1100	74.09		72.09		2		75.81	4.5	0.4	3	3	1
1200	74.02		72.02		2		75.72	4.5	0.4	3	3	1
1300	73.8		71.8		2		75.79	4.5	0.4	3	3	1
1400	73.89		71.56		2		75.78	4.5	0.4	3	3	1
1500	73.81		72.31		2		75.72	4.5	0.4	3	3	1
1600	73.85		71.6		2		75.75	4.5	0.4	3	3	1

Table 6.85: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
1600	73.85		71.6		2		75.75	4.5	0.4	3	3	1
1700	73.59		71.17		2		75.73	4.5	0.4	3	3	1
1800	73.8		71.44		2		75.65	4.5	0.4	3	3	1
1900	73.51		71.01		2		75.73	4.5	0.4	3	3	1
2000	73.53	72.11	71.7	74.11	2	75.11	75.65	4.5	0.4	3	3	1
2100	73.62		71.45		2		75.54	4.5	0.4	3	3	1
2200	73.49		71.24		2		75.41	4.5	0.4	3	3	1
2300	73.42		71.17		2		75.45	4.5	0.4	3	3	1
2400	73.36		70.86		2		75.48	4.5	0.4	3	3	1
2500	73.3		71.88		2		75.28	4.5	0.4	3	3	1
2600	73.3		70.8		2		75.23	4.5	0.4	3	3	1
2700	73.27		70.85		2		75.02	4.5	0.4	3	3	1
2800	73.3		70.8		2		75.04	4.5	0.4	3	3	1
2900	73.12		70.62		2		75.17	4.5	0.4	3	3	1
3000	73.06	71.71	71.64	73.71	2	74.71	75.07	4.5	0.4	3	3	1
3100	73.17		70.67		2		74.89	4.5	0.4	3	3	1
3200	73.21		70.96		2		75.02	4.5	0.4	3	3	1

Table 6.86: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
3300	72.98		70.73		2		74.96	4.5	0.4	3	3	1
3400	73.03		70.69		2		74.9	4.5	0.4	3	3	1
3500	73.04		71.54		2		74.77	4.5	0.4	3	3	1
3600	72.08		70.41		2		75.07	4.5	0.4	3	3	1
3700	72.86		70.36		2		74.94	4.5	0.4	3	3	1
3800	72.66		70.16		2		74.9	4.5	0.4	3	3	1
3900	72.64		69.89		2		74.72	4.5	0.4	3	3	1
4000	72.59	71.31	71.26	73.31	2	74.31	74.77	4.5	0.4	3	3	1
4100	72.54		69.87		2		75.02	4.5	0.4	3	3	1
4200	72.56		69.89		2		74.71	4.5	0.4	3	3	1
4300	72.33		69.5		2		74.84	4.5	0.4	3	3	1
4400	72.36		69.54		2		74.58	4.5	0.4	3	3	1
4500	72.2		71.03		2		74.25	4.5	0.4	3	3	1
4600	72.03		68.78		2		74.3	4.5	0.4	3	3	1
4700	72.01		68.59		2		74.5	4.5	0.4	3	3	1
4800	71.84		68.84		2		74.45	4.5	0.4	3	3	1
4900	71.82		68.74		2		74.27	4.5	0.4	3	3	1

Table 6.87: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
5000	71.42	70.91	70.42	72.91	2	73.91	74.4	4.5	0.4	3	3	1
5100	71.45		68.03		2		74.37	4.5	0.4	3	3	1
5200	71.6		67.7		2		74.27	4.5	0.4	3	3	1
5300	71.46		67.71		2		74.79	4.5	0.4	3	3	1
5400	71.43		67.76		2		74.39	4.5	0.4	3	3	1
5500	71.45		68.37		2		74.27	4.5	0.4	3	3	1
5600	71.53	70.67	70.37	72.67	2	73.67	74.33	4.5	0.4	3	3	1
5600	71.53	70.37	70.37	72.17	1.8	73.17	74.33	4.5	0.5	3	3	1
5700	71.64		69.39		1.8		74.03	4.5	0.5	3	3	1
5800	71.11		68.28		1.8		73.77	4.5	0.5	3	3	1
5900	71.39		68.72		1.8		73.84	4.5	0.5	3	3	1
6000	71.23	70.16	70.15	71.96	1.8	72.96	73.52	4.5	0.5	3	3	1
6100	71.36		68.86		1.8		73.27	4.5	0.5	3	3	1
6200	71.17		68.67		1.8		73.75	4.5	0.5	3	3	1
6300	71.21		68.88		1.8		73.42	4.5	0.5	3	3	1
6400	71.37		69.04		1.8		73.23	4.5	0.5	3	3	1

Table 6.88: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
6500	71.21		69.96		1.8		72.95	4.5	0.5	3	3	1
6600	71.29		69.21		1.8		73.06	4.5	0.5	3	3	1
6700	70.91		68.91		1.8		72.87	4.5	0.5	3	3	1
6800	71.05		68.8		1.8		72.74	4.5	0.5	3	3	1
6900	70.87		68.42		1.8		72.76	4.5	0.5	3	3	1
7000	70.74	69.66	69.66	71.46	1.8	72.46	72.62	4.5	0.5	3	3	1
7100	70.66		68.33		1.8		72.82	4.5	0.5	3	3	1
7200	70.93	69.56	68.6	71.36	1.8	72.36	72.97	4.5	0.5	3	3	1
7300	70.47		68.14		1.8		72.46	4.5	0.5	3	3	1
7400	70.94		68.36		1.8		73.22	4.5	0.5	3	3	1
7500	70.89		69.39		1.8		72.51	4.5	0.5	3	3	1
7600	70.8		68.55		1.8		72.56	4.5	0.5	3	3	1
7700	70.6		68.58		1.8		72.45	4.5	0.5	3	3	1
7800	70.61		68.28		1.8		72.49	4.5	0.5	3	3	1
7900	70.69		68.44		1.8		72.61	4.5	0.5	3	3	1
8000	70.58	69.16	69.16	70.96	1.8	71.76	72.56	4.5	0.5	3	3	1

Table 6.89: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
8100	70.54		68.21		1.8		72.62	4.5	0.5	3	3	1
8200	70.34		67.84		1.8		72.42	4.5	0.5	3	3	1
8300	70.29		67.62		1.8		72.13	4.5	0.5	3	3	1
8400	70.06		67.48		1.8		72.13	4.5	0.5	3	3	1
8500	69.74		68.91		1.8		72.04	4.5	0.5	3	3	1
8600	69.96		67.29		1.8		72.16	4.5	0.5	3	3	1
8700	69.9		67.07		1.8		72.16	4.5	0.5	3	3	1
8800	69.9		66.98		1.8		72.22	4.5	0.5	3	3	1
8900	69.88		67.13		1.8		72.06	4.5	0.5	3	3	1
9000	69.77	68.66	68.66	70.46	1.8	71.46	71.85	4.5	0.5	3	3	1
9100	69.72		66.72		1.8		71.88	4.5	0.5	3	3	1
9200	69.72		66.72		1.8		71.8	4.5	0.5	3	3	1
9300	69.7		67.03		1.8		71.73	4.5	0.5	3	3	1
9400	69.68		67.01		1.8		71.74	4.5	0.5	3	3	1
9500	69.65		68.41		1.8		71.7	4.5	0.5	3	3	1
9600	69.26		66.01		1.8		71.71	4.5	0.5	3	3	1

Table 6.90: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
9693	69.28		66.03		1.8		71.61	4.5	0.5	3	3	1
9793	69.26		66.26		1.8		71.56	4.5	0.5	3	3	1
9893	69.18		66.01		1.8		71.24	4.5	0.5	3	3	1
9993	68.83	68.16	68.16	69.96	1.8	70.96	71.37	4.5	0.5	3	3	1
9993	68.83	68.01	68.16	69.21	1.2	70.21	71.37	4	0.7	3	3	1
10093	68.82	67.94	65.9	69.14	1.2	70.14	71.76	4	0.7	3	3	1
10193	68.5		65.93		1.2		71.53	4	0.7	3	3	1
10293	69.27		66.52		1.2		71.26	4	0.7	3	3	1
10393	68.67		66.17		1.2		70.47	4	0.7	3	3	1
10493	68.74		67.66		1.2		70.35	4	0.7	3	3	1
10593	68.57		66.07		1.2		70.42	4	0.7	3	3	1
10693	68.35		66.1		1.2		70.15	4	0.7	3	3	1
10793	68.39		65.72		1.2		70.23	4	0.7	3	3	1
10893	68.11		65.11		1.2		70.27	4	0.7	3	3	1
10993	68.11		67.31		1.2		70.21	4	0.7	3	3	1
11093	68.06	67.24	65.64	68.44	1.2	69.44	69.78	4	0.7	3	3	1

Table 6.91: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
11193	68.17		65.92		1.2		69.92	4	0.7	3	3	1
11293	68.09		65.84		1.2		69.9	4	0.7	3	3	1
11393	68.09		65.67		1.2		69.97	4	0.7	3	3	1
11493	67.85		66.96		1.2		69.95	4	0.7	3	3	1
11593	67.77		65.44		1.2		69.71	4	0.7	3	3	1
11693	67.69		65.44		1.2		69.73	4	0.7	3	3	1
11793	67.45		65.4		1.2		69.41	4	0.7	3	3	1
11893	67.6		65.35		1.2		69.44	4	0.7	3	3	1
11993	67.45		66.31		1.2		69.39	4	0.7	3	3	1
12093	67.4	66.54	65.07	67.74	1.2	68.74	69.18	4	0.7	3	3	1
12193	67.15		64.4		1.2		69	2.5	1	3	3	1
12293	67.2		64.12		1.2		69.01	2.5	1	3	3	1
12393	67.13		63.97		1.2		69.17	2.5	1	3	3	1
12493	66.83		65.75		1.2		68.74	2.5	1	3	3	1
12593	66.91		63.83		1.2		68.54	2.5	1	3	3	1

Table 6.92: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
12693	66.81		63.64		1.2		68.86	2.5	1	3	3	1
12793	66.85		63.6		1.2		68.5	2.5	1	3	3	1
12893	66.59		63.59		1.2		68.48	2.5	1	3	3	1
12993	66.3		65.63		1.2		68.57	2.5	1	3	3	1
13093	66.29	65.54	63.29	66.74	1.2	67.74	68.52	2.5	1	3	3	1
13193	66.09		63.09		1.2		68.45	2.5	1	3	3	1
13293	65.81		62.81		1.2		68.37	2.5	1	3	3	1
13393	65.75		62.75		1.2		67.87	2.5	1	3	3	1
13493	65.8		65.13		1.2		67.62	2.5	1	3	3	1
13593	65.7		62.53		1.2		67.85	2.5	1	3	3	1
13693	65.6		62.52		1.2		67.77	2.5	1	3	3	1
13793	64.6		62.43		1.2		67.77	2.5	1	3	3	1
13893	64.85		61.35		1.2		67.17	2.5	1	3	3	1
13993	64.8		64.13		1.2		67.07	2.5	1	3	3	1
14093	64.8	64.54	61.3	65.74	1.2	66.74	66.97	2.5	1	3	3	1
14193	64.96		61.54		1.2		66.96	2.5	1	3	3	1
14293	65		61.75		1.2		66.77	2.5	1	3	3	1
14393	65.08	64.26	61.83	65.46	1.2	66.46	66.76	2.5	1	3	3	1

Table 6.93: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Table 6.94: 6 H MC of DMC (Id:70, Node No:24-217)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Designed crest level of bank	Actual crest level of bank	Bed width (ft)	Slope in 1000'	Inside Berm	Free board	Crest width	Outside berm	Distance	Structure
0	67.98	68	na	69.8	1.8	70.8	72.8	5	0.5	3	1	3	1	0	head sluice
100	68.01	67.95	na	69.75	1.8	70.75	72.8	5	0.5	3	1	3	1	6361	regulator
200	67.93	67.9	63.97	69.7	1.8	70.7	71.25	5	0.5	3	1	3	1	11361	regulator
300	67.88	67.85	63.88	69.65	1.8	70.65	71.22	5	0.5	3	1	3	1		
400	67.95	67.8	63.79	69.6	1.8	70.6	71.1	5	0.5	3	1	3	1		
500	67.8	67.75	63.72	69.55	1.8	70.55	71.11	5	0.5	3	1	3	1		
600	67.79	67.7	63.71	69.5	1.8	70.5	71.22	5	0.5	3	1	3	1		
700	67.89	67.65	63.89	69.45	1.8	70.45	71.15	5	0.5	3	1	3	1		
800	67.81	67.6	63.81	69.4	1.8	70.4	71.02	5	0.5	3	1	3	1		
900	67.83	67.55	63.83	69.35	1.8	70.35	71.05	5	0.5	3	1	3	1		
1000	67.78	67.5	63.76	69.3	1.8	70.3	71.17	5	0.5	3	1	3	1		
1100	67.9	67.45	63.82	69.25	1.8	70.25	71.22	5	0.5	3	1	3	1		

Table 6.95: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Designed crest level of bank	Actual crest level of bank	Bed width (ft)	Slope in 1000'	Inside Berm	Free board	Crest width	Outside berm
1200	67.78	67.4	63.8	69.2	1.8	70.2	71.08	5	0.5	3	1	3	1
1300	67.69	67.35	63.94	69.15	1.8	70.15	71.05	5	0.5	3	1	3	1
1400	67.66	67.3	63.74	69.1	1.8	70.1	71.07	5	0.5	3	1	3	1
1500	67.67	67.25	63.83	69.05	1.8	70.05	71.11	5	0.5	3	1	3	1
1600	67.9	67.2	64.24	69	1.8	70	71.08	5	0.5	3	1	3	1
1700	67.51	67.15	64.28	68.95	1.8	69.95	71.08	5	0.5	3	1	3	1
1800	67.68	67.1	63.85	68.9	1.8	69.9	70.92	5	0.5	3	1	3	1
1900	67.64	67.05	63.96	68.85	1.8	69.85	70.83	5	0.5	3	1	3	1
2000	67.7	67	63.96	68.8	1.8	69.8	70.59	5	0.5	3	1	3	1
2100	67.66	66.95	63.74	68.75	1.8	69.75	70.38	5	0.5	3	1	3	1
2200	67.64	66.9	64.14	68.7	1.8	69.7	70.25	5	0.5	3	1	3	1
2300	67.46	66.85	64.21	68.65	1.8	69.65	70.44	5	0.5	3	1	3	1
2400	67.47	66.8	64.22	68.6	1.8	69.6	70.49	5	0.5	3	1	3	1
2500	67.44	66.75	64.11	68.55	1.8	69.55	70.79	5	0.5	3	1	3	1
2600	67.34	66.7	64.09	68.5	1.8	69.5	70.65	5	0.5	3	1	3	1
2700	67.37	66.65	64.12	68.45	1.8	69.45	70.53	5	0.5	3	1	3	1

Table 6.96: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Designed crest level of bank	Actual crest level of bank	Bed width (ft)	Slope in 1000'	Inside Berm	Free board	Crest width	Outside berm
2800	67.32	66.6	64.16	68.4	1.8	69.4	70.45	5	0.5	3	1	3	1
2900	67.16	66.55	63.91	68.35	1.8	69.35	70.35	5	0.5	3	1	3	1
3000	67.27	66.5	64.11	68.3	1.8	69.3	70.2	5	0.5	3	1	3	1
3100	67.15	66.45	63.9	68.25	1.8	69.25	70.29	5	0.5	3	1	3	1
3200	67.13	66.4	63.97	68.2	1.8	69.2	70.14	5	0.5	3	1	3	1
3300	67.21	66.35	63.1	68.15	1.8	69.15	70.17	5	0.5	3	1	3	1
3400	66.94	66.3	63.69	68.1	1.8	69.1	70.14	5	0.5	3	1	3	1
3500	67.08	66.25	63.83	68.05	1.8	69.05	69.97	5	0.5	3	1	3	1
3600	67.16	66.2	63.91	68	1.8	69	69.89	5	0.5	3	1	3	1
3700	67.07	66.15	63.82	67.95	1.8	68.95	69.63	5	0.5	3	1	3	1
3800	67	66.1	64.25	67.9	1.8	68.9	69.85	5	0.5	3	1	3	1
3900	67.02	66.05	64.56	67.85	1.8	68.85	69.61	5	0.5	3	1	3	1
4000	67.15	66	64.65	67.8	1.8	68.8	69.78	5	0.5	3	1	3	1

Table 6.97: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Designed crest level of bank	Actual crest level of bank	Bed width (ft)	Slope in 1000'	Inside Berm	Free board	Crest width	Outside berm
4100	67.04	65.95	64.71	67.75	1.8	68.75	70.6	5	0.5	3	1	3	1
4200	67.22	65.9	64.97	67.7	1.8	68.7	69.42	5	0.5	3	1	3	1
4300	67.23	65.85	65.25	67.65	1.8	68.65	69.54	5	0.5	3	1	3	1
4370	68.29	65.83	65.6	67.63	1.8	68.63	69.48	5	0.5	3	1	3	1
4400	68.39	65.8	65.6	67.6	1.8	68.6	69.48	5	0.5	3	1	3	1
4475	68.83	65.77	65	67.57	1.8	68.57	69.36	5	0.5	3	1	3	1
4500	67.14	65.75	65.14	67.55	1.8	68.55	69.36	5	0.5	3	1	3	1
4600	67.17	65.7	65.17	67.5	1.8	68.5	69.19	5	0.5	3	1	3	1
4700	67.19	65.65	65.11	67.45	1.8	68.45	69.11	5	0.5	3	1	3	1
4800	66.99	65.6	64.68	67.4	1.8	68.4	69.12	5	0.5	3	1	3	1
4900	67.04	65.55	64.88	67.35	1.8	68.35	68.93	5	0.5	3	1	3	1
5000	66.62	65.5	64.62	67.3	1.8	68.3	68.26	5	0.5	3	1	3	1
5100	66.65	65.45	64.57	67.25	1.8	68.25	68.82	5	0.5	3	1	3	1
5200	66.74	65.4	64.66	67.2	1.8	68.2	68.91	5	0.5	3	1	3	1
5300	66.74	65.35	64.66	67.15	1.8	68.15	68.86	5	0.5	3	1	3	1
5400	66.49	65.3	64.49	67.1	1.8	68.1	68.82	5	0.5	3	1	3	1

Table 6.98: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Designed crest level of bank	Actual crest level of bank	Bed width (ft)	Slope in 1000'	Inside Berm	Free board	Crest width	Outside berm
5500	66.43	65.25	64.43	67.05	1.8	68.05	68.65	5	0.5	3	1	3	1
5600	66.53	65.2	64.45	67	1.8	68	68.49	5	0.5	3	1	3	1
5661	66.56	65.17	64.56	66.97	1.8	67.97	68.42	5	0.5	3	1	3	1
5761	66.28	65.12	64.16	66.92	1.8	67.92	68.47	5	0.5	3	1	3	1
5861	66.34	65.07	64.84	66.87	1.8	67.87	68.33	5	0.5	3	1	3	1
5961	66.09	65.02	64.01	66.82	1.8	67.82	68.44	5	0.5	3	1	3	1
6061	65.96	64.97	63.8	66.77	1.8	67.77	68.37	5	0.5	3	1	3	1
6161	65.96	64.92	63.45	66.72	1.8	67.72	68.26	5	0.5	3	1	3	1
6261	65.52	64.87	62.74	66.67	1.8	67.67	68.29	5	0.5	3	1	3	1
6361	65.32	64.82	64.82	66.62	1.8	67.62	68.25	5	0.5	3	1	3	1
6461	65.89	64.77	62.82	66.57	1.8	67.57	68.17	4	0.5	3	1	3	1
6561	65.88	64.72	62.63	66.52	1.8	67.52	68.38	4	0.5	3	1	3	1
6661	65.7	64.67	62.87	66.47	1.8	67.47	68.35	4	0.5	3	1	3	1
6761	65.54	64.62	62.52	66.42	1.8	67.42	68.29	4	0.5	3	1	3	1
6861	65.54	64.57	62.38	66.37	1.8	67.37	68.32	4	0.5	3	1	3	1

Table 6.99: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Designed crest level of bank	Actual crest level of bank	Bed width (ft)	Slope in 1000'	Inside Berm	Free board	Crest width	Outside berm
6961	65.13	64.52	61.88	66.32	1.8	67.32	68.22	4	0.5	3	1	3	1
7061	65.25	64.47	62	66.27	1.8	67.27	68.19	4	0.5	3	1	3	1
7161	65.05	64.42	61.89	66.22	1.8	67.22	68.09	4	0.5	3	1	3	1
7261	65.14	64.37	61.89	66.17	1.8	67.17	67.97	4	0.5	3	1	3	1
7361	65.18	64.32	61.93	66.12	1.8	67.12	67.98	4	0.5	3	1	3	1
7461	65.09	64.27	61.76	66.07	1.8	67.07	67.79	4	0.5	3	1	3	1
7561	64.94	64.22	61.61	66.02	1.8	67.02	67.76	4	0.5	3	1	3	1
7661	64.8	64.17	61.05	65.97	1.8	66.97	67.63	4	0.5	3	1	3	1
7761	64.52	64.12	60.69	65.92	1.8	66.92	67.49	4	0.5	3	1	3	1
7861	64.46	64.07	60.63	65.87	1.8	66.87	67.38	4	0.5	3	1	3	1
7961	64.49	64.02	60.66	65.82	1.8	66.82	67.53	4	0.5	3	1	3	1
8061	64.65	63.97	60.82	65.77	1.8	66.77	67.39	4	0.5	3	1	3	1
8161	64.66	63.92	61.16	65.72	1.8	66.72	67.33	4	0.5	3	1	3	1
8261	64.56	63.87	61.3	65.67	1.8	66.67	67.14	4	0.5	3	1	3	1
8361	64.57	63.82	61.37	65.62	1.8	66.62	66.92	4	0.5	3	1	3	1

Table 6.100: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Designed crest level of bank	Actual crest level of bank	Bed width (ft)	Slope in 1000'	Inside Berm	Free board	Crest width	Outside berm
8461	64.57	63.77	61.57	65.57	1.8	66.57	66.75	4	0.5	3	1	3	1
8561	64.51	63.72	61.43	65.52	1.8	66.52	66.89	4	0.5	3	1	3	1
8661	64.5	63.67	61.5	65.47	1.8	66.47	66.73	4	0.5	3	1	3	1
8761	64.53	63.62	61.53	65.42	1.8	66.42	66.41	4	0.5	3	1	3	1
8861	64.36	63.57	61.4	65.37	1.8	66.37	66.6	4	0.5	3	1	3	1
8961	64.25	63.52	61.43	65.32	1.8	66.32	66.58	4	0.5	3	1	3	1
9061	64.32	63.47	61.25	65.27	1.8	66.27	66.68	4	0.5	3	1	3	1
9161	64.2	63.42	61.2	65.22	1.8	66.22	66.5	4	0.5	3	1	3	1
9261	64.12	63.37	61.08	65.17	1.8	66.17	66.65	4	0.5	3	1	3	1
9361	64.13	63.32	60.88	65.12	1.8	66.12	66.79	4	0.5	3	1	3	1
9461	63.99	63.27	60.74	65.07	1.8	66.07	66.85	4	0.5	3	1	3	1
9561	64.04	63.22	60.71	65.02	1.8	66.02	66.75	4	0.5	3	1	3	1
9661	64.04	63.17	60.79	64.97	1.8	65.97	66.6	4	0.5	3	1	3	1
9761	63.74	63.12	60.49	64.92	1.8	65.92	66.56	4	0.5	3	1	3	1
9861	63.87	63.07	60.54	64.87	1.8	65.87	66.55	4	0.5	3	1	3	1
9961	63.75	63.02	60.54	64.82	1.8	65.82	66.44	4	0.5	3	1	3	1

Table 6.101: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Designed crest level of bank	Actual crest level of bank	Bed width (ft)	Slope in 1000’	Inside Berm	Free board	Crest width	Outside berm
10061	63.63	62.97	60.3	64.77	1.8	65.77	66.35	4	0.5	3	1	3	1
10161	63.76	62.92	60.43	64.72	1.8	65.72	66.31	4	0.5	3	1	3	1
10261	63.76	62.87	60.68	64.67	1.8	65.67	66.23	4	0.5	3	1	3	1
10361	63.5	62.82	60.42	64.62	1.8	65.62	66.1	4	0.5	3	1	3	1
10461	63.45	62.77	60.37	64.57	1.8	65.57	63.93	4	0.5	3	1	3	1
10561	63.52	62.72	60.36	64.52	1.8	65.52	65.72	4	0.5	3	1	3	1
10661	63.49	62.67	60.39	64.47	1.8	65.47	65.58	4	0.5	3	1	3	1
10761	63.15	62.62	60	64.42	1.8	65.42	65.7	4	0.5	3	1	3	1
10861	62.93	62.57	60.09	64.37	1.8	65.37	65.83	4	0.5	3	1	3	1
10961	62.99	62.52	58.99	64.32	1.8	65.32	64.84	4	0.5	3	1	3	1
11061	62.87	62.47	58.87	64.27	1.8	65.27	65.78	4	0.5	3	1	3	1
11161	62.67	62.42	58.67	64.22	1.8	65.22	65.73	4	0.5	3	1	3	1
11261	62.75	62.37	58.75	64.17	1.8	65.17	65.8	4	0.5	3	1	3	1
11361	62.82	62.32	62.32	64.12	1.8	65.12	66.81	4	0.5	3	1	3	1
11361	62.82	60.82	60.82	62.62	1.8	63.62	66.8	3	0.5	3	1	3	1
11461	62.76	60.77	60.64	62.57	1.8	63.57	65.98	3	0.5	3	1	3	1

Table 6.102: (continued) 6 F MC of DMC (Id:68, Node No:21-215)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Designed crest level of bank	Actual crest level of bank	Bed width (ft)	Slope in 1000'	Inside Berm	Free board	Crest width	Outside berm
11561	62.48	60.72	60.15	62.52	1.8	63.52	65.32	3	0.5	3	1	3	1
11661	62.33	60.67	59.82	62.47	1.8	63.47	64.89	3	0.5	3	1	3	1
11761	62.24	60.62	59.81	62.42	1.8	63.42	64.87	3	0.5	3	1	3	1
11861	62.09	60.57	59.59	62.37	1.8	63.37	64.65	3	0.5	3	1	3	1
11961	61.98	60.52	59.65	62.32	1.8	63.32	64.37	3	0.5	3	1	3	1
12061	61.96	60.47	59.38	62.27	1.8	63.27	64.99	3	0.5	3	1	3	1
12161	61.62	60.42	59.04	62.22	1.8	63.22	64.28	3	0.5	3	1	3	1
12261	61.36	60.37	59.36	62.17	1.8	63.17	64.48	3	0.5	3	1	3	1
12361	61.5	60.32	58.34	62.12	1.8	63.12	64.61	3	0.5	3	1	3	1
12461	61.51	60.27	58.76	62.07	1.8	63.07	64.5	3	0.5	3	1	3	1
12561	61.41	60.22	58.75	62.02	1.8	63.02	64.36	3	0.5	3	1	3	1
12661	61.48	60.17	58.48	61.97	1.8	62.97	64.28	3	0.5	3	1	3	1
12761	61.16	60.12	58.16	61.92	1.8	62.92	64.22	3	0.5	3	1	3	1
12861	61.16	60.07	58.41	61.87	1.8	62.87	64.18	3	0.5	3	1	3	1
12961	61.03	60.02	58.2	61.82	1.8	62.82	64.12	3	0.5	3	1	3	1
13061	61.1	59.97	58.35	61.77	1.8	62.77	64.02	3	0.5	3	1	3	1
13161	61.25	59.92	58.5	61.72	1.8	62.72	64.12	3	0.5	3	1	3	1

Table 6.103: 6 J MC (Id:71, Node No:24-218)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm	Distance	Structure
0	na	66.5	na	69	2.5	70.5	na	5.5	0.25	3	1.5	3	0	head sluice
100	68.27	66.5	66.5		2.5		71.18	5.5	0.25	3	1.5	3	3010	cart bridge
200	67.99	66.45	66.45		2.5		71.08	5.5	0.25	3	1.5	3	8500	regulator
300	67.9		64.24		2.5		70.88	5.5	0.25	3	1.5	3	8997	cart bridge
400	67.76		64.1		2.5		70.59	5.5	0.25	3	1.5	3	11910	fall= 1'
500	67.99	66.38	66.33	68.88	2.5	70.38	70.26	5.5	0.25	3	1.5	3	14525	cart bridge
600	67.85		64.1		2.5		70.39	5.5	0.25	3	1.5	3		
700	67.8		63.47		2.5		70.58	5.5	0.25	3	1.5	3		
800	67.91		63.66		2.5		70.76	5.5	0.25	3	1.5	3		
900	67.95		63.7		2.5		70.85	5.5	0.25	3	1.5	3		
1000	67.72	66.25	66.22	68.75	2.5	70.25	70.72	5.5	0.25	3	1.5	3		

Table 6.104: (continued) 6 J MC (Id:71, Node No:24-218)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000’	Crest width	Free board	Inside berm
1100	67.56		63.38		2.5		70.52	5.5	0.25	3	1.5	3
1200	67.33		63.08		2.5		70.41	5.5	0.25	3	1.5	3
1300	67.55		63.47		2.5		70.3	5.5	0.25	3	1.5	3
1400	67.5		63.32		2.5		70.35	5.5	0.25	3	1.5	3
1500	67.15	66.12	65.9	68.62	2.5	72.12	70.19	5.5	0.25	3	1.5	3
1600	67.03		62.78		2.5		70.12	5.5	0.25	3	1.5	3
1700	67.04		62.62		2.5		70.05	5.5	0.25	3	1.5	3
1800	66.9		62.15		2.5		70.28	5.5	0.25	3	1.5	3
1900	66.72		62.22		2.5		70.35	5.5	0.25	3	1.5	3
2000	66.94	66	62.61	68.5	2.5	70	70.31	5.5	0.25	3	1.5	3
2100	67.19		63.94		2.5		70.16	5.5	0.25	3	1.5	3
2200	67.02		63.02		2.5		70.09	5.5	0.25	3	1.5	3
2300	66.92		62.95		2.5		70.06	5.5	0.25	3	1.5	3
2400	66.92		62.74		2.5		69.98	5.5	0.25	3	1.5	3
2500	66.95	65.87	65.7	68.37	2.5	69.87	69.95	5.5	0.25	3	1.5	3
2600	66.81		62.31		2.5		69.92	5.5	0.25	3	1.5	3
2700	66.85		62.85		2.5		69.99	5.5	0.25	3	1.5	3
2800	66.91		62.58		2.5		70.09	5.5	0.25	3	1.5	3

Table 6.105: (continued) 6 J MC (Id:71, Node No:24-218)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
2900	66.91		62.41		2.5		70.23	5.5	0.25	3	1.5	3
3000	66.92	65.75	na	68.25	2.5	69.75	70.11	5.5	0.25	3	1.5	3
3100	66.83		62.58		2.5		69.89	5.5	0.25	3	1.5	3
3200	67.04		62.71		2.5		69.95	5.5	0.25	3	1.5	3
3300	66.92		62.42		2.5		70.01	5.5	0.25	3	1.5	3
3400	66.75		62		2.5		69.83	5.5	0.25	3	1.5	3
3500	66.72	65.62	65.62	68.12	2.5	69.62	69.96	5.5	0.25	3	1.5	3
3600	66.9		62.65		2.5		70.11	5.5	0.25	3	1.5	3
3700	66.81		62.65		2.5		69.86	5.5	0.25	3	1.5	3
3800	66.72		62.54		2.5		69.87	5.5	0.25	3	1.5	3
3900	66.68		62.35		2.5		69.62	5.5	0.25	3	1.5	3
4000	66.64	65.5	65.46	68	2.5	69.5	69.59	5.5	0.25	3	1.5	3
4100	66.42		61.67		2.5		69.72	5.5	0.25	3	1.5	3
4200	66.39		62.06		2.5		69.44	5.5	0.25	3	1.5	3
4300	66.47		62.14		2.5		69.37	5.5	0.25	3	1.5	3
4400	66.4		62.07		2.5		69.54	5.5	0.25	3	1.5	3

Table 6.106: (continued) 6 J MC (Id:71, Node No:24-218)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embank- ment	Crest level of embank- ment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
4500	66.55	65.37	65.37	67.87	2.5	69.37	69.71	5.5	0.25	3	1.5	3
4600	66.74		62.41		2.5		69.83	5.5	0.25	3	1.5	3
4700	66.66		62.58		2.5		69.72	5.5	0.25	3	1.5	3
4800	66.4		62.57		2.5		69.53	5.5	0.25	3	1.5	3
4900	66.65		62.73		2.5		69.35	5.5	0.25	3	1.5	3
5000	66.43	65.25	65.25	67.75	2.5	69.25	69.65	5.5	0.25	3	1.5	3
5100	66.48		62.23		2.5		69.75	5.5	0.25	3	1.5	3
5200	66.71		62.53		2.5		69.8	5.5	0.25	3	1.5	3
5300	66.41		62.41		2.5		69.73	5.5	0.25	3	1.5	3
5400	66.34		62.26		2.5		69.58	5.5	0.25	3	1.5	3
5500	66.56	65.12	62.12	67.62	2.5	69.12	69.46	5.5	0.25	3	1.5	3
5600	66.48		62.23		2.5		69.54	5.5	0.25	3	1.5	3
5700	66.48		62.65		2.5		69.4	5.5	0.25	3	1.5	3
5800	66.61		62.43		2.5		69.48	5.5	0.25	3	1.5	3
5900	66.39		64.97	67.52	2.5	69.02	69.31	5.5	0.25	3	1.5	3
6000	66.45	65	62.53	67.5	2.5	68.5	69.22	4.5	0.25	3	1	3
6100	66.32		62.66		2.5		69.15	4.5	0.25	3	1	3

Table 6.107: (continued) 6 J MC (Id:71, Node No:24-218)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
6200	66.38		62.63		2.5		69.09	4.5	0.25	3	1	3
6300	66.46		62.71		2.5		68.96	4.5	0.25	3	1	3
6400	66.25		62.92		2.5		68.95	4.5	0.25	3	1	3
6500	66.4	64.87	64.9	67.37	2.5	68.37	68.81	4.5	0.25	3	1	3
6600	66.35		62.6		2.5		68.69	4.5	0.25	3	1	3
6700	66.36		62.86		2.5		68.82	4.5	0.25	3	1	3
6800	66.4		63.15		2.5		68.73	4.5	0.25	3	1	3
6900	66.48		62.98		2.5		68.91	4.5	0.25	3	1	3
7000	66.2	64.75	64.7	67.25	2.5	68.25	68.92	4.5	0.25	3	1	3
7100	66.18		62.68		2.5		68.76	4.5	0.25	3	1	3
7200	66.24		62.74		2.5		68.75	4.5	0.25	3	1	3
7300	66.08		62.33		2.5		68.65	4.5	0.25	3	1	3
7400	66.02		62.36		2.5		68.49	4.5	0.25	3	1	3
7500	65.98	64.62	64.65	67.12	2.5	68.12	68.37	4.5	0.25	3	1	3
7600	66.06		62.4		2.5		68.2	4.5	0.25	3	1	3
7700	65.93		62.18		2.5		68.31	4.5	0.25	3	1	3

Table 6.108: (continued) 6 J MC (Id:71, Node No:24-218)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
7800	65.99		62.81		2.5		68.48	4.5	0.25	3	1	3
7900	66.02		62.69		2.5		68.32	4.5	0.25	3	1	3
8000	66.08	64.5	64.5	67	2.5	68	68.23	4.5	0.25	3	1	3
8100	66.2		63.45		2.5		68.5	4.5	0.25	3	1	3
8200	66.23		63.4		2.5		68.66	4.5	0.25	3	1	3
8300	66.13		63.13		2.5		70.96	4.5	0.25	3	1	3
8400	66.35		63.43		2.5		68.23	4.5	0.25	3	1	3
8500	66.18	64.37	62.68	66.87	2.5	67.87	68.29	4.5	0.25	3	1	3
8600	66.13		65.38		2.5		68.46	4.5	0.25	3	1	3
8700	67.32		64.32		2.5		68.51	4.5	0.25	3	1	3
8800	65.91		62.91		2.5		67.99	4.5	0.25	3	1	3
8900	65.92		62.74		2.5		67.86	4.5	0.25	3	1	3
9000	65.45	64.25	na	66.75	2.5	67.75	67.79	4.5	0.25	3	1	3
9100	65.62		62.37		2.5		67.85	4.5	0.25	3	1	3
9200	65.67		62.59		2.5		67.81	4.5	0.25	3	1	3
9300	65.64		62.56		2.5		67.83	4.5	0.25	3	1	3
9400	65.7		62.45		2.5		67.81	4.5	0.25	3	1	3

Table 6.109: (continued) 6 J MC (Id:71, Node No:24-218)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
9500	65.68	64.12	64.1	66.62	2.5	67.62	67.92	4.5	0.25	3	1	3
9600	65.7		62.95		2.5		67.82	4.5	0.25	3	1	3
9700	65.75		62.75		2.5		67.77	4.5	0.25	3	1	3
9800	65.92		63.17		2.5		67.89	4.5	0.25	3	1	3
9900	65.75		63		2.5		67.85	4.5	0.25	3	1	3
10000	65.72	64	63.97	66.5	2.5	67.5	67.87	4.5	0.25	3	1	3
10100	65.69		63.11		2.5		67.89	4.5	0.25	3	1	3
10200	65.59		62.93		2.5		67.78	4.5	0.25	3	1	3
10300	65.68		62.68		2.5		67.7	4.5	0.25	3	1	3
10400	65.75		62.75		2.5		67.65	4.5	0.25	3	1	3
10500	65.76	63.87	63.84	66.37	2.5	67.37	67.53	4.5	0.25	3	1	3
10600	65.81		63.06		2.5		67.59	4.5	0.25	3	1	3
10700	65.79		62.96		2.5		67.44	5	0.25	3	1	3
10800	65.53		62.78		2.5		67.35	5	0.25	3	1	3
10900	65.37		62.45		2.5		67.53	5	0.25	3	1	3
11000	65.5	63.76	63.75	66.25	2.5	67.25	67.55	5	0.25	3	1	3

Table 6.110: (continued) 6 J MC (Id:71, Node No:24-218)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
11100	65.32		62.57		2.5		67.39	5	0.25	3	1	3
11200	65.4		62.65		2.5		67.35	5	0.25	3	1	3
11300	65.26		62.43		2.5		67.26	5	0.25	3	1	3
11400	65.23		62.48		2.5		67.21	5	0.25	3	1	3
11500	65.24	63.66	63.66	66.16	2.5	67.12	67.08	5	0.25	3	1	3
11600	65.1		62.35		2.5		66.95	5	0.25	3	1	3
11700	65.01		62.01		2.5		66.83	5	0.25	3	1	3
11800	64.9		61.65		2.5		66.7	5	0.25	3	1	3
11900	64.91	63.58	na	66.08	2.5	na	66.57	5	0.25	3	1	3
12000	64.86	63	na	65	2	66	66.46	4	0.25	3	1	3
12100	64.78		62.95		2		66.39	4	0.25	3	1	3
12200	64.7		62.62		2		66.42	4	0.25	3	1	3
12300	64.79		62.61		2		66.53	4	0.25	3	1	3
12400	64.58		62.5		2		66.33	4	0.25	3	1	3
12500	64.41	62.87	62.91	64.87	2	65.87	66.31	4	0.25	3	1	3
12600	64.4		61.98		2		66.35	4	0.25	3	1	3
12700	64.4		62.15		2		66.3	4	0.25	3	1	3

Table 6.111: (continued) 6 J MC (Id:71, Node No:24-218)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
12800	64.38		62.2		2		66.28	4	0.25	3	1	3
12900	64.22		61.8		2		66.25	4	0.25	3	1	3
13000	64.02	62.75	62.75	64.75	2	65.75	66.2	4	0.25	3	1	3
13100	63.93		61.35		2		66.04	4	0.25	3	1	3
13200	63.75		60.57		2		66	4	0.25	3	1	3
13300	63.67		60.84		2		65.93	4	0.25	3	1	3
13400	63.75		60.57		2		65.81	4	0.25	3	1	3
13500	63.4	62.62	61.9	64.62	2	65.62	65.64	4	0.25	3	1	3
13600	63.45		60.37		2		65.91	4	0.25	3	1	3
13700	63.42		59.76		2		65.76	4	0.25	3	1	3
13800	63.38		59.38		2		65.59	4	0.25	3	1	3
13900	63.21		59.21		2		65.55	4	0.25	3	1	3

Table 6.112: (continued) 6 J MC (Id:71, Node No:24-218)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
14000	63.4	62.52	62.5	64.52	2	65.5	65.8	4	0.25	3	1	3
14100	63.24		59.58		2		65.72	4	0.25	3	1	3
14200	63.2		59.2		2		65.88	4	0.25	3	1	3
14300	63.5		60.25		2		65.82	4	0.25	3	1	3
14400	63.09		60.43		2		66.05	4	0.25	3	1	3
14500	63.4	62.37	62.37	64.37	2	65.37	65.73	4	0.25	3	1	3
14600	63.45		59.79		2		65.94	4	0.25	3	1	3
14700	62.52		58.52		2		65.26	4	0.25	3	1	3
14800	62.61		58.43		2		65.43	4	0.25	3	1	3
14900	62.95		58.62		2		65.52	4	0.25	3	1	3
15000	63.26	62.25	62.25	64.25	2	65.25	65.74	4	0.25	3	1	3
15100	63.02		58.84		2		65.93	4	0.25	3	1	3
15200	63.01		58.83		2		65.86	4	0.25	3	1	3

Table 6.113: (continued) 6 J MC (Id:71, Node No:24-218)

Distance in ft	Ground Level	Design Bed Level	Actual Bed Level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
15300	63.5		59.67		2		65.81	4	0.25	3	1	3
15400	63.52		60.19		2		65.77	4	0.25	3	1	3
15500	63.54	62.12	62.12	64.12	2	65.12	65.99	4	0.25	3	1	3
15600	63.56		60.81		2		65.47	4	0.25	3	1	3
15700	63.45		60.7		2		65.36	4	0.25	3	1	3
15800	63.54		60.71		2		65.42	4	0.25	3	1	3
15900	63.56		60.73		2		65.39	4	0.25	3	1	3
16000	63.51	62	60.76	64	2	65	65.38	4	0.25	3	1	3
16100	63.51		60.76		2		65.28	4	0.25	3	1	3
16200	63.47		60.47		2		65.37	4	0.25	3	1	3
16300	63.36		60.36		2		65.46	4	0.25	3	1	3
16400	63.46		60.71		2		65.35	4	0.25	3	1	3
16500	63.43	61.87	60.67	63.87	2	64.87	65.24	4	0.25	3	1	3
16600	63.46		60.8		2		65.15	4	0.25	3	1	3
16661	63.46	61.84	60.8	63.84	2	64.84	65.03	4	0.25	3	1	3

Table 6.114: 6 K EXTENSION of MC (Id:72, Node No:25-221)

Distance in chain	Ground Level	Design Bed Level	Actual Bed Level	Depth of cut	F.S.L (Existing)	F.S.L (Proposed)	F.S.D (ft)	Discharge (cusec)	Slope in 1000’	Free board	Bed width (ft)	Velocity (ft/s)	Distance	Structure
0	61.87	60	60.03	0.03	62.63	63	3	56.19	0.25	2	9	1.67	0	head regulator
10	61.6	59.75	58.15		62.33	62.75	3	56.19	0.25	2	9	1.67	83.92	cart bridge
20	61.39	59.5	58.64		62.03	62.5	3	56.19	0.25	2	9	1.67	116.92	fall=0.8’ (off-take of 6k/1)
30	60	59.75	58.22		61.73	62.75	3	56.19	0.25	2	9	1.67	162.4	cart bridge
40	60.94	59	58.61		61.43	62	3	56.19	0.25	2	9	1.67		
50	60.7	58.75	58.62		61.13	61.75	3	56.19	0.25	2	9	1.67		
60	60.47	58.5	58.67		60.83	61.5	3	56.19	0.25	2	9	1.67		
70	60	58.25	57.67		60.55	61.25	3	56.19	0.25	2	9	1.67		
80	59.48	58	56.65		60.25	61	3	56.19	0.25	2	9	1.67		
83.92	59.41	57.9	57.51		60.11	60.9	3	56.19	0.25	2	9	1.67		
90	59.05	57.75	55.55		59.81	60.75	3	56.19	0.25	2	9	1.67		

Table 6.115: (continued) 6 K EXTENSION of MC (Id:72, Node No:25-221)

Distance in chain	Ground Level	Design Bed Level	Actual Bed Level done	Depth of cut	F.S.L (Existing)	F.S.L (Proposed)	F.S.D (ft)	Discharge (cusec)	Slope in 1000'	Free board	Bed width (ft)	Velocity (ft/s)
100	58.19	57.5	54.25		59.31	60.5	3	56.19	0.25	2	9	1.67
110	57.88	57.25	55.38		58.81	60.25	3	56.19	0.25	2	9	1.67
116.92	57.74	57.07	55.86	0.99	58.46	60.07	3	56.19	0.25	2	9	1.67
116.92	na	54.87	na		57.66	57.07	2.2	25.34	0.3	2	6	1.42
120	57.31	54.78	55.31	0.33	57.45	56.98	2.2	25.34	0.3	2	6	1.42
130	57.07	54.48	55.19		57.05	56.68	2.2	25.34	0.3	2	6	1.42
140	58.58	54.18	54.99	0.81	56.65	56.38	2.2	25.34	0.3	2	6	1.42
150	56.25	53.88	54.48	0.6	56.25	56.08	2.2	25.34	0.3	2	6	1.42
160	54.9	53.58	52.4		55.85	55.78	2.2	25.34	0.3	2	6	1.42
162.92	55.28	53.39	53.03		55.73	55.59	2.2	25.34	0.3	2	6	1.42
170	54.82	53.48	52.32		55.3	55.48	2	18.82	0.3	2	6	1.35
180	54.03	53.18	50.13		54.7	55.18	2	18.82	0.3	2	6	1.35
190	52.13	52.88	47.13		54.1	54.88	2	18.82	0.3	2	6	1.35
200	52.31	52.58	49.06		55.5	54.58	2	18.82	0.3	2	6	1.35
210	52.13	52.28	49.13		52.9	54.28	2	18.82	0.3	2	6	1.35
220	51.93	51.93	49.6		52.3	53.93	2	18.82	0.3	2	6	1.35
226.92	51.29	51.77	50.18		51.88	53.77	2	18.82	0.3	2	6	1.35

Table 6.116: 6 K1 MC (Id:125, Node No:220-295)

Distance in Chain	Ground level	Design Bed Level	Actual Bed Level done	Depth of Cutting	FSL (Exisit-ing)	FSL (Pro-posed)
0	57.81	56.6	56.65	0.05	58.25	59.00
10	57.71	56.35	54.63		57.95	58.75
20	57.08	56.1	54.5		57.65	58.5
22	57.2	56.05	54.22		57.59	58.45
30	56.73	55.85	53.08		57.35	59.25
36	56.33	55.6	54.03		57.17	58.1
40	56.14	55.6	53.24		56.97	58
50	55.74	55.35	52.24		56.47	57.75
61	55.26	55.08	54.32		55.92	57.48
61	55.26	53.28	54.32		55.92	55.48
70	54.62	53.01	51.62		55.47	55.21
77	54.56	52.8	52.06		55.12	55
80	54.48	52.71	52.15		54.94	54.91
90.68	53.89	52.68	50.84		54.44	54.88
90.68	53.89	52.88	50.84		54.44	54.88
100	53.08	52.31	49.75		53.94	54.31
110.67	50.48	51.89	50.48		53.44	53.89

Table 6.117: 6 K1 EXTENSION of MC (Id:125, Node No:220-295)

Distance in ft	Ground Level	Design Bed Level	Depth of cut	F.S.L (Proposed)	F.S.D (ft)	Crest Level	Height of Bank	Crest width	Discharge (cusec)	Slope in 1000'	Free board	Bed width (ft)	Velocity (ft/s)	V/V0
0	51.9	50.25	1.65	52.45	2.2	53.95	2.05	3	20.09	0.4	1.5	4	1.53	1.1
500	51.78	50.05	1.73	52.25	2.2	53.75	1.97	3	20.09	0.4	1.5	4	1.53	1.1
1000	51.73	49.85	1.88	52.05	2.2	53.55	1.82	3	20.09	0.4	1.5	4	1.53	1.1
1500	50.77	49.65	1.77	51.85	2.2	53.35	2.58	3	20.09	0.4	1.5	4	1.53	1.1
2000	51.04	49.45	1.59	51.65	2.2	53.15	2.11	3	20.09	0.4	1.5	4	1.53	1.1
2500	50.71	49.25	1.46	51.45	2.2	52.95	2.24	3	20.09	0.4	1.5	4	1.53	1.1
3000	50.36	49.05	1.51	51.25	2.2	51.75	1.39	3	20.09	0.4	1.5	4	1.53	1.1
3500	50.21	48.85	1.36	51.05	2.2	52.55	2.34	3	20.09	0.4	1.5	4	1.53	1.1
4000	49.91	48.65	1.26	50.85	2.2	52.35	2.44	3	20.09	0.4	1.5	4	1.53	1.1
4500	49.56	48.45	1.11	50.65	2.2	52.15	2.59	3	20.09	0.4	1.5	4	1.53	1.1
5000	49.36	48.25	1.11	50.45	2.2	51.95	2.59	3	20.09	0.4	1.5	4	1.53	1.1
5500	48.81	48.05	0.76	50.25	2.2	51.75	2.94	3	20.09	0.4	1.5	4	1.53	1.1
5565	51.81	47.81	1.22	50.01	2.2	54.29	2.48	3	20.09	0.4	1.5	4	1.53	1.1

Table 6.118: (continued) 6 K1 EXTENSION of MC (Id:125, Node No:220-295)

Distance in ft	Ground Level	Design Bed Level	Depth of cut	F.S.L (Proposed)	F.S.D (ft)	Crest Level	Height of Bank	Crest width	Discharge (cusec)	Slope in 1000’	Free board	Bed width (ft)	Velocity (ft/s)	V/V0
5800	48.92	47.79	1.13	49.99	2.2	51.43	2.51	3	20.09	0.4	1.5	4	1.53	1.1
5800	48.92	46.83	2.09	48.53	1.7	50.03	1.11	3	10.81	0.4	1.5	3.25	1.304	1.1
6000	50.19	46.75	3.44	48.45	1.7	49.95	na	3	10.81	0.4	1.5	3.25	1.304	1.1
6500	48.69	46.55	2.14	48.25	1.7	49.75	1.06	3	10.81	0.4	1.5	3.25	1.304	1.1
7000	48.44	46.35	2.09	48.05	1.7	49.55	1.11	3	10.81	0.4	1.5	3.25	1.304	1.1
7500	47.88	46.15	1.73	47.85	1.7	49.35	1.47	3	10.81	0.4	1.5	3.25	1.304	1.1
8000	47.78	45.95	1.83	47.65	1.7	49.15	1.37	3	10.81	0.4	1.5	3.25	1.304	1.1
8500	47.37	45.75	1.62	47.45	1.7	48.95	1.58	3	10.81	0.4	1.5	3.25	1.304	1.1
9000	46.45	45.55	0.9	47.25	1.7	48.75	2.3	3	10.81	0.4	1.5	3.25	1.304	1.1
9500	46.66	45.35	1.31	47.05	1.7	48.55	1.89	3	10.81	0.4	1.5	3.25	1.304	1.1
10000	46.17	45.15	1.02	46.85	1.7	48.35	2.18	3	10.81	0.4	1.5	3.25	1.304	1.1
10500	46.55	44.95	1.6	46.65	1.7	48.15	1.6	3	10.81	0.4	1.5	3.25	1.304	1.1
11000	46.05	44.75	1.3	46.45	1.7	47.95	1.9	3	7.58	0.4	1.5	2.5	1.214	1.02
11200	45.88	44.67	1.21	46.37	1.7	47.87	1.99	3	7.58	0.4	1.5	2.5	1.214	1.02

Table 6.119: 6 L MC of DMC (Id:73, Node No:26-226)

Distance in ft	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Formation level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
0	60.94	58.94	63.94	3	65.44	11	0.225	4	1.5	4
100	60.91	60.88	63.91	3	65.41	11	0.225	4	1.5	4
200	60.89	59.4	63.89	3	65.39	11	0.225	4	1.5	4
300	60.87	59.35	63.87	3	65.37	11	0.225	4	1.5	4
400	60.85	59.42	63.85	3	65.35	11	0.225	4	1.5	4
500	60.82	59.3	63.82	3	65.32	11	0.225	4	1.5	4
600	60.8	59.32	63.8	3	65.3	11	0.225	4	1.5	4
700	60.78	59.3	63.78	3	65.28	11	0.225	4	1.5	4
800	60.76	58.41	63.76	3	65.26	11	0.225	4	1.5	4
900	60.74	57.65	63.74	3	65.24	11	0.225	4	1.5	4
1000	60.71	59.31	63.71	3	65.21	11	0.225	4	1.5	4
1100	60.69	59.3	63.69	3	65.19	11	0.225	4	1.5	4
1200	60.67	60.45	63.67	3	65.17	11	0.225	4	1.5	4
1300	60.64	60.35	63.64	3	65.14	11	0.225	4	1.5	4
1400	60.62	59.96	63.62	3	65.12	11	0.225	4	1.5	4
1500	60.6	60.11	63.6	3	65.1	11	0.225	4	1.5	4
1600	60.58	58.43	63.58	3	65.08	11	0.225	4	1.5	4
1700	60.55	60.52	63.55	3	65.05	11	0.225	4	1.5	4

Table 6.120: (continued) 6 L MC of DMC (Id:73, Node No:26-226)

Distance in ft	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Formation level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
1800	60.53	59.82	63.53	3	65.03	11	0.225	4	1.5	4
1900	60.51	59.84	63.51	3	65.01	11	0.225	4	1.5	4
2000	60.49	59.85	63.49	3	64.99	11	0.225	4	1.5	4
2100	60.46	59.74	63.46	3	64.96	11	0.225	4	1.5	4
2200	60.44	59.55	63.44	3	64.94	11	0.225	4	1.5	4
2300	60.42	59.73	63.42	3	64.92	11	0.225	4	1.5	4
2400	60.4	59.72	63.4	3	64.9	11	0.225	4	1.5	4
2500	60.37	58.65	63.37	3	64.87	11	0.225	4	1.5	4
2600	60.35	57.4	63.35	3	64.85	11	0.225	4	1.5	4
2700	60.33	58.34	63.33	3	64.83	11	0.225	4	1.5	4
2800	60.31	58.26	63.31	3	64.81	11	0.225	4	1.5	4
2900	60.29	58.73	63.29	3	64.79	11	0.225	4	1.5	4
3000	60.26	57.49	63.26	3	64.76	11	0.225	4	1.5	4
3100	60.24	57.43	63.24	3	64.74	11	0.225	4	1.5	4
3200	60.22	57.34	63.22	3	64.72	11	0.225	4	1.5	4
3300	60.19	59.9	63.19	3	64.69	11	0.225	4	1.5	4
3400	60.17	60.52	63.17	3	64.67	11	0.225	4	1.5	4

Table 6.121: (continued) 6 L MC of DMC (Id:73, Node No:26-226)

Distance in ft	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Formation level of embankment	Bed width (ft)	Slope in 1000’	Crest width	Free board	Inside berm
3500	60.15	60.08	63.15	3	64.65	11	0.225	4	1.5	4
3600	60.13	59.73	63.13	3	64.63	11	0.225	4	1.5	4
3700	60.1	59.98	63.1	3	64.6	11	0.225	4	1.5	4
3800	60.08	59.32	63.08	3	64.58	11	0.225	4	1.5	4
3900	60.06	59.92	63.06	3	64.56	11	0.225	4	1.5	4
4000	60.04	60.07	63.04	3	64.54	11	0.225	4	1.5	4
4100	60.01	59.75	63.01	3	64.51	11	0.225	4	1.5	4
4200	59.99	59.92	62.99	3	64.49	11	0.225	4	1.5	4
4300	59.97	59.75	62.97	3	64.47	11	0.225	4	1.5	4
4400	59.95	60.19	62.95	3	64.45	11	0.225	4	1.5	4
4500	59.92	60.32	62.92	3	64.42	11	0.225	4	1.5	4
4600	59.9	59.47	62.9	3	64.4	11	0.225	4	1.5	4
4700	59.88	59.94	62.88	3	64.38	11	0.225	4	1.5	4
4800	59.86	60.07	62.86	3	64.36	11	0.225	4	1.5	4
4900	59.84	57.76	62.84	3	64.34	11	0.225	4	1.5	4
5000	59.81	54.43	62.81	3	64.31	11	0.225	4	1.5	4
5100	59.79	58.19	62.79	3	64.29	11	0.225	4	1.5	4
5200	59.77	58.21	62.77	3	64.27	11	0.225	4	1.5	4
5300	59.74	57.63	62.74	3	64.24	11	0.225	4	1.5	4

Table 6.122: (continued) 6 L MC of DMC (Id:73, Node No:26-226)

Distance in ft	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Formation level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
5400	59.72	57.59	62.72	3	64.22	11	0.225	4	1.5	4
5500	59.7	57.52	62.7	3	64.2	11	0.225	4	1.5	4
5600	59.68	57.59	62.68	3	64.18	11	0.225	4	1.5	4
5700	59.65	56.84	62.65	3	64.15	11	0.225	4	1.5	4
5800	59.63	56.31	62.63	3	64.13	11	0.225	4	1.5	4
5900	59.61	55.55	62.61	3	64.11	11	0.225	4	1.5	4
6000	59.59	56.12	62.59	3	64.09	11	0.225	4	1.5	4
6100	59.56	57	62.56	3	64.06	11	0.225	4	1.5	4
6200	59.54	57.88	62.54	3	64.04	11	0.225	4	1.5	4
6300	59.52	53.97	62.52	3	64.02	11	0.225	4	1.5	4
6400	59.5	54.74	62.5	3	64	11	0.225	4	1.5	4
6500	59.47	56.03	62.47	3	63.97	11	0.225	4	1.5	4
6600	59.45	56.27	62.45	3	63.95	11	0.225	4	1.5	4
6700	59.43	56.3	62.43	3	63.93	11	0.225	4	1.5	4
6800	59.41	56.35	62.41	3	63.91	11	0.225	4	1.5	4
6900	59.39	56.61	62.39	3	63.89	11	0.225	4	1.5	4
7000	59.36	56.91	62.36	3	63.86	11	0.225	4	1.5	4

Table 6.123: (continued) 6 L MC of DMC (Id:73, Node No:26-226)

Distance in ft	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Formation level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
7100	59.34	57.09	62.34	3	63.84	11	0.225	4	1.5	4
7200	59.32	57.81	62.32	3	63.82	11	0.225	4	1.5	4
7300	59.29	59.32	62.29	3	63.79	11	0.225	4	1.5	4
7400	59.27	57.77	62.27	3	63.77	9.5	0.225	4	1	4
7500	59.25	57.58	62.25	3	63.75	9.5	0.225	4	1	4
7600	59.23	57.73	62.23	3	63.73	9.5	0.225	4	1	4
7700	59.2	57.48	62.2	3	63.7	9.5	0.225	4	1	4
7800	59.18	57.4	62.18	3	63.68	9.5	0.225	4	1	4
7900	59.16	57.36	62.16	3	63.66	9.5	0.225	4	1	4
8000	59.14	57.32	62.14	3	63.64	9.5	0.225	4	1	4
8100	59.11	57.08	62.11	3	63.61	9.5	0.225	4	1	4
8200	59.09	56.97	62.09	3	63.59	9.5	0.225	4	1	4
8300	59.07	57.36	62.07	3	63.57	9.5	0.225	4	1	4
8400	59.05	57.39	62.05	3	63.55	9.5	0.225	4	1	4
8500	59.02	57.41	62.02	3	63.52	9.5	0.225	4	1	4
8600	59	57.28	62	3	63.5	9.5	0.225	4	1	4
8700	58.98	57.64	61.98	3	63.48	9.5	0.225	4	1	4
8800	58.96	57.68	61.96	3	63.46	9.5	0.225	4	1	4

Table 6.124: (continued) 6 L MC of DMC (Id:73, Node No:26-226)

Distance in ft	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Formation level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
8900	58.94	57.654	61.94	3	63.44	9.5	0.225	4	1	4
9000	58.91	58.96	61.91	3	63.41	9.5	0.225	4	1	4
9100	58.89	57.96	61.89	3	63.39	9.5	0.225	4	1	4
9200	58.87	57.93	61.87	3	63.37	9.5	0.225	4	1	4
9300	58.84	57.96	61.84	3	63.34	9.5	0.225	4	1	4
9400	58.82	57.9	61.82	3	63.32	9.5	0.225	4	1	4
9500	58.8	58.88	61.8	3	63.3	9.5	0.225	4	1	4
9600	58.78	56.5	61.78	3	63.28	9.5	0.225	4	1	4
9700	58.75	57.04	61.75	3	63.25	9.5	0.225	4	1	4
9800	58.73	57.07	61.73	3	63.23	9.5	0.225	4	1	4
9900	58.71	59.18	61.71	3	63.21	9.5	0.225	4	1	4
10000	58.69	57.70,57.78	61.69	3	63.19	9.5	0.225	4	1	4
10100	58.66	57.69	61.66	3	63.16	9.5	0.225	4	1	4

Table 6.125: (continued) 6 L MC of DMC (Id:73, Node No:26-226)

Distance in ft	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Formation level of embankment	Bed width (ft)	Slope in 1000’	Crest width	Free board	Inside berm
10200	58.64	57.13	61.64	3	63.14	9.5	0.225	4	1	4
10300	58.62	56.95	61.62	3	63.12	9.5	0.225	4	1	4
10400	58.6	58.75	61.6	3	63.1	9.5	0.225	4	1	4
10500	58.57	57.9	61.57	3	63.07	9.5	0.225	4	1	4
10600	58.55	57.45	61.55	3	63.05	9.5	0.225	4	1.5	4
10700	58.53	57.46	61.53	3	63.03	9.5	0.225	4	1.5	4
10800	58.51	56.93	61.51	3	63.01	9.5	0.225	4	1.5	4
10900	58.49	57.49	61.49	3	62.99	9.5	0.225	4	1.5	4
11000	58.46	58.52	61.46	3	62.96	9.5	0.225	4	1.5	4
11100	58.44	56.85	61.44	3	62.94	9.5	0.225	4	1.5	4
11200	58.42	56.7	61.42	3	62.92	9.5	0.225	4	1.5	4
11300	58.39	56.89	61.39	3	62.89	9.5	0.225	4	1.5	4
11400	58.37	56.92	61.37	3	62.87	9.5	0.225	4	1.5	4
11500	58.35	57.45	61.35	3	62.85	9.5	0.225	4	1.5	4
11600	58.33	57.24	61.33	3	62.83	9.5	0.225	4	1.5	4
11700	58.3	56.6	61.3	3	62.8	9.5	0.225	4	1.5	4
11800	58.28	56.59	61.28	3	62.78	9.5	0.225	4	1.5	4

Table 6.126: (continued) 6 L MC of DMC (Id:73, Node No:26-226)

Distance in ft	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Formation level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
11900	58.26	56.65	61.26	3	62.76	9.5	0.225	4	1.5	4
12000	58.24	57.2	61.24	3	62.74	9.5	0.225	4	1.5	4
12100	58.21	58.22	61.21	3	62.71	9.5	0.225	4	1.5	4
12200	58.19	56.7	61.19	3	62.69	9.5	0.225	4	1.5	4
12300	58.17	57.11	61.17	3	62.67	9.5	0.225	4	1.5	4
12400	58.15	56.09	61.15	3	62.65	9.5	0.225	4	1.5	4
12500	58.12	55.84	61.12	3	62.62	9.5	0.225	4	1.5	4
12600	58.1	56.5	61.1	3	62.6	9.5	0.225	4	1.5	4
12700	58.08	56.44	61.08	3	62.58	9.5	0.225	4	1.5	4
12800	58.06	57.2	61.06	3	62.56	9.5	0.225	4	1.5	4
12844	58.05	58.05	61.05	3	62.55	9.5	0.225	4	1.5	4
12900	58.02	58.02	60.52	2.5	61.52	7	0.4	3	1	3
13000	57.98	58.11	60.48	2.5	61.48	7	0.4	3	1	3
13100	57.94	57.26	60.44	2.5	61.44	7	0.4	3	1	3
13200	57.9	57.56	60.4	2.5	61.4	7	0.4	3	1	3
13300	57.86	56.66	60.36	2.5	61.36	7	0.4	3	1	3
13400	57.82	56.49	60.32	2.5	61.32	7	0.4	3	1	3

Table 6.127: (continued) 6 L MC of DMC (Id:73, Node No:26-226)

Distance in ft	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Formation level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
13500	57.78	56.5	60.28	2.5	61.28	7	0.4	3	1	3
13600	57.74	56.5	60.24	2.5	61.24	7	0.4	3	1	3
13700	57.7	56.8	60.2	2.5	61.2	7	0.4	3	1	3
13800	57.66	56.73	60.16	2.5	61.16	7	0.4	3	1	3
13900	57.62	56.76	60.12	2.5	61.12	7	0.4	3	1	3
14000	57.58	55.77	60.08	2.5	61.08	7	0.4	3	1	3
14100	57.54	55.32	60.04	2.5	61.04	7	0.4	3	1	3
14200	57.5	55.99	60	2.5	61	7	0.4	3	1	3
14300	57.46	56.19	59.96	2.5	60.96	7	0.4	3	1	3
14400	57.42	56.16	59.92	2.5	60.92	7	0.4	3	1	3
14500	57.38	56.06	59.88	2.5	60.88	7	0.4	3	1	3
14600	57.34	56.02	59.84	2.5	60.84	7	0.4	3	1	3
14700	57.3	56.08	59.8	2.5	60.8	7	0.4	3	1	3
14800	57.26	56.26	59.76	2.5	60.76	7	0.4	3	1	3
14900	57.22	57.24	59.72	2.5	60.72	7	0.4	3	1	3
15000	57.18	56.24	59.68	2.5	60.68	7	0.4	3	1	3
15100	57.14	56.16	59.64	2.5	60.64	7	0.4	3	1	3
15200	57.1	57.24	59.6	2.5	60.6	7	0.4	3	1	3
15300	57.06	54.74	59.56	2.5	60.56	7	0.4	3	1	3

Table 6.128: (continued) 6 L MC of DMC (Id:73, Node No:26-226)

Distance in ft	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Formation level of embankment	Bed width (ft)	Slope in 1000’	Crest width	Free board	Inside berm
15400	57.02	54.47	59.52	2.5	60.52	7	0.4	3	1	3
15500	56.98	55.48	59.48	2.5	60.48	7	0.4	3	1	3
15600	56.94	56.15	59.44	2.5	60.44	7	0.4	3	1	3
15700	56.9	56.12	59.4	2.5	60.4	7	0.4	3	1	3
15800	56.86	55.56	59.36	2.5	60.36	7	0.4	3	1	3
15900	56.82	55.59	59.32	2.5	60.32	7	0.4	3	1	3
16000	56.78	55.53	59.28	2.5	60.28	7	0.4	3	1	3
16100	56.74	55.5	59.24	2.5	60.24	7	0.4	3	1	3
16200	56.7	55.05	59.2	2.5	60.2	7	0.4	3	1	3
16300	56.66	55.29	59.16	2.5	60.16	7	0.4	3	1	3
16400	56.62	55.41	59.12	2.5	60.12	7	0.4	3	1	3
16500	56.58	55.36	59.08	2.5	60.08	7	0.4	3	1	3
16600	56.54	55.33	59.04	2.5	60.04	7	0.4	3	1	3
16700	56.5	55.22	59	2.5	60	7	0.4	3	1	3
16800	56.46	55.59	58.96	2.5	59.96	7	0.4	3	1	3
16900	56.42	55.38	58.92	2.5	59.92	7	0.4	3	1	3
17000	56.38	54.86	58.88	2.5	59.88	7	0.4	3	1	3
17100	56.34	55.42	58.84	2.5	59.84	7	0.4	3	1	3

Table 6.129: (continued) 6 L MC of DMC (Id:73, Node No:26-226)

Distance in ft	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Formation level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
17200	56.3	54.77	58.8	2.5	59.8	7	0.4	3	1	3
17300	56.26	55.26	58.76	2.5	59.76	7	0.4	3	1	3
17400	56.22	54.75	58.72	2.5	59.72	7	0.4	3	1	3
17500	56.18	54.58	58.68	2.5	59.68	7	0.4	3	1	3
17600	56.14	54.28	58.64	2.5	59.64	7	0.4	3	1	3
17700	56.1	54.75	58.6	2.5	59.6	7	0.4	3	1	3
17800	56.06	55.95	58.56	2.5	59.56	7	0.4	3	1	3
17900	56.02	54.37	58.52	2.5	59.52	7	0.4	3	1	3
17944	56		58.5	2.5		7	0.4	3	1	3
18000	55.98	54.45	58.48	2.5	59.48	8	0.2	3	1	3
18100	55.96	54.77	58.46	2.5	59.46	8	0.2	3	1	3
18200	55.94	54.96	58.44	2.5	59.44	8	0.2	3	1	3
18300	55.92	54.87	58.42	2.5	59.42	8	0.2	3	1	3
18400	55.9	54.8	58.4	2.5	59.4	8	0.2	3	1	3
18500	55.88	54.43	58.38	2.5	59.38	8	0.2	3	1	3
18600	55.86	54.05	58.36	2.5	59.36	8	0.2	3	1	3
18700	55.84	54.14	58.34	2.5	59.34	8	0.2	3	1	3
19000	55.78	53.39	58.28	2.5	59.28	8	0.2	3	1	3
19100	55.76	53.96	58.26	2.5	59.26	8	0.2	3	1	3

Table 6.130: (continued) 6 L MC of DMC (Id:73, Node No:26-226)

Distance in ft	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Formation level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
19200	55.74	54.09	58.24	2.5	59.24	8	0.2	3	1	3
19300	55.72	54.01	58.22	2.5	59.22	8	0.2	3	1	3
19376				2.5		8	0.2	3	1	3
19400	55.7	55.69	58.2	2.5	59.2	8	0.2	3	1	3
19500	55.68	53.91	58.18	2.5	59.18	8	0.2	3	1	3
19600	55.66	53.99	58.16	2.5	59.16	8	0.2	3	1	3
19657	55.65	55.7	58.15	2.5	59.15	8	0.2	3	1	3
19757	55.63	55.93	58.13	2.5	59.13	4.5	0.2	3	1	3
19857	55.61	53.22	58.11	2.5	59.11	4.5	0.2	3	1	3
19957	55.59	53.09	58.09	2.5	59.09	4.5	0.2	3	1	3
20057	55.57	52.85	58.07	2.5	59.07	4.5	0.2	3	1	3
20157	55.55	52.83	58.05	2.5	59.05	4.5	0.2	3	1	3
20257	55.53	52.63	58.03	2.5	59.03	4.5	0.2	3	1	3
20357	55.51	52.77	58.01	2.5	59.01	4.5	0.2	3	1	3
20457	55.49	53.05	57.99	2.5	58.99	4.5	0.2	3	1	3
20557	55.47	52.88	57.97	2.5	58.97	4.5	0.2	3	1	3
20657	55.45	52.31	57.95	2.5	58.95	4.5	0.2	3	1	3

Table 6.131: (continued) 6 L MC of DMC (Id:73, Node No:26-226)

Distance in ft	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Formation level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
20757	55.43	53.28	57.93	2.5	58.93	4.5	0.2	3	1	3
20857	55.41	53.32	57.91	2.5	58.91	4.5	0.2	3	1	3
20957	55.39	53.15	57.89	2.5	58.89	4.5	0.2	3	1	3
21057	55.37	53.29	57.87	2.5	58.87	4.5	0.2	3	1	3
21057	55.37	53.29	57.87	2.5	NA	4.5	0.2	3	1	3
21157	55.35	53.24	57.85	2.5	NA	4.5	0.2	3	1	3
21257	55.33	52.88	57.83	2.5	NA	4.5	0.2	3	1	3
21357	55.31	53.15	57.81	2.5	NA	4.5	0.2	3	1	3
21457	55.29	53.49	57.79	2.5	NA	4.5	0.2	3	1	3
21557	55.27	53.5	57.77	2.5	NA	4.5	0.2	3	1	3
21657	55.25	53.39	57.75	2.5	NA	4.5	0.2	3	1	3
21757	55.23	53.73	57.73	2.5	NA	4.5	0.2	3	1	3
21857	55.21	53.53	57.71	2.5	NA	4.5	0.2	3	1	3
21957	55.19	54.38	57.69	2.5	NA	4.5	0.2	3	1	3
22057	55.17	55.92	57.67	2.5	NA	4.5	0.2	3	1	3
22157	55.15	53.21	57.65	2.5	NA	4.5	0.2	3	1	3
22257	55.13	51.96	57.63	2.5	NA	4.5	0.2	3	1	3
22357	55.11	50.92	57.61	2.5	NA	4.5	0.2	3	1	3

Table 6.132: (continued) 6 L MC of DMC (Id:73, Node No:26-226)

Distance in ft	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Formation level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
22457	55.09	50.79	57.59	2.5	NA	4.5	0.2	3	1	3
22557	55.07	53.3	57.57	2.5	NA	4.5	0.2	3	1	3
22657	55.05	55.37	57.55	2.5	NA	4.5	0.2	3	1	3
22757	55.03	52.37	57.53	2.5	NA	4.5	0.2	3	1	3
22857	55.01	52.36	57.51	2.5	NA	4.5	0.2	3	1	3
22957	54.99	52.35	57.49	2.5	NA	4.5	0.2	3	1	3
23057	54.97	52.41	57.47	2.5	NA	4.5	0.2	3	1	3
23157	54.95	52.47	57.45	2.5	NA	4.5	0.2	3	1	3
23257	54.93	52.14	57.43	2.5	NA	4.5	0.2	3	1	3
23357	54.91	52.24	57.41	2.5	NA	4.5	0.2	3	1	3
23457	54.89	52.21	57.39	2.5	NA	4.5	0.2	3	1	3
23557	54.87	52.09	57.37	2.5	NA	4.5	0.2	3	1	3
23657	54.85	51.72	57.35	2.5	NA	4.5	0.2	3	1	3
23757	54.83	51.19	57.33	2.5	NA	4.5	0.2	3	1	3
23857	54.81	50.98	57.31	2.5	NA	4.5	0.2	3	1	3
23957	54.79	51.09	57.29	2.5	NA	4.5	0.2	3	1	3
24057	54.77	51.04	57.27	2.5	NA	4.5	0.2	3	1	3
24157	54.75	53.26	57.25	2.5	NA	4.5	0.2	3	1	3

Table 6.133: (continued) 6 L MC of DMC (Id:73, Node No:26-226)

Distance in ft	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Formation level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
24257	54.73	50.98	57.23	2.5	NA	4.5	0.2	3	1	3
24357	54.71	54.3	57.21	2.5	NA	4.5	0.2	3	1	3
24457	54.69	51.33	57.19	2.5	NA	4.5	0.2	3	1	3
24557	54.67	51	57.17	2.5	NA	4.5	0.2	3	1	3
24657	54.65	50.98	57.15	2.5	NA	4.5	0.2	3	1	3
24757	54.63	51.26	57.13	2.5	NA	4.5	0.2	3	1	3
24857	54.61	51.8	57.11	2.5	NA	4.5	0.2	3	1	3
24957	54.59	52.04	57.09	2.5	NA	4.5	0.2	3	1	3
25057	54.57	51.74	57.07	2.5	NA	4.5	0.2	3	1	3
25157	54.55	51.92	57.05	2.5	NA	4.5	0.2	3	1	3
25195			2.5	2.5	NA	4.5	0.2	3	1	3
25257	54.53	51.86	57.03	2.5	NA	3	0.2	3	1	3
25357	54.51	51.88	57.01	2.5	NA	3	0.2	3	1	3
25457	54.49	53.87	56.99	2.5	NA	3	0.2	3	1	3
25557	54.47	52.23	56.97	2.5	NA	3	0.2	3	1	3
25657	54.45	52.32	56.95	2.5	NA	3	0.2	3	1	3
25757	54.43	52.78	56.93	2.5	NA	3	0.2	3	1	3
25857	54.41	53.27	56.91	2.5	NA	3	0.2	3	1	3
25957	54.39	53.58	56.89	2.5	NA	3	0.2	3	1	3

Table 6.134: (continued) 6 L MC of DMC (Id:73, Node No:26-226)

Distance in ft	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Formation level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
26157	54.35	53.53	56.85	2.5	NA	3	0.2	3	1	3
26257	54.33	53.94	56.83	2.5	NA	3	0.2	3	1	3
26357	54.31	54.14	56.81	2.5	NA	3	0.2	3	1	3
26457	54.29	54.24	56.79	2.5	NA	3	0.2	3	1	3
26557	54.27	54.23	56.77	2.5	NA	3	0.2	3	1	3
26657	54.25	54.23	56.75	2.5	NA	3	0.2	3	1	3
26757	54.23	54.2	56.73	2.5	NA	3	0.2	3	1	3
26857	54.21	54.24	56.71	2.5	NA	3	0.2	3	1	3
26957	54.19	55.44	56.69	2.5	NA	3	0.2	3	1	3
27057	54.17	54.17	56.67	2.5	NA	3	0.2	3	1	3
27157	54.15	54.26	56.65	2.5	NA	3	0.2	3	1	3
27257	54.13	54.28	56.63	2.5	NA	3	0.2	3	1	3
27357	54.11	54.32	56.61	2.5	NA	3	0.2	3	1	3
27457	54.09	54.2	56.59	2.5	NA	3	0.2	3	1	3
27557	54.07	54.21	56.57	2.5	NA	3	0.2	3	1	3
27657	54.05	54.11	56.55	2.5	NA	3	0.2	3	1	3
27757	54.03	54.13	56.53	2.5	NA	3	0.2	3	1	3
27759				2.5	NA	3	0.2	3	1	3
27795	54.01	54.13	56.51	2.5	NA	3	0.2	3	1	3

Table 6.135: 6 L1 MC of DMC (Id:126, Node No:223-296)

Distance in ft	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
0	55.26	53.82	57.26	2	58.26	58.76	4	0.3	3	1	3
100	55.21	55.44	57.21	2	58.21	58.69	4	0.3	3	1	3
200	55.16	54.98	57.16	2	58.16	58.7	4	0.3	3	1	3
300	55.11	54.72	57.11	2	58.11	58.64	4	0.3	3	1	3
400	55.06	54.51	57.06	2	58.06	58.42	4	0.3	3	1	3
500	55.01	54.44	57.01	2	58.01	58.38	4	0.3	3	1	3
600	54.96	54.72	56.96	2	57.96	58.42	4	0.3	3	1	3
700	54.91	54.9	56.91	2	57.91	58.45	4	0.3	3	1	3
800	54.86	54.73	56.86	2	57.86	58.6	4	0.3	3	1	3
900	54.81	54.44	56.81	2	57.81	58.63	4	0.3	3	1	3
1000	54.76	54.47	56.76	2	57.76	58.66	4	0.3	3	1	3
1100	54.71	54.34	56.71	2	57.71	58.7	4	0.3	3	1	3
1200	54.66	54.27	56.66	2	57.66	57.82	4	0.3	3	1	3
1300	54.61	54.44	56.61	2	57.61	57.87	4	0.3	3	1	3
1400	54.56	54.27	56.56	2	57.56	57.91	4	0.3	3	1	3
1500	54.51	54.41	56.51	2	57.51	57.94	4	0.3	3	1	3

Table 6.136: (continued) 6 L1 MC of DMC (Id:126, Node No:223-296)

Distance in ft	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
1600	54.46	54.33	56.46	2	57.46	58.43	4	0.3	3	1	3
1700	54.41	53	56.41	2	57.41	58.5	4	0.3	3	1	3
1800	54.36	52.54	56.36	2	57.36	58.47	4	0.3	3	1	3
1900	54.31	52.63	56.31	2	57.31	58.52	4	0.3	3	1	3
2000	54.26	52.81	56.26	2	57.26	57.8	4	0.3	3	1	3
2100	54.21	53.09	56.21	2	57.21	57.82	4	0.3	3	1	3
2200	54.16	52.65	56.16	2	57.16	57.86	4	0.3	3	1	3
2300	54.11	52.25	56.11	2	57.11	57.91	4	0.3	3	1	3
2400	54.06	52.26	56.06	2	57.06	57.79	4	0.3	3	1	3
2500	54.01	52.55	56.01	2	57.01	57.75	4	0.3	3	1	3
2600	53.96	51.99	55.96	2	56.96	57.7	4	0.3	3	1	3
2700	53.91	51.78	55.91	2	56.91	57.64	4	0.3	3	1	3
2800	53.86	51.54	55.86	2	56.86	57.69	4	0.3	3	1	3
2900	53.81	51.55	55.81	2	56.81	57.63	4	0.3	3	1	3
3000	53.76	51	55.76	2	56.76	57.61	4	0.3	3	1	3
3100	53.71	50.44	55.71	2	56.71	57.55	4	0.3	3	1	3
3200	53.66	54.4	55.66	2	56.66	58.02	4	0.3	3	1	3
3240	53.64	52.99	55.64	2	56.64	58.64	4	0.3	3	1	3

Table 6.137: (continued) 6 L1 MC of DMC (Id:126, Node No:223-296)

Distance in ft	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000'	Crest width	Free board	Inside berm
3240	52.39	52.69	53.79	1.4	55.36	57.97	3	0.5	3	1	3
3300	52.96	52.69	54.36	1.4	55.36	57.97	3	0.5	3	1	3
400	52.91	52.31	54.31	1.4	55.31	57.92	3	0.5	3	1	3
3500	52.86	51.72	54.26	1.4	55.26	57.87	3	0.5	3	1	3
3600	52.81	51.8	54.21	1.4	55.21	55.96	3	0.5	3	1	3
3700	52.76	51.68	54.16	1.4	55.16	55.83	3	0.5	3	1	3
3800	52.71	51.67	54.11	1.4	55.11	55.94	3	0.5	3	1	3
3900	52.66	51.55	54.06	1.4	55.06	55.9	3	0.5	3	1	3
4000	52.61	51.82	54.01	1.4	55.01	55.86	3	0.5	3	1	3
4100	52.56	51.95	53.96	1.4	54.96	55.68	3	0.5	3	1	3
4200	52.51	51.17	53.91	1.4	54.91	5.62	3	0.5	3	1	3
4300	52.46	50.56	53.86	1.4	54.86	55.57	3	0.5	3	1	3
4400	52.41	50.62	53.81	1.4	54.81	55.52	3	0.5	3	1	3
4500	52.36	50.83	53.76	1.4	54.76	55.47	3	0.5	3	1	3
4600	52.31	50.7	53.71	1.4	54.71	55.43	3	0.5	3	1	3

Table 6.138: (continued) 6 L1 MC of DMC (Id:126, Node No:223-296)

Distance in ft	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Formation level of embankment	Crest level of embankment	Bed width (ft)	Slope in 1000’	Crest width	Free board	Inside berm
4700	52.26	50.67	53.66	1.4	54.66	55.4	3	0.5	3	1	3
4800	52.21	50.5	53.61	1.4	54.61	55.64	3	0.5	3	1	3
4900	52.16	49.95	53.56	1.4	54.56	55.59	3	0.5	3	1	3
5000	52.11	49.75	53.51	1.4	54.51	55.55	3	0.5	3	1	3
5100	52.06	49.97	53.46	1.4	54.46	54.93	3	0.5	3	1	3
5200	52.01	49.76	53.41	1.4	54.41	54.89	3	0.5	3	1	3
5300	51.96	49.67	53.36	1.4	54.36	54.85	3	0.5	3	1	3
5400	51.91	49.46	53.31	1.4	54.31	54.81	3	0.5	3	1	3
5500	51.86	49.23	53.26	1.4	54.26	54.97	3	0.5	3	1	3
5600	51.81	49.18	53.21	1.4	54.21	54.94	3	0.5	3	1	3
5700	51.76	49.11	53.16	1.4	54.16	54.89	3	0.5	3	1	3
5800	51.71	49.03	53.11	1.4	54.11	54.75	3	0.5	3	1	3
5900	51.66	49.05	53.06	1.4	54.06	54.68	3	0.5	3	1	3
5940	51.64	49.05	53.04	1.4	54.04	54.61	3	0.5	3	1	3

Table 6.139: 6 L2 MC of DMC (Id:127, Node No:224-298)

Distance in chainage	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Crest level of embankment	Bed width (ft)	Slope in 1000’	Dischsrge (cusec)	V (ft/sec)	V/V0	Free board
0	50.6	NA	54.5	3.9	56	11.5	0.25	119	2	1	2
6		NA		3.9	NA	11.5	0.25	117	2	1	2
10	51.85	NA	54.25	3.9	56.25	11.5	0.25	117	2	1	2
20	50.1	NA	54	3.9	56	11.5	0.25	117	2	1	2
30	49.85	NA	53.75	3.9	55.75	11.5	0.25	117	2	1	2
40	49.6	NA	53.5	3.9	55.5	11.5	0.25	117	2	1	2
50	49.35	NA	53.25	3.9	55.25	11.5	0.25	117	2	1	2
60	49.1	NA	53	3.9	55	11.5	0.25	117	2	1	2
70	48.85	NA	52.75	3.9	54.75	11.5	0.25	117	2	1	2
74	48.75	NA	52.65	3.9	54.65	11.5	0.25	112	2	1	2
80	48.6	NA	52.5	3.9	54.5	11.5	0.25	112	2	1	2
90	48.35	NA	52.25	3.9	54.25	11.5	0.25	110	2	1	2
92	48.3	NA	51.9	3.6	53.7	10.6	0.25	99	1.88	0.99	1.5
92	48.6	NA	51.9	3.6	53.7	10.6	0.25	94	1.88	0.99	1.5
94	48.65	NA	52.15	3.6	53.65	10.6	0.25	94	1.88	0.99	1.5
100	48.4	NA	52	3.6	53.5	10.6	0.25	94	1.88	0.99	1.5
110	48.15	NA	51.75	3.6	55.25	10.6	0.25	94	1.88	0.99	1.5

Table 6.140: (continued) 6 L2 MC of DMC (Id:127, Node No:224-298)

Distance in chainage	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Crest level of embankment	Bed width (ft)	Slope in 1000’	Dischsrge (cusec)	V (ft/sec)	V/V0	Free board
120	47.9	NA	51.5	3.6	53	10.6	0.25	94	1.88	0.99	1.5
130	47.7	NA	51.1	3.6	52.75	10.6	0.25	94	1.88	0.99	1.5
130	45.85	NA	49.25	3.6	52.75	10.6	0.25	84	1.83	1	1.5
140	45.6	NA	49	3.6	52.75	10.6	0.25	84	1.83	1	1.5
150	45.33	NA	48.75	3.6	52.75	10.6	0.25	84	1.83	1	1.5
160	45.12	NA	48.5	3.6	52.75	10.6	0.25	84	1.83	1	1.5
160	45.1	NA	48.5	3.6	52.75	10.6	0.25	84	1.83	1	1.5
170	44.85	NA	48.25	3.6	52.75	10.6	0.25	84	1.83	1	1.5
170	44.82	NA	48.25	3.6	52.75	10.6	0.25	78	1.83	1	1.5
180	44.6	NA	48	3.6	52.75	10.6	0.25	78	1.83	1	1.5
190	44.37	NA	47.75	3.6	52.75	10.6	0.25	78	1.83	1	1.5
190	44.35	NA	47.75	3.6	52.75	10.6	0.25	78	1.83	1	1.5
200	44.1	NA	47.5	3.6	52.75	10.6	0.25	78	1.83	1	1.5
200	44.07	NA	47.5	3.6	52.75	10.6	0.25	78	1.83	1	1.5
210	45.85	NA	47.25	3.6	52.75	10.6	0.25	78	1.83	1	1.5
220	43.6	NA	47	3.6	52.75	10.6	0.25	78	1.83	1	1.5
220	43.9	NA	47	3.6	49.5	10.6	0.25	78	1.83	1	1.5
229	43.7	NA	46.77	3.1	49.5	9.7	0.25	67	1.7	0.99	1.5

Table 6.141: (continued) 6 L2 MC of DMC (Id:127, Node No:224-298)

Distance in chainage	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Crest level of embankment	Bed width (ft)	Slope in 1000’	Dischsrge (cusec)	V (ft/sec)	V/V0	Free board
229	43.67	NA	46.77	3.1	49.5	9.7	0.25	67	1.7	0.99	1.5
230	44.17	NA	46.75	2.6	49.5	7.6	0.25	36	1.84	0.96	1.25
230	44.15	NA	46.75	2.6	49.5	7.6	0.25	36	1.84	0.96	1.25
240	43.9	NA	46.5	2.6	49.5	7.6	0.25	36	1.84	0.96	1.5
250	43.65	NA	46.25	2.6	49.5	7.6	0.25	36	1.84	96	1.5
255	43.52	NA	46.12	2.6	49.5	7.6	0.25	36	1.84	0.95	1.5
255	43.65	NA	46.12	2.4	49.5	7.2	0.25	29.4	1.4	0.95	1.5
260	43.6	NA	46	2.4	49.5	7.2	0.25	29.4	1.4	0.95	1.5
260	43.57	NA	46	2.4	49.5	7.2	0.25	29.4	1.4	0.95	1.5
270	43.55	NA	45.75	2.4	49.5	7.2	0.25	29.4	1.4	0.95	1.5
280	43.12	NA	45.5	2.4	49.5	7.2	0.25	29.4	1.4	0.95	1.5
280	43.1	NA	45.5	2.4	49.5	7.2	0.25	29.4	1.4	0.95	1.5
290	42.85	NA	45.25	2.4	49.5	7.2	0.25	29.4	1.4	0.95	1.5
290	42.82	NA	45.25	2.4	49.5	7.2	0.25	29.4	1.4	0.95	1.5
300	42.6	NA	45	2.4	49.5	7.2	0.25	29.4	1.4	0.95	1.5
310	42.38	NA	44.75	2.4	49.5	7.2	0.25	29.4	1.4	0.95	1.5
310	42.35	NA	44.75	2.4	49.5	7.2	0.25	29.4	1.4	0.95	1.5
320	42.1	NA	44.5	2.4	49.5	7.2	0.25	29.4	1.4	0.95	1.5

Table 6.142: (continued) 6 L2 MC of DMC (Id:127, Node No:224-298)

Distance in chainage	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Crest level of embankment	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	V/V0	Free board
320	42.07	NA	44.5	2.4	49.5	7.2	0.25	29.4	1.4	0.95	1.5
329	41.92	NA	44.27	2.4	49.5	7.2	0.25	29.4	1.4	0.95	1.5
329	41.87	NA	44.27	2.4	49.5	7.2	0.25	29.4	1.4	0.95	1.5
330	41.85	NA	44.25	2.4	49.5	7.2	0.25	24.5	1.4	0.95	1.5
330	41.73	NA	44.25	2.4	49.5	7.2	0.25	24.5	1.4	0.95	1.5
340	41.6	NA	44	2.4	49.5	7.2	0.25	24.5	1.4	0.95	1.5
340	41.55	NA	44	2.4	49.5	7.2	0.25	24.5	1.4	0.95	1.5
350	41.35	NA	43.75	2.4	49.5	7.2	0.25	24.5	1.4	0.95	1.5
350	41.32	NA	43.75	2.4	49.5	7.2	0.25	24.5	1.4	0.95	1.5
360	41.1	NA	43.5	2.4	49.5	7.2	0.25	24.5	1.4	0.95	1.5
370	40.88	NA	43.25	2.4	49.5	7.2	0.25	24.5	1.4	0.95	1.5
370	40.85	NA	43.25	2.4	49.5	7.2	0.25	24.5	1.4	0.95	1.5
380	40.65	NA	43	2.4	49.5	7.2	0.25	24.5	1.4	0.95	1.5
380	40.6	NA	43	2.4	49.5	7.2	0.25	24.5	1.4	0.95	1.5
381	40.57	NA	42.97	1.8	49.5	5.7	0.3	16.8	1.26	1.03	1.5
381	41.17	NA	42.97	1.8	49.5	5.7	0.3	16.8	1.26	1.03	1.5
390	40.9	NA	42.7	1.8	49.5	5.7	0.3	16.8	1.26	1.03	1.5

Table 6.143: (continued) 6 L2 MC of DMC (Id:127, Node No:224-298)

Distance in chainage	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Crest level of embankment	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	V/V0	Free board
396	40.72	NA	42.52	1.8	49.5	5.7	0.3	16.8	1.26	1.03	1.5
396	41.02	NA	42.52	1.8	49.5	5.7	0.3	16.8	1.26	1.03	1.5
400	40.9	NA	42.4	1.5	49.5	4.5	0.3	7.6	1.26	1.03	1.5
410	40.6	NA	42.1	1.5	49.5	4.5	0.3	7.6	1.26	1.03	1.5
420	40.3	NA	41.8	1.5	49.5	4.5	0.3	7.6	1.26	1.03	1.5
430	40	NA	41.5	1.5	49.5	4.5	0.3	7.6	1.26	1.03	1.5
436	39.92	NA	41.32	1.2	49.5	4.5	0.3	7.6	1.26	1.03	1.5
436	40.22	NA	41.32	1.2	49.5	4.5	0.3	7.6	1.26	1.03	1.5
440	40	NA	41.2	1.2	49.5	3.6	0.3	5	0.9	0.96	1.5
450	39.73	NA	40.9	1.2	49.5	3.6	0.3	5	0.9	0.96	1.5
450	39.7	NA	40.9	1.2	49.5	3.6	0.3	5	0.9	0.96	1.5
453	39.64	NA	40.81	1.2	49.5	3.6	0.3	5	0.9	0.96	1.5
453	39.61	NA	40.81	1.2	49.5	3.6	0.3	5	0.9	0.96	1.5

Table 6.144: 6 L3 (Old) MC of DMC (Id:129, Node No:225-300)

Distance in chainage	Design Bed Level	Actual Bed Level	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	V/V0	Structure
0	52	52.76	2.5	8.25	0.25	39.7	1.48	0.98	regulator
9	51.77	54.79	2.5	8.25	0.25	39.7	1.48	0.98	
15	51.63	54.53	2.5	8.25	0.25	39.7	1.48	0.98	
21	51.47	55.01	2.5	8.25	0.25	39.7	1.48	0.98	
30	51.45	55.12	2.3	8.25	0.25	32.8	1.41	0.99	
30	51.42	55.12	2.3	8.25	0.25	29.1	1.41	0.99	
36	51.33	54.66	2.3	8.25	0.25	29.1	1.41	0.99	
36	51.3	54.66	2.3	8.25	0.25	29.1	1.41	0.99	
45	51.08	56.08	2.3	8.25	0.25	29.1	1.41	0.99	
51	50.92	56.04	2.3	8.25	0.25	29.1	1.41	0.99	
60	50.7	55.38	2.3	8.25	0.25	29.1	1.41	0.99	
69	50.48	55.2	2.3	8.25	0.25	29.1	1.41	0.99	
69	50.78	54.9	2	6	0.3	20.4	1.33	1.03	
81	50.42	54.84	2	6	0.3	20.4	1.33	1.03	
90	50.14	53.95	2	6	0.3	20.4	1.33	1.03	
90	50.34	53.95	1.8	5.25	0.3	14.6	1.22	1	
99	50.08	53.44	1.8	5.25	0.3	14.6	1.22	1	
111	49.72	53.32	1.8	5.25	0.3	14.4	0.9	0.96	
120	49.45	51.87	1.8	5.25	0.3	14.4	0.9	0.96	
129	49.78	51.62	1.2	3.6	0.3	5.1	0.9	0.96	
141	49.48	52.3	1.2	3.6	0.3	5.1	0.9	0.96	
150	49.15	51.17	1.2	3.6	0.3	2.1	0.9	0.96	
159	48.88	50.46	1.2	3.6	0.3	2.1	0.9	0.96	
165	48.7	50.78	1.2	3.6	0.3	2.1	0.9	0.96	
171	48.52	51.14	1.2	3.6	0.3	2.1	0.9	0.96	
182	48.19	48.99	1.2	3.6	0.3	2.1	0.9	0.96	

Table 6.145: 6 L3 (New) MC of DMC (Id:129, Node No:225-300)

Distance in chainage	Design Bed Level	Actual Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	V/V0	Free Board	Structure
0	52	52.76	54.5	2.5	8.25	0.25	39.7	1.48	0.98	1.5	Head Regulator
9	51.77	54.79	54.27	2.5	8.25	0.25	39.7	1.48	0.98	1.5	
15	51.63	54.53	54.13	2.5	8.25	0.25	39.7	1.48	0.98	1.5	
21	51.47	55.01	53.97	2.5	8.25	0.25	39.7	1.48	0.98	1.5	
30	51.45	55.12	53.75	2.3	8.25	0.25	32.8	1.41	0.99	1.5	
30	51.42	55.12	53.72	2.3	8.25	0.25	32.8	1.41	0.99	1.5	
36	51.33	60.66	53.63	2.3	8.25	0.25	29.1	1.41	0.99	1.5	
36	51.3	59.96	53.6	2.3	8.25	0.25	29.1	1.41	0.99	1.5	
45	51.08	56.08	53.38	2.3	8.25	0.25	29.1	1.41	0.99	1.5	
51	50.92	56.04	53.22	2.3	8.25	0.25	29.1	1.41	0.99	1.5	
60	50.7	55.38	53	2.3	8.25	0.25	29.1	1.41	0.99	1.5	
69	50.48	55.2	52.78	2.3	8.25	0.25	29.1	1.41	0.99	1.5	
69	50.78	54.9	52.78	2	6	0.3	20.4	1.33	1.03	1.5	
81	50.42	54.84	52.42	2	6	0.3	20.4	1.33	1.03	1.5	

Table 6.146: (continued) 6 L3 (New) MC of DMC (Id:129, Node No:225-300)

Distance in chainage	Design Bed Level	Actual Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	V/V0	Free Board	Structure
90	50.14	53.95	52.14	2	6	0.3	20.4	1.33	1.03	1.5	
90	50.34	53.95	52.14	1.8	5.25	0.3	14.6	1.22	1	1.5	
99	50.8	53.44	51.88	1.8	5.25	0.3	14.6	1.22	1	1.5	
111	49.72	53.32	51.52	1.8	5.25	0.3	14.4	1.22	1	1.5	
120	49.45	51.87	51.25	1.2	3.6	0.3	5.1	0.9	0.96	1.5	
129	49.78	51.62	50.98	1.2	3.6	0.3	5.1	0.9	0.96	1.5	
141	49.48	52.3	50.62	1.2	3.6	0.3	5.1	0.9	0.96	1.5	
150	49.2	51.17	50.4	1.2	3.6	0.3	5.1	0.9	0.96	1.5	
150	49.15	51.17	50.35	1.2	3.6	0.3	2.1	0.9	0.96	1.5	
159	48.88	50.46	50.08	1.2	3.6	0.3	2.1	0.9	0.96	1.5	
165	48.7	50.78	49.9	1.2	3.6	0.3	2.1	0.9	0.96	1.5	
171	48.52	51.14	49.72	1.2	3.6	0.3	2.1	0.9	0.96	1.5	
182	48.19	52.59	49.3	1.2	3.6	0.3	2.1	0.9	0.96	1.5	

Table 6.147: 6 M MC of DMC (Id:74, Node No:27-227)

Distance in chainage	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	V/V0	Free board	Distance	Structure
0	42.3	NA	44	1.7	5	0.3	13	1.19	1.02	1.5	0	head regulator
9	42.03	NA	43.73	1.7	5	0.3	13	1.19	1.02	1.5		
10	42	NA	43.7	1.7	5	0.3	13	1.19	1.02	1.5		
15	41.85	NA	43.55	1.7	5	0.3	13	1.19	1.02	1.5		
18	41.76	NA	43.46	1.7	5	0.3	13	1.19	1.02	1.5		
20	41.7	NA	43.4	1.7	5	0.3	13	1.19	1.02	1.5		
20	42	NA	43.4	1.4	4.5	0.3	8	1.04	1	1.5		
24	41.88	NA	43.28	1.4	4.5	0.3	8	1.04	1	1.5		
30	41.7	NA	43.1	1.4	4.5	0.3	8	1.04	1	1.5		
36	41.52	NA	42.92	1.4	4.5	0.3	8	1.04	1	1.5		
40	41.4	NA	42.8	1.4	4.5	0.3	8	1.04	1	1.5		

Table 6.148: (continued) 6 M MC of DMC (Id:74, Node No:27-227)

Distance in chainage	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	V/V0	Free board	Distance	Structure
42	41.34	NA	42.74	1.4	4.5	0.3	8	1.04	1	1.5		
47	41.19	NA	42.59	1.4	4.5	0.3	8	1.04	1	1.5		
48	41.16	NA	42.56	1.4	4.5	0.3	7	1.04	1	1.5		
50	41.1	NA	42.5	1.4	4.5	0.3	7	1.04	1	1.5		
51	41.07	NA	42.47	1.4	4.5	0.3	7	1.04	1	1.5		
60	40.8	NA	42.2	1.4	4.5	0.3	7	1.04	1	1.5		
69	40.53	NA	41.93	1.4	4.5	0.3	7	1.04	1	1.5		
70	40.5	NA	41.9	1.4	4.5	0.3	7	1.04	1	1.5		
75	40.35	NA	41.75	1.4	4.5	0.3	7	1.04	1	1.5		
80	40.2	NA	41.6	1.4	4.5	0.3	7	1.04	1	1.5		
89	39.93	NA	41.33	1.4	4.5	0.3	7	1.04	1	1.5		
90	39	NA	40.4	1.4	4.5	0.3	7	1.04	1	1.5		

Table 6.149: 6 N MC (Id:75, Node No:27-228)

Distance in chainage	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Formation level of embankment	Height of bank	Crest level	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	V/V0	Free board	Distance	Structure
0	45.58	44.7	48.48	2.9	49.98	3.92	49.98	9.5	0.25	53.8	1.65	1.01	1.5	0	Head regulator
9	45.35	45.35	48.48	2.9	49.98	3.92	49.98	9.5	0.25	53.8	1.65	1.01	1.5		
10	45.33	45.35	48.83	2.9	49.73	4.58	49.73	9.5	0.25	53.8	1.65	1.01	1.5		
12	45.33	45.18	48.83	2.9	49.73	4.58	49.73	9.5	0.25	53.8	1.65	1.01	1.5		
18	45.33	45.43	47.88	2.9	49.13	3.98	49.73	9.5	0.25	53.8	1.65	1.01	1.5		
20	44.08	45.43	47.88	2.9	49.48	3.98	49.48	9.5	0.25	53.8	1.65	1.01	1.5		
21	44.05	44.05	47.88	2.9	49.48	3.98	49.48	9.5	0.25	53.8	1.65	1.01	1.5		
24	44.05	47.14	47.88	2.9	49.48	3.98	49.48	9.5	0.25	53.8	1.65	1.01	1.5		
28	44.88	47.14	47.08	2.9	49.28	3.54	49.28	9.5	0.25	53.8	1.65	1.01	1.5		
28	45.08	47.14	47.08	2.9	49.28	3.54	49.28	8.75	0.25	45.47	1.65	0.99	1.5		
30	45.03	45.03	47.73	2.7	49.34	3.54	49.25	8.75	0.25	45.47	1.56	0.99	1.5		
36	45.03	44.89	47.73	2.7	49.34	3.54	49.25	8.75	0.25	45.47	1.56	0.99	1.5		
40	44.78	44.89	47.48	2.7	48.98	2.99	48.98	8.75	0.25	45.47	1.56	0.99	1.5		

Table 6.150: (continued) 6 N MC (Id:75, Node No:27-228)

Distance in chainage	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Formation level of embankment	Height of bank	Crest level	Bed width (ft)	Slope in 1000’	Dischsrge (cusec)	V (ft/sec)	V/V0	Free board	Distance	Structure
42	44.75	44.73	47.48	2.7	48.98	2.99	48.98	8.75	0.25	45.47	1.56	0.99	1.5		
46	44.63	44.73	47.33	2.7	48.83	3.15	48.83	8.75	0.25	45.47	1.56	0.99	1.5		
46	43.03	44.73	47.33	2.3	48.83	3.15	48.83	7.25	0.25	27.77	1.36	0.95	1.5		
48	43.03	44.54	47.33	2.3	48.83	3.15	48.83	7.25	0.25	27.77	1.36	0.95	1.5		
50	44.93	44.54	47.23	2.3	48.73	3.21	48.73	7.25	0.25	27.77	1.36	0.95	1.5		
51	44.9	44.9	47.23	2.3	48.73	3.21	48.73	7.25	0.25	27.77	1.36	0.95	1.5		
60	44.68	44.68	46.98	2.3	48.48	3.42	48.48	7.25	0.25	27.77	1.36	0.95	1.5		
60	41	41.1	43.3	2.3	48.48	3.42	44.8	7.25	0.25	27.77	1.36	0.95	1.5		
66	41	39.97	43.3	2.3	48.48	3.42	44.8	7.25	0.25	27.77	1.36	0.95	1.5		
70	40.75	39.97	43.05	2.3	44.55	0.85	44.55	7.25	0.25	27.77	1.36	0.95	1.5		
72	40.72	40.72	43.05	2.3	44.55	0.85	44.55	7.25	0.25	27.77	1.36	0.95	1.5		
78	40.55	40.55	42.85	2.3	44.35	2.33	44.35	7.25	0.25	27.77	1.36	0.95	1.5		
80	40.5	40.55	42.8	2.3	44.3	2.68	44.3	7.25	0.25	22.22	1.36	0.95	1.5		
84	40.4	40.4	42.8	2.3	44.3	2.68	44.3	7.25	0.25	22.22	1.36	0.95	1.5		
90	40.25	40.25	42.55	2.3	44.05	2.99	44.05	7.25	0.25	22.22	1.36	0.95	1.5		
99	40.02	40.02	42.3	2.3	44.36	3.3	43.8	7.25	0.25	22.22	1.36	0.95	1.5		

Table 6.151: (continued) 6 N MC (Id:75, Node No:27-228)

Distance in chainage	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Formation level of embankment	Height of bank	Crest level	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	V/V0	Free board	Distance	Structure
100	40	40.02	42.3	2.3	43.6	3.3	43.8	7.25	0.25	22.22	1.36	0.95	1.5		
105	39.87	39.87	42.3	2.3	43.6	3.3	43.8	7.25	0.25	22.22	1.36	0.95	1.5		
110	39.75	39.87	43.55	2.3	43.55	2.71	43.55	7.25	0.25	22.22	1.36	0.95	1.5		
112	39.7	39.87	43.5	2.3	43.5	2.86	43.5	7.25	0.25	22.22	1.36	0.95	1.5		
112	40.1	39.87	43.5	1.9	43.5	2.86	43.5	5.5	0.30	16.4	1.3	1.03	1.5		
114	40.04	40.04	43.5	1.9	43.5	2.86	43.5	5.5	0.30	16.4	1.3	1.03	1.5		
120	39.86	39.86	43.36	1.9	43.26	3.42	43.36	5.5	0.30	16.4	1.3	1.03	1.5		
129	39.86	39.46	43.36	1.9	43.1	3.26	43.36	5.5	0.30	16.4	1.3	1.03	1.5		
130	39.59	39.59	42.96	1.6	42.96	3.26	42.96	5.5	0.30	16.4	1.11	1.03	1.5		
130	39.86	39.59	42.96	1.6	42.96	3.26	42.96	4.2	0.50	9.6	1.11	0.985	1.5		
138	39.62	39.62	42.96	1.6	42.96	3.26	42.96	4.2	0.50	9.6	1.11	0.985	1.5		
140	39.56	39.62	42.66	1.6	42.66	3.01	42.66	4.2	0.50	9.6	1.11	0.985	1.5		
144	39.56	39.12	42.66	1.6	42.66	3.01	42.66	4.2	0.50	9.6	1.11	0.985	1.5		
150	39.26	39.26	42.36	1.6	42.36	2.75	42.36	4.2	0.50	9.6	1.11	0.985	1.5		
156	39.26	39.16	42.36	1.6	42.36	2.75	42.36	4.2	0.50	9.6	1.11	0.985	1.5		
159	38.99	38.99	42.36	1.6	42.29	2.68	42.06	4.2	0.50	9.6	1.11	0.985	1.5		
160	38.96	38.99	42.06	1.6	42.06	2.68	42.06	4.2	0.50	9.6	1.11	0.985	1.5		

Table 6.152: Left Bank Main Canal

Distance in chainage	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	Free board	Distance	Structure
720.00	NA	NA	NA	12	118	0.125	6564	3.87	4	770	regulator
874.00	NA	NA	NA	12	118	0.125	6564	3.87	4	1193	regulator
1193	159.09	NA	171.09	12	118	0.125	6564	3.87	4	1310	regulator,offtake of Damodar main canal(Q=1494 cusec)
1193	148.09	NA	160.09	12	118	0.125	6564	3.87	4	1360	regulator
1199	148.01	NA	160.01	12	118	0.125	6564	3.87	4	1414	regulator
1211	147.86	NA	159.86	12	118	0.125	6564	3.87	4	1564	regulator
1223	147.71	NA	159.71	12	118	0.125	6564	3.87	4	1750	offtake of L/5
1235	147.56	NA	159.56	12	118	0.125	6564	3.87	4	1784	regulator
1247	147.41	NA	159.41	12	118	0.125	6564	3.87	4	1964	regulator
1259	147.26	NA	159.26	12	118	0.125	6564	3.87	4	2010	outlet
1271	147.11	NA	159.11	12	118	0.125	6564	3.87	4		
1285	146.96	NA	158.96	12	118	0.125	6564	3.87	4		
1295	146.81	NA	158.81	12	118	0.125	6564	3.87	4		
1307	146.66	NA	158.66	12	118	0.125	6564	3.87	4		

Table 6.153: (continued) Left Bank Main Canal

Distance in chainage	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	Free board
1310	146.63	NA	158.63	12	118	0.125	6564	3.87	4
1310	138.13	NA	150.13	12	89	0.125	5070	3.75	4
1319	138.02	NA	150.02	12	89	0.125	5070	3.75	4
1331	137.86	NA	149.86	12	89	0.125	5070	3.75	4
1343	137.7	NA	149.7	12	89	0.125	5070	3.75	4
1350	137.62	NA	149.62	12	89	0.125	5070	3.75	4
1360	137.5	NA	149.5	12	89	0.125	5070	3.75	4
1370	137.37	NA	149.37	12	89	0.125	5070	3.75	4
1380	137.25	NA	149.25	12	89	0.125	5070	3.75	4
1390	137.12	NA	149.12	12	89	0.125	5070	3.75	4
1400	137	NA	149	12	89	0.125	5070	3.75	4
1410	136.87	NA	148.87	12	89	0.125	5070	3.75	4
1414	136.83	NA	148.83	12	89	0.125	5070	3.75	4
1414	126.83	NA	138.83	12	89	0.125	5070	3.75	4
1427	126.67	NA	138.67	12	89	0.125	5070	3.75	4
1439	126.52	NA	138.52	12	89	0.125	5070	3.75	4
1451	126.37	NA	138.37	12	89	0.125	5070	3.75	4
1457	126.3	NA	138.3	12	89	0.125	5070	3.75	4
1469	126.22	NA	138.22	12	89	0.125	5070	3.75	4
1474	126.08	NA	138.08	12	89	0.125	5070	3.75	4
1484	125.96	NA	137.96	12	89	0.125	5070	3.75	4
1496	125.83	NA	137.83	12	89	0.125	5070	3.75	4
1504	125.71	NA	137.71	12	89	0.125	5070	3.75	4
1514	125.58	NA	137.58	12	89	0.125	5070	3.75	4
1524	125.46	NA	137.46	12	89	0.125	5070	3.75	4
1534	125.33	NA	137.33	12	89	0.125	5070	3.75	4
1544	125.21	NA	137.21	12	89	0.125	5070	3.75	4

Table 6.154: (continued) Left Bank Main Canal

Distance in chainage	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	Free board
1554	125.08	NA	137.08	12	89	0.125	5070	3.75	4
1564	124.96	NA	136.96	12	89	0.125	5070	3.75	4
1564	116.96	NA	128.96	12	89	0.125	5070	3.75	4
1574	116.84	NA	128.84	12	89	0.125	5070	3.75	4
1584	116.71	NA	128.71	12	89	0.125	5070	3.75	4
1594	116.59	NA	128.59	12	89	0.125	5070	3.75	4
1604	116.46	NA	128.46	12	89	0.125	5070	3.75	4
1614	116.34	NA	128.34	12	89	0.125	5070	3.75	4
1624	116.21	NA	128.21	12	89	0.125	5070	3.75	4
1634	116.09	NA	128.09	12	89	0.125	5070	3.75	4
1644	115.96	NA	127.96	12	89	0.125	5070	3.75	4
1654	115.84	NA	127.84	12	89	0.125	5070	3.75	4
1664	115.71	NA	127.71	12	89	0.125	5070	3.75	4
1674	115.59	NA	127.59	12	89	0.125	5070	3.75	4
1684	115.46	NA	127.46	12	89	0.125	5070	3.75	4
1694	115.34	NA	127.34	12	89	0.125	5070	3.75	4
1704	115.21	NA	127.21	12	89	0.125	5070	3.75	4
1714	115.09	NA	127.09	12	89	0.125	5070	3.75	4
1724	114.96	NA	126.96	12	89	0.125	5070	3.75	4
1734	114.84	NA	126.84	12	89	0.125	5070	3.75	4
1744	114.71	NA	126.71	12	89	0.125	5070	3.75	4
1754	114.59	NA	126.59	12	89	0.125	5070	3.75	4
1764	114.46	NA	126.46	12	89	0.125	5070	3.75	4
1774	114.54	NA	126.54	12	89	0.125	5070	3.75	4
1784	114.21	NA	126.21	12	89	0.125	5070	3.75	4
1784	108.21	NA	120.21	12	83	0.125	4757	3.75	4
1794	108.09	NA	120.09	12	83	0.125	4757	3.75	4

Table 6.155: (continued) Left Bank Main Canal

Distance in chainage	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	Free board
1804	107.96	NA	119.96	12	83	0.125	4757	3.72	4
1810	107.86	NA	119.86	12	83	0.125	4757	3.72	4
1820	107.76	NA	119.76	12	83	0.125	4757	3.72	4
1830	107.63	NA	119.63	12	83	0.125	4757	3.72	4
1840	107.51	NA	119.51	12	83	0.125	4757	3.72	4
1850	107.38	NA	119.38	12	83	0.125	4757	3.72	4
1860	107.26	NA	119.26	12	83	0.125	4757	3.72	4
1870	107.13	NA	119.13	12	83	0.125	4757	3.72	4
1880	107.01	NA	119.01	12	83	0.125	4757	3.72	4
1890	106.88	NA	118.88	12	83	0.125	4757	3.72	4
1900	106.76	NA	118.76	12	83	0.125	4757	3.72	4
1910	106.63	NA	118.63	12	83	0.125	4757	3.72	4
1920	106.51	NA	118.51	12	83	0.125	4757	3.72	4
1930	106.38	NA	118.38	12	83	0.125	4757	3.72	4
1940	106.26	NA	118.26	12	83	0.125	4757	3.72	4
1945	106.2	NA	118.2	12	83	0.125	4757	3.72	4
1950	106.13	NA	118.13	12	83	0.125	4757	3.72	4
1960	106.01	NA	118.01	12	83	0.125	4757	3.72	4
1965	105.96	NA	117.96	12	83	0.125	4757	3.72	4
1965	100.96	NA	112.96	12	83	0.125	4757	3.72	4
1970	100.88	NA	112.88	12	83	0.125	4757	3.72	4
1980	100.76	NA	112.76	12	83	0.125	4757	3.72	4
1990	100.63	NA	112.63	12	83	0.125	4757	3.72	4
2000	100.51	NA	112.51	12	83	0.125	4757	3.72	4
2010	100.38	NA	112.38	12	83	0.125	4757	3.72	4
2020	100.26	NA	112.26	12	83	0.125	4757	3.72	4
2030	100.13	NA	112.13	12	83	0.125	4757	3.72	4

Table 6.156: (continued) Left Bank Main Canal

Distance in chainage	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	Free board
2040	100.01	NA	112.01	12	83	0.125	4757	3.72	4
2050	99.88	NA	111.88	12	83	0.125	4757	3.72	4
2060	99.75	NA	111.75	12	83	0.125	4757	3.72	4
2070	99.63	NA	111.63	12	83	0.125	4757	3.72	4
2080	99.51	NA	111.51	12	83	0.125	4757	3.72	4
2090	99.38	NA	111.38	12	83	0.125	4757	3.72	4
2095	99.32	NA	111.32	12	83	0.125	4757	3.72	4
2100	99.26	NA	111.26	12	83	0.125	4757	3.72	4
2110	99.13	NA	111.13	12	83	0.125	4757	3.72	4
2120	99.01	NA	111.01	12	83	0.125	4757	3.72	4
2130	98.88	NA	110.88	12	83	0.125	4757	3.72	4
2140	85.26	86.27	97.26	12	83	0.125	4757	3.72	4
2150	85.03	83.31	97.03	12	83	0.125	4757	3.72	4
2160	85.01	84.56	97.01	12	83	0.125	4757	3.72	4
2170	84.88	85.43	96.88	12	83	0.125	4757	3.72	4
2180	84.76	85.86	96.76	12	83	0.125	4757	3.72	4
2190	84.63	86.42	96.63	12	83	0.125	4757	3.72	4
2200	84.51	86	96.51	12	83	0.125	4757	3.72	4
2210	84.38	85.32	96.38	12	83	0.125	4757	3.72	4
2220	84.26	85.58	96.26	12	83	0.125	4757	3.72	4
2230	84.13	85.85	96.13	12	83	0.125	4757	3.72	4
2240	84.01	85.03	96.01	12	83	0.125	4757	3.72	4
2250	83.88	86.22	95.88	12	83	0.125	4757	3.72	4
2260	83.78	87.44	95.78	12	83	0.125	4757	3.72	4
2270	83.63	86.73	95.63	12	83	0.125	4757	3.72	4
2280	83.51	86.89	95.51	12	82	0.125	4687	3.72	4
2290	83.38	86.67	95.38	12	82	0.125	4687	3.72	4

Table 6.157: (continued) Left Bank Main Canal

Distance in chainage	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	Free board
2300	83.26	86.36	95.26	12	82	0.125	4687	3.72	4
2310	83.15	85.78	95.15	12	82	0.125	4687	3.72	4
2320	83.01	85.89	95.01	12	82	0.125	4687	3.72	4
2330	82.88	85.35	94.88	12	82	0.125	4687	3.72	4
2340	82.76	85.5	94.76	12	82	0.125	4687	3.72	4
2350	82.63	85.64	94.63	12	82	0.125	4687	3.72	4
2360	82.51	84.37	94.51	12	82	0.125	4687	3.72	4
2370	82.38	84.89	94.38	12	82	0.125	4687	3.72	4
2380	82.26	84.3	94.26	12	82	0.125	4687	3.72	4
2390	82.13	83.22	94.13	12	82	0.125	4687	3.72	4
2400	82.01	83.45	94.01	12	82	0.125	4687	3.72	4
2410	81.88	83.43	93.88	12	82	0.125	4687	3.72	4
2420	81.76	83.3	93.76	12	82	0.125	4687	3.72	4
2430	81.63	82.36	93.63	12	82	0.125	4687	3.72	4
2440	81.51	81.65	93.51	12	82	0.125	4687	3.72	4
2450	81.38	81.44	93.38	12	82	0.125	4687	3.72	4
2460	81.26	81.55	93.26	12	82	0.125	4687	3.72	4
2470	81.13	81.69	93.13	12	82	0.125	4687	3.72	4
2480	81.01	81.85	93.01	12	82	0.125	4687	3.72	4
2490	80.88	81.96	92.88	12	82	0.125	4687	3.72	4
2500	80.76	81.93	92.76	12	82	0.125	4687	3.72	4
2510	80.63	81.86	92.63	12	82	0.125	4687	3.72	4
2520	80.51	82.18	92.51	12	82	0.125	4687	3.72	4
2530	80.38	82.02	92.38	12	82	0.125	4687	3.72	4
2540	80.26	81.92	92.26	12	82	0.125	4687	3.72	4
2550	80.13	81.83	92.13	12	82	0.125	4687	3.72	4
2560	80.01	81.26	92.01	12	82	0.125	4687	3.72	4

Table 6.158: (continued) Left Bank Main Canal

Distance in chainage	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	Free board
2570	79.88	80.97	91.88	12	82	0.125	4687	3.72	4
2580	79.76	80.23	91.76	12	82	0.125	4687	3.72	4
2590	79.63	79.37	91.63	12	82	0.125	4687	3.72	4
2600	79.51	78.9	91.51	12	82	0.125	4687	3.72	4
2610	79.38	78.41	91.38	12	82	0.125	4687	3.72	4
2620	79.26	78.42	91.26	12	82	0.125	4687	3.72	4
2630	79.13	78.85	91.13	12	82	0.125	4687	3.72	4
2640	79.01	78.42	91.01	12	82	0.125	4687	3.72	4
2650	78.88	79.07	90.88	12	82	0.125	4687	3.72	4
2660	78.76	76.14	90.76	12	82	0.125	4687	3.72	4
2660	73.76	76.14	85.76	12	82	0.125	4687	3.72	4
2670	73.63	74.47	85.63	12	82	0.125	4687	3.72	4
2680	73.51	77.23	85.51	12	82	0.125	4687	3.72	4
2690	73.38	73.63	85.38	12	82	0.125	4687	3.72	4
2700	73.26	72.96	85.26	12	82	0.125	4687	3.72	4
2710	73.13	74.11	85.13	12	82	0.125	4687	3.72	4
2720	73.01	73.73	85.01	12	82	0.125	4687	3.72	4
2730	72.88	74.97	84.88	12	82	0.125	4687	3.72	4
2740	72.76	72.88	84.76	12	82	0.125	4687	3.72	4

Table 6.159: (continued) Left Bank Main Canal

Distance in chainage	Design Bed Level	Actual Bed level done	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	Free board
2750	72.63	72.64	84.63	12	82	0.125	4687	3.72	4
2760	72.51	74.15	84.51	12	82	0.125	4687	3.72	4
2770	72.38	73.55	84.38	12	82	0.125	4687	3.72	4
2780	72.26	72.86	84.26	12	82	0.125	4687	3.72	4
2790	72.13	73.18	84.13	12	82	0.125	4687	3.72	4
2800	72.01	72.75	84.01	12	82	0.125	4687	3.72	4
2800	73.01	72.75	84.01	11	80	0.125	3607	3.62	4
2810	72.88	71.49	83.88	11	80	0.125	3607	3.62	4
2820	72.76	71.37	83.76	11	80	0.125	3607	3.62	4
2830	72.63	70.89	83.63	11	80	0.125	3607	3.62	4
2840	72.51	72.07	83.51	11	80	0.125	3607	3.62	4
2850	72.38	68.9	83.38	11	80	0.125	3607	3.62	4
2860	72.26	68.21	83.26	11	80	0.125	3607	3.62	4
2870	72.13	68.05	83.13	11	80	0.125	3607	3.62	4
2870	70.13	68.05	79.13	9	68	0.125	2177	3.2	4
2880	70.01	68.83	79.01	9	68	0.125	2177	3.2	4
2890	69.88	67.56	78.88	9	68	0.125	2177	3.2	4
2900	69.76	67.6	78.76	9	68	0.125	2177	3.2	4
2910	68.63	66.9	77.63	9	68	0.125	2177	3.2	4
2920	69.51	67.31	78.51	9	68	0.125	2177	3.2	4
2930	69.38	66.42	78.38	9	68	0.125	2177	3.2	4
2940	69.26	66.28	78.26	9	68	0.125	2177	3.2	4
2950	69.13	66.23	78.13	9	68	0.125	2177	3.2	4
2960	69.01	64.95	78.01	9	68	0.125	2177	3.2	4
2970	68.88	65.75	77.88	9	68	0.125	2177	3.2	4

Table 6.160: Panagarh Branch Canal (Id:7, Node No:37-85)

Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	V/V0	Free board	Distance	Structure
0	195.64	204.14	8.5	59	0.15	1909	3.34	1.009	3	0	offtake
0	194.64	203.14	8.5	59	0.15	1909	3.34	1.009	3	9	inlet
50	193.89	202.39	8.5	59	0.15	1909	3.34	1.009	3	23	inlet
100	193.14	201.64	8.5	59	0.15	1909	3.34	1.009	3	65.3	inlet
150	192.89	201.39	8.5	59	0.15	1909	3.34	1.009	3	86	inlet
205	191.57	200.07	8.5	59	0.15	1909	3.34	1.009	3	100.42	inlet
258.02	190.77	199.27	8.5	59	0.15	1909	3.34	1.009	3	161	inlet
300	190.17	198.67	8.5	59	0.15	1909	3.34	1.009	3	169.9	inlet
350	189.42	197.92	8.5	59	0.15	1909	3.34	1.009	3	263.02	inlet
408.02	188.52	197.02	8.5	59	0.15	1909	3.34	1.009	3		
450.02	187.77	196.27	8.5	59	0.15	1909	3.34	1.009	3		
490	187.17	195.67	8.5	59	0.15	1909	3.34	1.009	3		
545	186.42	194.92	8.5	59	0.15	1909	3.34	1.009	3		
593	185.67	194.17	8.5	59	0.15	1909	3.34	1.009	3		
658.02	184.77	193.27	8.5	59	0.15	1909	3.34	1.009	3		

Table 6.161: (continued) Panagarh Branch Canal (Id:7, Node No:37-85)

Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	V/V0	Free board
690.17	184.17	192.67	8.5	59	0.15	1909	3.34	1.009	3
753.02	183.35	191.85	8.5	59	0.15	1909	3.34	1.009	3
753.02	171.81	180.31	8.5	57	0.15	1838	3.3	0.998	3
798.02	171.13	179.63	8.5	57	0.15	1838	3.3	0.998	3
848.02	170.38	178.88	8.5	57	0.15	1838	3.3	0.998	3
869.32	170.06	178.56	8.5	53	0.15	1698	3.29	0.994	3
872.32	170.02	178.52	8.5	53	0.15	1698	3.29	0.994	3
872.32	159.02	167.52	8.5	53	0.15	1698	3.29	0.994	3
898.01	158.63	167.13	8.5	53	0.15	1698	3.29	0.994	3
948	157.88	166.38	8.5	53	0.15	1698	3.29	0.994	3
998	157.13	165.63	8.5	52	0.15	1675	3.28	0.992	3
1006.52	136.35	144.85	8.5	52	0.15	1675	3.28	0.992	3
1098.06	134.98	143.48	8.5	52	0.15	1675	3.28	0.992	3
1148	134.23	142.73	8.5	52	0.15	1675	3.28	0.992	3
1203.02	133.4	141.9	8.5	52	0.15	1675	3.28	0.992	3
1213.02	133.25	141.75	8.5	52	0.15	1675	3.28	0.992	3
1213.02	132.9	141.4	8.5	52	0.15	1675	3.28	0.992	3
1248.02	132.38	140.88	8.5	52	0.15	1675	3.28	0.992	3
1298.02	131.63	140.13	8.5	52	0.15	1675	3.28	0.992	3
1348.02	130.8	139.3	8.5	52	0.15	1675	3.28	0.992	3
1398.02	130.13	138.63	8.5	52	0.15	1675	3.28	0.992	3
1413.02	129.8	138.3	8.5	52	0.15	1675	3.28	0.992	3
1413.02	130.13	138.38	8.25	51	0.15	1563	3.22	0.992	3
1448.02	129.63	137.88	8.25	51	0.15	1563	3.22	0.992	3
1498.09	128.88	137.13	8.25	51	0.15	1563	3.22	0.992	3
1548.02	128.136	136.386	8.25	51	0.15	1563	3.22	0.992	3
1598.02	127.34	135.59	8.25	51	0.15	1563	3.22	0.992	3
1632.02	126.87	135.12	8.25	51	0.15	1563	3.22	0.992	3

Table 6.162: (continued) Panagarh Branch Canal (Id:7, Node No:37-85)

Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	V/V0	Free board
1632.02	127.87	136.12	8.25	51	0.15	1563	3.22	0.992	3
1648.02	127.64	134.89	7.25	43	0.15	1074	2.95	0.994	3
1700.02	126.64	133.89	7.25	43	0.15	1074	2.95	0.994	3
1700.02	113.59	120.84	7.25	43	0.15	1074	2.95	0.994	3
1713.02	113.44	120.44	7	43	0.15	1037	2.95	0.994	3
1713.02	99.04	106.04	7	43	0.15	1037	2.95	0.994	3
1758.02	99.27	106.27	7	43	0.15	1037	2.95	0.994	3
1803.02	98.08	105.08	7	26	0.175	671	2.92	1	2.5
1832.02	94.96	101.96	7	26	0.175	671	2.92	1	2.5
1853.02	97.66	104.66	7	26	0.175	671	2.92	1	2.5
1877.02	97.88	104.88	7	26	0.175	671	2.92	1	2.5
1877.02	94.18	101.18	7	26	0.175	671	2.92	1	2.5
1898.02	93.82	100.82	7	26	0.175	671	2.92	1	2.5
1925.02	91.35	98.35	7	26	0.175	671	2.92	1	2.5
1925.02	87.38	94.13	6.75	24	0.175	590	2.94	0.991	2.5
1948.02	86.68	93.43	6.75	24	0.175	590	2.94	0.991	2.5
1998.02	85.81	92.56	6.75	24	0.175	590	2.94	0.991	2.5
2107.02	83.89	88.64	4.75	19	0.225	257	2.29	1.005	2.5
2107.02	82.68	87.43	4.75	19	0.225	257	2.29	1.005	2.5
2148.02	81.76	86.51	4.75	19	0.225	257	2.29	1.005	2.5
2213.02	80.29	85.04	4.75	17	0.225	225	2.26	0.992	2.5
2213.02	75.54	80.29	4.75	17	0.225	225	2.26	0.992	2.5
2248.02	74.76	79.51	4.75	17	0.225	225	2.26	0.992	2.5
2298.02	73.63	78.38	4.75	17	0.225	225	2.26	0.992	2.5
2348.02	72.51	77.26	4.75	17	0.225	225	2.26	0.992	2.5
2360	72.23	76.98	4.75	17	0.225	225	2.26	0.992	2.5
2360	70.73	75.48	4.75	17	0.225	225	2.26	0.992	2.5

Table 6.163: (continued) Panagarh Branch Canal (Id:7, Node No:37-85)

Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000’	Dischsrge (cusec)	V (ft/sec)	V/V0	Free board
2398	69.88	74.63	4.75	17	0.225	225	2.26	0.992	2.5
2438	68.98	73.73	4.75	17	0.225	225	2.26	0.992	2.5
2438	63.23	67.23	4	17	0.225	166	2.04	NA	2
2508	61.66	65.66	4	13	0.25	137	2.07	1.015	2
2508	55.91	59.91	4	13	0.25	137	2.07	1.015	2
2538	55.16	59.16	4	13	0.25	137	2.07	1.015	2
2584.34	53.75	57.75	4	13	0.25	137	2.07	1.015	2
2584.34	51	55	4	13	0.25	137	2.07	1.015	2
2643.42	49.77	53.77	4	13	0.25	137	2.07	1.015	2
2643.42	45.77	49.27	3.5	13	0.25	110	1.88	1.02	2
2668.02	45.16	48.66	3.5	13	0.25	110	1.88	1.02	2
2698.02	44.41	47.91	3.5	13	0.25	110	1.88	1.02	2
2748.02	43.16	46.66	3.5	13	0.25	110	1.88	1.02	2
2808.02	41.66	45.16	3.5	13	0.25	110	1.88	1.02	2
2837.5	40.92	44.42	3.5	13	0.25	110	1.88	1.02	2
2837.5	41.67	44.42	2.75	9	0.25	52	1.61	1	2
2858.02	41.16	43.91	2.75	9	0.25	52	1.61	1	2
2899.46	40.12	42.87	2.75	9	0.25	52	1.61	1	2
2899.46	36.79	39.12	2.33	9	0.25	38	1.43	0.94	2
2975.72	35.64	37.97	2.33	9	0.25	38	1.43	0.94	2
2975.72	34.39	36.72	2.33	9	0.25	38	1.43	0.94	2
3010.02	32.78	35.11	2.33	9	0.25	38	1.43	0.94	2

Table 6.164: PC1 of PBC (Id:99, Node No:160-263)

Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	Free board	Structure
0	64.45	66.75	2.3	7	0.3	29	1.5	2	head regu- lator
10	64.15	66.45	2.3	7	0.3	29	1.5	2	
10	64.35	66.45	2.1	6.5	0.4	24	1.41	1.5	
20	63.95	66.05	2.1	6.5	0.4	24	1.41	1.5	
30	63.55	65.65	2.1	6.5	0.4	24	1.41	1.5	
30	61.55	63.65	2.1	6.5	0.4	24	1.41	1.5	
40	61.15	63.25	2.1	6.5	0.4	24	1.41	1.5	
50	60.75	62.85	2.1	6.5	0.4	24	1.41	1.5	
50	61.05	62.85	1.8	5.5	0.4	18	1.43	1.5	
60	60.65	62.45	1.8	5.5	0.4	18	1.43	1.5	
70	60.25	62.05	1.8	5.5	0.4	18	1.43	1.5	
80	59.85	61.65	1.8	5.5	0.4	18	1.43	1.5	
90	59.45	61.25	1.8	5.5	0.4	18	1.43	1.5	
96.48	59.19	60.99	1.8	5.5	0.4	18	1.43	1.5	
96.48	56.59	57.99	1.4	4.5	0.4	10	1.21	1.5	
100	56.45	57.85	1.4	4.5	0.4	10	1.21	1.5	
110	56.05	57.45	1.4	4.5	0.4	10	1.21	1.5	
120	55.65	57.05	1.4	4.5	0.4	10	1.21	1.5	
130	55.25	56.65	1.4	4.5	0.4	10	1.21	1.5	
140	54.85	56.25	1.4	4.5	0.4	10	1.21	1.5	
150	54.45	55.85	1.4	4.5	0.4	10	1.21	1.5	
155	54.25	55.65	1.4	4.5	0.4	10	1.21	1.5	
155	54.65	56.05	1.4	2	0.4	3	1	1.5	
160	54.45	55.85	1.4	2	0.4	3	1	1.5	
170	54.05	55.45	1.4	2	0.4	3	1	1.5	

Table 6.165: PC2 of PBC (Id:100, Node No:161-264)

Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	Free board
0	59.7	61.5	1.8	5.5	0.4	18	1.43	1.5
10	59.3	61.1	1.8	5.5	0.4	18	1.43	1.5
10	59.7	61.1	1.4	4.5	0.4	9	1.21	1.5
20	59.3	60.7	1.4	4.5	0.4	9	1.21	1.5
30	58.9	60.3	1.4	4.5	0.4	9	1.21	1.5
40	58.5	59.9	1.4	4.5	0.4	9	1.21	1.5
50	58.1	59.5	1.4	4.5	0.4	9	1.21	1.5
60	57.7	59.1	1.4	4.5	0.4	9	1.21	1.5
66	57.46	58.86	1.4	4.5	0.4	9	1.21	1.5
67.5	55.16	56.36	1.2	3.5	0.4	8	1.26	1.5
70	55	56	1	2	0.4	2	1	1.5
72.5	54.9	55.9	1	2	0.4	2	1	1.5
72.5	55.1	56.1	1	2	0.4	2	1	1.5
80	54.8	55.8	1	2	0.4	2	1	1.5
90	54.4	55.4	1	2	0.4	2	1	1.5
96	54.16	55.16	1	2	0.4	2	1	1.5
96	50.16	51.16	1	2	0.4	2	1	1.5
100	50	51	1	2	0.4	2	1	1.5
110	49.6	50.6	1	2	0.4	2	1	1.5
118	49.28	50.28	1	2	0.4	2	1	1.5

Table 6.166: 14A BC of PBC (Id:36, Node No:81-158)

Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	V/V0	Free board	Distance	Structure
0	101.52	106.27	4.75	28	0.2	336	2.3	1	2.5	60	regulator
10	101.32	106.07	4.75	28	0.2	336	2.3	1	2.5	165	regulator
20	101.12	105.87	4.75	28	0.2	336	2.3	1	2.5	242	regulator
30	100.92	105.67	4.75	28	0.2	336	2.3	1	2.5	410	offtake of 14/B
40	100.72	105.47	4.75	28	0.2	336	2.3	1	2.5	445	regulator
50	100.52	105.27	4.75	28	0.2	336	2.3	1	2.5	535	regulator
60	100.32	105.07	4.75	28	0.2	336	2.3	1	2.5	740.7	offtake of 14/B
60	96.32	101.07	4.75	28	0.2	336	2.3	1	2.5	780	regulator
70	96.12	100.87	4.75	28	0.2	336	2.3	1	2.5	865	regulator
75	96.02	100.77	4.75	28	0.2	336	2.3	1	2.5		
80	95.92	100.67	4.75	28	0.2	336	2.3	1	2.5		
90	95.72	100.47	4.75	28	0.2	334	2.3	1	2.5		
95	95.62	100.37	4.75	28	0.2	334	2.3	1	2.5		
95	95.87	100.37	4.5	28	0.2	325	2.2	1	2.5		
100	95.77	100.27	4.5	28	0.2	325	2.3	1	2.5		

Table 6.167: (continued) 14A BC of PBC (Id:36, Node No:81-158)

Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	V/V0	Free board
110	95.57	100.07	4.5	28	0.2	325	2.3	1	2.5
120	95.37	99.87	4.5	28	0.2	325	2.3	1	2.5
130	95.17	99.67	4.5	28	0.2	325	2.3	1	2.5
140	94.97	99.47	4.5	28	0.2	325	2.3	1	2.5
150	94.77	99.27	4.5	28	0.2	325	2.3	1	2.5
160	94.57	99.07	4.5	28	0.2	325	2.3	1	2.5
165	94.47	98.97	4.5	28	0.2	325	2.3	1	2.5
165	88.47	92.97	4.5	28	0.2	325	2.3	1	2.5
170	88.37	92.87	4.5	28	0.2	325	2.3	1	2.5
180	88.17	92.67	4.5	28	0.2	325	2.3	1	2.5
190	87.97	92.47	4.5	28	0.2	314	2.2	1	2.5
200	87.77	92.27	4.5	28	0.2	314	2.2	1	2.5
210	87.57	92.07	4.5	28	0.2	314	2.2	1	2.5
212	87.55	92.05	4.5	28	0.2	314	2.2	1	2.5
212	82.53	87.03	4.5	28	0.2	314	2.2	1	2.5
220	82.37	86.87	4.5	28	0.2	314	2.2	1	2.5
230	82.17	86.67	4.5	28	0.2	309	2.2	1	2.5
240	81.97	86.47	4.5	28	0.2	309	2.2	1	2.5
250	81.77	86.27	4.5	28	0.2	309	2.2	1	2.5
260	81.57	86.07	4.5	26	0.2	289	2.2	1	2.5
270	81.37	85.87	4.5	26	0.2	289	2.2	1	2.5
275	81.27	85.77	4.5	26	0.2	289	2.2	1	2.5
280	81.17	85.67	4.5	26	0.2	281	2.2	1	2.5
290	80.97	85.47	4.5	26	0.2	281	2.2	1	2.5
300	80.71	85.21	4.5	26	0.2	281	2.2	1	2.5
310	80.57	85.07	4.5	26	0.2	278	2.2	1	2.5
320	80.37	84.87	4.5	26	0.2	278	2.2	1	2.5
330	80.17	84.67	4.5	26	0.2	278	2.2	1	2.5

Table 6.168: (continued) 14A BC of PBC (Id:36, Node No:81-158)

Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	V/V0	Free board
340	79.97	84.47	4.5	26	0.2	278	2.2	1	2.5
350	79.77	84.27	4.5	24	0.2	273	2.21	1	2.5
360	79.57	84.07	4.5	24	0.2	273	2.21	1	2.5
370	79.37	83.87	4.5	24	0.2	267	2.21	1	2.5
376	79.25	83.75	4.5	24	0.2	267	2.21	1	2.5
380	79.17	83.67	4.5	24	0.2	261	2.21	1	2.5
390	78.97	83.47	4.5	24	0.2	261	2.02	0.99	2.5
400	78.77	83.27	4.5	24	0.2	256.26	2.02	0.99	2.5
410	78.57	83.07	4.5	24	0.2	256.26	2.02	0.99	2.5
411.45	78.54	82.54	4	24	0.2	256.26	2.02	0.99	2.5
411.45	76.29	80.29	4	24	0.2	211	2.02	0.99	2.5
420	76.12	80.12	4	24	0.2	208	2.02	0.99	2.5
430	75.92	79.92	4	24	0.2	208	2.02	0.99	2.5
440	75.72	79.72	4	24	0.2	208	2.02	0.99	2.5
445	75.62	79.62	4	24	0.2	208	2.02	0.99	2.5
445	72.62	76.62	4	24	0.2	208	2.02	0.99	2.5
450	72.52	76.52	4	24	0.2	208	2.02	0.99	2.5
460	72.32	76.32	4	24	0.2	208	2.02	0.99	2.5
470	72.12	76.12	4	24	0.2	208	2.02	0.99	2.5
480	71.92	75.92	4	24	0.2	208	2.02	0.99	2.5
490	71.72	75.72	4	24	0.2	208	2.02	0.99	2.5
500	71.52	75.52	4	24	0.2	208	2.02	0.99	2.5
510	71.32	75.32	4	24	0.2	196	2.2	1	2
520	71.12	75.12	4	24	0.2	196	2.2	1	2
530	70.92	74.92	4	24	0.2	196	2.2	1	2
535	90.82	94.82	4	24	0.2	196	2.2	1	2
535	65.82	70.32	4.5	17	0.25	193	2.2	1	2
540	65.7	70.2	4.5	17	0.25	193	2.2	1	2

Table 6.169: (continued) 14A BC of PBC (Id:36, Node No:81-158)

Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	V/V0	Free board
550	65.45	69.95	4.5	17	0.25	193	2.2	1	2
560	65.2	69.7	4.5	17	0.25	193	2.2	1	2
570	64.95	69.45	4.5	17	0.25	193	2.2	1	2
574	64.85	69.35	4.5	17	0.25	188	2.2	1	2
580	64.7	69.2	4.5	17	0.25	188	2.2	1	2
590	64.45	68.95	4.5	17	0.25	182	2.2	1	2
600	64.2	68.7	4.5	17	0.25	182	2.2	1	2
610	63.95	68.45	4.5	17	0.25	182	2.2	1	2
615	65.87	70.37	4.5	17	0.25	175	2.2	1	2
620	63.7	68.2	4.5	17	0.25	175	1.9	1	2
630	65.45	69.95	4.5	17	0.25	175	1.9	1	2
640	63.8	68.3	4.5	17	0.25	172	1.9	1	2
650	64.95	69.45	4.5	17	0.25	172	1.9	1	2
656	62.8	67.3	4.5	17	0.25	172	1.9	1	2
660	63.7	68.2	4.5	17	0.25	167	1.9	1	2
670	62.45	66.95	4.5	17	0.25	167	1.9	1	2
680	62.2	66.7	4.5	17	0.25	167	1.9	1	2
685.25	62.12	66.62	4.5	17	0.25	167	1.9	1	2
685.25	58.87	62.62	3.75	17	0.25	163	1.96	1	2
690	58.7	62.45	3.75	17	0.25	163	1.96	1	2
700	58.45	62.2	3.75	17	0.25	157	1.96	1	2
710	58.2	61.95	3.75	17	0.25	157	1.96	1	2
720	57.95	61.7	3.75	17	0.25	157	1.96	1	2
730	57.7	61.45	3.75	17	0.25	157	1.96	1	2
740	57.45	61.2	3.75	17	0.25	157	1.96	1	2
740.7	57.43	61.18	3.75	13	0.25	111	1.96	1	2
750	57.2	60.95	3.75	13	0.25	111	1.96	1	2

Table 6.170: (continued) 14A BC of PBC (Id:36, Node No:81-158)

Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000’	Dischsrge (cusec)	V (ft/sec)	V/V0	Free board
760	56.95	60.7	3.75	13	0.25	111	1.96	1	2
770	56.7	60.45	3.75	13	0.25	111	1.96	1	2
780	56.45	60.2	3.75	13	0.25	106	1.9	1	2
782	56.4	60.15	3.75	13	0.25	106	1.9	1	2
782	54.65	58.4	3.75	13	0.25	100	1.9	1	2
790	54.45	58.2	3.75	13	0.25	100	1.9	1	2
800	54.2	57.95	3.75	13	0.25	100	1.9	1	2
800	52.45	56.2	3.75	13	0.25	100	1.9	1	2
810	52.2	55.95	3.75	11	0.25	90	1.87	1	2
820	51.95	55.7	3.75	11	0.25	90	1.87	1	2
830	51.7	55.45	3.75	11	0.25	84	1.87	1	2
840	51.45	55.2	3.75	11	0.25	84	1.87	1	2
850	51.2	54.95	3.75	11	0.25	84	1.87	1	2
860	50.98	54.73	3.75	11	0.25	84	1.87	1	2
865	50.82	54.57	3.75	11	0.25	84	1.87	1	2
865	47.07	50.57	3.5	11	0.25	74	1.77	1	2
870	46.97	50.47	3.5	11	0.25	74	1.77	1	2
880	46.77	50.27	3.5	11	0.25	74	1.77	1	2
890	46.57	50.07	3.5	11	0.25	70	1.77	1	2
900	46.37	49.87	3.5	11	0.25	70	1.77	1	2
910	46.17	49.67	3.5	11	0.2	60	1.77	1	2
920	45.97	49.47	3.5	11	0.2	60	1.77	1	2
930	45.77	49.27	3.5	9	0.2	56	1.7	1	2
940	45.57	49.07	3.5	9	0.2	56	1.7	1	2
950	45.37	48.87	3.5	9	0.2	51	1.7	1	2
960	45.17	48.67	3.5	9	0.2	51	1.7	1	2
970	44.97	48.47	3.5	9	0.2	46	1.7	1	2
980	44.77	48.27	3.5	9	0.2	46	1.7	1	2

Table 6.171: (continued) 14A BC of PBC (Id:36, Node No:81-158)

Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	V/V0	Free board
990	44.57	48.07	3.5	9	0.2	46	1.7	1	2
1000	44.37	47.87	3.5	9	0.2	46	1.7	1	2
1000	45.37	47.87	2.5	9	0.2	35	1.39	1	2
1010	45.17	47.67	2.5	9	0.2	35	1.39	1	2
1020	44.97	47.47	2.5	9	0.2	35	1.39	1	2
1030	44.77	47.27	2.5	9	0.2	30	1.39	1	2
1040	44.57	47.07	2.5	9	0.2	30	1.39	1	2
1050	44.37	46.87	2.5	8.5	0.2	21	1.18	1.01	1.5
1060	4417	4419.5	2.5	8.5	0.2	21	1.18	1.01	1.5
1070	43.97	46.47	2.5	6	0.2	16	1.18	0.99	1.5
1080	43.77	46.27	2.5	6	0.2	16	1.18	0.99	1.5
1090	43.57	46.07	2.5	6	0.2	12	1.18	0.99	1.5
1100	43.37	45.87	2.5	6	0.2	12	1.18	0.99	1.5
1110	43.17	45.67	2.5	6	0.2	8	1.18	0.99	1.5
1120	42.97	45.47	2.5	6	0.2	8	1.18	0.99	1.5
1130	42.77	45.27	2.5	6	0.2	8	1.18	0.99	1.5

Table 6.172: Various Distributaries of Panagarh Branch Canal(PBC)

Name of Canal	Distance in chainage	Design Bed Level	F.S.L	structure
PB of PBC	0	124.8	129.8	
	40	123.8	128.6	
	40	116.1	121.1	
	50	115.8	120.8	
	56	NA	NA	cross drainage
	94	114.48	119.48	merge with existing damodar branch canal
	94	111.43	116.43	
	114.08	110.63	116.33	offtake of 11 BC
	114.08	105.59	110.59	starting point of 14BC
	156.28	104.32	109.32	
P5 of PBC	0	90.81	92.61	
	50	89.31	91.11	

Table 6.173: Various Distributaries of Panagarh Branch Canal(PBC)

Name of Canal	Distance in chainage	Design Bed Level	F.S.L	structure
	60	89.01	90.81	regulator
	60	85.5	86.8	
	100	84.3	85.6	
	120	83.7	85	
P7 of PBC	0	45.23	47.73	
	5.5	45.12	47.62	
	10	43.89	46.39	
	10	43.8	46.3	
	50	43	45.5	
	50	43.3	45.5	
	63	43.04	45.24	
	63	43.44	45.24	
	80	43.1	44.9	
	80	43.3	44.9	
	100	42.9	44.5	
	130	42.3	43.9	
	150	41.9	43.5	
	150	42.2	43.5	
	164	41.92	43.22	

Table 6.174: P6 of PBC (Id:39, Node No:83-163)

Distance in chainage	Design Bed Level	Actual Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000’	Dischsrge (cusec)	V (ft/sec)	Free board	Structure
0	83.44	83.44	85.84	2.4	7.2	0.3	34	1.55	2	regulator
10	83.14	83.14	85.54	2.4	7.2	0.3	34	1.55	2	
10	83.24	83.24	85.54	2.3	7	0.3	29	1.5	2	
20	82.94	82.94	85.24	2.3	7	0.3	29	1.5	2	
30	82.64	83.38	84.94	2.3	7	0.3	29	1.5	2	
30	82.74	82.74	84.94	2.2	6.5	0.3	27.5	1.44	2	
40	82.44	82.44	84.64	2.2	6.5	0.3	27.5	1.44	2	
50	82.14	82.14	84.34	2.2	6.5	0.3	27.5	1.44	2	
50	82.34	82.34	84.34	2	6	0.3	22	1.55	1.5	
60	82.04	82.04	84.04	2	6	0.3	22	1.35	1.5	
60	78.24	78.24	80.04	1.8	5.5	0.3	16	1.25	1.5	
70	77.94	77.94	79.74	1.8	5.5	0.3	16	1.25	1.5	
80	77.64	77.64	79.44	1.8	5.5	0.3	16	1.25	1.5	
86	77.64	78.56	79.44	1.8	5.5	0.3	16	1.25	1.5	
90	77.34	79.2	79.14	1.8	5.5	0.3	16	1.25	1.5	
90	77.54	77.54	79.14	1.6	5	0.3	12	1.19	1.5	
100	77.24	75.68	78.84	1.6	5	0.3	12	1.19	1.5	
106	77.24	75.96	78.84	1.6	5	0.3	12	1.19	1.5	
110	76.94	75.46	78.54	1.6	5	0.3	12	1.19	1.5	
120	76.64	75.74	78.24	1.4	5	0.3	12	1.19	1.5	
120	76.84	75.74	78.24	1.4	4	0.5	7.5	1.02	1.5	
130	76.54	76.54	77.94	1.4	4	0.3	7.5	1.02	1.5	
140	76.24	76.24	77.64	1.4	4	0.3	7.5	1.02	1.5	
150	75.94	75.94	77.34	1.4	4	0.3	4	1.06	1.5	
150	76.14	76.14	77.34	1.4	3.5	0.3	4	1.06	1.5	
160	75.84	75.84	77.04	1.4	3.5	0.3	4	1.06	1.5	
165	75.84	75.99	77.04	1.4	3.5	0.3	4	1.06	1.5	
170	75.54	75.54	76.74	1.4	3.5	0.3	4	1.06	1.5	

Table 6.175: Damodar Branch Canal (Id:8, Node No:13-99)

Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V/V0	Distance	Structure
0	141.25	150.25	9	30	0.15	1200	0.64	0	Head Sluice of branch canal
32.2	140.79	149.75	9	30	0.15	1200	0.64	32.2	offtake of dist 1 bc
32.2	142	149.75	7.75	25	0.15	1050	0.81	45.5	regulator
45.5	141.81	150.06	8.25	25	0.15	1050	0.81	110.9	syphone
57.7	141.64	149.89	8.25	25	0.15	1050	0.81	149.35	syphone
98.8	141.02	149.27	8.25	25	0.15	1050	0.81	173	regulator
110.9	140.84	149.09	8.25	25	0.15	1050	0.81	193.6	khari regulator
134.8	140.48	148.73	8.25	25	0.15	1050	0.81	286	merging of link channel
149.35	140.25	148.5	8.25	25	0.15	1050	0.81	288.56	offtake of dist 2 bc
173	140.25	148.5	8.25	25	0.15	1050	0.81	316	syphone with fall
193.6	139.6	147.85	8.25	25	0.15	1050	0.81	341.9	merging of feeder channel

Table 6.176: (continued) Damodar Branch Canal (Id:8, Node No:13-99)

Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V/V0	Distance	Structure
193.6	140	148.25	8.25	25	0.15	1000	0.81	441	offtake of disty no 4 bc
230.26	139.2	147.45	8.25	25	0.15	1000	0.81	539.83	off take of dist 6 bc
288.56	138.33	146.58	8.25	25	0.15	1000	0.81	556	flush inlet and escape
316	137.92	146.17	8.25	25	0.15	1000	0.81	588.46	offtake of dist 7 bc
316	135.92	144.17	8.25	25	0.15	1000	0.81	595.76	flush inlet and escape
330.9	135.69	143.94	8.25	25	0.15	1000	0.81	637	offtake of disty no 8 bc
362	135.23	143.48	8.25	25	0.15	1000	0.81	640	regulator
398.85	134.68	142.93	8.25	25	0.15	1000	0.81	662	flush inlet and escape
429.88	134.68	142.93	8.25	25	0.15	1000	0.81	695.27	flush inlet and escape
441	134.04	142.29	8.25	25	0.15	1000	0.81	719.22	flush inlet and escape
477	133.5	141.75	8.25	25	0.15	1000	0.81	768.5	Regulator
517.5	132.89	141.14	8.25	22	0.15	850	0.81	792	flush inlet and escape

Table 6.177: (continued) Damodar Branch Canal (Id:8, Node No:13-99)

Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V/V0	Distance	Structure
539.83	132.57	140.82	8.25	22	0.15	850	0.8	793.37	offtake of dist 9bc
544.78	132.48	140.73	8.25	22	0.15	500	0.79	926	offtake of disty 10 bc
556	132.31	140.56	8.25	22	0.15	675	0.75	1027	Merging of PB
588.46	131.83	140.08	8.25	22	0.15	675	0.75	1043	syphone aquaduct
595.76	131.72	139.97	8.25	22	0.15	650	0.75	1047	offtake of disty 11 BC
637	131.09	139.34	8.25	22	0.15	650	0.75	1130.6	syphone aquaduct
640	131.05	139.3	8.25	22	0.15	500	0.72		
662	130.72	138.97	8.25	22	0.15	500	0.72		
695.27	130.22	138.47	8.25	22	0.15	500	0.72		
703.07	130.1	138.35	8.25	22	0.15	500	0.72		
719.22	129.86	138.11	8.25	22	0.15	500	0.72		
768.5	129.11	137.36	8.25	22	0.15	500	0.72		

Table 6.178: (continued) Damodar Branch Canal (Id:8, Node No:13-99)

Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000’	Dischsrge (cusec)	V/V0	Distance	Structure
793.37	128.74	136.99	8.25	22	0.15	500	0.68		
854.7	128.13	136.38	8.25	22	0.15	410	0.68		
881.86	127.42	135.67	8.25	22	0.15	410	0.68		
926	126.77	134.27	8.25	22	0.15	410	0.68		
926	126.62	134.12	8.25	7	0.15	21.7	0.66		
935.72	122.92	128.12	8.25	7	0.4	21.7	1.1		
960	121.95	127.9	5.95	18	0.4	320	1.1		
960	115.95	121.15	5.95	18	0.4	320	1.1		
1027.8	113.24	119.19	5.95	7	0.4	300	1.2		
1047.8	112.24	118.19	5.95	7	0.5	300	1.2		
1047.8	110.74	113.69	2.95	12	0.5	150	1.2		
1091	108.58	111.53	2.95	12	0.5	150	1.2		
1091	107.58	110.53	2.95	12	0.5	150	1.2		
1132	105.53	108.48	2.95	12	0.5	150	1.2		

Table 6.179: Distributaries of Damodar Branch Canal

Name of canal	Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	V/V0	Hyd. grad	Distance	Structure
Disty 2 BC	0	144	145.25	1.25	2	01:01	9.45	1.15	0.9	3	0	Head sluice
	30	143.45	144.7	1.25	2	01:01	9.45	1.15	0.9	3	42.5	regulator
	37	132.47	133.72	1.25	2	01:01	9.45	1.15	0.9	3		
	37	131.97	133.72	1.75	2	01:01	9.45	1.15	0.9	1		
	50	130.67	132.42	1.75	2	01:01	9.45	1.15	0.9	1		
	70	128.67	130.42	1.75	2	01:01	9.45	1.15	0.9	1		
	70	128.17	129.42	1.25	2	01:01	9.45	1.15	0.9	2		
	90	125.67	126.92	1.25	2	01:01	9.45	1.15	0.9	2		
Disty 4 BC	0	135.93	137.43	1.5	6.25	01:01	16.9	1.3	0.79	0.5	0	Head sluice
	50	133.43	134.93	1.5	6.25	01:01	16.9	1.3	0.79	0.5	43	regulator
	60	NA	NA	1.5	5	01:01	16.9	1.3	0.79	0.8	90	regulator
	83	NA	NA	1.5	5	01:01	16.9	1.3	0.79	0.8		
	100	129.43	130.93	1.5	3.5	01:01	16.9	1.3	0.79	0.8		
	136	127.49	128.99	1.5	3.5	01:01	16.9	1.3	0.79	0.4		
Disty 6 BC	0			1.8	6.5	01:01	24.23	1.62	0.8	0.3	0	head sluice
	50	135.59	137.39	1.8	4.5	01:01	24.23	1.62	0.8	0.55	50	regulator
	100	132.85	134.65	1.8	4.5	01:01	24.23	1.62	0.8	0.55	90	regulator

Table 6.180: (continued) Distributaries of Damodar Branch Canal

Name of canal	Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	V/V0	Hyd. grad	Distance	Structure
	150	131	132.8	1.8	4.5	01:01	24.23	1.62	0.8	2	145	regulator
	157.57		NA	1.8	4.5	01:01	24.23	1.62	0.8	2		
	183.57	125.58	127.38	1.8	1	01:01	24.23	1.62	0.8	2		
Disty 7 BC	0	136.62	138.82	2.2	7	01:01	21.63	0.16	0.74	0.25	0	head sluice
	50	135.39	137.59	2.2	7	01:01	21.63	0.16	0.74	0.25	59.5	offtake of disty 7A of BC
	59.5	135.14	137.34	2.2	7	01:01	21.63	0.16	0.74	0.25		
	59.5	135.04	136.64	1.6	3.5	01:01	21.63	0.16	0.74	1		
	100	131.35	132.95	1.6	3.5	01:01	21.63	0.16	0.74	1		
	101.5	131.21	132.41	1.2	3	01:01	21.63	0.16	0.74	1		
	101.5	129.56	130.76	1.2	3	01:01	21.63	0.16	0.74	0.6		
	140.12	125.75	126.95	1.2	2	01:01	21.63	0.16	0.74	0.6		
Disty 7A BC	0	135.49	137.09	1.6	5	01:01	9.09	0.95	0.9	0.25	0	head sluice
	36	134.59	136.19	1.6	5	01:01	9.09	0.95	0.9	0.25		
	36	134.19	135.39	1.2	3.2	01:01	9.09	0.95	0.9	1		
	50	132.79	133.99	1.2	3.2	01:01	9.09	0.95	0.9	1		

Table 6.181: (continued) Distributaries of Damodar Branch Canal

Name of canal	Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000’	Dischsrge (cusec)	V (ft/sec)	V/V0	Hyd. grad	Distance	Structure
	60	NA	NA	1.2	2.5	01:01	9.09	0.95	0.9	1		
	90	NA	NA	1.2	2	01:01	9.09	0.95	0.9	1.6		
	100	128.19	129.39	1.2	2	01:01	9.09	0.95	0.9	1.6		
	110	127.59	128.79	1.2	2	01:01	9.09	0.95	0.9	1.6		
Disty 8 BC	0	136.3	137.96	1.66	12.5	01:01	47.22	1.8	0.87	0.6	0	head sluice
	33	134.32	135.98	1.66	12.5	01:01	47.22	1.8	0.87	0.6	32.94	offtake of disty 8A bc
	33	134.82	136.07	1.25	6.5	01:01	47.22	1.8	0.87	0.4	33	regulator with head sluice
	50	133.14	134.39	1.25	3.5	01:01	47.22	1.8	0.87	1.4	89	regulator
	100	127.34	128.59	1.25	3	01:01	47.22	1.8	0.87	1		
	120	125.34	126.59	1.25	2.5	01:01	47.22	1.8	0.87	1		
Disty 8A BC	0	134.12	135.62	1.5	11	01:01	36.91	1.18	0.87	0.8	0	regulator with head sluice
	50	129.89	131.39	1.5	9.5	01:01	36.91	1.18	0.87	1	51.5	regulator
	80	126.91	128.41	1.5	6.9	01:01	36.91	1.18	0.87	1	79.35	offtake of disty 8A/1
	80	126.41	127.91	1.5	6.9	01:01	36.91	1.18	0.87	1	114.7	regulator
	100	124.42	125.92	1.5	6.9	01:01	36.91	1.18	0.87	1		

Table 6.182: (continued) Distributaries of Damodar Branch Canal

Name of canal	Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000’	Dischsrge (cusec)	V (ft/sec)	V/V0	Hyd. grad	Distance	Structure
	148.9	117.85	119.35	1.5	1.9	01:01	36.91	1.18	0.87	1.4		
Disty 8A/1 BC	0	126.31	127.31	1.2	6	01:01	8.51	1.18	0.87	0.5		
	50	122.21	123.41	1.2	3	01:01	8.51	1.18	0.87	1.5		
	85.76	116.85	118.05	1.2	2	01:01	8.51	1.18	0.87	1.5		
Disty 8A/2 BC	0	123.01	124.41	1.4	7	01:01	1.1	1.19	0.89	0.4	0	head sluice
	30			1.4	6.5	01:01	1.1	1.19	0.89	0.4	43	syphon
	50	121.01	122.41	1.4	6.5	01:01	1.1	1.19	0.89	0.4	94	regulator
	64			1.4	5	01:01	1.1	1.19	0.89	0.6	150	regulator
	94			1.4	3	01:01	1.1	1.19	0.89	1.4		
	100	117.81	119.21	1.4	3	01:01	1.1	1.19	0.89	1.4		
	130			1.4	2	01:01	1.1	1.19	0.89	1.8		

Table 6.183: (continued) Distributaries of Damodar Branch Canal

Name of canal	Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	V/V0	Hyd. grad	Distance	Structure
	150	110.01	111.41	1.4	2	01:01	1.1	1.19	0.89	1.8		
	163	107.67	109.07	1.4	2	01:01	1.1	1.19	0.89	1.8		
Disty 9 BC	0	130.25	132.75	2.5	6	01:01	43.89	1.6	0.9	0.8	247.45	regulator
	14.18	123.12	125.62	2.5	6	01:01	43.89	1.6	0.9	0.8		
	14.18	127.37	129.87	2.5	6	01:01	43.89	1.6	0.9	0.8		
	50	124.5	127	2.5	5.5	01:01	43.89	1.6	0.9	0.8		
	67.01	123.14	125.64	2.5	5.5	01:01	43.89	1.6	0.9	1		
	67.01	122.64	125.14	2.5	5.5	01:01	43.89	1.6	0.9	1		
	100	119.9	122.4	2.5	4.5	01:01	43.89	1.6	0.9	0.8		
	130.18	116.88	119.38	2.5	4.5	01:01	43.89	1.6	0.9	0.8		
	130.18	114.88	117.38	2.5	4.5	01:01	43.89	1.6	0.9	0.8		
	150	113.29	115.79	2.5	4.5	01:01	43.89	1.6	0.9	0.8		
	194.18	109.76	112.26	2.5	4.25	01:01	43.89	1.6	0.9	0.5		
	200	108.26	110.76	2.5	4.75	01:01	43.89	1.6	0.9	0.5		
	200	107.97	110.47	2.5	4.75	01:01	43.89	1.6	0.9	0.5		
	250	105.68	108.18	2.5	3.5	01:01	43.89	1.6	0.9	1.4		
	264.18	105.11	107.61	2.5	3.5	01:01	43.89	1.6	0.9	1.4		

Table 6.184: (continued) Distributaries of Damodar Branch Canal

Name of canal	Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000’	Dischsrge (cusec)	V (ft/sec)	V/V0	Hyd. grad	Distance	Structure
Disty 10 BC	0	130.9	132.6	1.7	6	01:01	19.6	1.53	1.1	0.6	0	head sluice
	29.63	129.12	130.82	1.7	6	01:01	19.6	1.53	1.1	0.6		
	29.63	126.82	128.32	1.5	1.5	01:01	19.6	1.53	1.1	1.1		
	47.3	124.87	126.37	1.5	1.5	01:01	19.6	1.53	1.1	1.1		
	47.3	121.17	122.87	1.5	1.5	01:01	19.6	1.53	1.1	1		
	50	121.04	122.54	1.5	1.5	01:01	19.6	1.53	1.1	1		
	58.63	120.24	121.74	1.5	1.5	01:01	19.6	1.53	1.1	1.4		
	58.63	115.54	116.74	1.2	1.2	01:01	19.6	1.53	1.1	1.5		
	100	109.61	110.81	1.2	1.2	01:01	19.6	1.53	1.1	1.5		
	150	103.16	104.36	1.2	1.2	01:01	19.6	1.53	1.1	1.4		
	151.89	102.98	104.18	1.2	1.2	01:01	19.6	1.53	1.1	1.4		
Disty 11 BC	0	111	115	4	8	01:01	87.89	1.89	0.5	0.4	0.75	head regulator
	40.52	109.38	113.38	4	8	01:01	87.89	1.89	0.5	0.4	136	regulator
	40.52	108.38	111.88	3.5	9	01:01	87.89	1.89	0.5	0.4	240	regulator
	50	108	111.5	3.5	9	01:01	87.89	1.89	0.5	0.4	292.8	regulator
	100	106	109.5	3.5	9	01:01	87.89	1.89	0.5	0.4	360.73	regulator
	130.53	104.78	108.28	3.5	9.5	01:01	87.89	1.89	0.5	0.3	392	regulator

Table 6.185: (continued) Distributaries of Damodar Branch Canal

Name of canal	Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	V/V0	Hyd. grad	Distance	Structure
	130.53	102.28	105.28	3	9	01:01	87.89	1.89	0.5	0.3	425.2	regulator
	130	101.5	104.5	3	9	01:01	87.89	1.89	0.5	0.3		
	200	99.9	102.9	3	9	01:01	87.89	1.89	0.5	0.5		
	212.43	99.5	102	2.5	9	01:01	87.89	1.89	0.5	0.4		
	230	97.65	100.15	2.5	8	01:01	87.89	1.89	0.5	0.4		
	300	95.84	98.34	2.5	8	01:01	87.89	1.89	0.5	0.15		
	350	93.2	95.7	2.5	8	01:01	87.89	1.89	0.5	1		
	400	93.05	95.55	2.5	8	01:01	87.89	1.89	0.5	1		
	430	92.61	95.11	2.5	3	01:01	87.89	1.89	0.5	0.2		
	450	90.55	92.55	2	6	01:01	87.89	1.89	0.5	0.2		
	500	87.55	89.55	2	2	01:01	87.89	1.89	0.5	0.1		
	512	86.35	88.35	2	2	01:01	87.89	1.89	0.5	0.1		
Disty 11A BC	0	94.15	95.65	1.5	5	01:01	11.62	1.19	0.89	0.5	0	head sluice
	20	94.15	95.65	1.5	2.5	01:01	11.62	1.19	0.89	0.7		
	59.9	91.75	93.25	1.5	2.5	01:01	11.62	1.19	0.89	0.7		
Disty 13 BC	0	111	115	4	6.5	01:01	1.1	NA	2.04	0.4		
	50	108.5	112	3.5	7.5	01:01	1.1	NA	1.87	0.5		

Table 6.186: (continued) Distributaries of Damodar Branch Canal

Name of canal	Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	V/V0	Hyd. grad	Distance	Structure
	66.35	107.85	111.35	3.5	7.5	01:01	1.1	NA	1.87	0.5		
	66.35	106.35	109.85	3.5	7	01:01	1.1	NA	1.87	0.5		
	100	104.67	108.17	3.5	7	01:01	1.1	NA	1.87	0.5		
	112	104.07	107.57	3.5	10	01:01	1.1	NA	1.87	0.5		
	112	103.37	106.87	3.5	10	01:01	1.1	NA	1.7	0.3		
	150	102.43	105.43	3	10	01:01	1.1	NA	1.7	0.3		
	200	100.93	103.93	3	10	01:01	1.1	NA	1.7	0.3		
	203.44	100.83	102.83	2	5	01:01	1.1	NA	1.5	0.15		
	250	100.13	102.13	2	5	01:01	1.1	NA	1.5	0.15		
	277.73	99.72	101.72	2	5	01:01	1.1	NA	1.5	0.15		
Disty 13A BC	0	100.43	102.93	2.5	6.5	01:01	1.1	NA	NA	0.5		
	50	97.93	100.43	2.5	6.5	01:01	1.1	NA	NA	0.5		
	50	96.93	99.43	2.5	5.5	01:01	1.1	NA	NA	0.3		
	100	95.23	97.73	2.5	3	01:01	1.1	NA	NA	0.5		
	120	94.23	96.73	2.5	3	01:01	1.1	NA	NA	0.5		
	120	93.98	95.48	1.5	2.5	01:01	1.1	NA	NA	0.5		
	145.75	92.69	94.19	1.5	2.5	01:01	1.1	NA	NA	0.5		

Table 6.187: Feeder canal of Damodar Branch Canal (Id:2, Node No:11-13)

Distance in chainage	Design Bed Level	Actual Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	Free Board	Distance	Structure
0	142.67	162.71	151.92	9.25	41	0.15	2400	3.25	3	0	head regulator
1.5	142.67	167.6	151.92	9.25	41	0.15	2400	3.25	3		
2.5	142.67	158.99	151.92	9.25	41	0.15	2400	3.25	3		
3.5	142.67	167.75	151.92	9.25	41	0.15	2400	3.25	3		
5	142.6	161.7	151.85	9.25	41	0.15	2400	3.25	3		
10	142.52	161.16	151.77	9.25	41	0.15	2400	3.25	3		
15	142.45	160.41	151.7	9.25	41	0.15	2400	3.25	3		
20	142.37	164.01	151.62	9.25	41	0.15	2400	3.25	3		
25	142.3	159.06	151.55	9.25	41	0.15	2400	3.25	3		
30	142.22	158.6	151.47	9.25	41	0.15	2400	3.25	3		
30.7	142.22	154.31	151.47	9.25	41	0.15	2400	3.25	3		
31	142.22	161.66	151.47	9.25	41	0.15	2400	3.25	3		
35	142.15	157.67	151.4	9.25	41	0.15	2400	3.25	3		
40	142.07	156.89	151.32	9.25	41	0.15	2400	3.25	3		
45	142	155.44	151.25	9.25	41	0.15	2400	3.25	3		
50	141.92	155.26	151.17	9.25	41	0.15	2400	3.25	3		
55	141.92	155.99	151.17	9.25	41	0.15	2400	3.25	3		
55.15	141.83	157.34	151.08	9.25	41	0.15	2400	3.25	3		
55.75	141.83	146.17	151.08	9.25	41	0.15	2400	3.25	3		

Table 6.188: Navigation Damodar Main Canal (Id:195, Node No:371-374)

Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	V/V0	Hyd. grad	Distance	Structure
0	47.548	50.288	2.74	19.2	01:01	56.633	0.972	0.95	0.16	0	head regulator
25	47.426	50.166	2.74	19.2	01:01	56.633	0.972	0.95	0.16	272.41	syphone
50	47.305	50.045	2.74	19.2	01:01	56.633	0.972	0.95	0.16	389.14	offtake of disty 1mc
75	47.183	49.923	2.74	19.2	01:01	56.633	0.972	0.95	0.16	405.37	syphone
100	47.062	49.802	2.74	19.2	01:01	56.633	0.972	0.95	0.16	501.4	offtake of disty 2
125	46.939	49.679	2.74	19.2	01:01	56.633	0.972	0.95	0.16	636.33	syphone
150	46.817	49.557	2.74	19.2	01:01	56.633	0.972	0.95	0.16	721.83	syphon
175	46.695	49.435	2.74	19.2	01:01	56.633	0.972	0.95	0.16	725.99	offtake
200	46.573	49.313	2.74	19.2	01:01	56.633	0.972	0.95	0.16	753.18	dy no 3 offtake
225	46.451	49.191	2.74	19.2	01:01	56.633	0.972	0.95	0.16	828.79	regulator
250	46.327	49.067	2.74	19.2	01:01	56.633	0.972	0.95	0.16	891	dy no 4 and 4A offtake
275	46.21	48.95	2.74	19.2	01:01	56.633	0.972	0.95	0.16	953	dy 4B offtake
275	46.127	48.867	2.74	19.2	01:01	56.633	0.972	0.95	0.16	1003	dy 5 mc offtake
300	45.906	48.646	2.74	19.2	01:01	56.633	0.972	0.95	0.16	1005.01	regulator

Table 6.189: (continued) Navigation Damodar Main Canal (Id:195, Node No:371-374)

Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	V/V0	Hyd. grad	Distance	Structure
325	45.785	48.525	2.74	19.2	01:01	56.633	0.972	0.95	0.16	1103	offtake
350	45.664	48.404	2.74	19.2	01:01	56.633	0.972	0.95	0.16	1103.43	regulator
375	45.543	48.283	2.74	19.2	01:01	56.633	0.972	0.95	0.16	1265.28	kurmun regulator
400	45.422	48.162	2.74	19.2	01:01	56.633	0.972	0.95	0.16	1349	fagupur regulator
405.37	45.396	48.136	2.74	19.2	01:01	56.633	0.972	0.95	0.16		
405.37	45.246	48.066	2.82	18.288	01:01	56.633	0.95	1.12	0.16		
465.37	45.003	47.823	2.82	18.288	01:01	56.633	0.95	1.12	0.16		
505.37	44.744	47.564	2.82	18.288	01:01	56.633	0.95	1.12	0.16		
555.37	44.517	47.337	2.82	18.288	01:01	56.633	0.95	1.12	0.16		
605.37	44.247	47.067	2.82	18.288	01:01	56.633	0.95	1.12	0.16		
655.37	44.013	46.833	2.82	18.288	01:01	56.633	0.95	1.12	0.15		
705.37	43.803	46.623	2.82	18.288	01:01	56.633	0.95	1.12	0.15		
725.99	43.691	46.511	2.82	18.288	01:01	56.633	0.95	1.12	0.15		
725.99	44.072	46.51	2.438	12.192	01:01	56.633	0.954	1.02	0.15		
736.54	44.005	46.443	2.438	12.192	01:01	56.633	0.954	1.02	0.15		
736.54	42.98	45.418	2.438	12.192	01:01	33.979	0.954	1.02	0.25		

Table 6.190: (continued) Navigation Damodar Main Canal (Id:195, Node No:371-374)

Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	V/V0	Hyd. grad
755.37	42.823	45.261	2.438	12.192	01:01	33.979	0.954	1.02	0.25
805.37	42.443	44.881	2.438	12.192	01:01	33.979	0.954	1.02	0.25
833.79	42.226	44.664	2.438	12.192	01:01	33.979	0.954	1.02	0.25
833.79	40.398	42.836	2.438	12.192	01:01	33.979	0.954	1.02	0.25
856.37	40.233	42.671	2.438	12.192	01:01	33.979	0.954	1.02	0.25
859.29	40.21	42.648	2.438	12.192	01:01	33.979	0.954	1.02	0.25
859.29	38.982	41.42	2.438	12.192	01:01	33.979	0.954	1.02	0.25
905.37	38.633	41.071	2.438	12.192	01:01	33.979	0.954	1.02	0.25
955.37	38.262	40.7	2.438	12.192	01:01	33.979	0.954	1.02	0.25
1005.01	37.874	40.312	2.438	12.192	01:01	33.979	0.954	1.02	0.25
1005.01	36.665	39.103	2.438	12.192	01:01	33.979	0.954	1.02	0.25
1005.37	36.662	39.1	2.438	12.192	01:01	33.979	0.954	1.02	0.25
1055.37	36.271	38.709	2.438	12.192	01:01	33.979	0.954	1.02	0.25
1103.4	35.905	38.343	2.438	12.192	01:01	33.979	0.954	1.02	0.25
1103.4	34.836	37.274	2.438	12.192	01:01	33.979	0.954	1.02	0.25
1105.37	34.823	37.261	2.438	12.192	01:01	33.979	0.954	1.02	0.25
1155.37	34.442	36.88	2.438	12.192	01:01	33.979	0.954	1.02	0.25
1205.37	34.061	36.499	2.438	12.192	01:01	33.979	0.954	1.02	0.25
1255.37	33.68	36.118	2.438	12.192	01:01	33.979	0.954	1.02	0.25
1265.28	33.6	36.038	2.438	12.192	01:01	33.979	0.954	1.02	0.25
1265.28	32.53	34.968	2.438	12.192	01:01	33.979	0.954	1.02	0.25
1305.37	32.232	34.67	2.438	12.192	01:01	33.979	0.954	1.02	0.25
1349.75	31.894	34.332	2.438	7.62	01:01	33.979	0.954	1.02	0.25
1349.75	30.369	32.502	2.133	6.096	01:01	33.979	0.966	0.92	0.4
1355.57	30.327	32.46	2.133	6.096	01:01	33.979	0.966	0.92	0.4
1379.14	30.037	32.17	2.133	6.096	01:01	33.979	0.966	0.92	0.4
1379.14	28.665	30.798	2.133	6.096	01:01	33.979	0.966	0.92	0.4
1396.01	28.462	30.595	2.133	6.096	01:01	33.979	0.966	0.92	0.4

Table 6.191: Distributaries of Damodar Main Canal

Name of canal	Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000’	Dischsrge (cusec)	V (ft/sec)	V/V0	Hyd. grad	Distance	Structure
Disty 2 MC	0	149.95	NA	5	6	01:01	75	1.36	0.6	0.15	0	head sluice
	50	149.2	NA	5	5	01:01	75	1.36	0.6	0.15	65	syphon aqueduct
	65	148.98	NA	5	5	01:01	75	1.36	0.6	0.15	94.5	offtake of disty 2A of MC
	65	149.48	NA	4.5	5	01:01	75	1.36	0.6	1	95	regulator
	95	149	NA	4.5	5	01:01	75	1.36	0.6	1	138	regulator
	95	149.28	NA	3	3	01:01	75	1.36	0.6	1	202	regulator
	100	148.78	NA	3	3	01:01	75	1.36	0.6	0.8		
	117	147.68	NA	3	3	01:01	75	1.36	0.6	0.8		
	138	144.98	NA	3	3	01:01	75	1.36	0.6	0.8		
	138	139.98	NA	3	3	01:01	75	1.36	0.6	0.4		
	150	139.02	NA	3	3	01:01	75	1.36	0.6	0.4		
	200	135.9	NA	3	3	01:01	75	1.36	0.6	1		
	208	135.58	NA	3	3	01:01	75	1.36	0.6	1		
	208	136.08	NA	2	2	01:01	75	1.36	0.6	1		

Table 6.192: (continued) Distributaries of Damodar Main Canal

Name of canal	Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	V/V0	Hyd. grad	Distance	Structure
	228	134.08	NA	2	2	01:01	75	1.36	0.6	1		
Disty 2A MC	0	150.53	153.53	3	3	01:01	20	1.11	0.65	0.2	3.5	head sluice
	3.5	150.4	153.4	3	3	01:01	20	1.11	0.65	0.2	15.15	syphon aqueduct
	3.5	150.15	153.15	3	3	01:01	20	1.11	0.65	0.2	67.75	regulator
	48.5	149.26	152.26	3	3	01:01	20	1.11	0.65	0.2		
	48.5	149.76	152.76	3	3	01:01	20	1.11	0.65	0.2		
	50	149.73	152.23	2.5	3	01:01	20	1.11	0.65	0.5		
	84	149.05	151.55	2.5	3	01:01	20	1.11	0.65	0.5		
	84	149.35	151.35	2	2	01:01	20	1.11	0.65	0.5		
	94.75	149.02	151.02	2	2	02:01	20	1.11	0.65	0.5		
Disty 3 MC	0	142.05	145.55	3.5	5	NA	4.66	1.56	0.8	0.3	14	syphone and head sluice
	9.2	142.05	145.55	3.5	5	NA	4.66	1.56	0.8	0.3	51.64	regulator
	9.2	142.05	145.55	3.5	5	NA	4.66	1.56	0.8	0.3	108	regulator
	46.64	140.65	144.15	3.5	5	NA	4.66	1.56	0.8	0.3	139.64	regulator
	46.64	141.15	144.15	3	4.5	NA	4.66	1.56	0.8	0.5		
	82.339	139.31	142.31	3	4.5	NA	4.66	1.56	0.8	0.5		

Table 6.193: (continued) Distributaries of Damodar Main Canal

Name of canal	Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000’	Dischsrge (cusec)	V (ft/sec)	V/V0	Hyd. grad	Distance	Structure
	82.339	139.81	141.81	2	4	NA	4.66	1.56	0.8	0.8		
	100	138.43	140.43	2	4	NA	4.66	1.56	0.8	0.8		
	139.64	135.31	137.31	2	4	NA	4.66	1.56	0.8	0.8		
	139.64	135.31	137.31	2	4	NA	4.66	1.56	0.8	0.8		
	139.64	134.81	136.81	2	2	NA	4.66	1.56	0.8	1		
	150	133.71	135.71	2	2	NA	4.66	1.56	0.8	1		
	168.64	131.91	133.91	2	2	NA	4.66	1.56	0.8	1		
Disty 4 MC	0	130	133	3	4	01:01	25.6	1.21	0.71	0.15	0.6	syphon, head sluice
	10	128.52	131.02	2.5	3	01:01	11	1.21	0.71	0.15		
	41.73	127.9	130.4	2.5	3	01:01	12	1.21	0.71	0.15		
Disty 4A MC	0	129.09	131	2	3	01:01	8.5	0.85	0.64	0.2	0	head sluice
	31	128.4	130.4	2	3	01:01	8.5	0.85	0.64	0.2		
Disty 4B MC	0	128.33	131.83	3.5	5	01:01	35.3	1.38	0.84	0.15	0	syphon, head sluice
	50	127.58	131.08	3.5	5	01:01	35.3	1.38	0.84	0.15	69.07	regulator
	69.07	127.3	130.8	3.5	5	01:01	35.3	1.38	0.84	0.15	156.25	regulator

Table 6.194: (continued) Distributaries of Damodar Main Canal

Name of canal	Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000'	Dischsrge (cusec)	V (ft/sec)	V/V0	Hyd. grad	Distance	Structure
	69.07	125.8	128.3	2.5	4	01:01	35.3	1.38	0.84	0.5		
	100	124.25	126.75	2.5	4	01:01	35.3	1.38	0.84	0.5		
	125.07	123	125.5	2.5	4	01:01	35.3	1.38	0.84	0.5		
	125.07	123.5	125.5	2	4	01:01	35.3	1.38	0.84	0.5		
	150	122.25	124.25	2	4	01:01	35.3	1.38	0.84	0.5		
	156.4	121.94	123.94	2	4	01:01	35.3	1.38	0.84	0.5		
Disty 4C MC	0	125.24	130.24	5	5	01:01	57.6	1.15	0.7	0.6		
	3.1	124.78	129.78	5	4	01:01	57.6	1.15	0.7	0.6		
	3.1	124.28	129.28	5	4	01:01	57.6	1.15	0.7	0.6		
	50	127.4	132.4	5	4	01:01	57.6	1.15	0.7	0.4		
	100	119.32	124.32	5	4	01:01	57.6	1.15	0.7	0.4		
	105	119.14	124.14	5	4	01:01	57.6	1.15	0.7	0.5		
	150	116.89	121.89	5	3	01:01	57.6	1.15	0.7	0.5		
	200	114.86	119.86	5	3	01:01	57.6	1.15	0.7	0.5		
	243.44	112.74	117.74	5	3	01:01	57.6	1.15	0.7	0.5		

Table 6.195: (continued) Distributaries of Damodar Main Canal

Name of canal	Distance in chainage	Design Bed Level	F.S.L	F.S.D (ft)	Bed width (ft)	Slope in 1000’	Dischsrge (cusec)	V (ft/sec)	V/V0	Hyd. grad	Distance	Structure
	243.44	113.24	118.24	5	2	01:01	57.6	1.15	0.7	0.5		
	250	112.91	117.91	5	2	01:01	57.6	1.15	0.7	0.5		
	299.34	110.45	115.45	5	2	01:01	57.6	1.15	0.7	0.5		
Disty MC 5	0	120.24	122.74	2.5	6.5	01:01	37.4	1.66	0.95	5	0	head sluice
	20.55			2.5	5	01:01	37.4	1.66	0.95	7		
	50	117.15	119.63	2.5	4	01:01	37.4	1.66	0.95	7		
	58.3	116.33	119.05	2.5	4	01:01	37.4	1.66	0.95	7		
Disty MC 7	0	105.05		1.5		01:01	10	1.25	0.9	1	0	head sluice
	3	107.06		1.75		01:01	10	1.25	0.9	0.81		
	46.87	101.95		1.75		01:01	10	1.25	0.9	0.81		
	46.87	100.87		1.5		01:01	10	1.25	0.9	0.81		
	50	100.68		1.5		01:01	10	1.25	0.9	0.6		
	83.45	99.28		1.5		01:01	10	1.25	0.9	0.25		

Chapter 7

Integrated simulation of canal network flow and groundwater flow models

7.1 Overview

The main objective of this work is development of integrated model that can simulate the different processes of basin irrigation by solving the relevant differential equations using numerical procedures. This chapter combines the individual simulation models described in the previous chapters (on channel flow, basin flooding, unsaturated flow and groundwater movement) into one integrated framework for carrying out simulation runs for a given basin irrigation scenario. It will be assumed that the input parameters would include: (1) the inflow to the field to be conveyed by the main watercourse channel and distributed into its branches and further delivered to the basin cells into which the field is divided; (2) the evapotranspiration rate of the crop being grown in the fields; (3) precipitation, if any, on the basin cells, (4) the soil parameters as required for the unsaturated and groundwater (saturated) flow model; and (5) the hydraulic boundary conditions along the periphery of the domain for simulating the groundwater flow models.

The computation strategy of the integrated model may also be elaborated here for the ease of understanding. Overall, the model is run for the specified time of simulation in steps of smaller time intervals. As may be appreciated, the processes integrated in this model require different minimum time steps for their individual convergence. The smallest of these, which also governs the total time of simulation, is that required for solving the unsaturated flow equation -requiring time steps of the order of seconds. The next is the one-dimensional flow in the channel network, requiring time steps of the order of minutes. The basin to basin flow movement computation requires slightly relaxed time step, of the order of 10 minutes. Finally the groundwater flow simulation model is run with time steps of the order of a day or some suitable fraction.

The computation starts with the specified inflow (which could be a function of time), with the channel network flow model estimating the outflows from the different unregulated field outlets. The basin flow model, already loaded with the evapotranspiration and rainfall values, if any, picks up these canal flow inputs and proceeds with the calculations of inter-cell flow movement, simultaneously evaluating the loss of water by infiltration. The depths of water in the flooded basin cells are considered as the pressure head conditions at the upper boundary for the computational cells of the one-dimensional unsaturated flow computation domain in each basin. For the basin cells without any standing water, the upper boundary condition applied is of the flux type, with the evapotranspiration rate being applied as the negative inflow and rainfall (if at all) as the positive inflow for the respective cell.

It may be added here that the model framework is such that it does not subtract the infiltration loss computed for individual cells to update the depths of water in the respective cells for a given iterative step of computation. This may be considered a drawback, but it is assumed that the infiltration rate is generally small compared to the surface flow rate and does not affect substantially the depth of water flooding the basins. Although the computations could have been carried out iteratively, by running the basin flood model and the unsaturated model in sequence repeatedly within a time step, it is felt that the added time required may not be worth the effort. Anyway, the depths of standing water in the basins are updated in the next round of computations undertaken for the subsequent time step.

The unsaturated flow model also computes the outflows from bottom boundaries of the vertical soil columns below each cell. These values are accepted as inputs for the groundwater flow simulation model. The model also considers a sink term for the cells that require pumping to meet the respective evapotranspiration requirements. For situations considering no crop being grown, this sink term does not apply to the groundwater model.

The aforesaid steps are repetitively carried out, progressing in time, till the user specified time of simulation is reached.

7.2 Illustrative examples for the integrated model

In order to demonstrate the performance of the proposed model, an illustrative study area is chosen as shown in Figures 7.1 and 7.2. As may be observed from the figures, the two regions are similar and, in fact, represent the same plot of land used as an example in Chapter 3. The channel network of Figure 7.2, however, has one of the branches blocked. Apart from this the water channel and land surface gradient features are similar to those mentioned in Chapter 3. The subdivision of the field is also similar, with 348 basin cells discretising the domain for running with both the surface as well as the groundwater models. The basin cells are assumed to have a uniform bund height of 50 *mm*. Some of the cells in Figures 7.1and 7.2 are shaded and marked, where the elevations of the unconfined groundwater table (measured above an arbitrary datum) are noted for further processing. The groundwater aquifer is assumed to have the following boundary conditions defined: (1) on the East and West boundaries, the head of water (measured above the datum) remains steady at 26 m and 27 m respectively, and (2) the North and South boundaries are impervious. The unsaturated zone is assumed to be isotropic and homogeneous. Initially the unsaturated zone soil is considered to be near saturation with a uniform pressure head of -10 cm throughout the soil profile. van Genuchten soil water retention model is considered with the following model parameters, n =1.31 and α =0.025. The saturated and residual water contents are taken as 0.46 and 0.083 respectively. Saturated hydraulic conductivity of the unsaturated zone and saturated zone is considered to be 0.37 m/day. Specific yield of the unconfined aquifer is taken as 0.38. For all the scenarios the saturated zone and unsaturated zone soil properties are kept uniform for all triangular basins. With the above defined parameters, the two scenarios are experimented each for the two plots

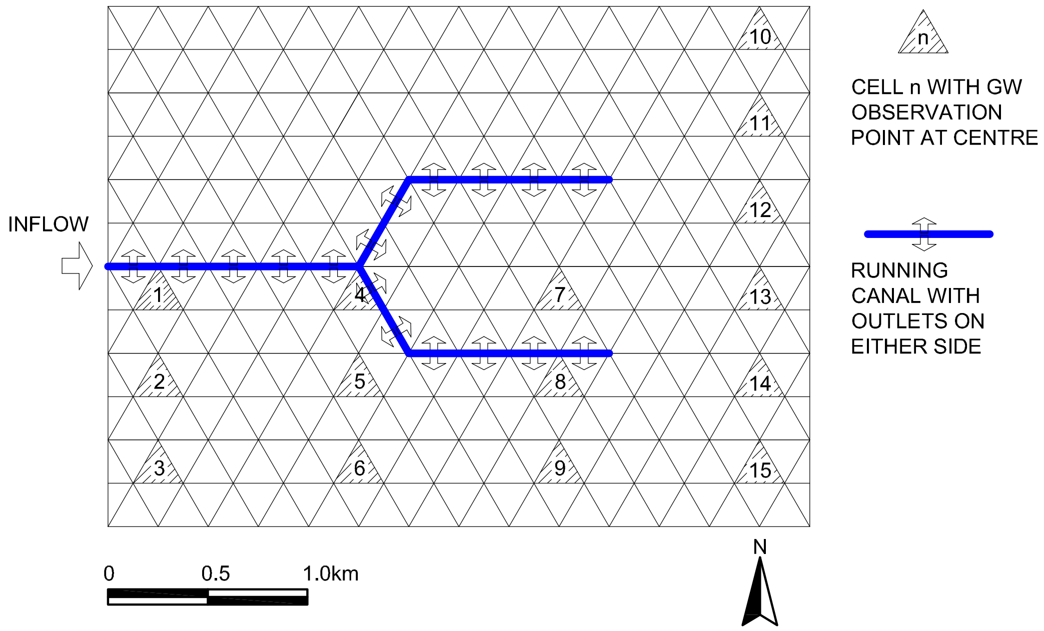


Figure 7.1: Illustrative study area (with channel network 1)

shown in Figures 7.1 and 7.2. In the first two tests (referred to further on as Scenario I and II respectively), the plot of Figure 7.1 is considered with a canal flow of 30 m^3/s. For the next two tests (Scenario III and IV respectively), the plot of Figure 7.2 is considered with the canal flow assumed as 20 m^3/s. Scenarios I and III assume that there is no crop growing in the fields and in Scenarios II and IV, a crop requiring 6 mm per day of water is assumed to be growing. In all the cases, the canal is assumed to run only for three days at a stretch from the beginning, beyond which the flow to the plots is stopped. The computations proceed with an initial steady state groundwater profile for all the cells based upon the prescribed boundary conditions for the aquifer (Figure 7.3). As the computations proceed in time, the groundwater head is noted at the centroid of the cells marked in Figures 7.1 and 7.2 for presentation in the analysis. The simulations are carried out till the end of the sixth day from the start.

7.2.1 Scenario-I

The results of the simulations carried out for the conditions as appropriate to Scenario I are presented in this section. These are: (1) surface inundation maps showing the flooding sequence of the cells (Figures 7.4 through 7.8); (b) surface plot of the time-varying groundwater table

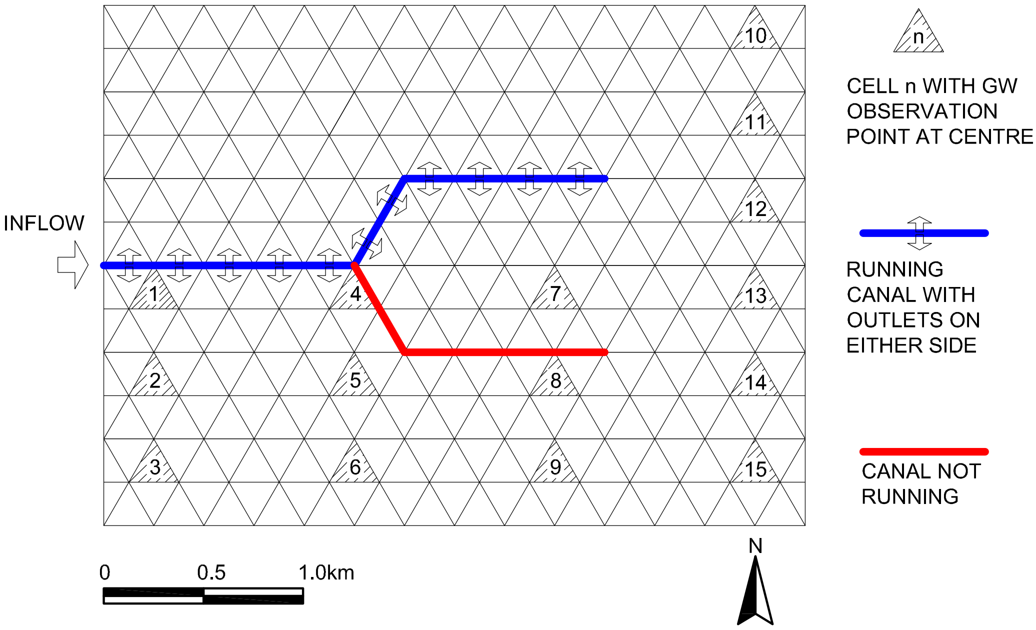


Figure 7.2: Illustrative study area (with channel network 2)

(Figure 7.9); and (c) plot of groundwater levels at the observation points indicated in Figure 7.1 (presented in Figures 7.10 through 7.14). In the surface inundation graphics, the "wet" cells are coloured dark; the "partially wet cells" light gray, with the cells without any standing water not shaded.

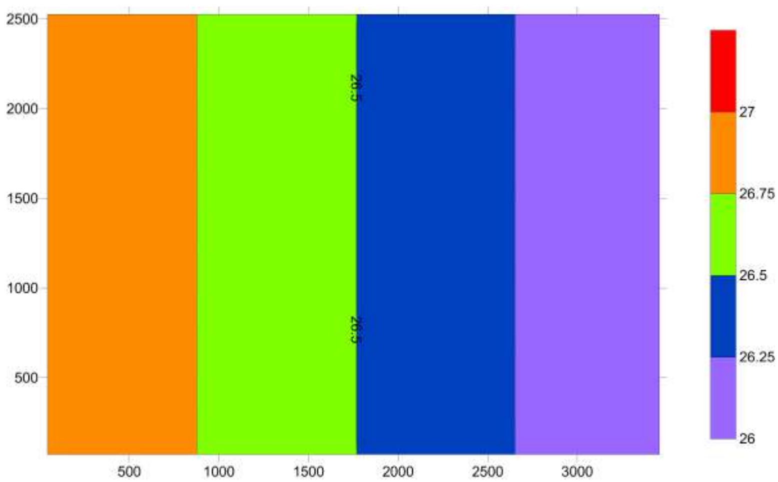


Figure 7.3: Steady state groundwater contour

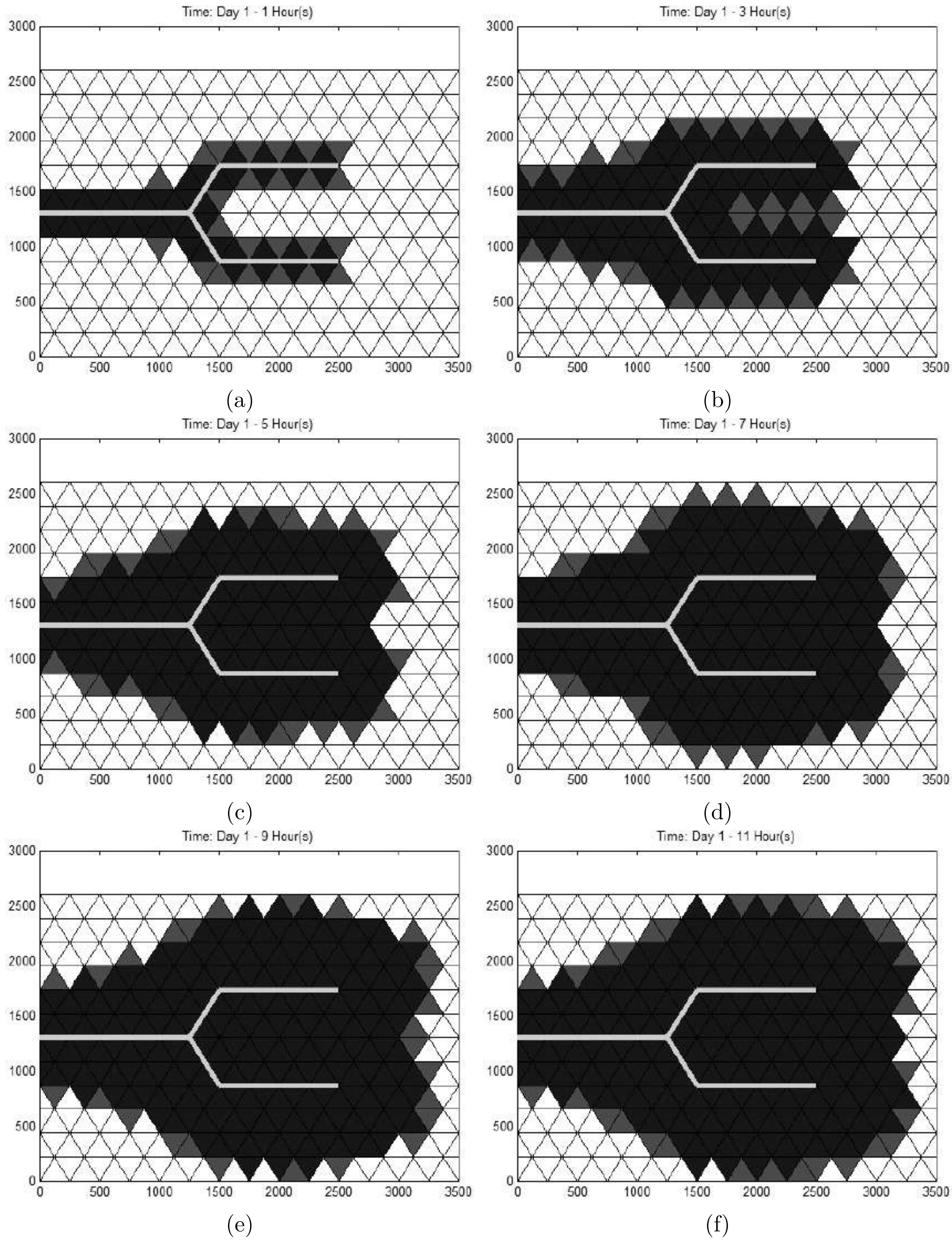


Figure 7.4: Progress of basin cell inundation (Scenario-I, Day 1, Period 1)

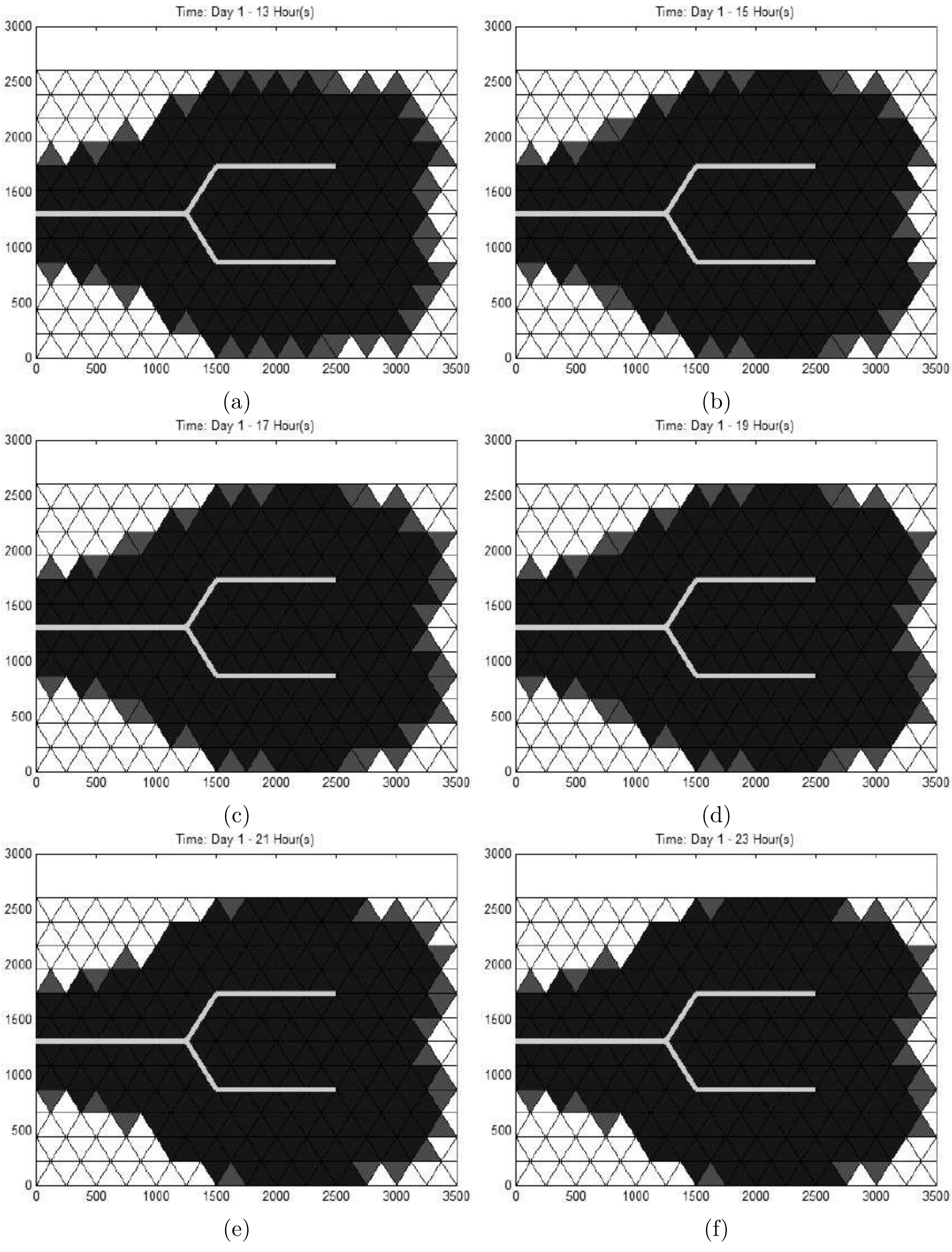


Figure 7.5: Progress of basin cell inundation (Scenario-I, Day 1, Period 2))

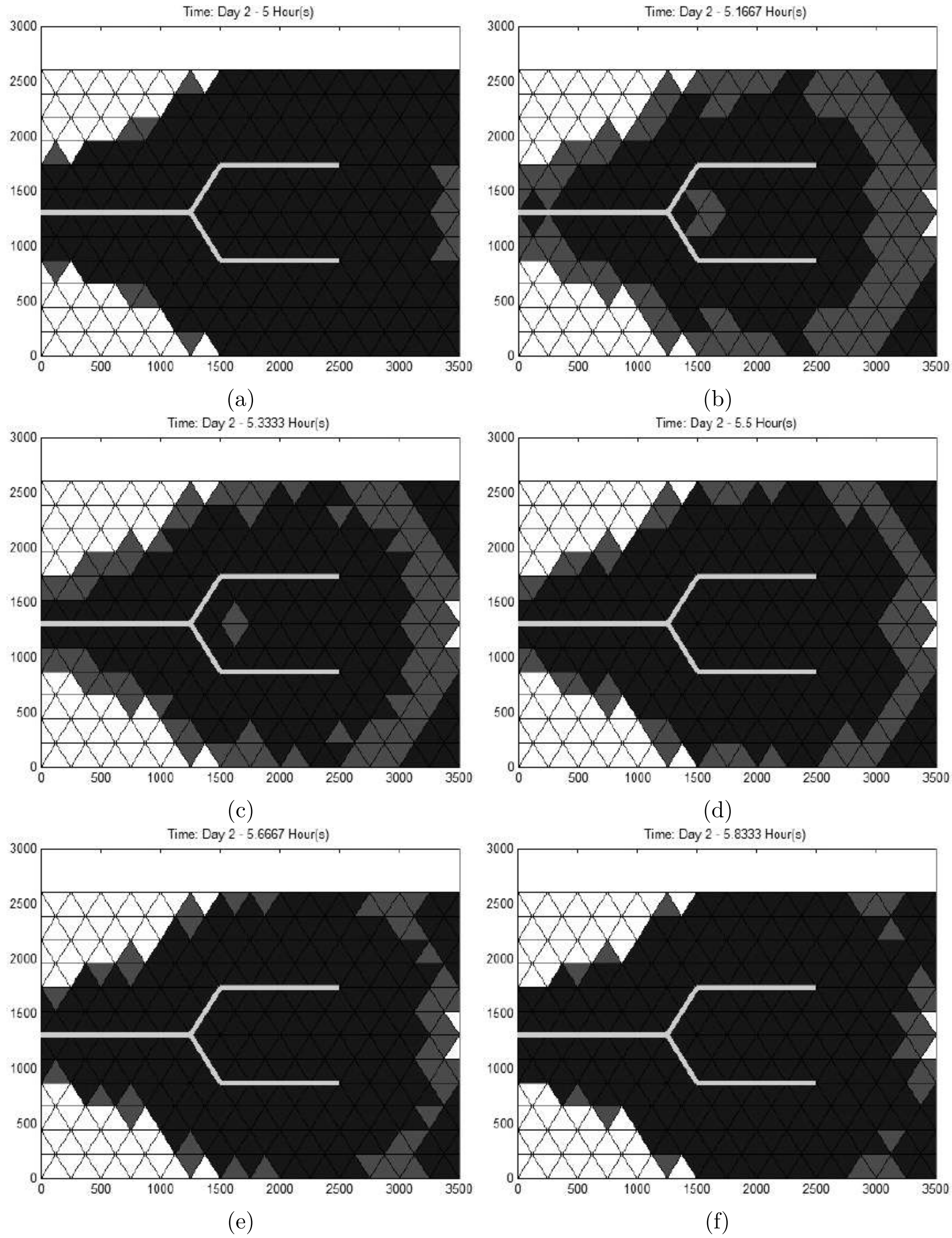


Figure 7.6: Progress of basin cell inundation (Scenario-I, Day 2)

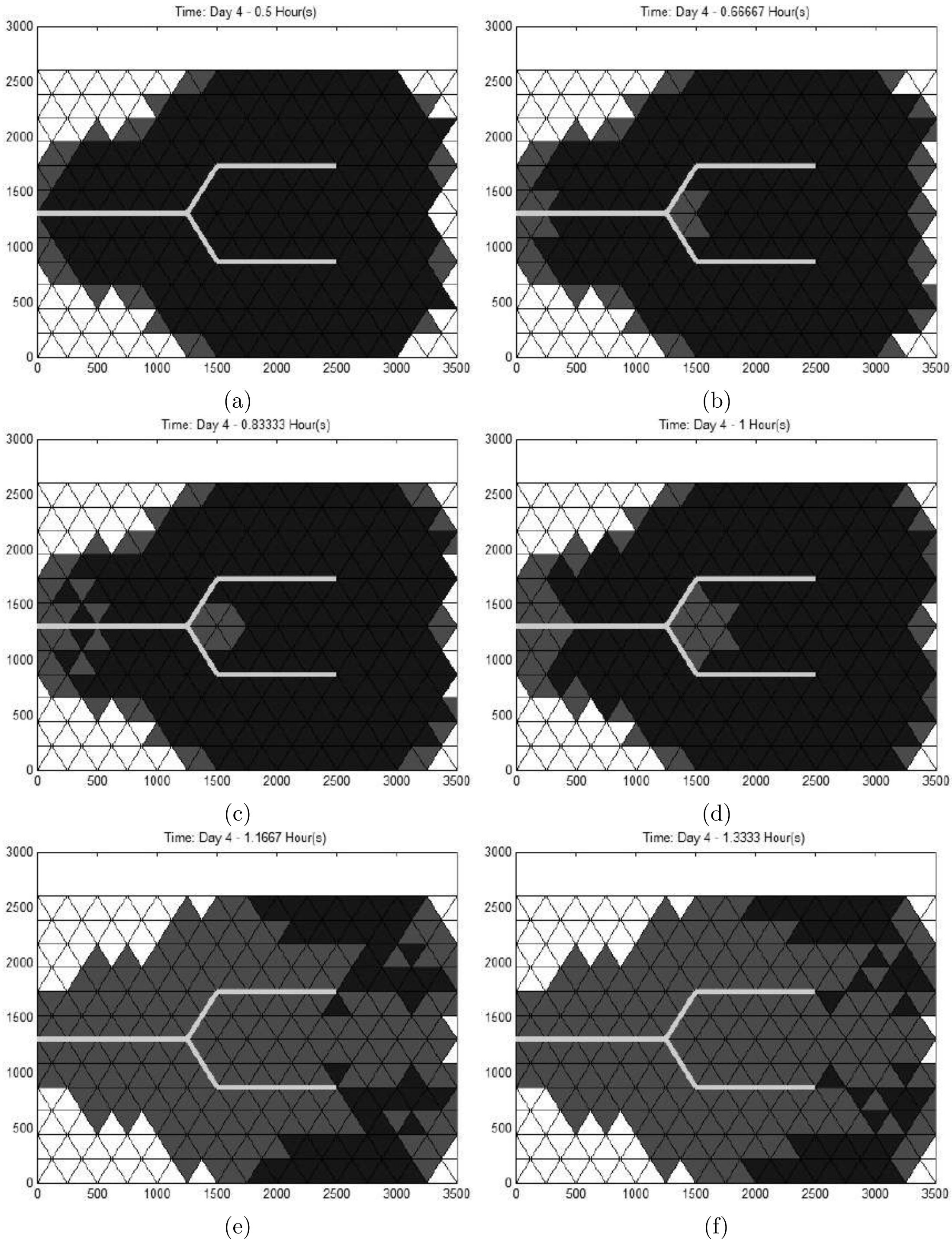


Figure 7.7: Progress of basin cell inundation (Scenario-I, Day 4, Period 1)

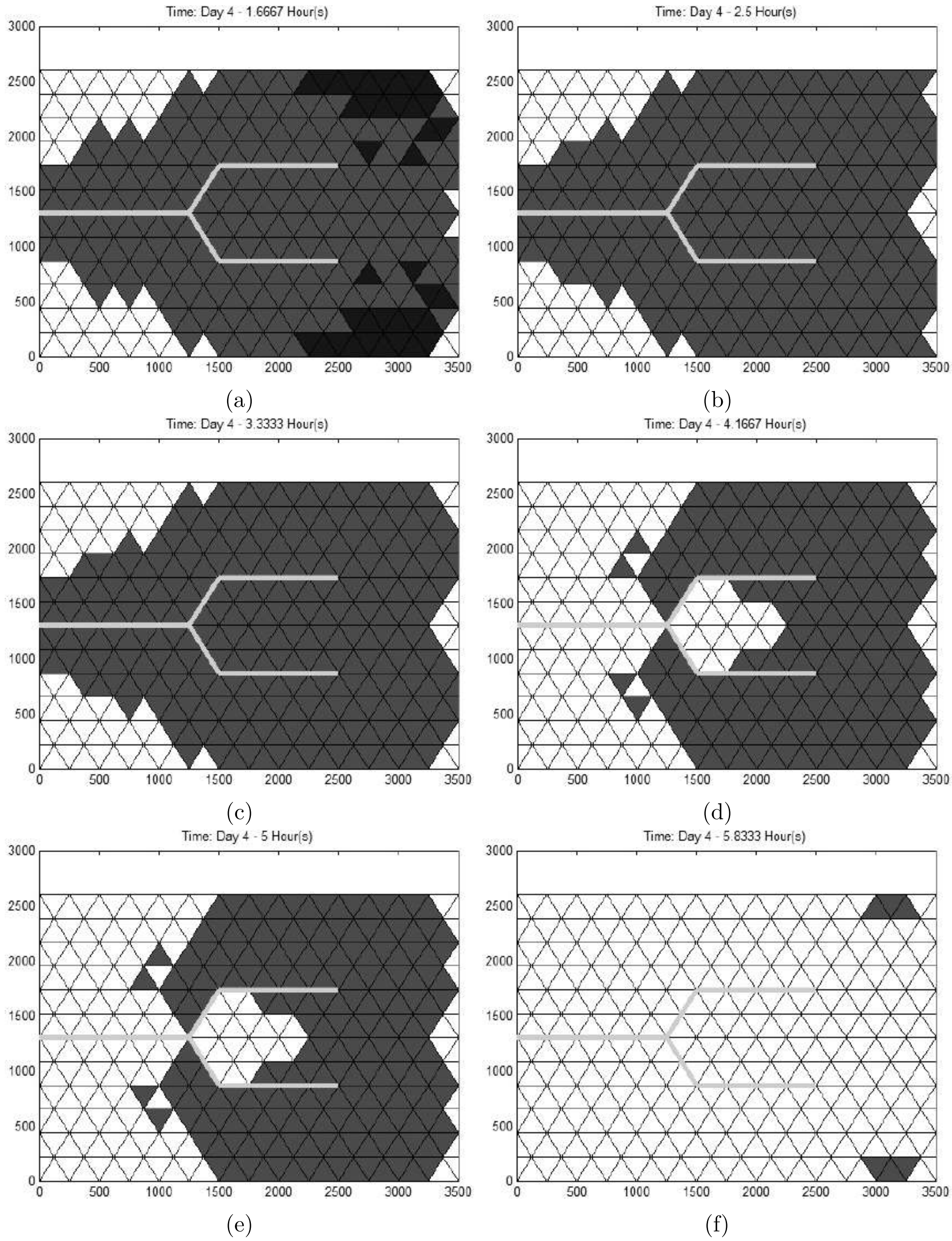
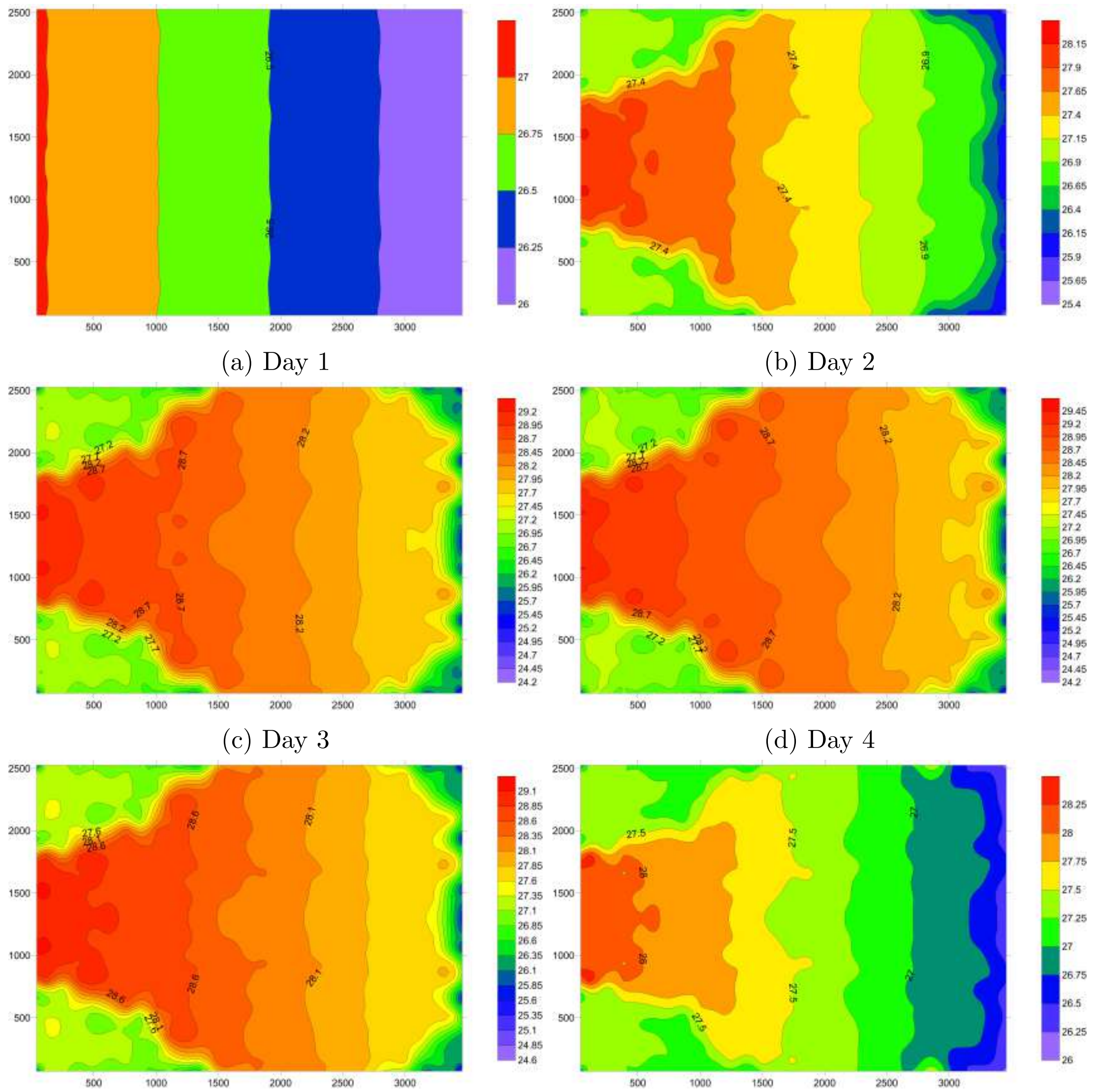


Figure 7.8: Progress of basin cell inundation (Scenario-I, Day 4, Period 2)



(a) Day 1 (b) Day 2

(c) Day 3 (d) Day 4

(e) Day 5 (f) Day 6

Figure 7.9: Surface plots of groundwater table (Scenario I)

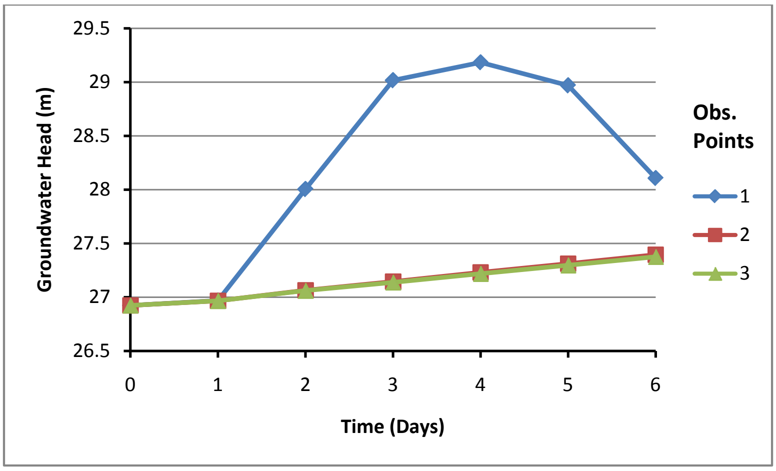


Figure 7.10: Groundwater head plot with every passing day for observation points 1, 2, and 3

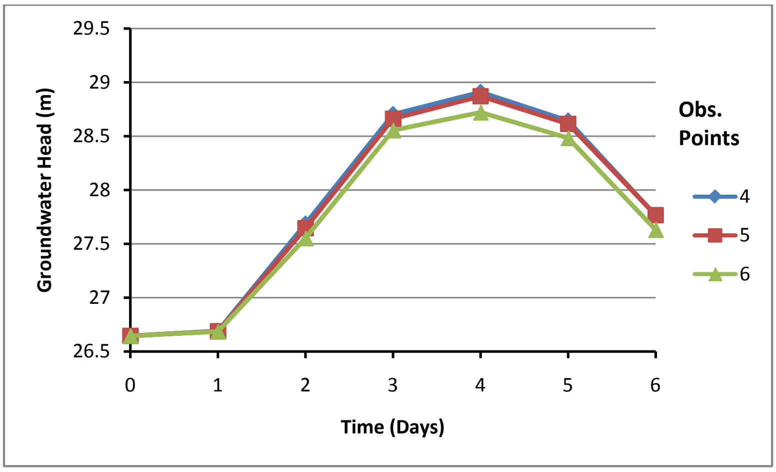


Figure 7.11: Groundwater head plot (with time in days) for observation points 4, 5, and 6

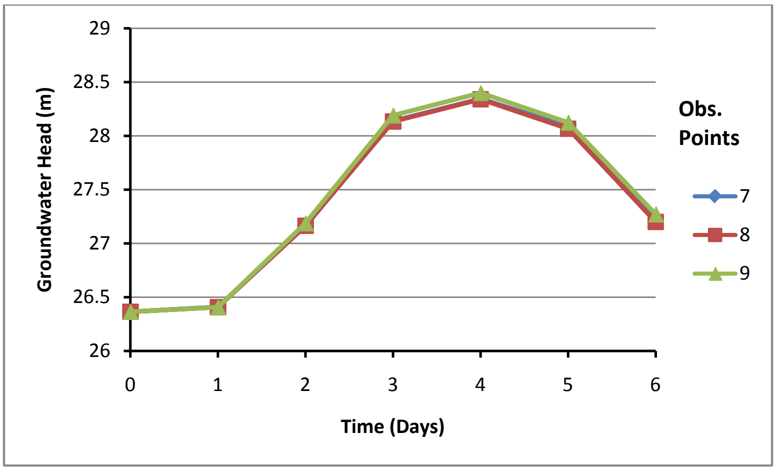


Figure 7.12: Groundwater head plot (with time in days) for observation points 7, 8, and 9

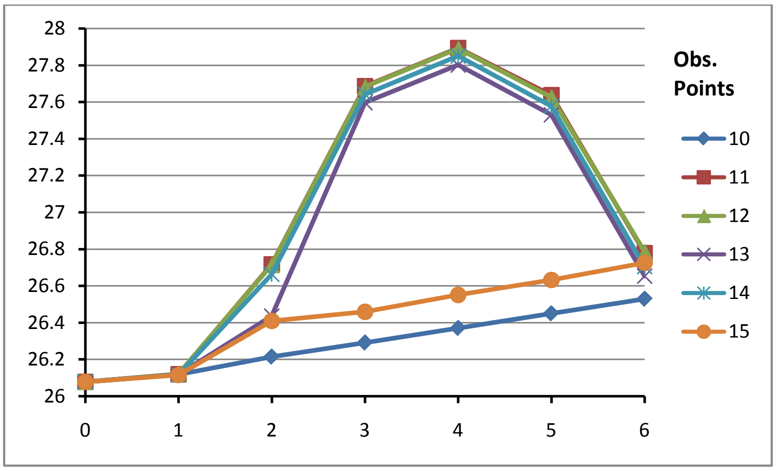


Figure 7.13: Groundwater head plot (with time in days) for observation points 10 to 15

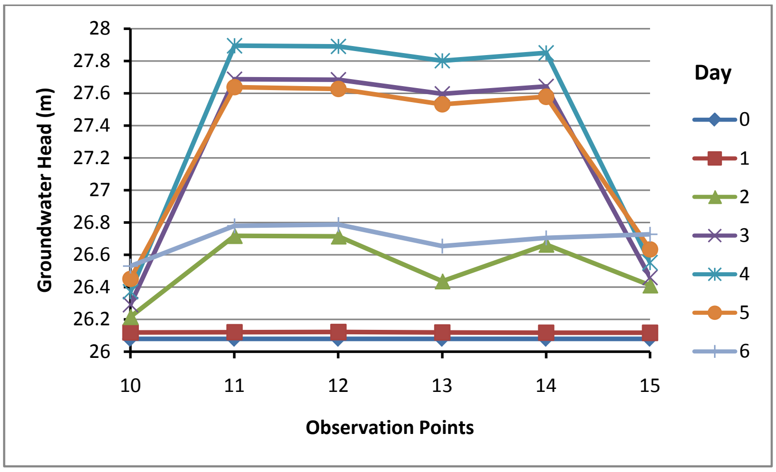
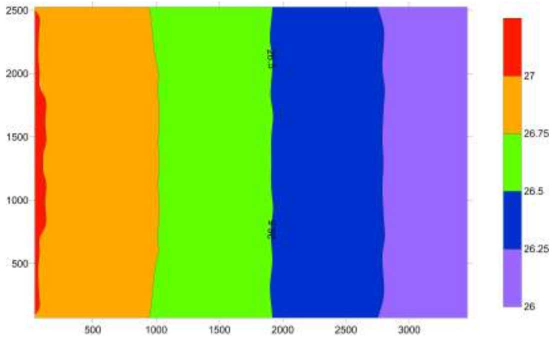


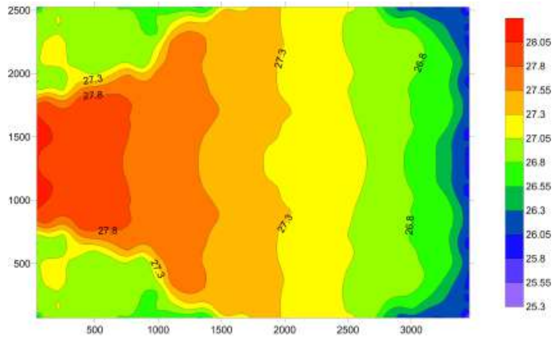
Figure 7.14: Groundwater head variation across a section passing through observation points 10 to 15, plotted at interval of days

7.2.2 Scenario-II

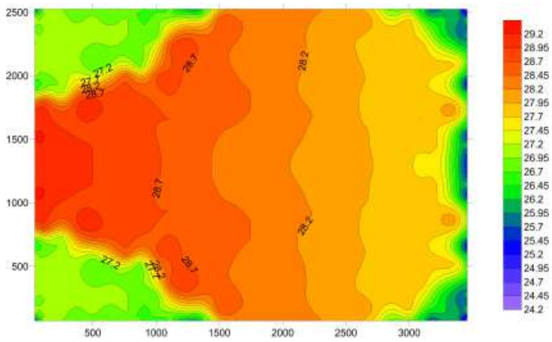
The computation results for Scenario II are presented in this section. Since the progress of the inundation front from basin to basin as well as the general rise and fall patterns of groundwater table are not very different from those simulated during Scenario I, these are omitted. Instead, the following graphs are included: (a) surface plot of the time-varying groundwater table (Figure 7.15), and (b) comparative graphs showing the difference in groundwater elevation for cells 3, 6, 9 and 15 (Figures 7.16 to 7.19). These cells are close to the periphery of the field and illustrates the effect of groundwater extraction due to pumping most prominently.



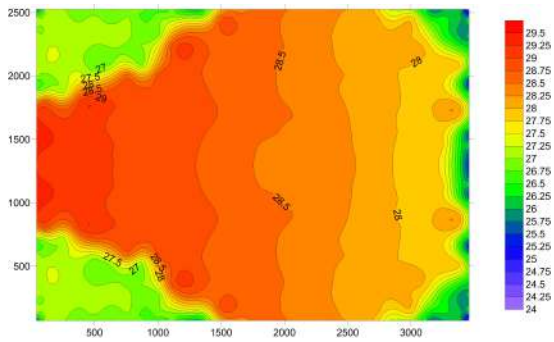
(a) Day 1



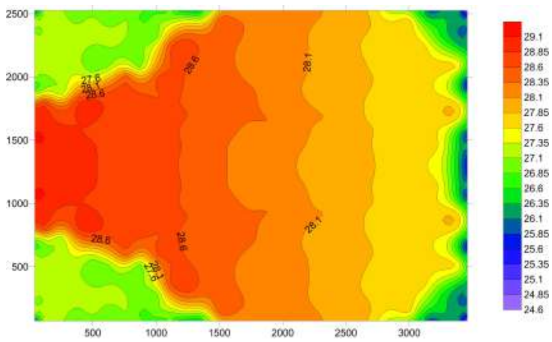
(b) Day 2



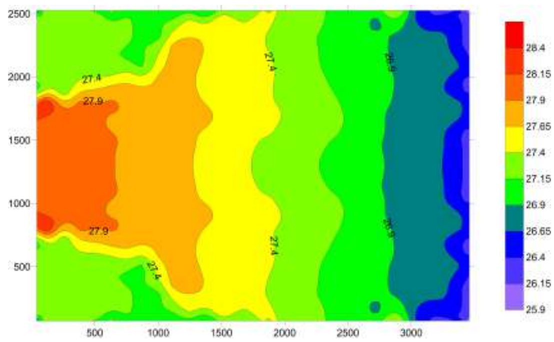
(c) Day 3



(d) Day 4



(e) Day 5



(f) Day 6

Figure 7.15: Surface plots of groundwater table (Scenario II)

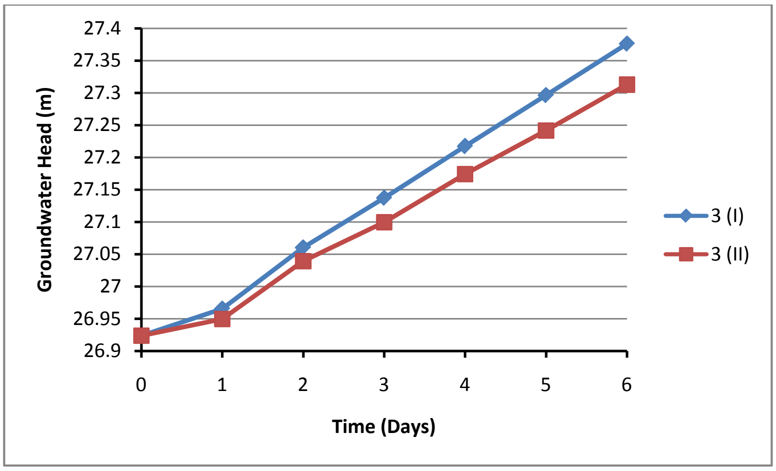


Figure 7.16: Groundwater head comparison at cell 3 for Scenario I [graph 3 (I)] and Scenario II [graph 3 (II)]

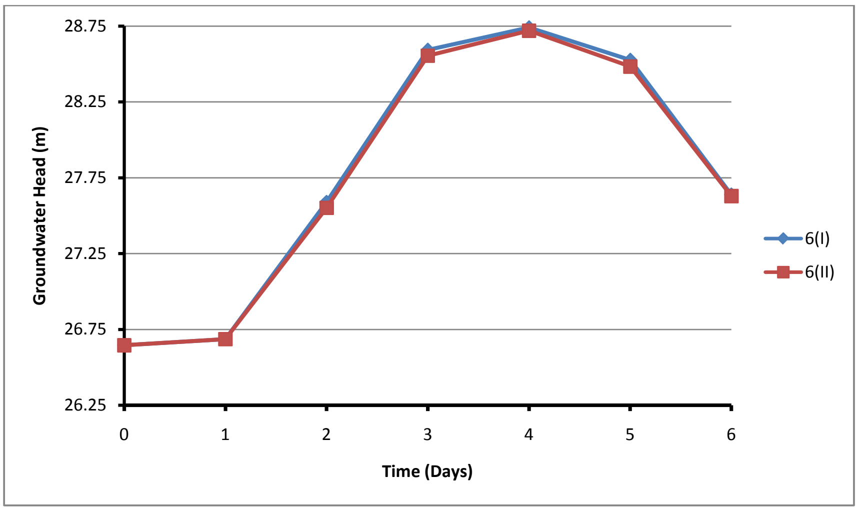


Figure 7.17: Groundwater head comparison at cell 6 for Scenario I [graph 6 (I)] and Scenario II [graph 6 (II)]

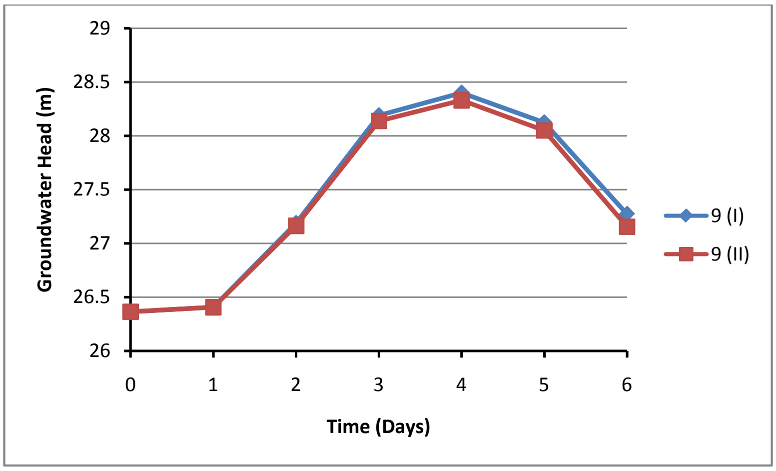


Figure 7.18: Groundwater head comparison at cell 9 for Scenario I [graph 9 (I)] and Scenario II [graph 9 (II)]

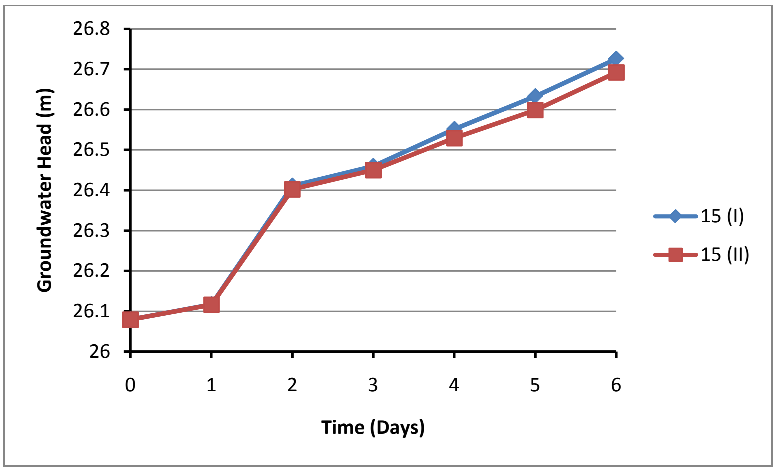


Figure 7.19: Groundwater head comparison at cell 15 for Scenario I [graph 15 (I)] and Scenario II [graph 15 (II)]

7.2.3 Scenario-III

The simulation results for Scenario III are presented here. As for Scenario I, the following graphic images are presented: (1) progress of surface inundation through the basin cells (Figure 7.20 through 7.23); (b) surface plot of the time-varying groundwater table (Figure 7.24); (c) plot of groundwater levels at the observation points (Figure 7.25 through 7.29). In the surface inundation graphics, as in the previous cases, a dark shade marks the "wet" cells; light gray, the "partially wet cells", and the remaining are those which are without any standing water.

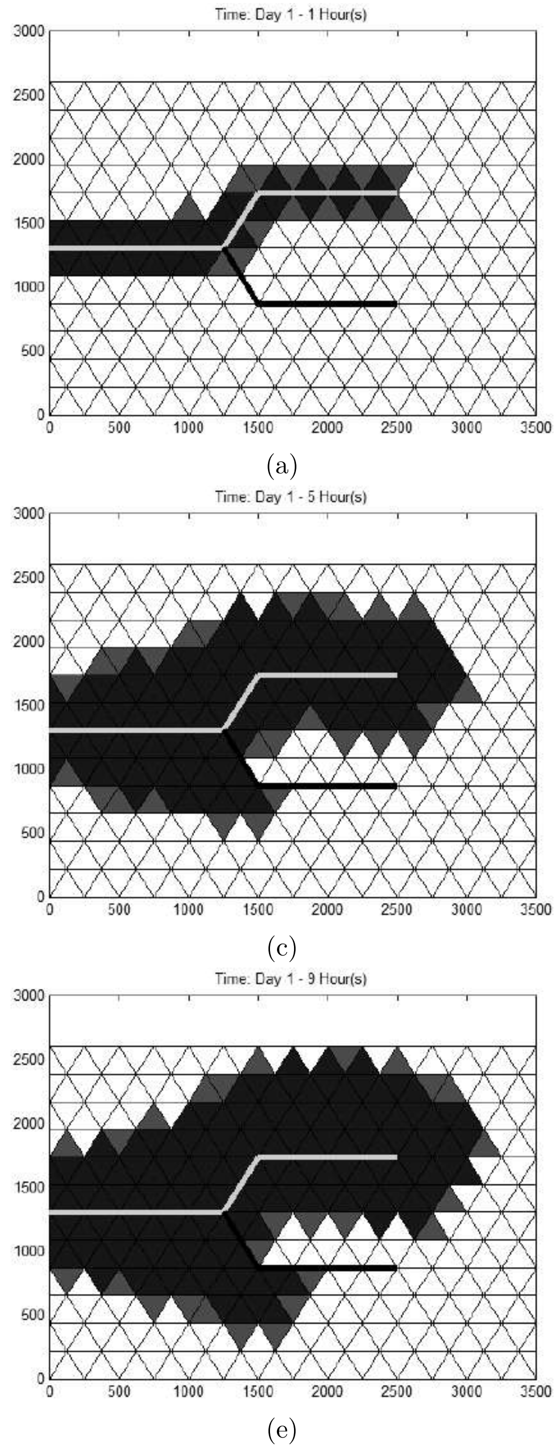


Figure 7.20: Progress of basin cell inundation (Scenario III, Day 1, Period 1)

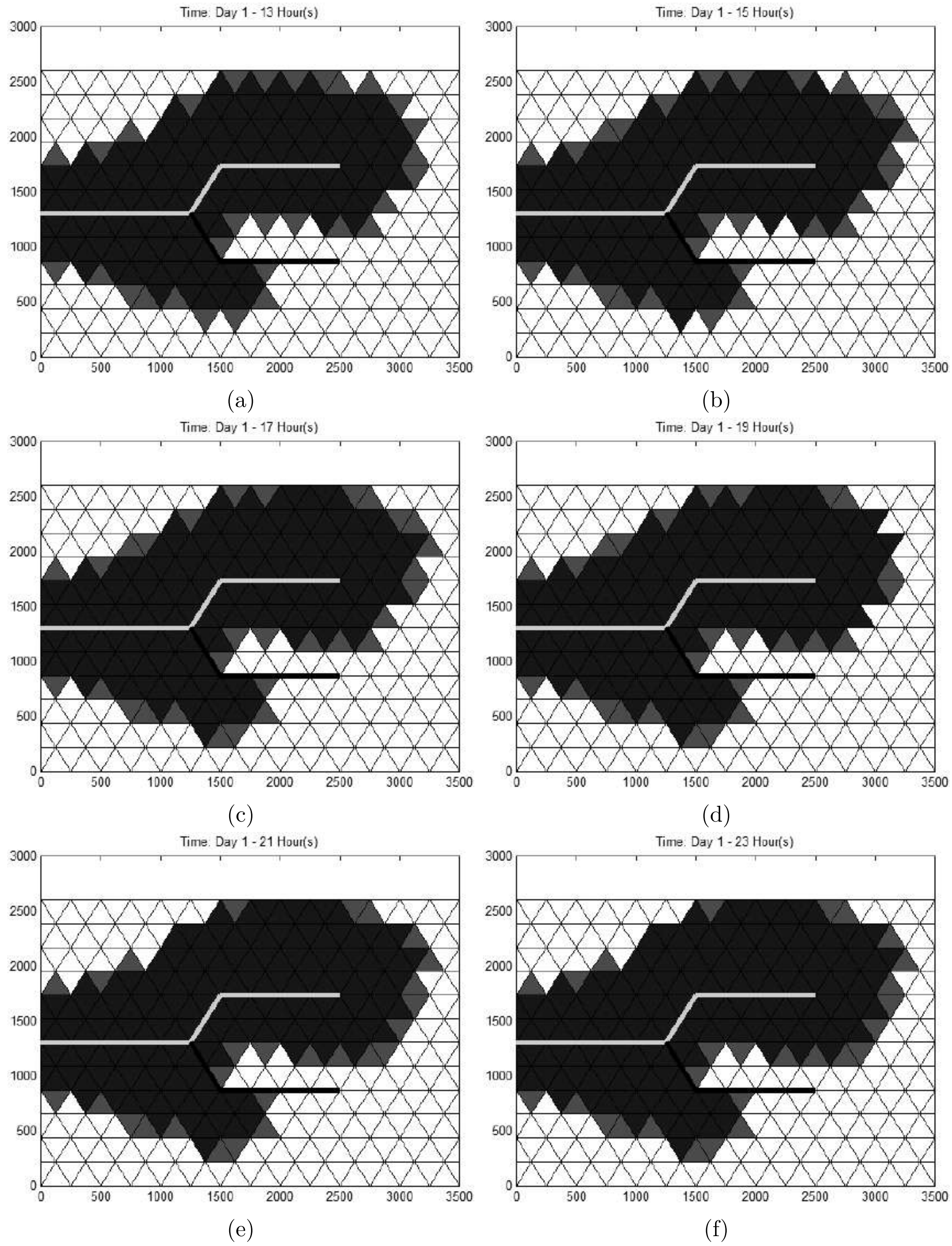


Figure 7.21: Progress of basin cell inundation (Scenario III, Day 1, Period 2)

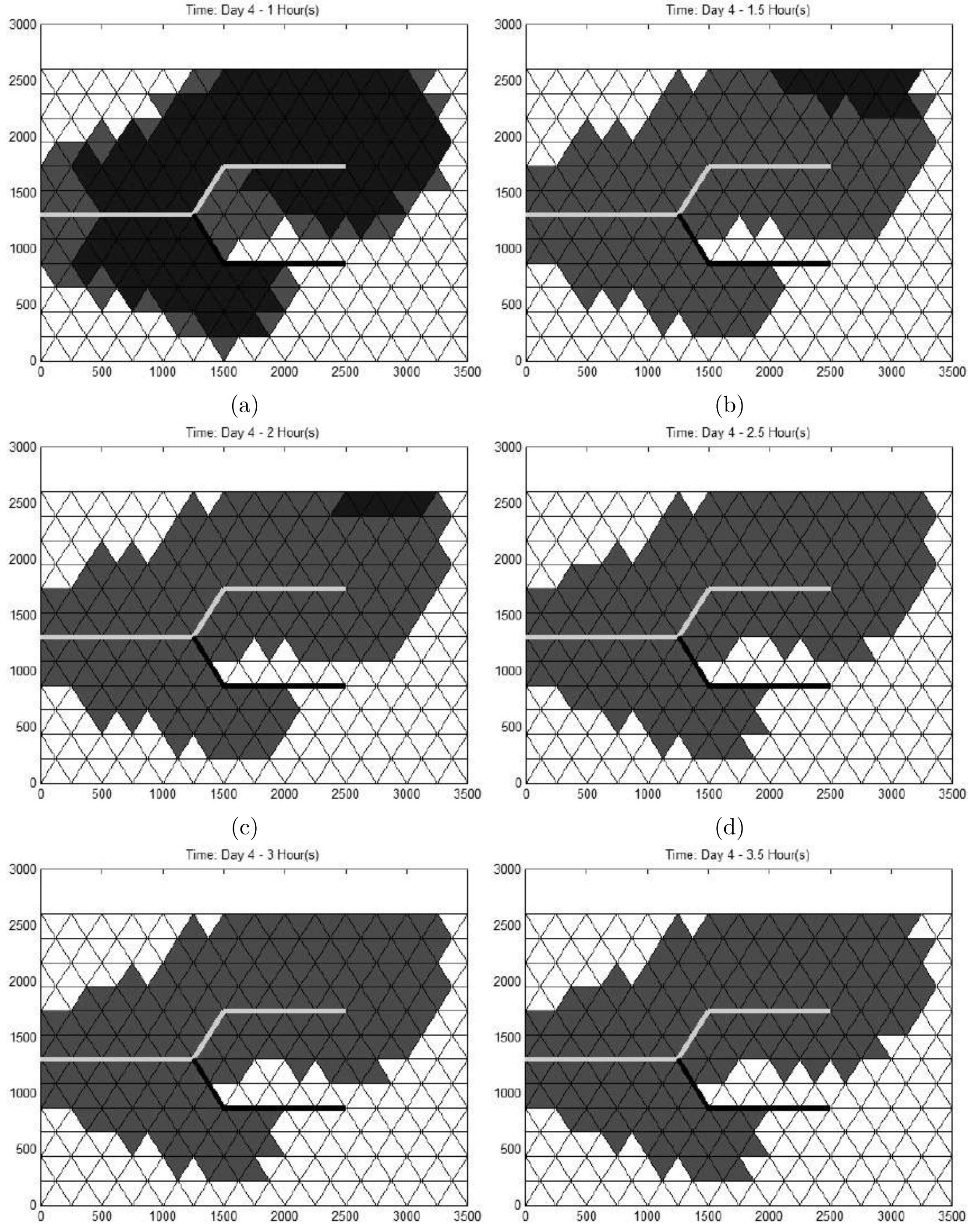
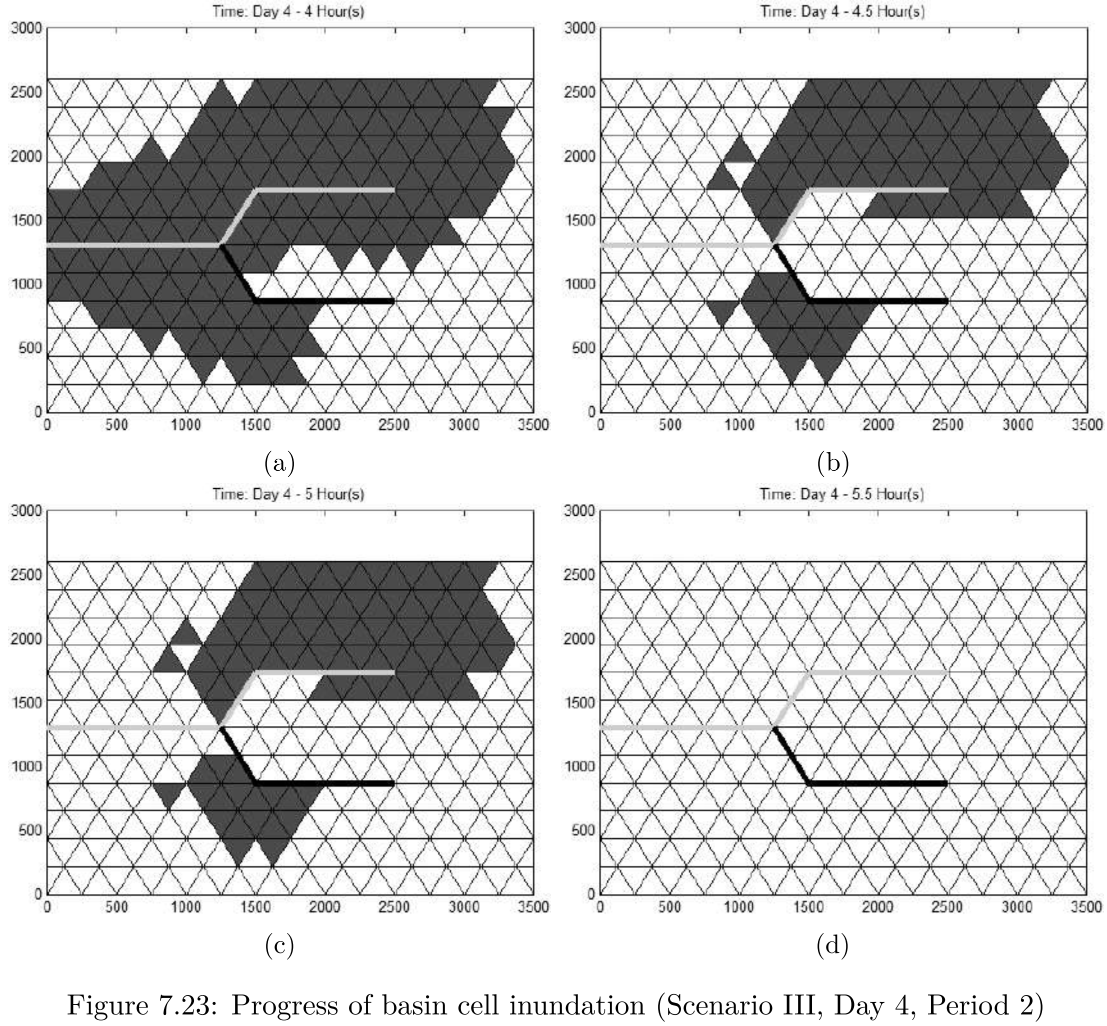
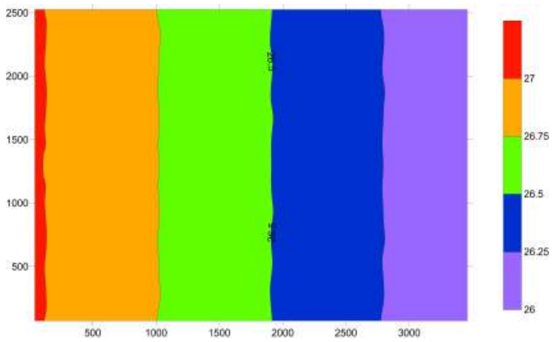


Figure 7.22: Progress of basin cell inundation (Scenario III, Day 4, Period 1)

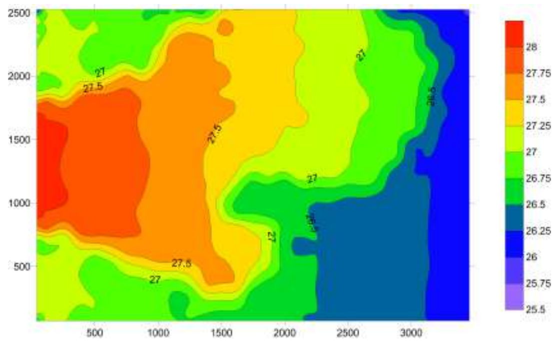


(a) (b) (c) (d)

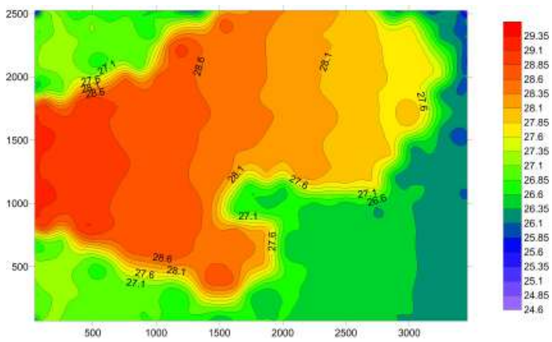
Figure 7.23: Progress of basin cell inundation (Scenario III, Day 4, Period 2)



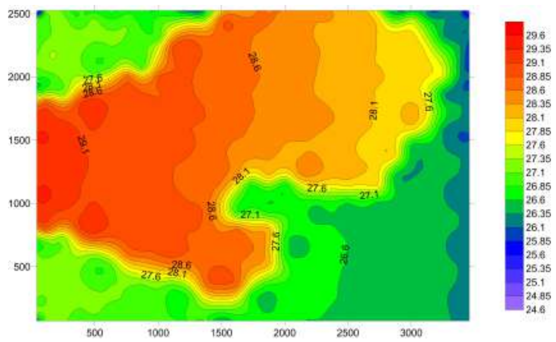
(a) Day 1



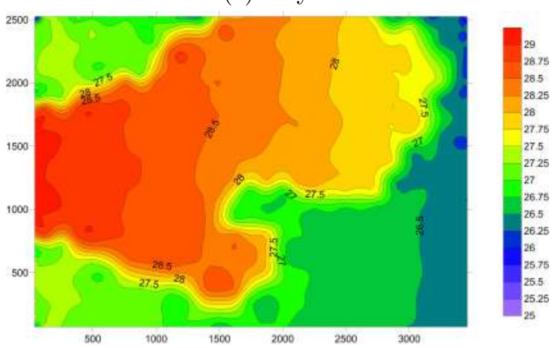
(b) Day 2



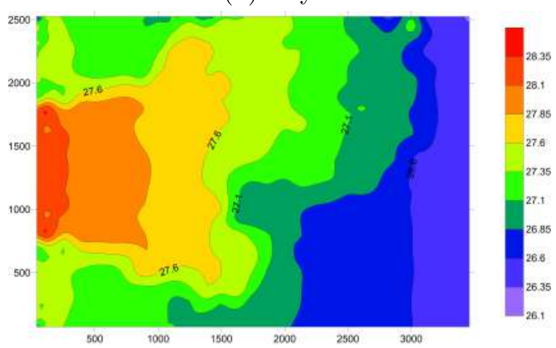
(c) Day 3



(d) Day 4



(e) Day 5



(f) Day 6

Figure 7.24: Surface plots of groundwater table (Scenario III)

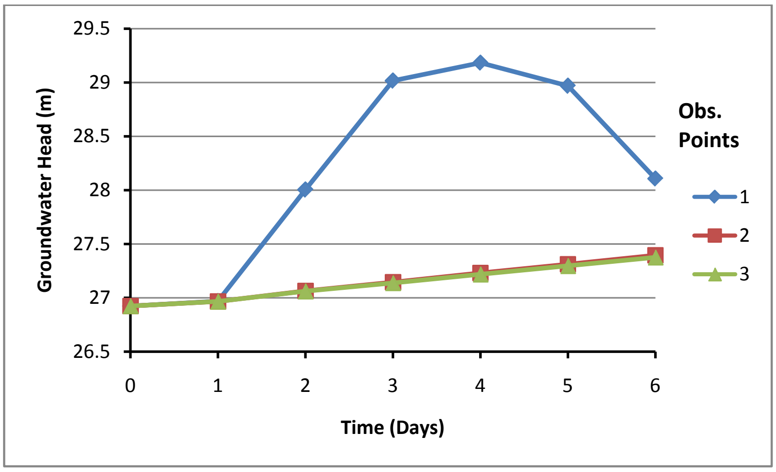


Figure 7.25: Groundwater head plot with time (in days) for observation points 1, 2, and 3

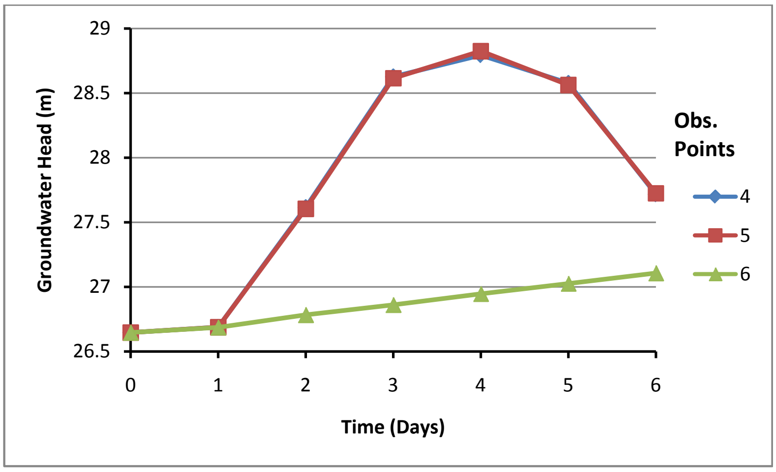


Figure 7.26: Groundwater head plot with time (in days) for observation points 4, 5, and 6

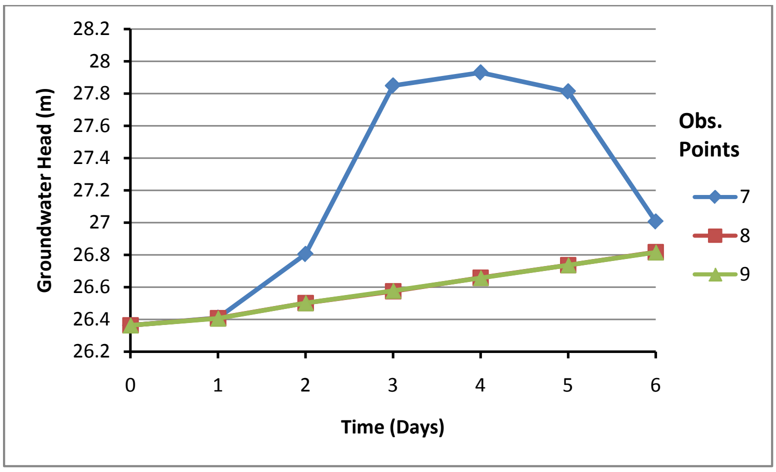


Figure 7.27: Groundwater head plot with time (in days) for observation points 7, 8, and 9

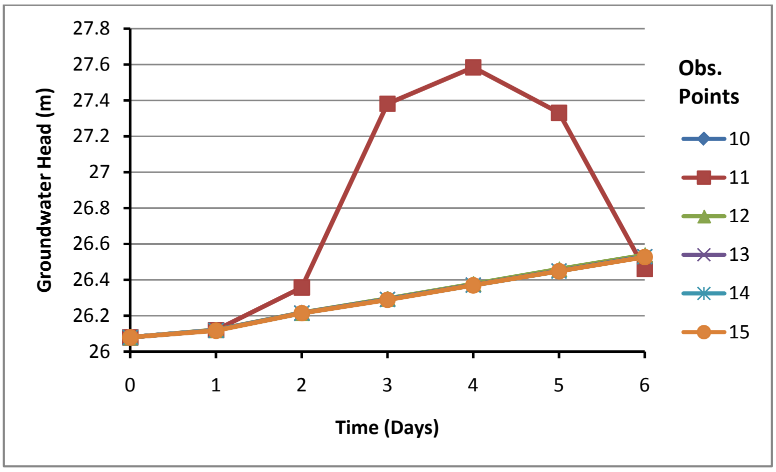


Figure 7.28: Groundwater head plot with time (in days) for observation points 10 to 15

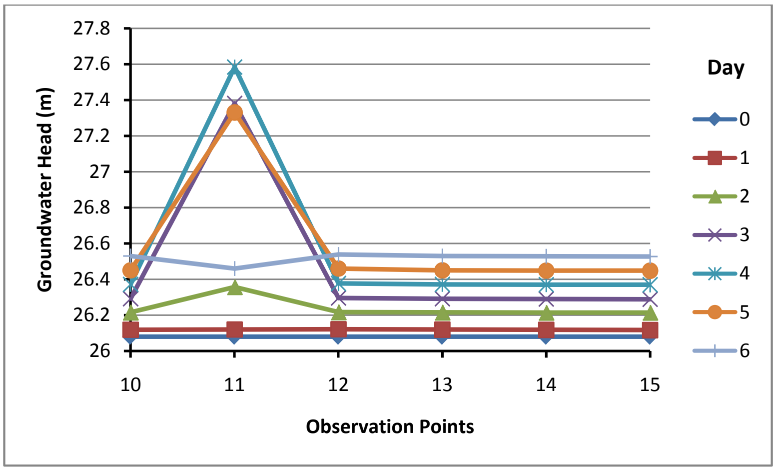
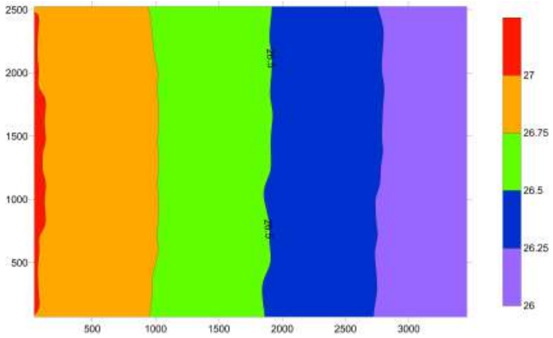


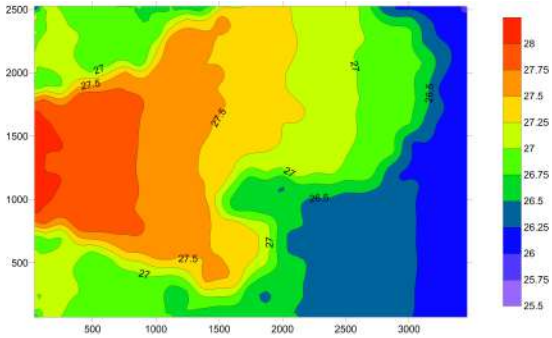
Figure 7.29: Groundwater head variation across a section passing through observation points 10 to 15, plotted at interval of days.

7.2.4 Scenario-IV

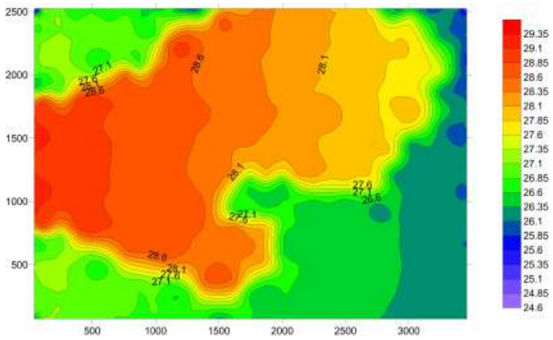
The computation results for Scenario IV appear in this section. As for Scenario II, the progress of the inundation front from basin to basin as well as the general rise and fall patterns of groundwater table being not very different from those of Scenario III, are not presented. The graphics included here are: (a) surface plot of the time-varying groundwater table (Figure 7.30), and (b) comparative graphs showing the difference in groundwater elevation for cells 3, 6, 9 and 15, Figures 7.31 to 7.34.



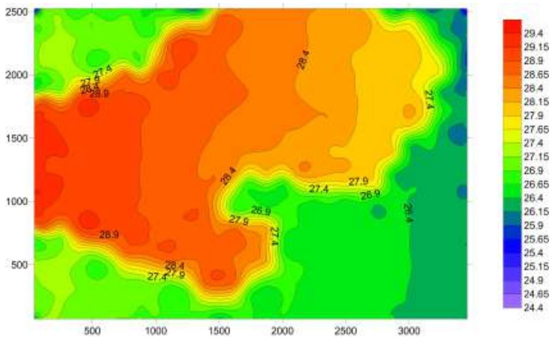
(a) Day 1



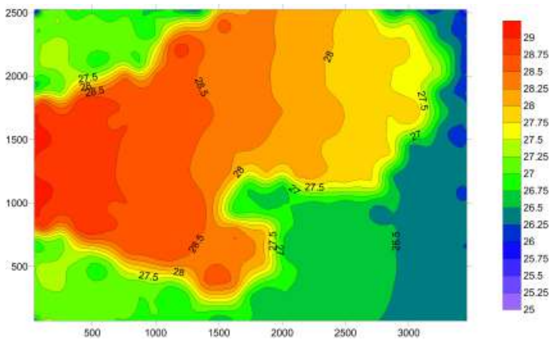
(b) Day 2



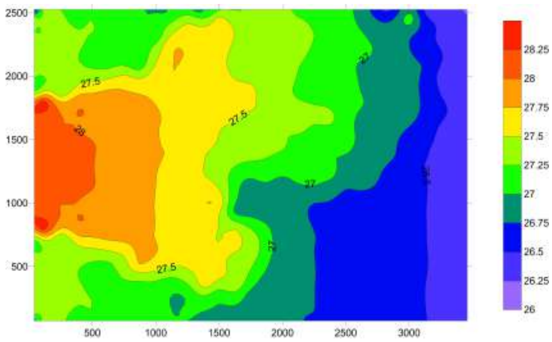
(c) Day 3



(d) Day 4



(e) Day 5



(f) Day 6

Figure 7.30: Surface plots of groundwater table (Scenario IV)

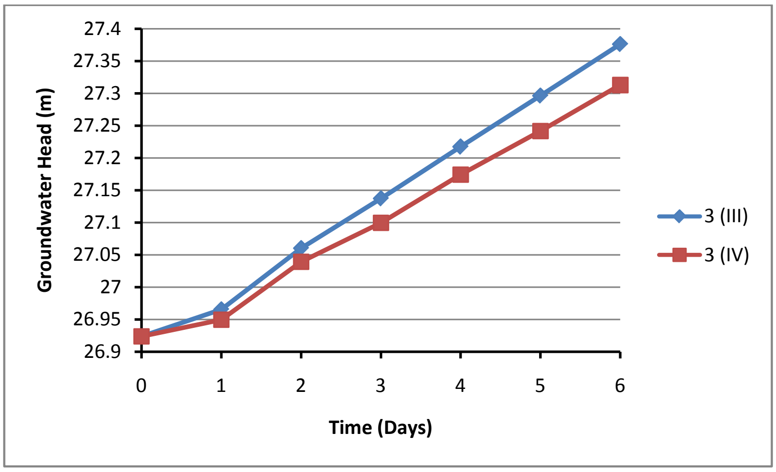


Figure 7.31: Groundwater head comparison at cell 3 for Scenario III [graph 3 (III)] and Scenario IV [graph 3 (IV)]

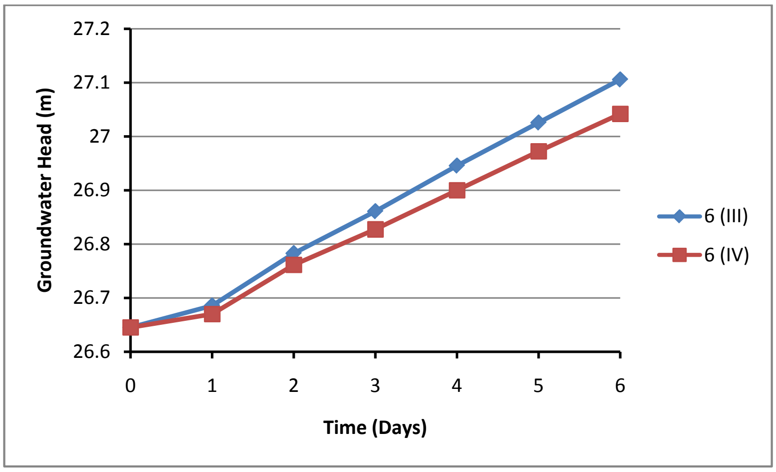


Figure 7.32: Groundwater head comparison at cell 6 for Scenario III [graph 6 (III)] and Scenario IV [graph 6 (IV)]

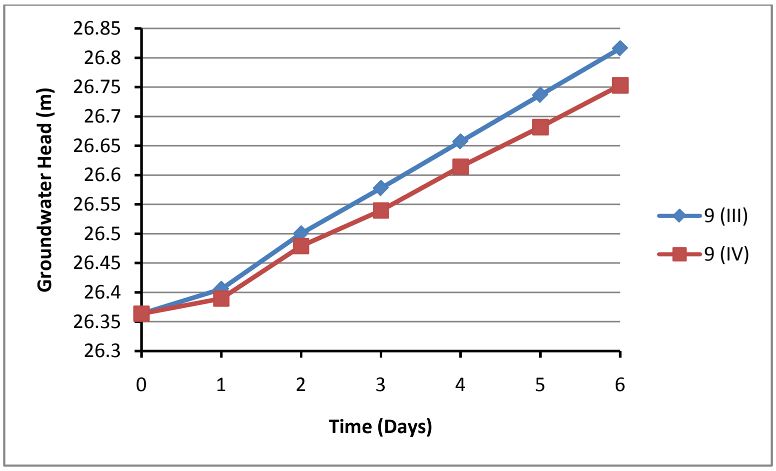


Figure 7.33: Groundwater head comparison at cell 9 for Scenario III [graph 9 (III)] and Scenario IV [graph 9 (IV)]

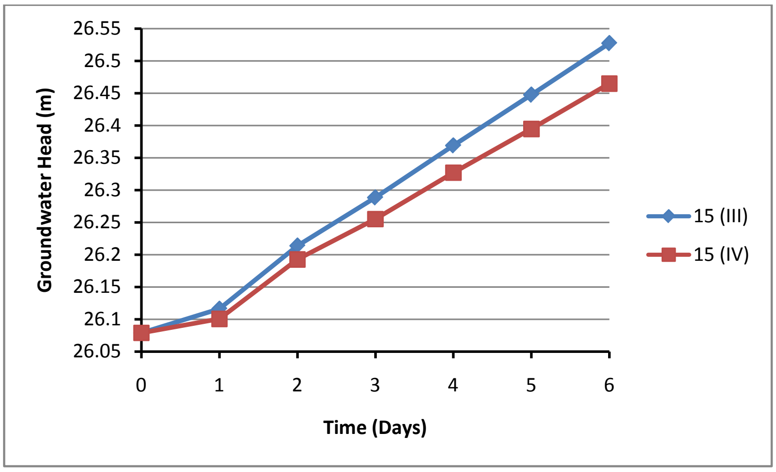


Figure 7.34: Groundwater head comparison at cell 15 for Scenario III [graph 15 (III)] and Scenario IV [graph 15 (IV)]

SL no	Scenario	Remarks
1	Scn 1	Both working
2	Scn 2	one working

Table 7.1: Conjunctive Water use scenarios

From a study of the plotted figures for the different cases, the following inferences may be drawn: (a) the surface inundation progresses from basin to basin as long as water flows into the channel and attains a dynamic equilibrium at some point of time when the inflow matches the total loss of water by infiltration, (2) the groundwater table nearer to the canal rises faster than those farther away, and (3) a mound of groundwater is developed during the first three days when recharge takes place from the water seeping from the flooded basin cells; subsequently, the mound recedes as the water in the cells gradually continue to dry up, (4) the influence of a growing crop in depleting the groundwater table (effected by pumping to meet the crop water need) is observed more prominently for the regions away from the bulk recharge area and where the surface cells are dry, (5) the groundwater mound, developed during the recharge days when the canals are running, depletes once the canal waters are shut off but forcing the groundwater at the points far away to rise by the steep groundwater surface gradient, and (6) on closure of the canal water supply, the already flooded basins show a clean recession of standing water and very soon dry up if pumping is not initiated due to infiltration.

This chapter presents a framework for an integrated simulation model for basin irrigation and is proved with different possible scenarios on a test plot. The logical conclusions drawn from the numerical experiments carried out demonstrate that the model responds well to the factors affecting the basin irrigation scenario and may, therefore, be used in further intensive applications.

Chapter 8

Conclusions

8.1 Summary of Project

The following conclusions can be drawn from the current work:

1. Assessment of the present water resource scenario was performed for the left bank irrigation system.

    - Boro rice cultivation maps were generated for the period 1989 to 2018. Validation of the maps were performed based on field data. Sharp increase in Boro rice cultivation area was observed over past two decades.
    - Future Boro rice cultivation maps were also generated based on secondary data and climatic variables. Reduction in Boro rice cultivation area was observed for the years 2035 and 2050.
    - Canal regulation charts (2001-2018) for the Boro season were prepared based on information from the Government of West Bengal. The regulation map reveals that water is generally supplied partially in the upstream reaches only.
    - Groundwater level study for different years show consistent decline of water table.
    - Weekly average discharge values were also show in graphical form.

2. A numerical simulation model is proposed surface flood modeling for irrigation water supply.

    - The 2D model for cell to cell water transfer was validated again MIKE 21. The developed model performs satisfactorily for all test cases.

3. Unsaturated and saturated groundwater flow models were developed based on finite volume approach.

    - The groundwater response to different situations arising out of withdrawal and recharge scenarios are not very different from those simulated by MODFLOW.

- The proposed model can be used efficiently for simulating groundwater dynamics for different scenarios of withdrawal and recharge.

4. Canal and water course models were developed for for canal network flow simulation.
    - A steady flow in the main canal, its branches, distributaries, minors and water-courses would finally result in a steady outflow through the field outlets.
    - Whatever unsteadiness that may occur during the changeover periods of discharges in the canal branches, is likely to die down rather quickly, and may not substantially influence the flow conditions of a ten-day constant discharge period in an irrigation canal schedule.
5. Canal cross section survey was conducted to see the present condition of the DVC canal system.
    - Hydraulics structures were also located during survey process.
    - Canal related information were obtained from survey process and different offices of Irrigation and Waterways Department.
6. Canal network flow, unsaturated flow, and saturated ground water flow models were integrated for conjunctive water use.
    - Illustrative example was tested under different hypothetical scenarios.
    - The integrated model performs satisfactorily for illustrative problem.
7. Due to data scarcity the investigation regarding possibility of the storage of spilled water from upstream dam(s) was not performed.

8.2 Recommendations

In the absence of complete real data sets (detailed canal operation related information), the model was tested on hypothetical data sets to illustrate the performance of the individual as well as the integrated model.

8.3 Future scope of work

The model may be refined to take into account more realistic processes like generalised three dimensional saturated and unsaturated soil water flow, varying soil hydraulic parameters, two-dimensional basin flooding, etc. It may also be validated with real world data and applied for actual decision making by the water managers of canal irrigated districts.

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