SPACE TECH
IN SOCIO-ECONOMIC DEVELOPMENT

WATER RESOURCE ASSESSMENT AND MODELING

Koh-e-Suleman Using Remote Sensing

Space Technology Applications in Socio-economic Development

WATER RESOURCE ASSESSMENT AND MODELING

Koh-e-Suleman

Using Remote Sensing

Disclaimer

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IN PAKISTAN,
ABOUT 44%
POPULATION
HAS NO ACCESS TO
SAFE DRINKING
WATER.

01.

Introduction

Water is an important commodity for all forms of life, from the simplest of living organisms to the most complex of human systems. Huge portion of our planet is water (almost 70%), however, only 3% of this is fresh water that can be used for drinking, bathing, and irrigation. Two-third of the fresh water is in the form of glaciers or unavailable for our use, thus, huge population of the world lack access to water. In our present world of 7.7 billion people, water shortage is an important issue. The pressure on water resources will further aggravate by year 2050, when the world population will reach around 10 billion people and the number of people living in water scare region will increase from 47% to 57% .

As an agrarian country, Pakistan has ample water resources, with rivers streaming down the world's largest glaciers Himalayas and Karakoram heights. Out of its total geographical area of 79.61 million hectares, 22.05 million hectares is cultivated, and 19.02 million hectares is under irrigation. Irrigated agriculture contributes around 90% agriculture production of the country. Agriculture is the cornerstone of Pakistan's economy and accounts for 25% of GDP. Agriculture is also the principal consumer of water, and water use for agriculture will continue to dominate as the population is growing. In order to get an idea of importance of water for agriculture, Figure 01 shows water usage by sectors for the year 2016. Regardless of the ample water resources, the uneven spatio-temporal distributions and degrading quality makes it a finite resource in Pakistan. Climate change is expected to further exacerbate stress on the available water resources.

[1]Boretti, A., and Rosa, L. (2019). Reassessing the projections of the world water development report. NPJ Clean Water, 2(1), 1-6.

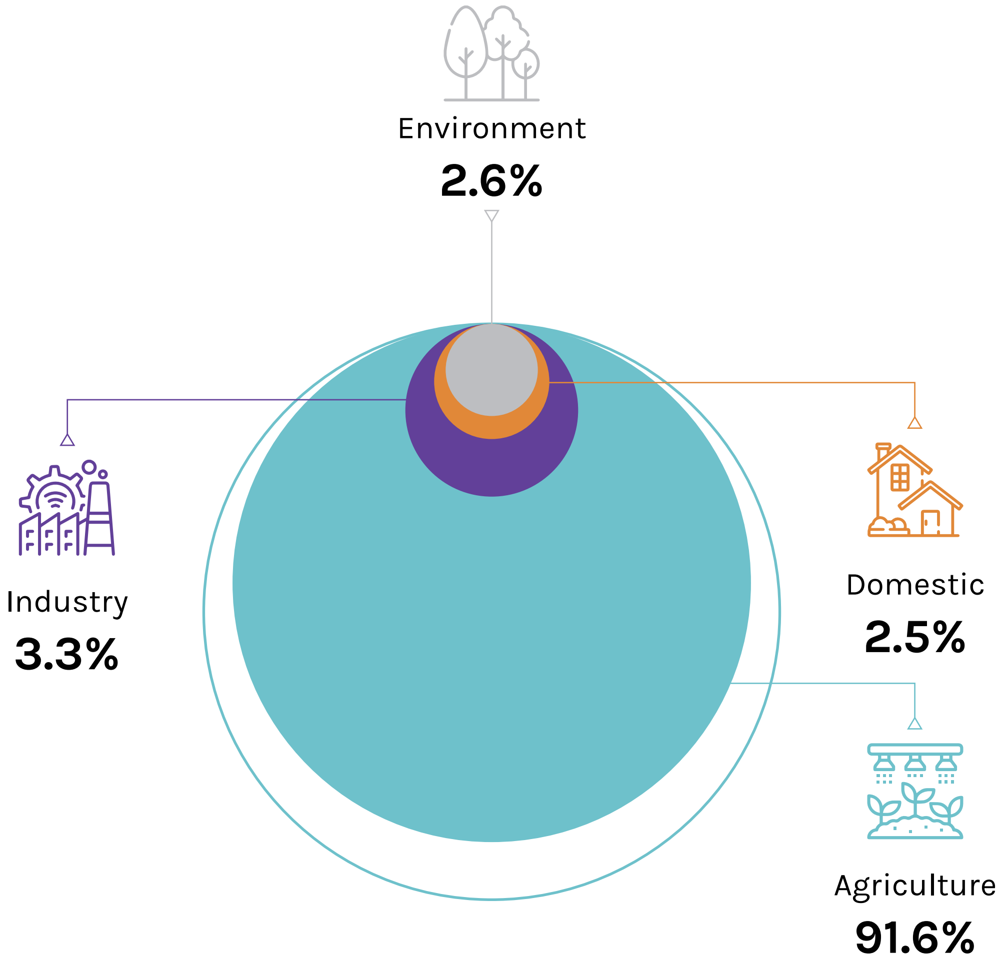


Figure 01 | Water Usage by Sectors in Pakistan, 2016
[Source: Ahmad, (2016)[2]]

Rapid increase in population and climate change will impose additional pressure on the existing scare water resources. Thus, it is utmost important to manage water resources efficiently. Space technology, particularly satellite-based remote sensing, has proven its capability to combat the issue relating to water resources management. Continous spatio-temporal observations of the earth has become a vital source for managing the declining water resources for the benefit of humankind and the environment friendly activities. Furthermore, it has made possible monitoring systems to mitigate water crises, such as flooding and droughts. Satellite-based remote sensing provides observation of several hydrological states and variables such as precipitation, soil moisture, water storage, and evaporation over both time and space. It is particularly useful for countries and regions with no or scare hydrometeorological networks.

[2] Ahmad S. (2016). Water Sector of Pakistan: A Situational Analysis. Development Advocate Pakistan, 3(4): 1-9

1.1 Study Area

The project area "Koh-e-Suleman" is situated in Dera Ghazi (D.G) Khan District of Punjab province (Figure 02). The climate of the project area is dry both in summer and winter, and an average rainfall of 203.92 mm (based on D.G Khan meteorological station's data 2001-2015) is recorded here. The water resource of the project area consists of several natural and artificial lakes and about 200 hill torrents originating from Suleman Range flows through D.G Khan District towards River Indus. The rainfall pattern of the area is highly uncertain with heavy rainfall in a year leading to extreme floods.

Hill torrents (locally known as Rodh Kohi) are unique water carrying structure which drains the flood water from mountains with very high speed and hit the localities infrastructure in its way. Due to high flood potential in D.G Khan hill torrents, this area is socio-economically weak. The flood events usually lead to massive economic damages on the infrastructure, houses, and irrigated lands in the order of billion rupees. Conversely, in dry season vast region of nearly 640 thousand acres, cultivable piedmont, fails to receive valuable irrigation water. Conventionally, local people use small embankments to divert low flood flows to irrigate their fields, however, these small earthen embankments usually fail during high flow events. Piedmont area of the hill torrent is very fertile, but due to erratic nature of floods, this area is rarely used for cultivation. The flood water destroys the infrastructure and agriculture badly. This situation demands management improvement for hill torrent floods. In this study, existing management practices and water quality were reviewed. A rapid analysis of the water resources was conducted for three potential storage dams focusing on flood control, irrigation and water quality for drinking using Geographical Information System and Remote Sensing Technology.

[1]Boretti, A., and Rosa, L. (2019). Reassessing the projections of the world water development report. NPJ Clean Water, 2(1), 1-6.

1.2 Problem Statement

Hill torrents generally associated with uncertain flood flows have kept D.G Khan area socio economically weak. Catastrophic flood events cause loss of billions of rupees to infrastructure, houses, and irrigated lands.

Figure 02 | Digital Elevation Map (DEM) of the Study Area

1.3
Literature Review

1.3.1 Hill Torrent Management

Hill torrent management at Koh-e-Suleman is of utmost importance because it brings flash floods of shorter duration but very high magnitude. Moreover, it has great potential for agriculture if managed properly. Conventionally, the flows of the hill torrents of Pachad Area have been used for irrigation of local agriculture areas by the farmers' own diversion arrangement during low floods. Since independence, several studies by different government officials proposed plan for the management of major hill torrents originating from Koh-e-Suleman region. However, these could not be implemented due to one reason or the other. Summary of the studies are as follows:

- Mr. M Ahmed, Geologist of Survey of Pakistan thoroughly investigated the Sanghar Hill torrent in 1951 and reported that storage reservoir is not feasible due to high silt load.

- In 1952, Executive Engineer Malik Ramiz Ahmad suggested bifurcation and trifurcation of off-takes at the head of nullahs for better flood spreading in the fields.

- In 1958, Mr. G. E. Meads, an FAO Expert proposed storage dams, check dams, and retarding dams at various hill torrents, but these proposals were not executed due to poor geological conditions and low financial returns.

- In 1971, a pickup weir was constructed at a cost of Rs. 3.71 million on Vehowa Hill torrent by Small Dam Organization. It has been damaged several times and large amount have been spent for its restoration. Even these repairs were inadequate and proved ineffective for finding out comprehensive solution for the problem.

- After 1976 high flood, Govt. of the Punjab designated a committee consisting of irrigation experts to study the flood problems in the study area. This committee recommended creation of "Hill Torrent and Pachad Development Authority" for flood management of hill torrents.

- In September 1976, Derajcn's Superintending Engineer Mr. Muhammad Ismail Shaheed, proposed a detailed mechanism for carrying the hill torrent flood through Pachad Areas by distributaries and irrigation channels. The new cross-drainage work was proposed to transport flood water through the existing canal system and a trained network of drains to lead the hill torrent flood to Indus River.

• In 1980's on a request of Govt. of Punjab, Federal Flood Commission hired NESPAK to look into the flood issues of D.G Khan hill torrents. NESPAK carried out a comprehensive study of 13 major hill torrents and proposed a multi-purpose management plan. The management mainly comprised the diversion arrangements and flood control facilities. In 1990's the report was updated as part of the **"Master Feasibility Studies for Flood Management of Hill Torrents of Pakistan"**. A complete feasibility study was carried out of the project area along with economic analysis of the proposed plan based on which a pilot project was formulated and executed on Kaha hill torrent.

• The initiation of Chashma Right Bank Canal (CRBC) was an important intervention in the Koh-e-Suleman hill torrent. Large part of the hill torrents has come under command of CRBC. This intervention has affected the entire scenario of the project area, and it was necessary to revise and update the management plan proposed by NESPAK. Thereupon, Govt. of the Punjab asked NESPAK to submit the revised feasibility in 2005.

• Yasin and Nabi, (2014), using GIS and Hydrological Modeling assessed the potential of storage reservoirs in Mithawan hill torrents.

• Saher et al., (2015) proposed an integrated methodology to conserve the hill torrent flood of D.G Khan Region. The methodology comprised of geo-informatics software that works as a decision-making system for selection of best site for earthen reservoirs. The result for three potential reservoir sites were analyzed for its hydrological analysis and concluded that geo-informatics tools can potentially resolve engineering challenges to mitigate and manage the hill torrent floods.

• Qureshi et al., (2016) reviewed the existing literature for hill torrent management in general and Kaha hill torrent in specific. They reported the existing structure at Kaha hill torrent consists of 13 dispersion structures as a rigid PCC structures, constructed during 2011 to 2013. In this study, they proposed construction of 124m high dam that will improve protection against 100-year return period flood and increase cropping area by 05 times by increasing irrigation potential.

Proper management of hill torrents can significantly enhance agricultural production, ensure food security, and improve livelihoods of people living in these areas. In this study, a rapid assessment of the water resources of Koh-e-Suleman region was carried out by combined used of remote sensing and geoinformation system to give directions for detailed assessment plans.

1.3.2 Existing Situation of Water Supply

Housing Urban Development and Public Health Engineering Department (HUD and PHED) is the provincial administrative department of Government of the Punjab which is responsible for provision of drinking water to the communities in rural and urban areas of the province. Koh-e-Suleman area comprises of 09 rural UCs. Rural Water Supply Schemes (RWSS) were installed by Public Health Engineering Department (PHED) in Koh-e-Suleman Area. According to PHED data, there are total 83 RWSS present in 09 UCs, which are maintained and run by Community Based Organizations (CBOs) and Zila Councils. Complete list of RWSS names is attached with Annex A. Number of functional and dysfunctional schemes present in each UC is articulated in Table 01.

Among total 83 No. of RWSS present in area, 53% of the water supply schemes, are currently non-functional, which is major constraint in provision of water to people. Proportion of functional and dysfunctionality of RWSS is shown in Figure 03 and 04. Mubarki and Mithwan are the UCs in which all RWSS are functional while maximum number of schemes are non-functional in Tuman Leghari. No scheme is functional in Bairoot Mundwani and Tuman Khosa which need attention towards interventions for supply of clean drinking water to people.

Table 01 | Functional and Non-functional Schemes

UCs	Total Schemes	Functional	Non-functional
Bairoot Mundwani	3	0	3
Barthi	7	3	4
Fazla Katch	4	2	2
Mithwan	3	3	0
Mubarki	4	4	0
Theekar	11	5	6
Tuman Khosa	3	0	3
Tuman Leghari (Bala)	34	15	19
Tuman Leghari (Zareen)	14	7	7
Grand Total	**83**	**39**	**44**

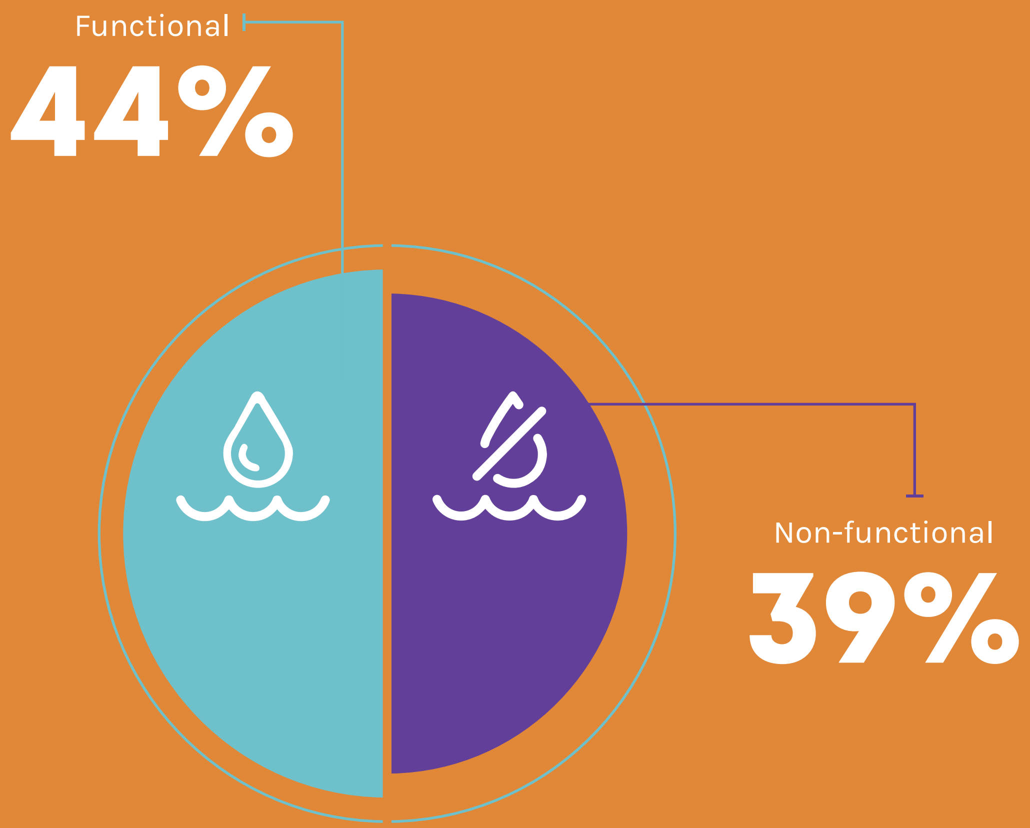


Figure 03 | Overall Status of RWSS

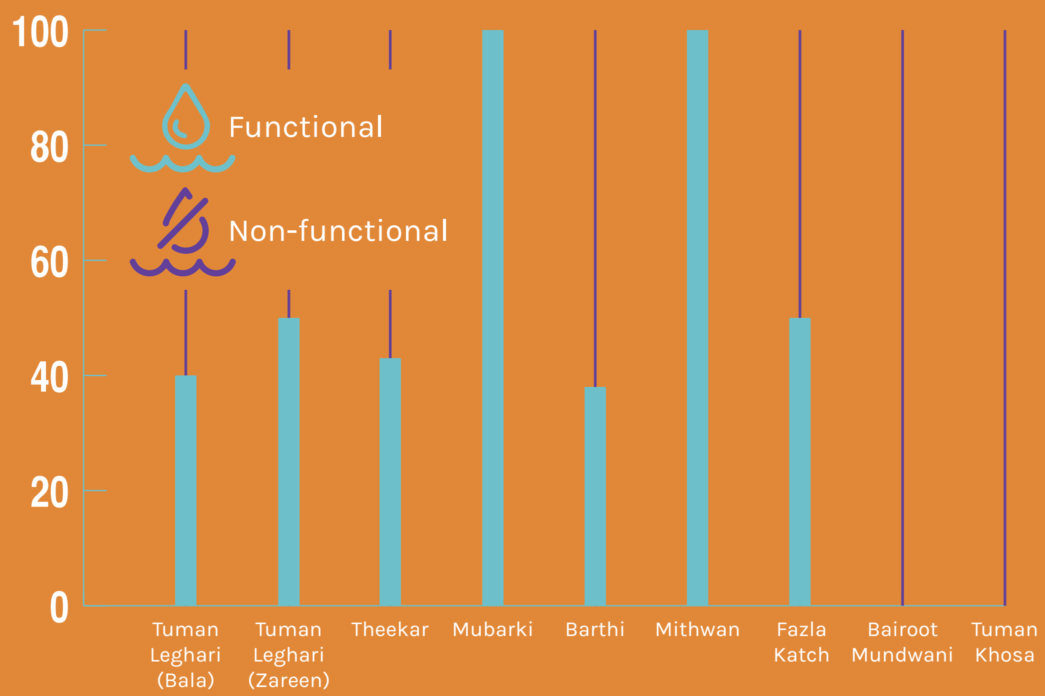
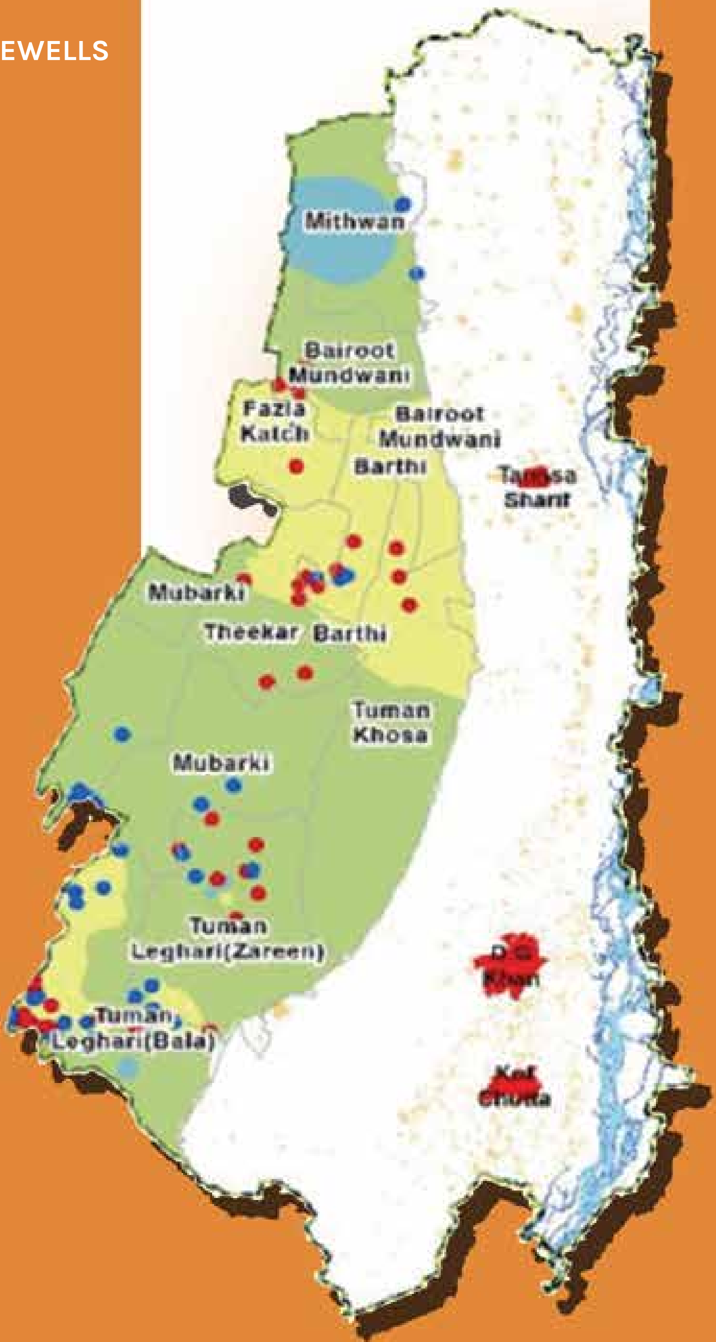


Figure 04 | Functionality of Water Supply Scheme

GIS-based map is presented to express PHED rural water supply schemes present in tribal area along with water quality of groundwater as expressed in Figure 05.

UC NAME	TUBEWELLS
Bairoot Mundwani	3
Barthi	7
Fazla Katch	4
Mithwan	3
Mubarki	4
Theekar	11
Tuman Khosa	3
Tuman Leghari (Bala)	34
Tuman Leghari (Zareen)	14
Grand Total	**83**



LEGEND

Tubewells

- Dysfunctional
- Functional
- UC Boundary
- Rural Settlments
- Urban Settlemnts

TDS(mg/l)

- 0 - 300
- 301 - 500
- 500 - 800

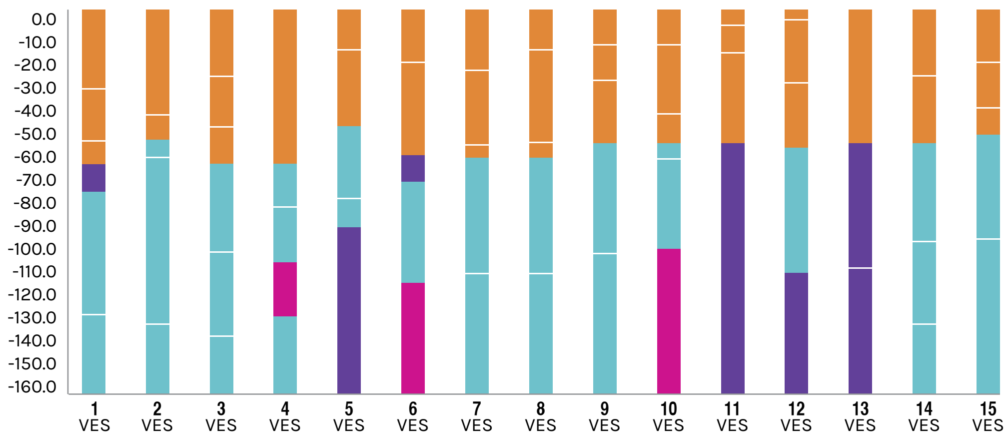
N

0 80km

Figure 05 | Rural Water Supply Schemes (Rural Tubewells in Koh-e-Suleman)

1.3.3 Groundwater Strata Situation

Electric Resistivity Survey (ERS) was conducted at various locations in tribal areas in 2016 by consultants of which report reveal that freshwater quality zones are present below 50m from ground level. Bore can be drilled to extract water and to provide water after minute treatment. Ground water strata is shown in Figure 06.



Variable surface materials

(0-20 Ωm) Dominantly clay/silt

(21-40 Ωm) Dominantly find sand with clay
(Water quality just acceptable)

(>-40 Ωm) Medium/Course sand with kanker and
holds fresh water

Figure 06 | Ground Water Strata

1.4 Objectives

- Improvement of drinking water performance and repair of tubewell
- Conservation of water through better water resources management
- Rainwater harvesting for agriculture
- Enhance ground water recharging by storage reservoirs
- Improved ability of land to hold water for water resource assessment
- Maintaining adequate vegetative cover for controlling soil erosion

1.5 Datasets

- Digital Elevation Model (DEM) – used for developing slope, contour, and drainage network maps
- Rainfall – used for estimating runoff using HEC-HMS modeling
- Land Cover Map – ESA CCI Land Cover (Annex B)

TUBEWELL IRRIGATION BROUGHT REVOLUTION IN STATE CONTROLLED IRRIGATION SECTOR

02. Methodology

Storage dams are one of the primary sources of harvesting rainwater in hill torrents for the sake of agricultural and drainage usage.

- ArcGIS is used for processing and displaying multiple spatial datasets for selection of the suitable dam sites. DEM dataset was used as input to derive slope, contour, and stream network map using hydrology tool in spatial analyst tool in Arc Toolbox. Streams of 3rd and 4th order were selected from stream network map. Stream network map was superimposed over contour and slope map to select suitable sites location. A site with small river channel width (closely spaced contours) and wide and flat sloping valley upstream of the dam site (widely spaced contours) are preferred site for dam construction. By visual inspection on Google Earth, it was found that the selected sites have minimum resettlement.

- ArcHydro tool was used to process the DEM for terrain preprocessing and watershed processing, where watershed was delineated considering the proposed dam site as pour point.

- The total water inflow at the dam site was estimated using hydrological modeling. HEC-HMS software was used to estimate runoff from rainfall. HEC-HMS was setup for SCS-curve number method to simulate runoff for Jan. 2001 to Dec. 2015. Flowchart of the methodology is given in Figure 07.

- Water quality and electrical resistivity survey data from the survey carried out by UNICEF in 2015-2016 in Punjab to map the Koh-e-Suleman region using ArcGIS.

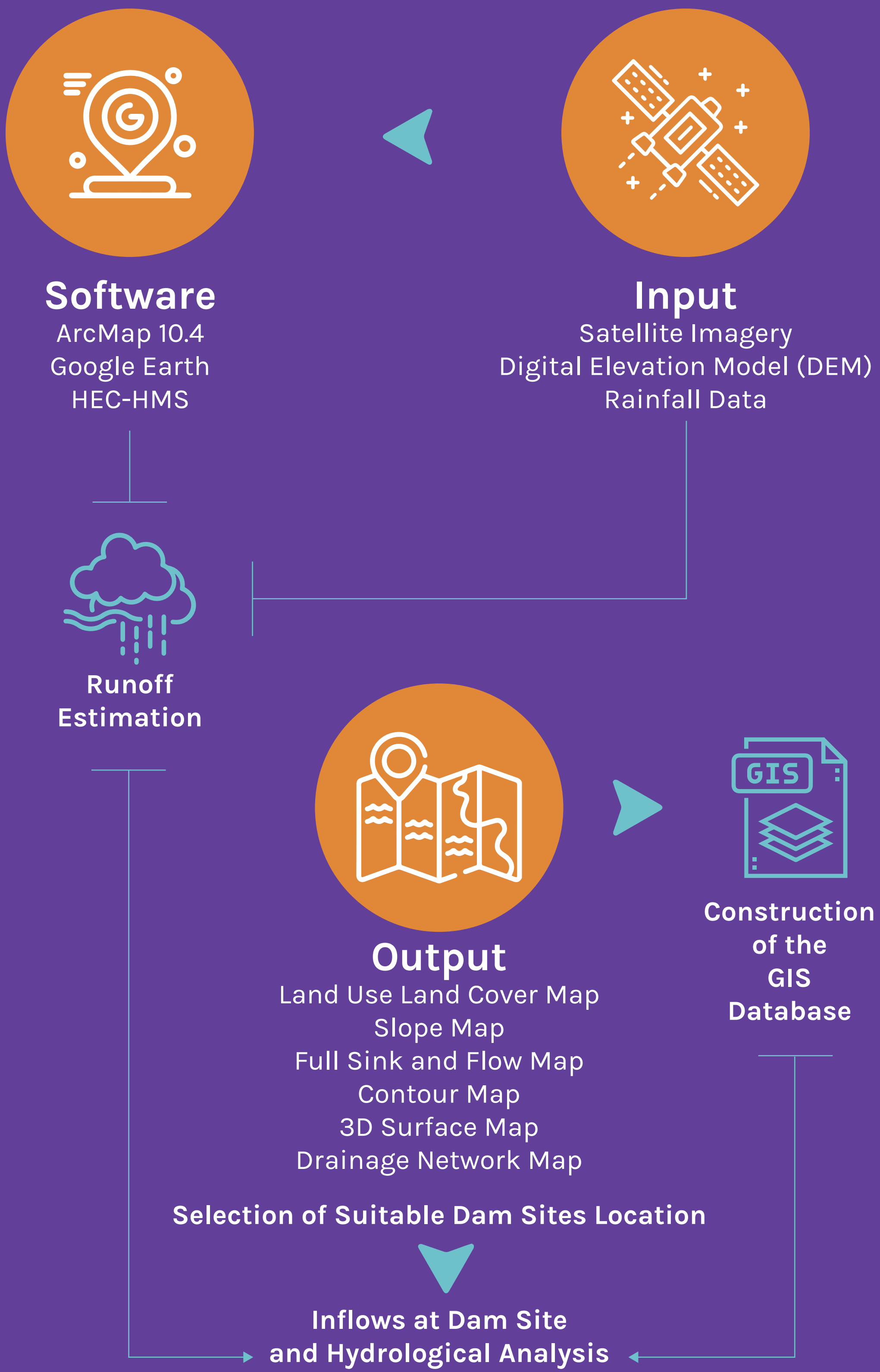


Figure 07 | Step by Step Methodology

03. Hydrological Analysis

3.1 Dam Site Selection and Demarcation of Contributing Watersheds

Dam site selection is a complex problem since it is affected by, as well as it influences, many different factors including both environmental factors and human society factors. Proposed dam sites have been selected based on following three factors, derived by using GIS and remote sensing data:

- Slope (<10%) – to ensure the safety against landslides and lower pressure on embankment
- Contours – used to select the dam axis, reservoir area and volume
- Stream order – higher order streams were selected to ensure enough inflows at the dam sites

The maps of 03 parameters are attached with Annex B.

The watershed that contributes to the dam sites, have been demarcated at respective drainage points using Arc Hydro tools of ArcGIS. Calculated areas of these potential catchments are provided in Table 02. The selected dam sites, its contributing watershed, and proposed reservoirs are shown in Figures 08-10. The Google Earth images are attached with Annex C.

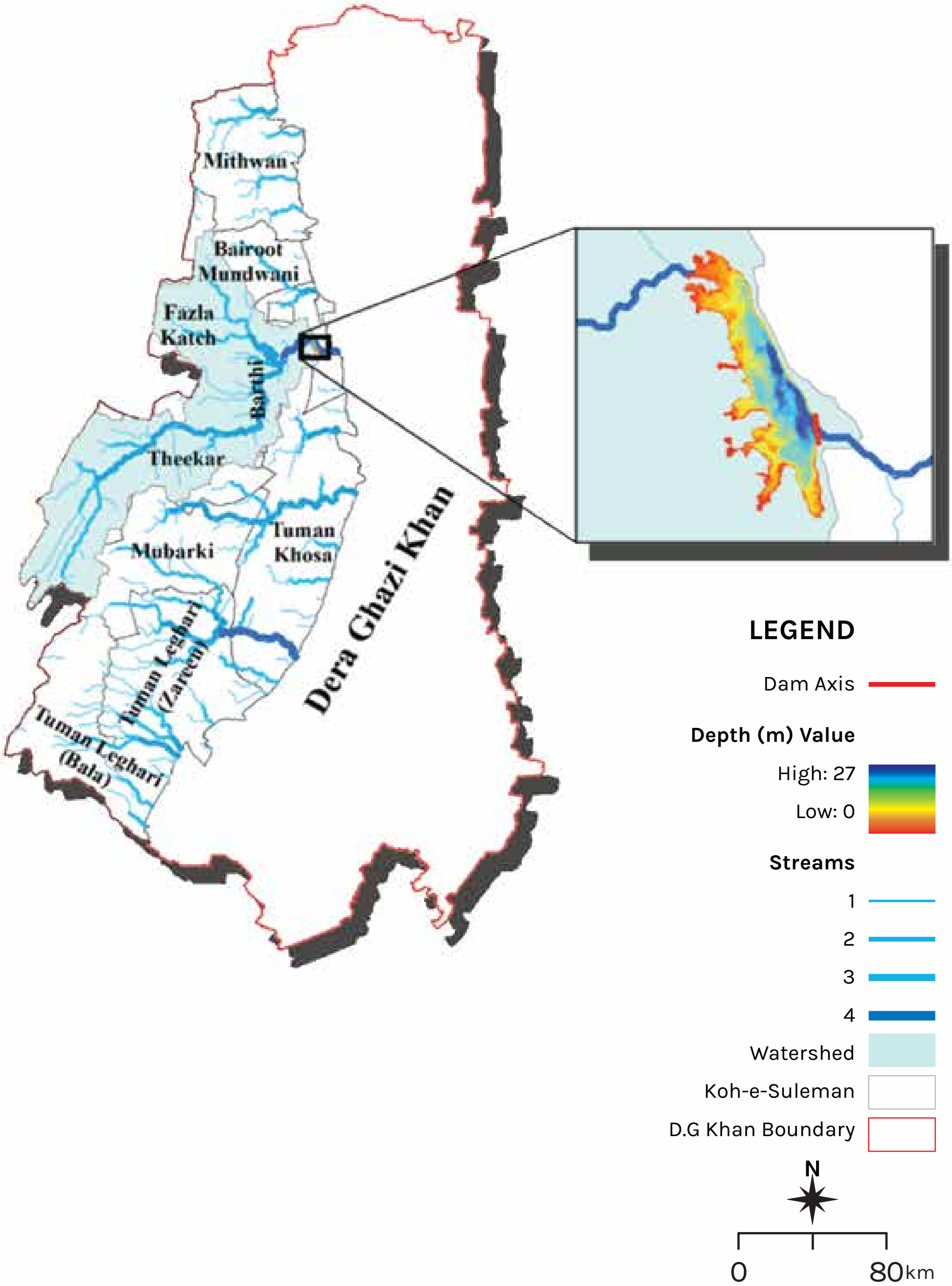


Figure 08 | Dam Site 01 Located 15 km upstream from Taunsa (Aerial)

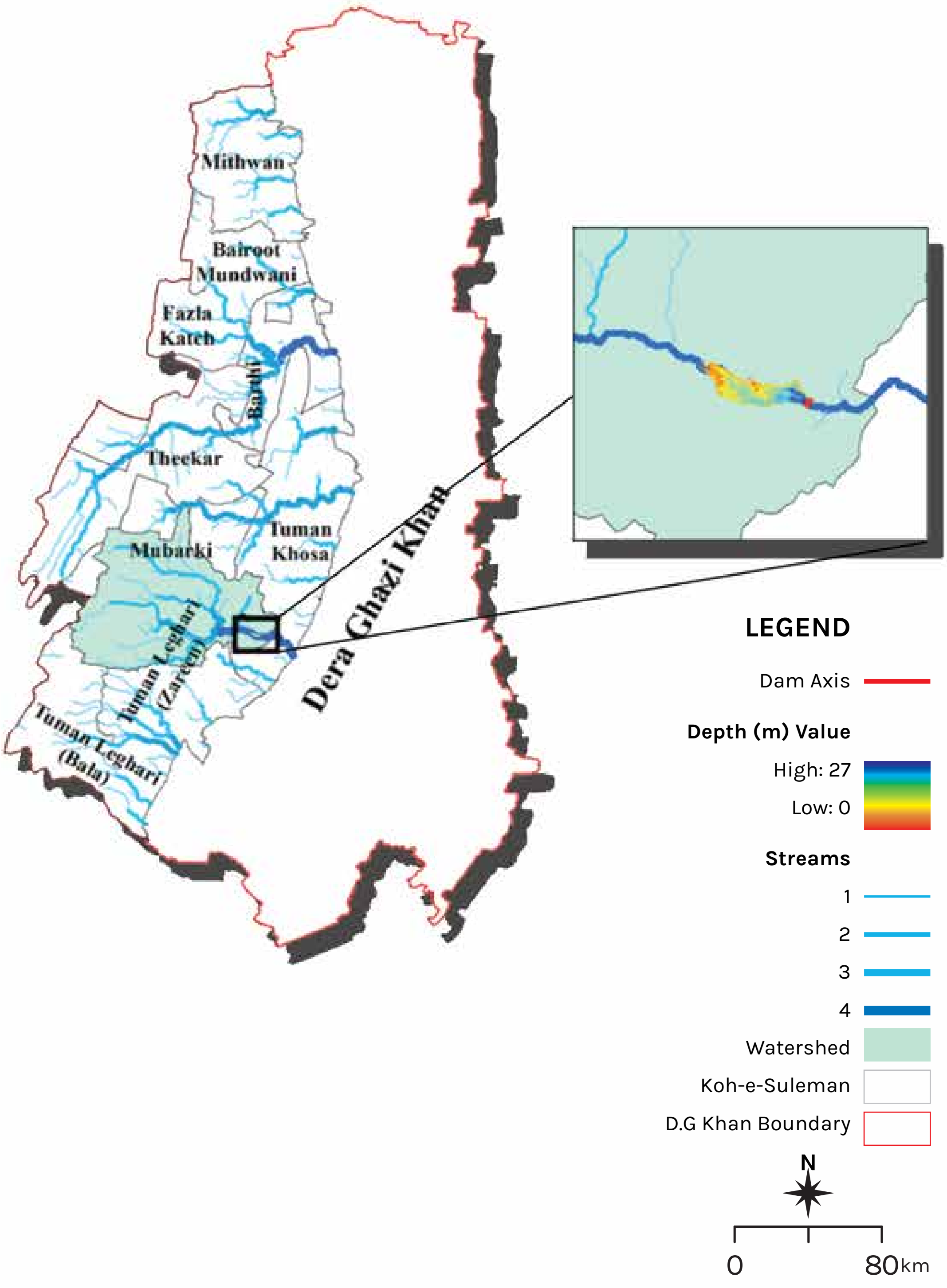


Figure 09 | Dam Site 02 Located 25 km from D.G Khan (Aerial)

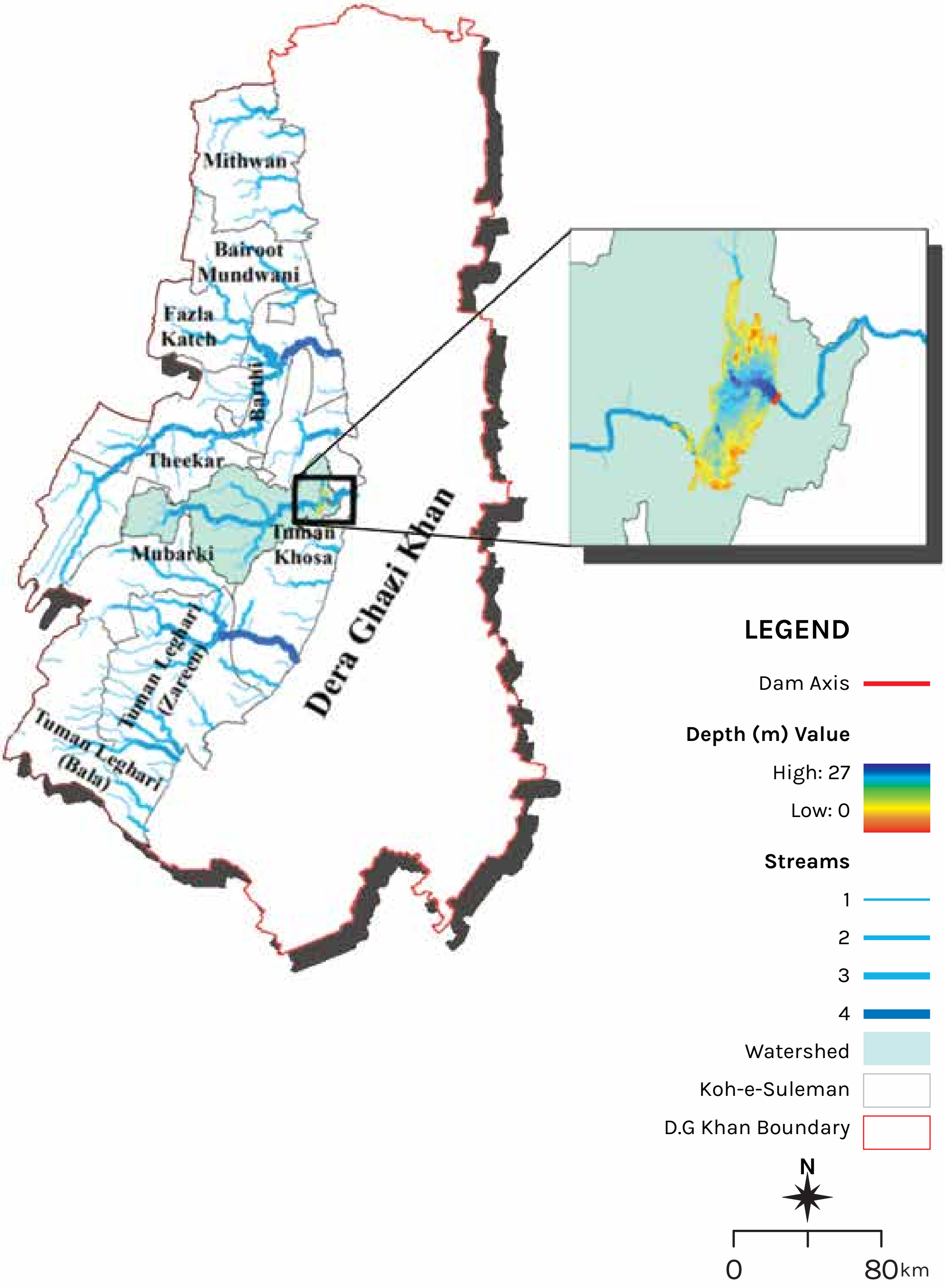


Figure 10 | Dam Site 03 Located 11 km from Gadi (Aerial)

3.2 Available Hydro Meteorological Data

3.2.1 Discharge Data

No authentic flow data of the hill torrents is available at the proposed dam sites or anywhere else in the torrents.

3.2.2 Rainfall Data

No rain gauge exits in the catchment areas; thus, analysis and synthesis of the nearby recorded rainfall data is required for estimation of the rainfall over the catchments. D.G Khan meteorological station is the nearest gauge station in the study area; thus, daily rainfall data was used for rapid analysis for a period of 2001-2015. Figure 11 shows time series of the annual rainfall data and the mean annual rainfall is 203.92 mm of the D.G Khan gauge station.

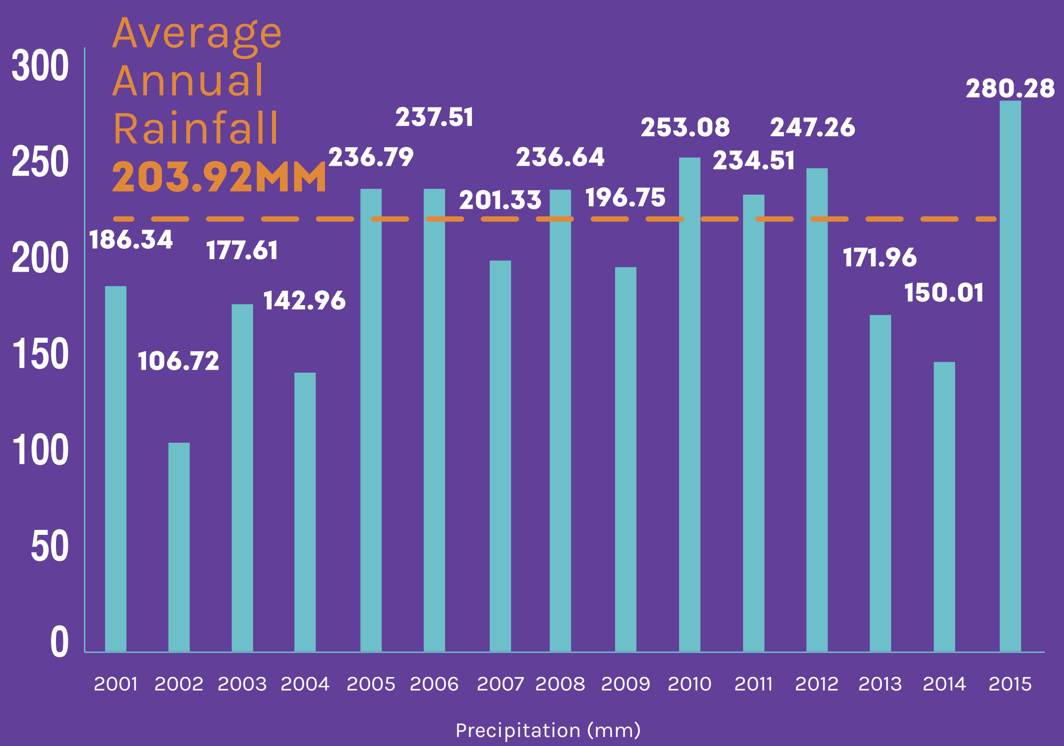


Figure 11 | Mean Annual Precipitation of D.G Khan Meteorological Station

3.3 Estimation of Surface Runoff

Soil Conservation Services (SCS) method is used to compute surface runoff from the catchment of hill torrents using observed daily rainfall data at D.G Khan (2001-2015). The direct runoff due to rainfall has been estimated using US-SCS Curve Number method. Curve number 86 has been used for runoff calculation (Javed et al., 2007). The summary of the hydrological analysis of the three proposed sites is given in Table 02.

Present development plan of the Koh-e-Suleman region has been proposed by keeping in view two issues, i.e., to substantially reduce the flood peaks and to improve the irrigated agriculture. For this purpose, three potential dam sites were identified. The storage potential of the sites was evaluated using DEM. The details of the potential dam sites are given in the Table 02.

It is anticipated that thousands of acres of barren land have the potential for agriculture if the available water from these hill torrents is stored. Moreover, it will help to safeguard the localities from extreme flood during wet year, thus, combating damages to property, crops, livestock, and infrastructure.

Table 02 | Summary of the Hydrology and Specification of the Potential Dam Sites

	Dam Site-1	Dam Site-2	Dam Site-3
Peak Discharge (cusecs)	15000	8616	5400
Date of Peak Discharge	15 Sep. 2011	15 Sep. 2011	15 Sep. 2011
Volume (Th. Ac-ft)	3580.07	1915.80	1221.74
Dam Height (ft)	To be determined	To be determined	To be determined
Dam Length (m)	440	231	367
Watershed Area (sq. km)	1397.44	742.64	478.17
Reservoir Surface Area (sq. km)	2.28	2.00	7.56
Stream Order	4^{th}	4^{th}	3^{rd}

3.4
Water Quality Analysis

3.4.1 Groundwater Quality

Provision of safe drinking water (water with microbial, chemical, and physical characteristics that meet WHO guidelines or national standards on drinking water quality) is one of the significant aspects to protect human health.

Groundwater of the considered area majorly is of acceptable water quality and lie in freshwater zone. Drinking water quality parameters are:

Total Dissolved Solids (TDS)
Arsenic
Nitrate
Fluoride

Water quality data on above mentioned parameters was extracted to evaluate the quality of water. Secondary data of water quality survey carried out by UNICEF in 2015-2016 in Punjab was considered to investigate water quality of tribal area of Koh-e-Suleman.

3.4.2 Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) is considered one of the main parameters in water quality which majorly seems to be less than 600 mg/l in Koh-e-Suleman area against standard value of 1000 mg/l (as per Punjab Drinking Water Quality Standards). Groundwater of Fazla Katch, Barthi, and Tuman Leghari have TDS value of 500-800 mg/l which may be due to dissolved organic matter that can be used after little treatment via filtration in package plants. Overall TDS value results indicate the presence of acceptable water quality. The map of TDS is shown in Figure 12.

Figure 12 | Ground Water Quality in terms of TDS

3.4.3 Arsenic, Nitrate, and Fluoride

The most important contaminants from a health standpoint are naturally occurring chemicals that are usually found in groundwater i.e., Arsenic, Fluoride, Nitrates etc. Secondary available data of water quality was also assessed for consideration of other water quality parameters in the area. Statistical analysis of ground water samples (226 Nos) collected by UNICEF and tested in 2016 for water quality parameters namely arsenic, iron and nitrate revealed that only 0.4% samples were found with iron levels surpassed the PEQS standard value of 1.5 mg/l. No sample was found with arsenic and nitrate level exceeding the standard value of 50 mg/l. In nutshell, 97% of the groundwater quality zone present in said tribal area have the fresh and drinking water which can be make available for supply of clean drinking water by either rehabilitation of non-functional schemes or by installation of packaged plants. GIS-based maps of water quality extracted from reports are attached at Annex D.

DAMS PROVIDE A RANGE OF ECONOMIC, ENVIRONMENTAL, & SOCIAL BENEFITS

04.

Proposed Interventions

4.1

Dam Embankment Design

4.1.1 Dam Height

Dam height above the lowest level in the river channel will be determined based on (i) the gross storage (live storage + dead storage) capacity of dam, (ii) the space required to pass maximum design flood over the spillway (called flood surcharge), (iii) the wave height generated from extreme winds, (iv) the wave runup over the upstream sloping face due to wind gusts, and (v) the free board. Figure 13 shows the sample cross section of small Earth Dam embankment.

4.1.2 Dam Design Criteria

The basic design criteria used for the design of the embankment dam is:

The embankment, foundation, and abutment must be stable under all conditions of construction.

Seepage through embankment, foundation and abutments must be controlled to prevent excessive uplift pressure, piping, and sloughing.

Freeboard must be sufficient to prevent overtopping by waves, unforeseen rise of flood level and should include appropriate allowance towards embankment settlement.

In case dam is in a region subject to earthquake it should be designed for the earthquake, which can reasonably be anticipated and will not impart the function of the structure.

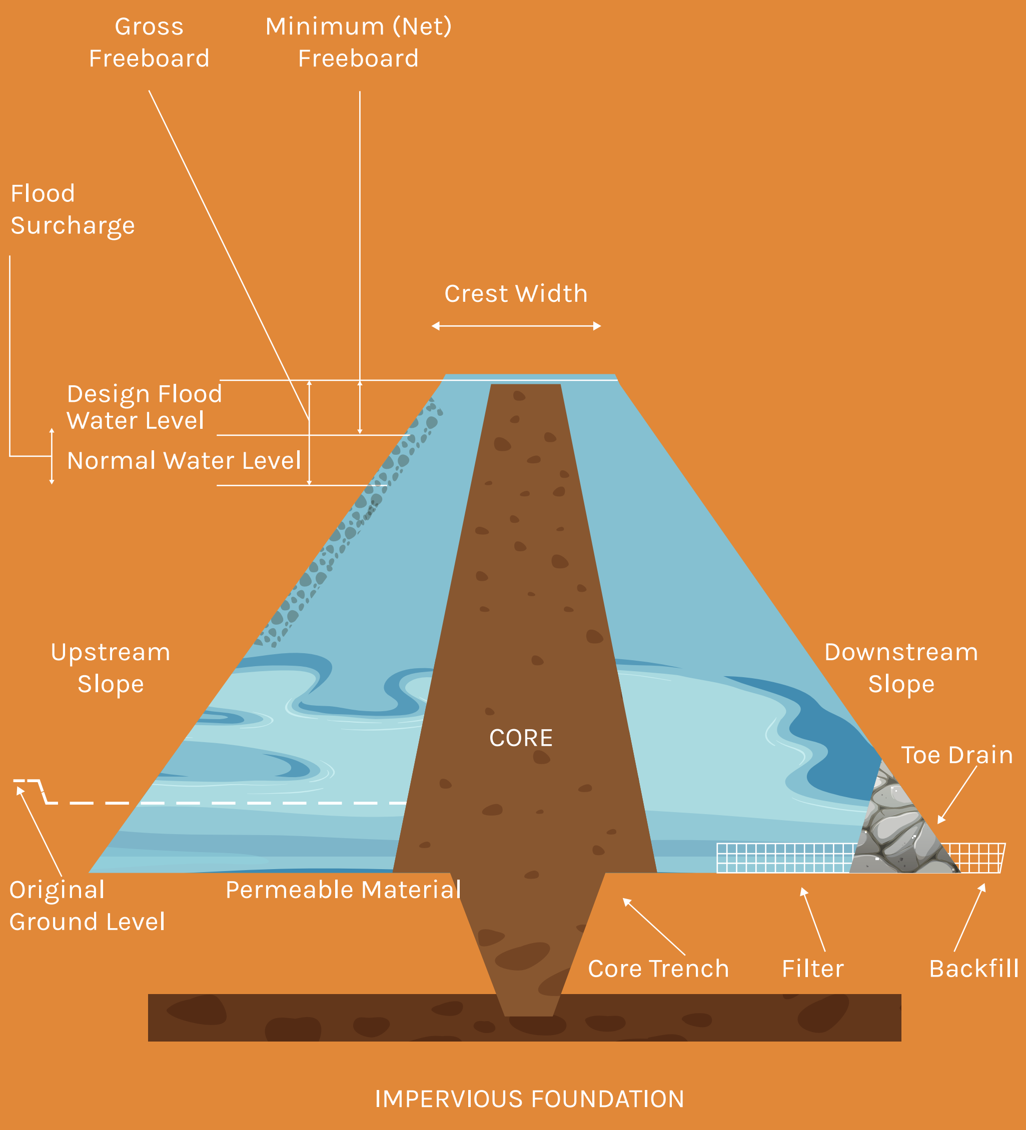


Figure 13 | Cross Section of Small Earth Fill Dam

4.2 Water Quality Package Plant

As the chemical quality of ground water seems to be good enough there will be no specific treatment required for arsenic, nitrate, and fluoride contamination. While microbial contamination and organic matter present in groundwater need to be removed via chlorination and filtration. To provide safe drinking water to the residents in the area, water extracted from tubewells is proposed to be treated through installation of package plants.

Priority should be given to make non-functional water supply schemes to make them functional. Second priority should be given to utilize the existing water supply schemes and provide water in clusters to settlements after treatment through package plant.

According to PHED schemes data, Bairoot Mundwani and Tuman Khosa are the UCs where no functional water supply scheme is present and safe water needs to be supplied, here after getting water treated through nearby schemes. While Tuman Leghari also need attention as large number of schemes are also non-functional over there.

Solar-based Package Plants are proposed for the provision of safe drinking water, where groundwater pumped through tubewells/schemes, having TDS <1000 mg/l, will be delivered to the Low-Level Reservoir/Sahulat center after minor treatment which will include provisions of sand filter, activated carbon filter for removal of any suspended solid and removal of any organic contaminants and disinfection for the removal any biological contaminants. Schematic diagram of Package Plant is shown in Figure 14. While no filter is recommended for chemical contamination because of absence of arsenic, nitrate, and fluoride in area. Specs for 250- and 500-liters plants for tribal areas from studies are attached with Annex E which can be changed as per actual demand.

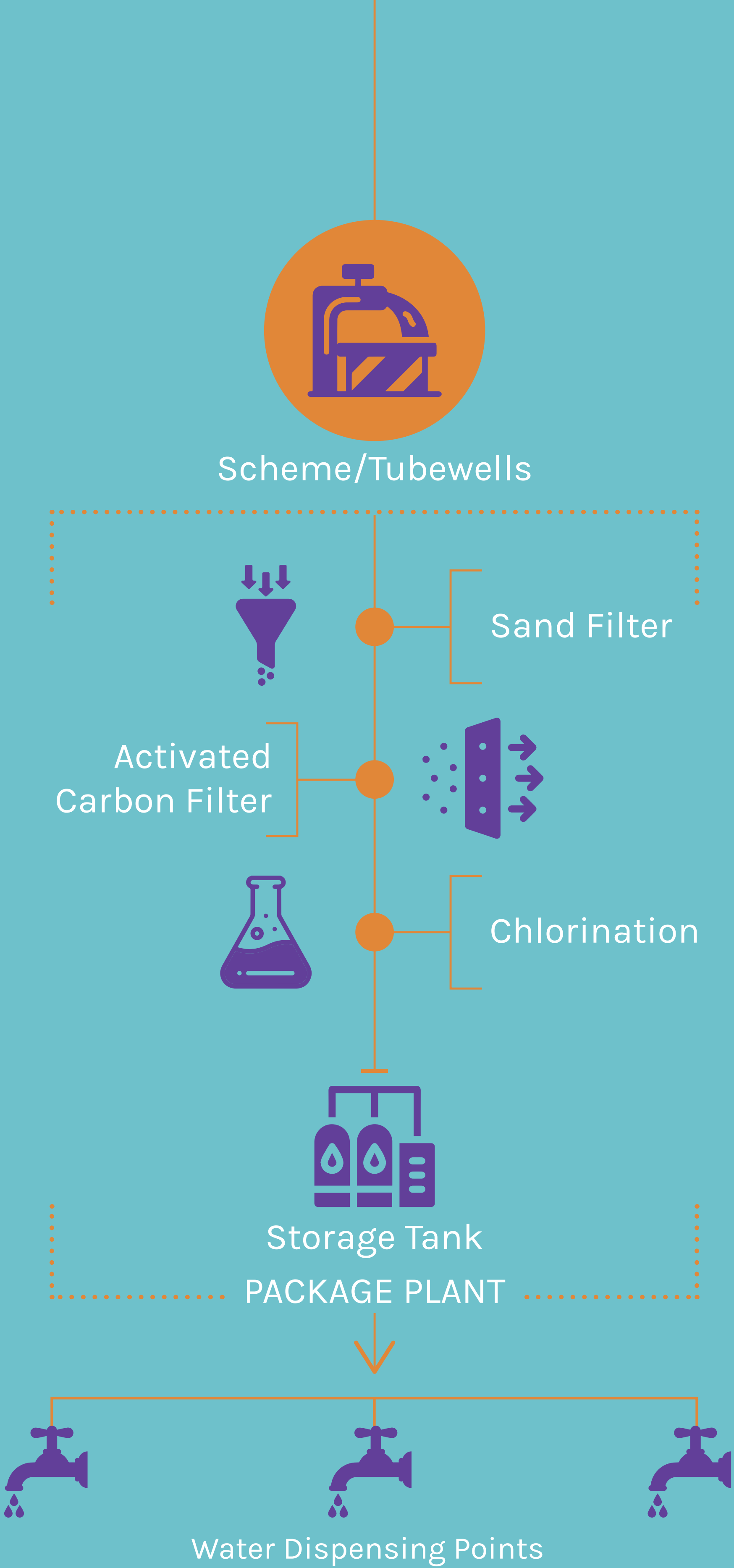


Figure 14 | Schematic Diagram for Package Plant

ANNEXURES

Annex A.

Rural Water Supply Schemes in Koh-e-Suleman

Table 03 | List of Rural Water Supply Schemes in Koh-e-Suleman

Sr.#	RWSS Name	UC Name
1	RWSS Phugla situated at Moza Phugla Janubi Tuman Qaisrani Tribal Area	Bairoot Mundwani
2	RWSS Nallah Sharqi situated at Basti Loharki U/C Baihroot Tuman Qaisrani Tribal Area	Bairoot Mundwani
3	RWSS Bhanwer U/C Bhairoot Tuman Qaisrani Tribal Area	Bairoot Mundwani
4	RWSS Tundani situated at Moza Barthi Shumali Tuman Buzdar Tribal Area	Barthi
5	RWSS Rodo situated at Basti Rodo Gharbi U/C Baihroot Tuman Qaisrani Tribal Area	Barthi
6	RWSS Jatto Kalat situated at Basti Jatto Kalat Moza Barthi Janubi Tribal Area	Barthi
7	RWSS Jaffarani situated at Basti Ahmad Din Jafarani U/C Barthi Tribal Area	Barthi
8	RWSS Hathi Mar situated at Bharjali U/C Barthi Tuman Buzdar Tribal Area	Barthi
9	RWSS Gulkhani Kalat U/C Barthi Tuman Buzdar Tribal Area	Barthi
10	RWSS Barthi/Sardr Kalat U/C Barthi Tuman Buzdar Tribal Area	Barthi
11	RWSS Thaleel situated at Basti Thaleel U/C Fazla Katch Tribal Area	Fazla Katch

Sr.#	RWSS Name	UC Name
12	RWSS Mehal Tanga situated at Basti Lal Muhammad Moza Manka Janubi U/C Fazla Katch Tribal Area	Fazla Katch
13	RWSS Katchi Wanga U/C Fazla Katch Tuman Buzdar Tribal Area	Fazla Katch
14	RWSS Challanah situated at Moza Challanah U/C Fazla Katch Tribal Area	Fazla Katch
15	RWSS Mithwan T/W No.2	Mithwan
16	RWSS Mithwan T/W No.1 U/C Mithwan	Mithwan
17	RWSS Roan Ghoo situated at Basti Mubakri Sand Moza Dab Jahnani U/C Mubarki Tuman Leghari Tribal Area	Mubarki
18	RWSS Mut Chandia situated at Basti Ali Muhammad U/C Mubarki Tribal Area	Mubarki
19	RWSS Kharar Buzdar U/C Mubarki Tuman Buzdar Tribal Area	Mubarki
20	RWSS Basti Lal Muhammad U/C Mubarki Tuman Buzdar Tribal Area	Mubarki
21	RWSS Theaker situated at Phatak U/C Theaker Tuman Buzdar Tribal Area	Theekar
22	RWSS Sohar Duff situated at Basti Sohar Duff Moza Barthi Janubi Tribal Area	Theekar
23	RWSS Pughlo Mori Bun situated at Basti Ghous Bux Ludwani U/C Theaker Tribal Area	Theekar
24	RWSS Peer Marki situated at Neeli Ludwani Moza Sora U/C Barthi Tribal Area	Theekar
25	RWSS Nogozay situated at Basti Khor Khantic U/C Barthi Tribal Area	Theekar
26	RWSS Marban U/C Mubarki Tuman Buzdar Tribal Area	Theekar
27	RWSS Manjhwail Sham U/C Mubarki Tuman buzdar	Theekar
28	RWSS Fakhar Abad U/C Mubarki Tuman Buzdar Tribal Area	Theekar

Sr.#	RWSS Name	UC Name
29	RWSS Durman situated at Sirati Moza Sirati Tuman Buzdar Tribal Aree	Theekar
30	RWSS Chora Khad situated at Basti Wadera Khair Muhammad U/C Mubarki Tuman Buzdar	Theekar
31	RWSS Bun Misnut situated at Basti Gatha Rikh U/C Mubarki Tribal Area	Theekar
32	RWSS Zain Moza Zain U/C Barthi Tribal Area	Tuman Khosa
33	RWSS Shum Zain Moza Shum U/C Barthi Tuman Buzdar Tribal Area	Tuman Khosa
34	RWSS Dara Mohi U/C Barthi Tribal Area	Tuman Khosa
35	TWSS Thak Lahar U/C Tuman Leghari	Tuman Leghari (Bala)
36	RWSS Zewer Kandi U/C Tuman Laghari Tribal Area	Tuman Leghari (Bala)
37	RWSS Taratani U/C Tuman Laghari Bala Tribal Area	Tuman Leghari (Bala)
38	RWSS Taokli Thal U/C Tuman Laghari Balai	Tuman Leghari (Bala)
39	RWSS Siah Gar Balai situated at Basti Nawaz U/C Tuman Laghari Balai	Tuman Leghari (Bala)
40	RWSS Rakhi Mounh U/C Tuman Leghari Zareen	Tuman Leghari (Bala)
41	RWSS Rakhi Ghage situated at Basti Muhammad Yousaf U/C Tuman Leghari	Tuman Leghari (Bala)
42	RWSS Nelagh Janubi U/C Tuman Leghari Balai	Tuman Leghari (Bala)
43	RWSS Khunnar Loop Basti Haji Jeevan Hajwani U/C Tuman Leghari	Tuman Leghari (Bala)
44	RWSS Juma Khan/Jalal Khan U/C Tuman Leghari Tribal Area	Tuman Leghari (Bala)
45	RWSS Jarani Basti / Basti Karam Khan U/C Tuman Leghari Tribal Area	Tuman Leghari (Bala)
46	RWSS Jan M.Gandha U/C Tuman Laghari	Tuman Leghari (Bala)
47	RWSS Hori Khad U/C Tuman Laghari Tribal Area	Tuman Leghari (Bala)
48	RWSS Gujri Thoke U/C Tuman Leghari	Tuman Leghari (Bala)

Sr.#	RWSS Name	UC Name
49	RWSS Good No.2/TB Hospital Khar U/C Tuman Laghari	Tuman Leghari (Bala)
50	RWSS Girdu Dabak U/C Tuman Laghari Balai	Tuman Leghari (Bala)
51	RWSS Garm Auf Balai and Zareen U/C Tuman Laghari	Tuman Leghari (Bala)
52	RWSS Fort Munro T/W No.5 situated at Khar U/C Tuman Leghari	Tuman Leghari (Bala)
53	RWSS Fort Munro T/W No.4 situated at Khar U/C Tuman Laghari Balai	Tuman Leghari (Bala)
54	RWSS Fort Munro T/W No.3 situated at Khar U/C Tuman Leghari	Tuman Leghari (Bala)
55	RWSS Fort Munro T/W No.2 situated at Khar	Tuman Leghari (Bala)
56	RWSS Fort Munro T/W No.1 situated at Khar U/C Tuman Leghari Balai	Tuman Leghari (Bala)
57	RWSS Dada Koh U/C Tuman Leghari Tribal Area	Tuman Leghari (Bala)
58	RWSS Chotti Sar/new Scheme name Nian Dair U/C Tuman Leghari Tribal Area	Tuman Leghari (Bala)
59	RWSS Bishmani /Niagh Bough,Norang Khan U/C Tuman Leghari Tribal Area	Tuman Leghari (Bala)
60	RWSS Bian Duff/Basti Muhammad Khan situated at began Spring U/C Tuman Leghari Tribal Area	Tuman Leghari (Bala)
61	RWSS Bewata U/C Tuman Laghari Balai	Tuman Leghari (Bala)
62	RWSS Basti Wadera Shah Ali U/C Tuman Laghari Tribal Area	Tuman Leghari (Bala)
63	RWSS Basti Muhammad khan/Jamal Khan situated at Tali Pull U/C Tuman Leghari Tribal Area	Tuman Leghari (Bala)
64	RWSS Basti Lal Bukhish/Awais Khan U/C Tuman Leghari Tribal Area	Tuman Leghari (Bala)
65	RWSS Basti Faiz Muhammadand Basti Yousaf situated at Digi U/C Tuman Leghari Tribal Area	Tuman Leghari (Bala)
66	RWSS Aptaro Padhari situated at Boys Primary School Padhari U/C Tuman Leghari Tribal Area	Tuman Leghari (Bala)

Sr.#	RWSS Name	UC Name
67	RWSS Abdul Rehman near Girdu U/C Tuman Leghari Balai	Tuman Leghari (Bala)
68	Source of Schemes, RWSS Basti Daulat/ Siri Sharqi/ Dholi situated at Moza Dholi U/C Tuman Leghari	Tuman Leghari (Zareen)
69	RWSS Soriaigh Kooh U/C Tuman Lagari Tribal Area	Tuman Leghari (Zareen)
70	RWSS Shamboo Moza Shamboo U/C Tuman Leghari Zareen Tribal Area	Tuman Leghari (Zareen)
71	RWSS Roonghan Moza Sohrain Katch Tuman Leghari Zareen Tribal Area	Tuman Leghari (Zareen)
72	RWSS Post Mubarki U/C Mubarki Tribal Area	Tuman Leghari (Zareen)
73	RWSS Nikki situated at Moza Khar Shank Ronghan U/C Tuman Leghari Tribal Area	Tuman Leghari (Zareen)
74	RWSS Mubarki Leghari situated at Basti Meer Khan Moza Shafach U/C Tuman Leghari Zareen	Tuman Leghari (Zareen)
75	RWSS Lundani Loop situated at Moza Manhi U/C Tuman Leghari Tribal Area	Tuman Leghari (Zareen)
76	RWSS Lower Pusht Thobi situated at Moza Thobi U/C Tuman Leghari Zareen Tribal Area	Tuman Leghari (Zareen)
77	RWSS Bian Duff situated at Moza Shambo U/C Tuman Laghari Zareen Tribal Area	Tuman Leghari (Zareen)
78	RWSS Basti Loriani(Golu Kandagh) situated at Mouza Baser Bun U/C Tuman Leghari Tribal Area	Tuman Leghari (Zareen)
79	RWSS Basti Fazal Khan Zard Khor U/C Tuman Leghari Zareen	Tuman Leghari (Zareen)
80	RWSS Barge Hansar U/C Tuman Laghari Tribal Area	Tuman Leghari (Zareen)
81	RWSS Anum Ghazari situated at Basti Ahmad Khan Moza Sohrain Katch U/C Tuman Laghari Tribal Area	Tuman Leghari (Zareen)
82	RWSS Haji Ismail / Rozay Khan U/C Tuman Laghari Tribal Area	Tuman Leghari (Bala)
83	RWSS Dhamani U/C Mithwan Tuman Qaisrani Tribal Area	Mithwan

Annex B.

Slope, Contour, and Stream Network Maps of Koh-e-Suleman

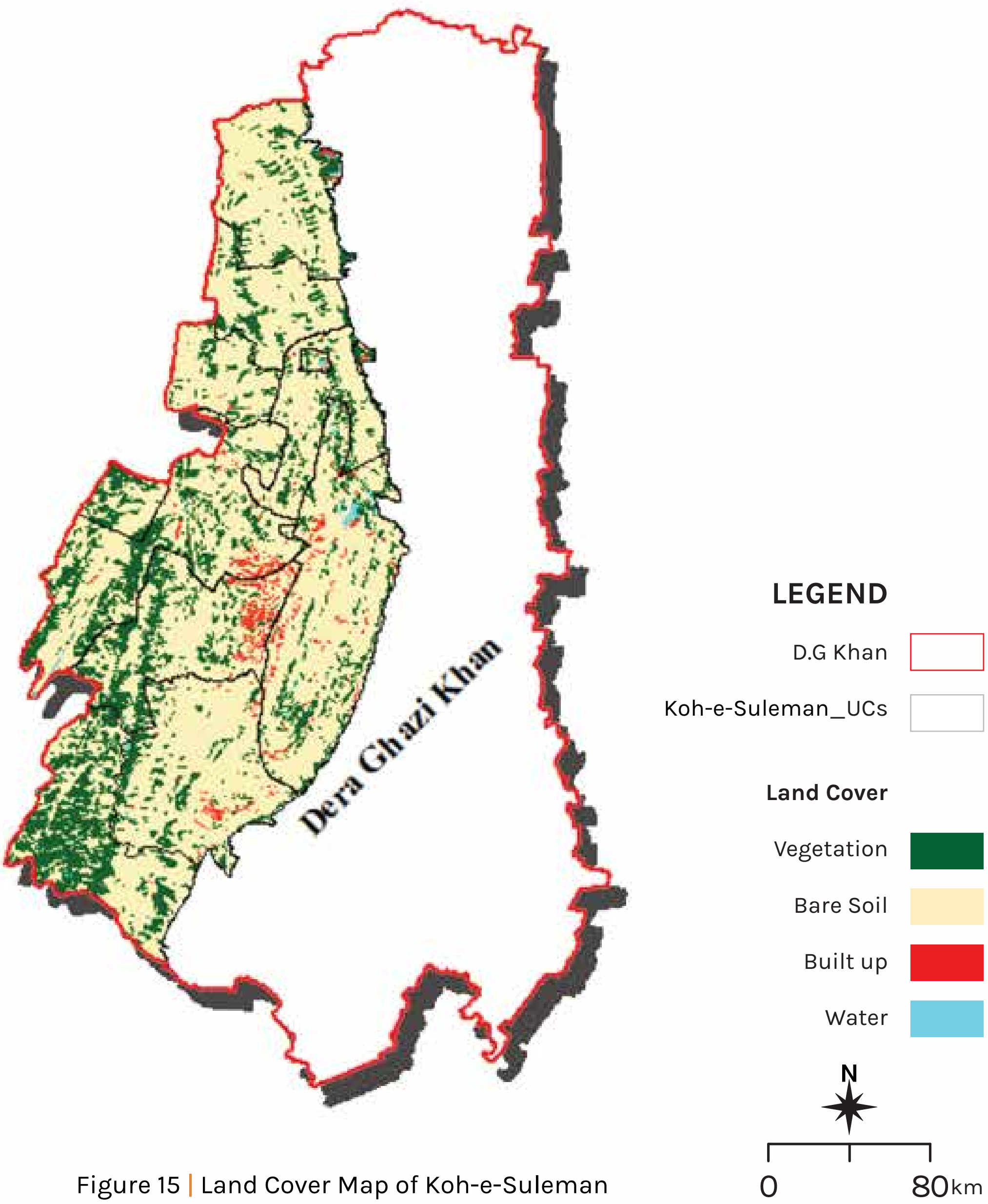


Figure 15 | Land Cover Map of Koh-e-Suleman

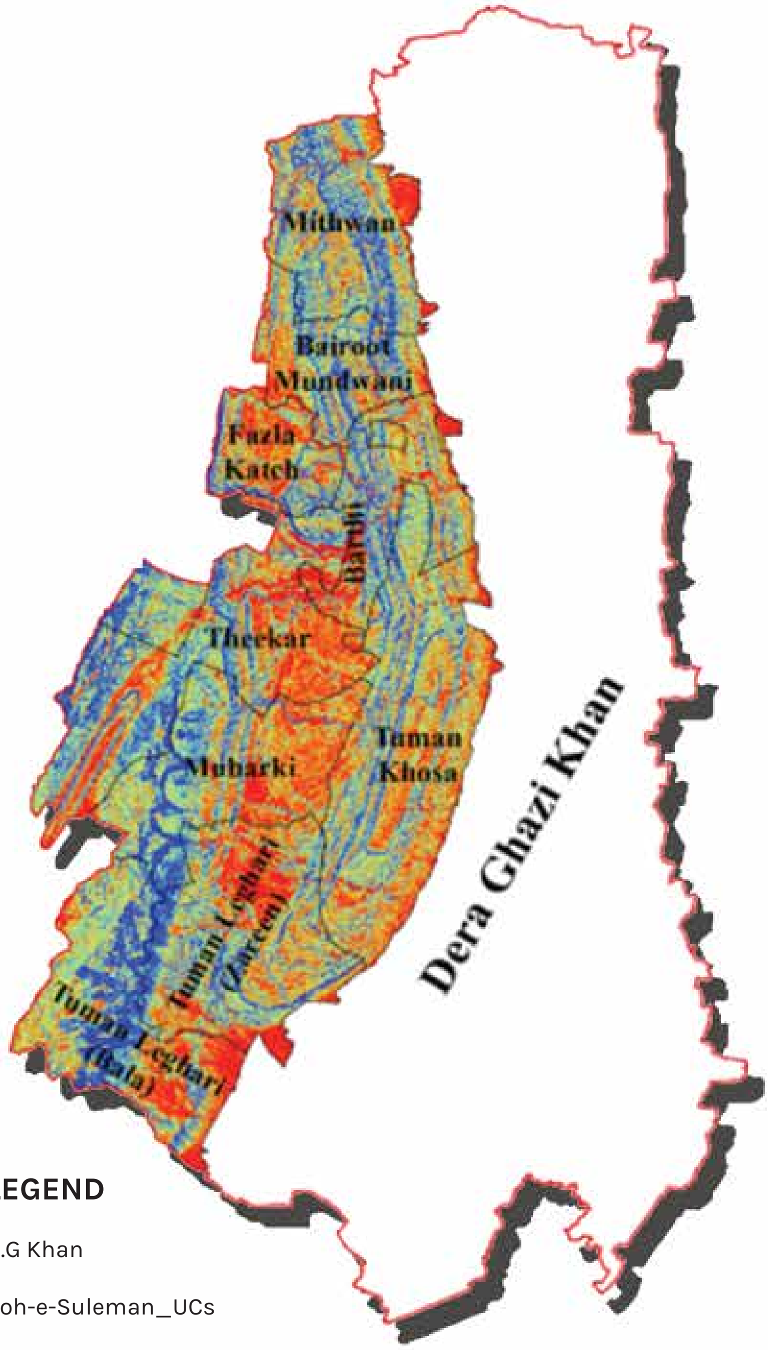


Figure 16 | Slope Map Koh-e-Suleman

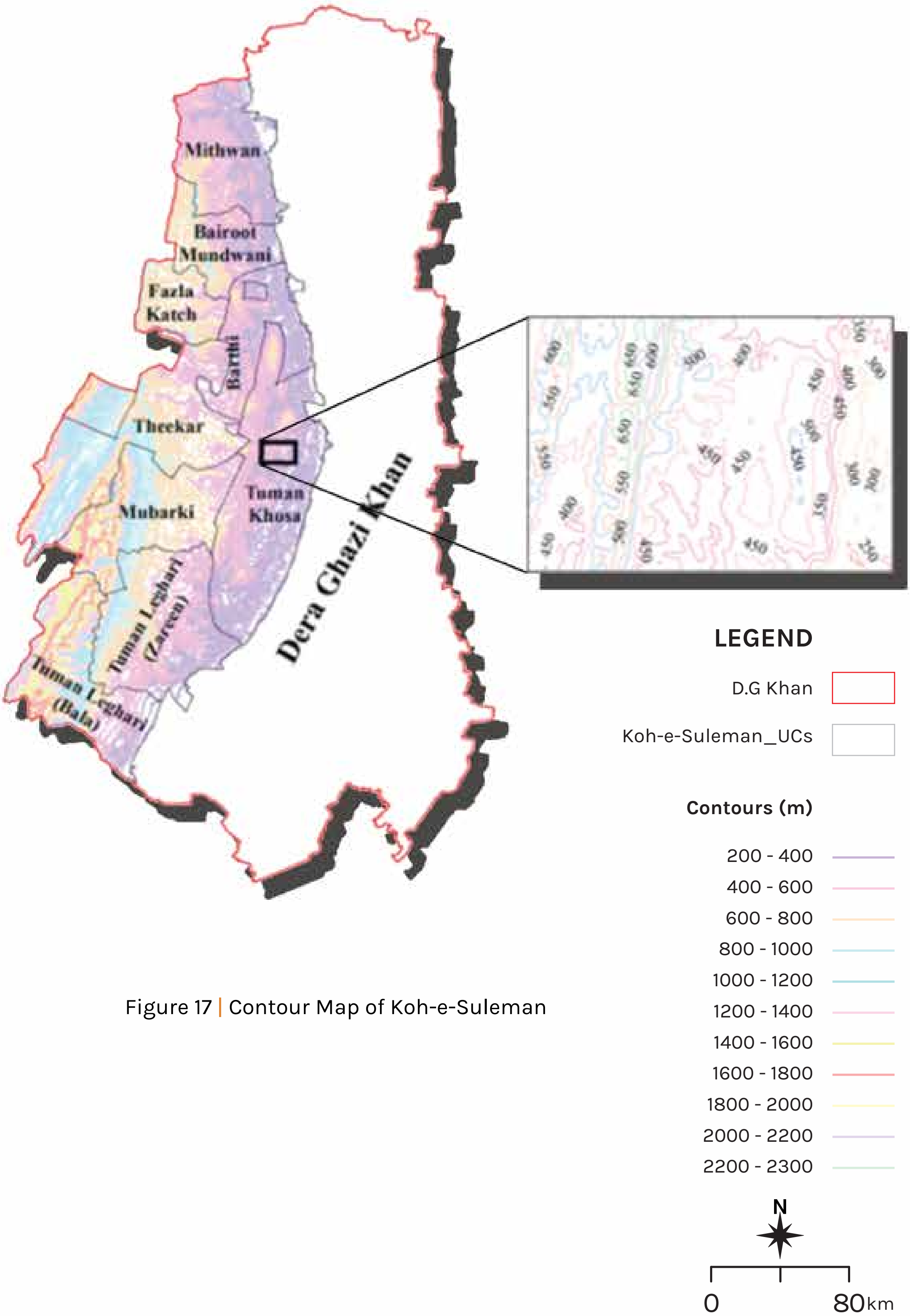


Figure 17 | Contour Map of Koh-e-Suleman

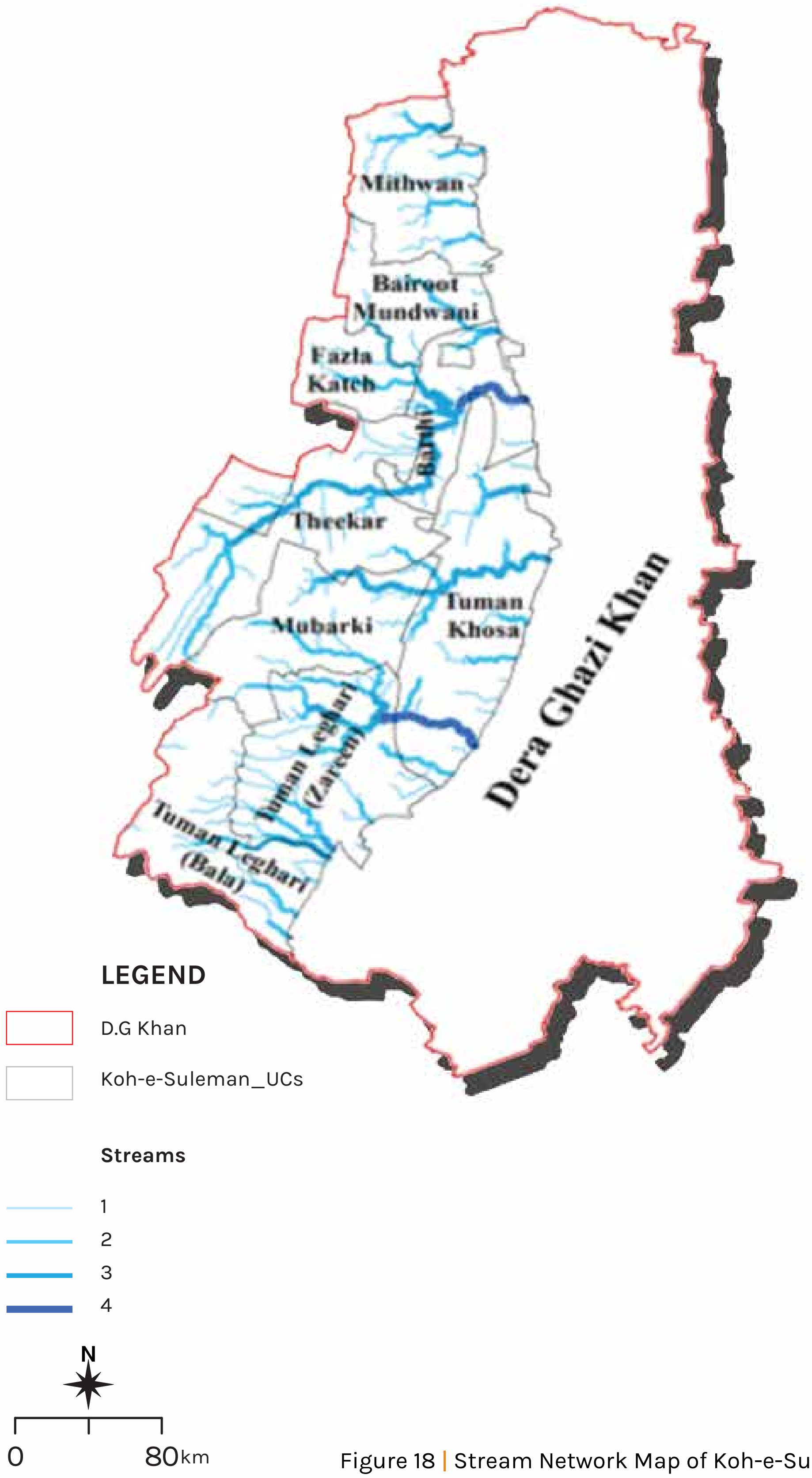


Figure 18 | Stream Network Map of Koh-e-Suleman

Annex C.

Google Earth Images of the 03 Dam Sites

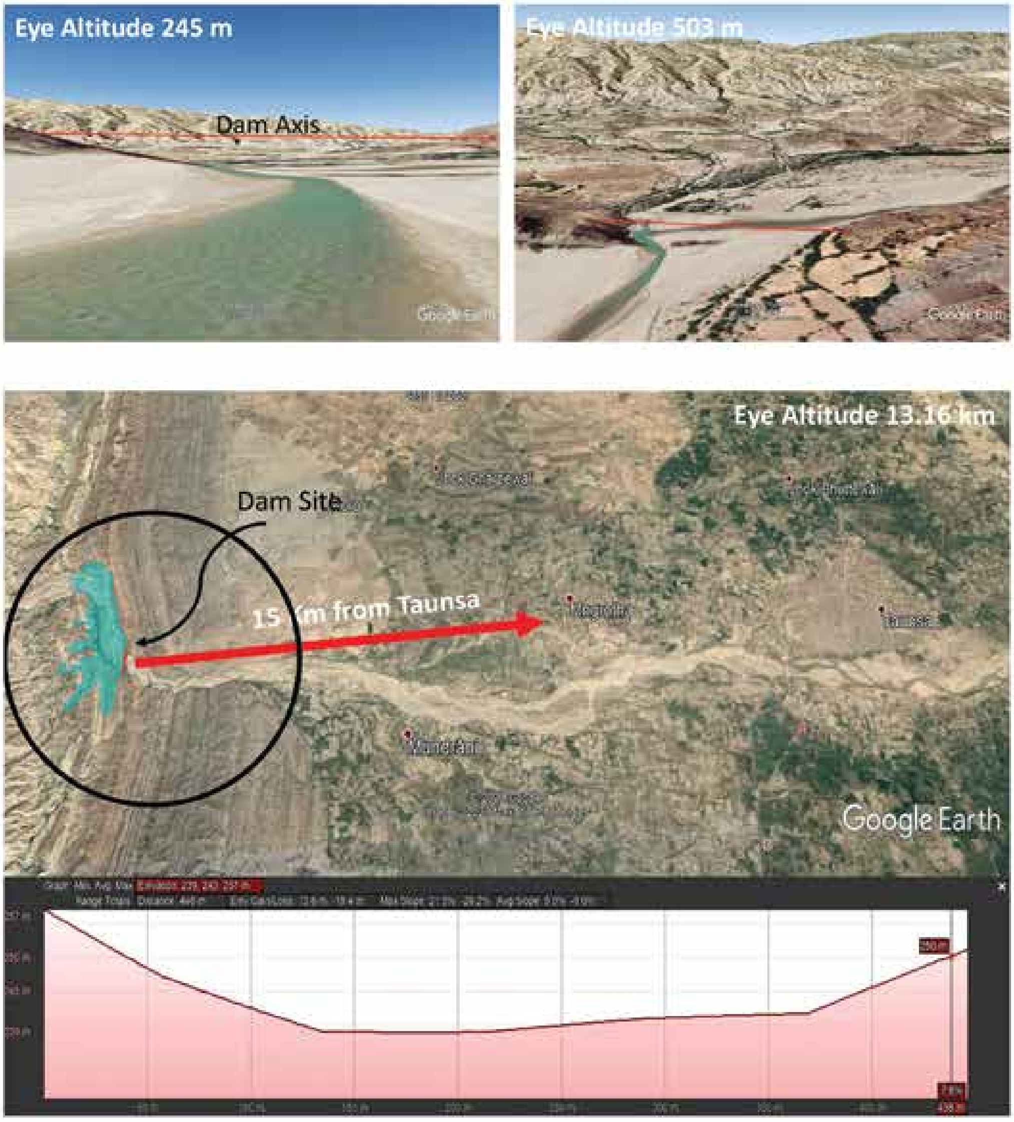


Figure 19 | Google Earth Image of Dam Site 01

Figure 20 | Google Earth Image of Dam Site 02

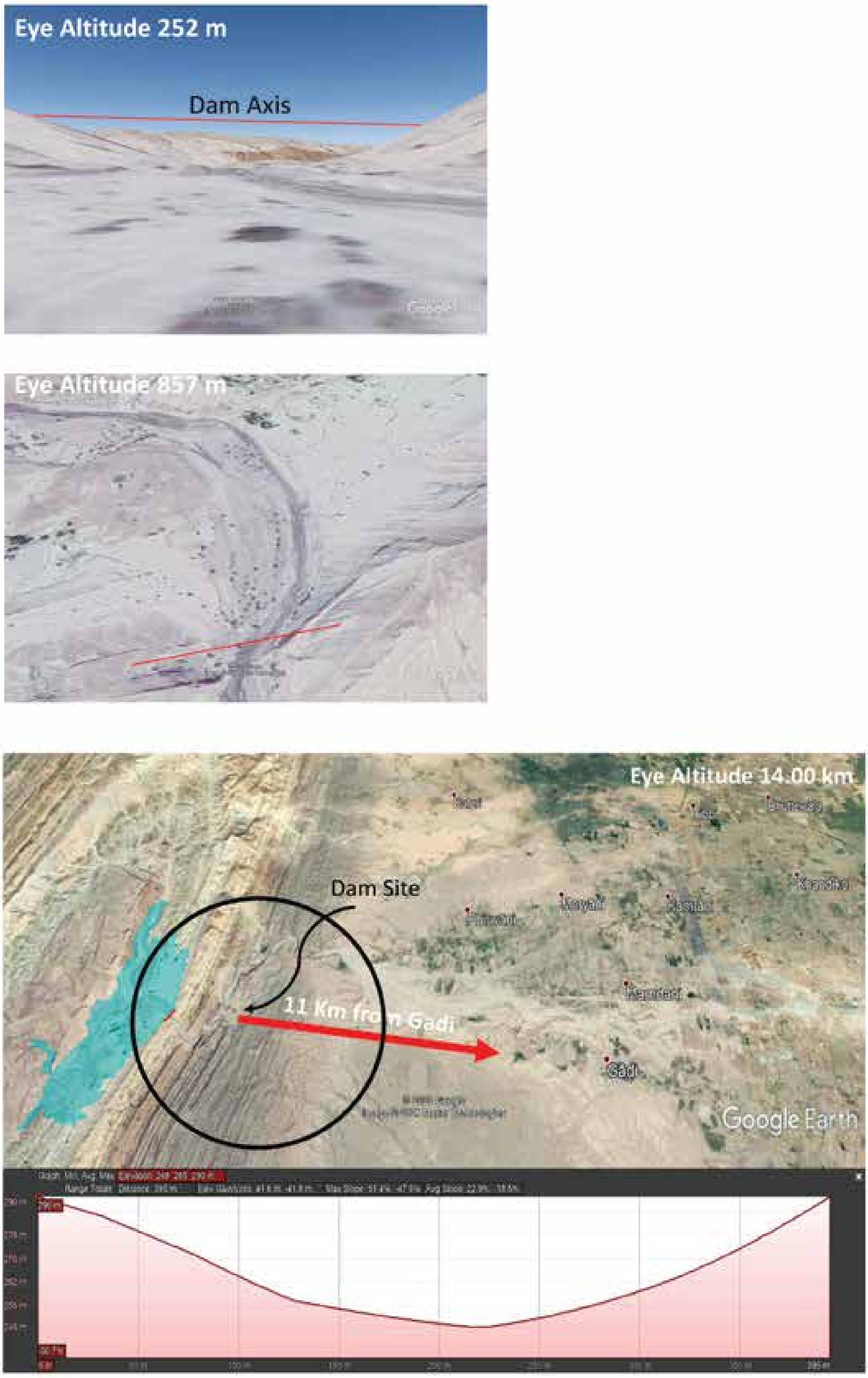


Figure 21 | Google Earth Image of Dam Site 03

Annex D.

Water Quality Maps Arsenic

GIS-based mapped arsenic condition in Koh-e-Suleman area is illustrated in figure below.

Water Quality Map, Tehsil Tribal Area (Package 3) (Arsenic)

Figure 22 | Arsenic Mapping

Fluoride

GIS-based mapped fluoride condition in Koh-e-Suleman area is illustrated in Figure 23:

Figure 23 | Fluoride Mapping

Annex E.
Filtration Unit Specification

Filtration Units using Sand Filter and Active Carbon Filter

Pre Filtration (Pressure Sand Filtration)	**Capacity 500 L/h**
Mounting	If turbidity is <10 NTU
Filtration Rate	On (same) skid, material $$304
Backwash Rate	10 m/h
Backwashing Time	30 m/h
	Adjustable by Local Timer
	0.8-1.0 mm
	UC 1.4-1.7
Sand Effective Size	Depth 0.6-1.0 mm
	SG ≥ 2.63
Vessel	FRP
Vessel Diameter/Height	Minimum 300mm/1600 mm
Feed Pump	Centrifugal type, eff>60%
Piping for Units	PE or PVC PN 25
Piping for Units	PE or PVC PN 25
Dosing Units for	$FeCl_3$ and NaOCl or ClO_2 or $KMNO_4$
Automatic 3-way Valve	For chemical dosing

Activated Carbon Filtration	
Filtration Rate	8 m/h
Empty Bed Contact Time EBCT	5 Minutes
Backwash Rate	25 m/h
Base Material	Coconut Shell, Wood, Bituminous Coal, Lignite coal
Effective Size	1.2-1.6 mm
Uniformity Coefficient	≤ 1.9
Surface Area	500 m^2/g
Vessel Material	FRP
Vessel Diameter/Height	Minimum 300mm/1600mm
Replacement	On depletion of the adsorption capacity

Filtration Units using Sand Filter and Active Carbon Filter

Pre Filtration	**If turbidity is <10 NTU**
(Pressure Sand Filtration)	On (same) skid, material $$304
Mounting	10 m/h
Filtration Rate	30 m/h
Backwash Rate	Adjustable by Local Timer
Backwashing Time	0.8-1.0 mm
	UC 1.4-1.7
Sand Effective Size	Depth 0.6-1.0 mm
	SG ≥ 2.63
Vessel	FRP
Vessel Diameter/height	Minimum 250mm/1600 mm
Feed Pump	Centrifugal type, eff>60%
Piping for Units	PE or PVC PN 25
Piping for Units	PE or PVC PN 25
Dosing Units for	FeCl3 and NaOCl or ClO2 or KMNO4
Automatic 3-way Valve	For chemical dosing
Activated Carbon Filtration	
Filtration Rate	8 m/h
Empty Bed Contact Time EBCT	5 Minutes
Backwash Rate	25 m/h
Base Material	Coconut shell, Wood, Bituminous coal, lignite coal
	1.2-1.6 mm
Effective Size	
Uniformity Coefficient	≤ 1.9
Surface Area	500 m2/g
Vessel Material	FRP
Vessel Diameter/Height	Minimum 250mm/1600mm
Replacement	On depletion of the adsorption capacity

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