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Wilmington District

Southeast Afghanistan Water Resources Assessment


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Contour Irrigation, Ster Kalay, Paktya Province

Prepared For:

U.S. Army - Task Force Yukon
4th Brigade Combat Team (Airborne)
25th Infantry Division

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14. ABSTRACT

The objective of this study was to evaluate potential water resource projects in Southeast Afghanistan that will benefit the people of that region. This study was prepared at the request of the US Army Corps of Engineers' Transatlantic Programs Center and Afghanistan Engineer District in support of the U.S. Army Task Force Yukon Commander, FOB Salerno. The USDA and USGS were partners with USACE in this assessment. The study report will assist the Commander in identifying potential water resource projects that may include; irrigation storage dams, erosion control, hydropower, flood control, groundwater resources, irrigation canals and drains. Appendix contains supporting maps, calculations and detail result tables. The study was primarily based on analysis of high-resolution satellite images, digital elevation models, available spatial data, assistance of regional experts, the authors' in-country experience, on-site observations and publications.

15. SUBJECT TERMS
Water resources, water balance, micro-hydropower, hydropower, dam, diversion, watershed assessment, irrigation, remote sensing, Afghanistan, Khost, Paktya, Logar, Wardak, Ghazni, Paktika, watershed restoration, watershed characterization, decision support modeling.

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Acronyms

ACC – Afghan Conservation Corps
ADT – Agri-Business Development Team
AED – Afghanistan Engineer District (Corps of Engineers, Kabul)
AIMS – Afghanistan Information Management Service
BARC – Burned Area Reflectance Classification
CDP – Criterion Decision Plus software © Infoharvest
CIR – Color Infrared
CRREL – Cold Regions Research and Engineering Laboratory (Corps of Engineers, ERDC)
DACAAR – Danish non-governmental, humanitarian organization
DEM – Digital Elevation Model
DSM – Decision Support Model
ERDC – Engineering Research and Development Center (Corps of Engineers)
FAO – Food and Agriculture Organization of the United Nations
FOB – Forward Operating Base
GIS – Geographic Information System
ha – hectare, 1 ha = 10,000 m^2, 100 ha = 1 km^2, 1 ha = 2.47 acre
km – kilometer, 1 km = 0.62 mile
km^2 – kilometer squared, 1 km^2 = 0.386 mi^2
kW – kilowatt, 1 kW = 1,000 W
KW-hr – kilowatt-hour
IWMI – International Water Management Institute
m – meter, 1 m = 3.28 feet
m^3/s — flow in cubic meter per second, cumec
M-m^3 – one million m^3, one million cubic meters
MAIL – Ministry of Agriculture, Irrigation and Livestock
MEW – Ministry of Energy and Water
MGRS – Military Grid Reference System
MRRD – Ministry of Rural Rehabilitation and Development
NGA – National Geospatial-Intelligence Agency
NIMA – National Imagery and Mapping Agency
NOAA – National Oceanic and Atmospheric Administration
NRCS – Natural Resources Conservation Service (USDA)
PRT – Provincial Reconstruction Team
SMART – Simple Multi-Attribute Rating Technique
SRTM – Shuttle Radar Topography Mission
TF - Task Force
UN-FAO – United Nations Food and Agriculture Organization
UNICEF – United Nations International Children’s Emergency Fund
USACE – United States Army Corps of Engineers
USAID – United States Agency for International Development
USDA – United States Department of Agriculture
USFS – United States Forest Service (USDA)
USGS – United States Geological Survey
UTM – Universal Transverse Mercator
WGS – World Geodetic System

Executive Summary

Southeast Afghanistan is a region of water resource challenges. Annual potential evaporation from vegetation and land surface greatly exceeds precipitation. Farmers generally rely on irrigation for their crops and groundwater for safe household water supplies. The region has an agrarian-based economy with the majority of settlements located along narrow strips of cultivated land in the river valleys and broad depositional valleys. Most of the land is irrigated by small-scale, traditional methods controlled by small communities. The principal livestock is sheep, a high value component of the region's agriculture. Erosion and sedimentation are on-going and severe problems as are security and remoteness. Poor grazing practices exacerbated many of the water resource problems in the region. The region has some of the largest forested areas in Afghanistan, an important economic resource. Deforestation has also contributed to watershed erosion problems.

The purpose of the Southeast Afghanistan Water Resources Assessment was to evaluate potential water resource improvement projects that the U.S. Army's Task Force Yukon can practically and effectively implement in cooperation with the Islamic Republic of Afghanistan. The study was primarily based on analysis of high-resolution satellite images, digital elevation models, available spatial data, assistance of regional experts, the authors' in-country experience, on-site observations and publications. Though these methods cannot substitute for on-site analyses, remote sensing does allow for the evaluation of hundreds of project sites relatively quickly. The subsequent analysis determined which sites are likely to have the highest potential for success. Time on the ground in this remote, unsecure area can then be focused only on the best project sites, saving both time and funds as well as reducing risk to personnel.

Two hundred and ninety-five potential water resource project locations were evaluated in this study, along with their associated watersheds. Soil, slope, elevation and geological characteristics were evaluated for all project areas. Digital spatial data were used to estimate reservoir and dam engineering characteristics. Of the 295 sites, 159 possible irrigation storage dam sites were identified. Evaluation of these sites was based on storage potential, constructability, irrigation benefits (including potential capacity as well as benefiting existing agriculture), inundation impacts and watershed stability. Components of watershed stability and potential sedimentation included recent deforestation, stream system stability and upland erosion.

Because of the large number of sites and complexity of evaluation factors, a structured decision support model was implemented for both irrigation storage dams and watershed management. The approach both clarified the criteria used in evaluation, and allowed the modification of criteria by Task Force Yukon for changing conditions.

The remaining 136 sites were potential micro-hydropower and irrigation diversion dams. These were subjectively and graphically reviewed because enough detailed data were not available for implementation of a decision support model.

Additional products from this study include groundwater summaries, streamflow and climate datasets, GIS shapefiles, analysis of sedimentation data, a decision support model to guide watershed restoration and project-level planning support provided to field personnel. To address small-scale projects, a workshop was given in June 2009 at FOB Salerno, Afghanistan.

This report emphasizes projects that can be relatively quickly constructed and implemented, but is more importantly intended to be a planning document and the first stage of implementing a sustainable water management strategy in southeast Afghanistan, including both short-term structural improvements and longer-term watershed restoration.

1.0 Introduction

1.1 Location and General Description

The water resource study area includes the provinces of Khost, Paktya, Logar, Wardak and Ghazni in southeast Afghanistan. A map of the study provinces with Afghanistan's major river watersheds is provided in Figure 1-1. This study also includes updated information on the neighboring Paktika Province to supplement the water resources report prepared in May 2008.

Southeast Afghanistan has an agrarian-based economy. The majority of the settlements are located along narrow strips of cultivated land in the river valleys. Most of the land is irrigated by small-scale, traditional methods. Complex networks of irrigation diversions, canals and drains are used below Sardeh and Sultan Dams in Ghazni and in the open floodplain of the Logar River. The principle livestock is sheep and is a high value component of the region's agriculture. Poor grazing practices have exacerbated many of the water resource issues in the region. Khost and Paktya Provinces have some of the largest forested areas in Afghanistan, which are an important economic resource for the region.

Southeast Afghanistan has an arid to semi-arid climate. Annual precipitation ranges from under 200 mm in western Ghazni Province to over 400 mm in Khost and northern Wardak. Most of the precipitation occurs during winter but the eastern provinces of Khost, Paktya and Paktika can receive over 100 mm of rainfall during the summer monsoons. Annual potential evapotranspiration greatly exceeds precipitation for the entire study area making most crops reliant on irrigation. The annual evapotranspiration rate at Gardez in Paktya is 1,300 mm.

Elevations range from over 5,000 m along the far western extension of the Hindu Kush Mountains in Wardak to 500 m as the Shamal River enters Pakistan, see Figure 1-2. The study area is drained by three major river watersheds. Most of Ghazni Province and the western portions of Wardak and Paktya drain into the Helmand River basin. Khost Province and eastern Paktya drain east into Pakistan and eventually flow into the Indus River. Logar and eastern Wardak Provinces are included in the Kabul River basin that also joins the Indus River.

The five study provinces along with Paktika have a combined population of approximately 3,360,000 (CSO, 2008). Table 1-1 includes population by province, land area, estimated cultivated area and irrigated area (AIMS, 2005). Only 45% of the population in the six provinces has access to safe water sources (UNICEF, 2004).

Table 1-1 – Province Population and Land Cover

Province	Capital	Population	Land Area	Cultivated Area	Irrigated Area
			(km^2)	(km^2)	(km^2)
Khost	Khost	511,600	4,260	1,330	352
Paktya	Gardez	490,900	5,480	1,035	676
Logar	Pul-i Alam	349,000	4,700	2,966	471
Wardak	Maydan Shahr	531,200	9,880	4,700	889
Ghazni	Ghazni	1,092,600	21,950	4,007	2,435
Paktika	Sharan	387,300	19,460	1,871	688

Figure 1-1- Location Map (AIMS, 2005)

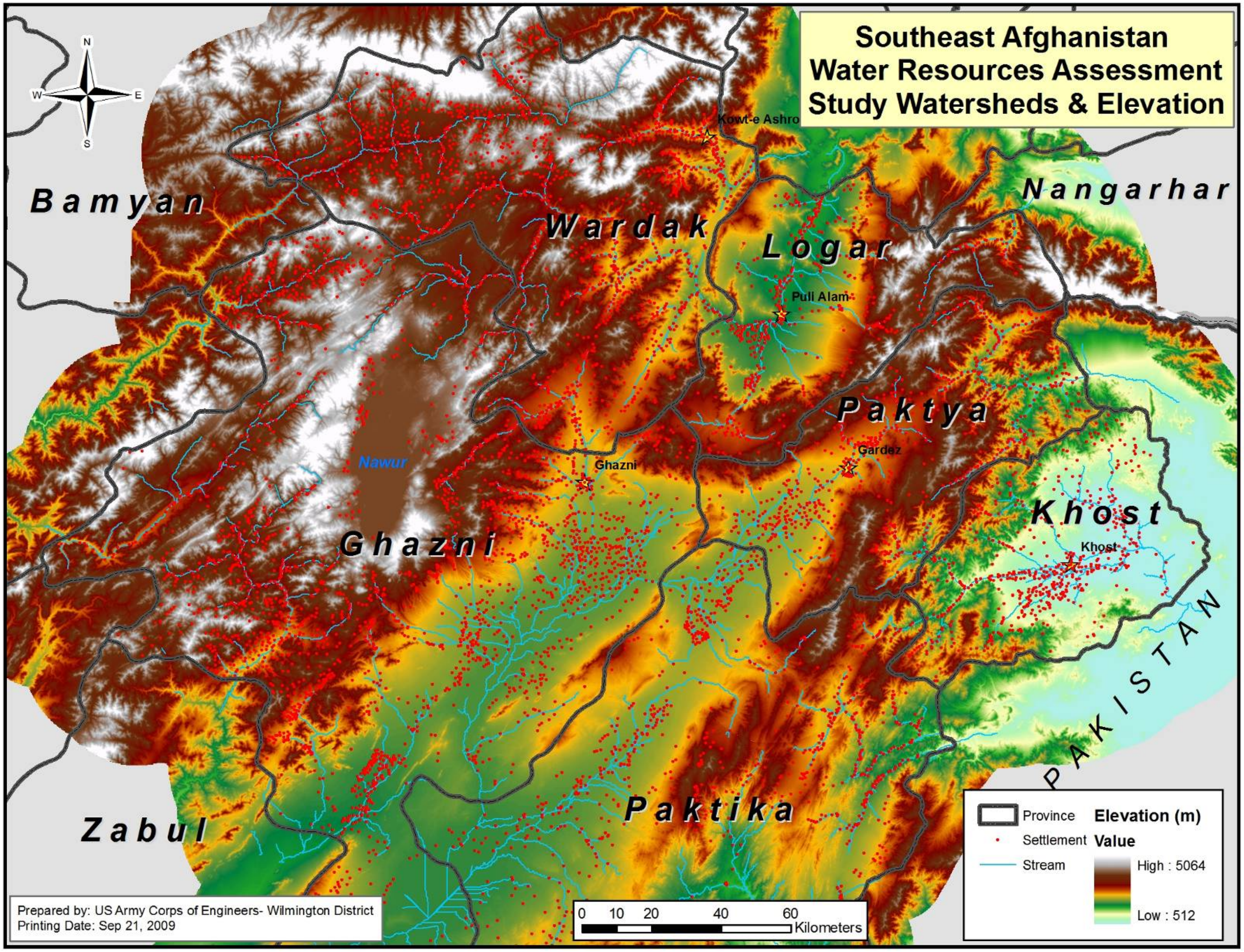


Figure 1-2 – Study Area Elevation and Settlements

1.2 Study Purpose and Scope

The purpose of this study was to evaluate potential water resource projects in the Southeast Afghanistan Provinces of Khost, Paktya, Logar, Wardak and Ghazni that will benefit the people of that region. The September 2008 Scope of Work (SOW) was prepared at the request of the US Army Corps of Engineers' Transatlantic Programs Center and Afghanistan Engineer District in support of Combined Task Force (CTF) Currahee, 4th Brigade Combat Team, 101st Airborne Division (Air Assault). Area command changed from CTF Currahee to Task Force (TF) Yukon, 4th Brigade Combat Team (Airborne), 25th Infantry Division in March 2009.

This assessment will assist TF Yukon in identifying potential water resource projects and improve utilization of existing resources. Projects include watershed restoration, hydropower, flood control, erosion control, groundwater resources, irrigation diversions and storage dams. The assessment focuses on the medium scale water resource projects such as 5 to 12 m high irrigation storage dams and micro-hydropower. This assessment does not address large-scale projects such as multi-purpose dams or municipal water systems. These large projects require years of analysis, design and coordination and are outside the current mission of TF Yukon.

Due to security issues in the study region, much of the engineering analysis in this assessment was performed using GIS tools and remote sensing data from satellites and aircraft. The advantage of using remote sensing is that hundreds of potential project sites can be evaluated without sending personnel to the site. Field time for personnel would be focused only at the sites that have been evaluated and determined to have a high potential for success.

Using remote sensing data does put restrictions on the amount of detailed analysis and design that can be performed. This study was not able to address small-scale water supply, irrigation diversions and canals due to limitations in the elevation dataset. Project cost estimates were not provided due to remoteness of the project sites and uncertainties in cost for labor, materials, transportation and security.

The U.S. Geologic Survey (USGS) was a partner in this study. The USGS was responsible for entering all available streamflow records into a publically accessible database and calculating streamflow statistics. A groundwater and water quality data search was conducted by the USGS of the study area. The purpose of this search was to review the amount and quality of available data and determine the most appropriate method to assess the aquifers and groundwater resources in the region.

The U.S. Department of Agriculture (USDA) served an integral role in this study. The USDA utilized remote sensing technology to evaluate the condition of the project watersheds. The potential for success in restoring and stabilizing the watersheds was determined. Because remote sensing techniques were not able to address all small-scale projects, the USDA provided hands-on workshops to address those issues at TF Yukon's Forward Operating Base Salerno in Khost. The workshop included erosion control, rangeland management, agricultural soil assessments, gabion structures, irrigation methods, potable water supply and restoring vegetation. Participant recommendations included providing similar workshops prior to deployment (Fripp, 2009).

2.0 Data Collection Effort

2.1 Vector and Grid Spatial Data

Existing geographic information system (GIS) data used in the analysis and in preparing maps were obtained from the Afghanistan Information Management Services (AIMS). GIS shapefiles and prepared maps of Afghanistan are available online at the following AIMS web site, http://www.aims.org.af/ . AIMS prepared provincial boundaries, streamgage stations and settlement shapefiles were used in the mapping.

New shapefiles were created of watersheds, water resource project sites, elevation contours, inundation contours, streamlines and other supporting hydrologic parameters. These shapefiles were projected in WGS84 UTM Zone 42 North. All GIS shapefiles will be delivered on external hard drives to TF Yukon in Khost and to AED in Kabul, back-up files kept at Wilmington District. Shapefiles were created of the historic meteorological monitoring stations but available location coordinates were only accurate to the whole minute of latitude and longitude.

2.2 Remote Sensing Data

This study was based on the use of remotely sensed data gathered by satellites and aircraft. A significant part of this water resource assessment was the effort required to locate, acquire and process the remote sensing data. Approximately 1.5 TB of imagery and elevation data was processed and delivered. A full summary and catalog of the data is provided in Appendix A. The data was collected with the intent of being made available for future or more detailed studies of Khost, Paktya, Logar, Wardak, and Ghazni Provinces by the Provincial Reconstruction Teams (PRT's) and Agri-business Development Teams (ADT's) resident in Afghanistan. As an addendum to the original SOW, additional and updated remote sensing data sets were collected of Paktika Province.

QuickBird-2 and Ikonos satellite images were the primary commercial imagery sources that were acquired through the National Geospatial-Intelligence Agency (NGA) from DigitalGlobe Incorporated and GeoEye respectively. The QuickBird imagery was delivered from DigitalGlobe as a pan-sharpened, plane-rectified, 0.60 meter, 4-band image file. The QuickBird images provide both a natural color (bands 3,2,1) and near-infrared false color composite (bands 4,3,2) of the ground surface. The infrared imagery was used in the evaluation of vegetation. Every QuickBird image was orthorectified to remove the terrain distortions and projected to WGS84 UTM Zone 42 North by GIS Staff at the USACE Wilmington District. A subsequent step of rescaling from a 16-bit to an 8-bit file was performed to reduce the file sizes.

IKONOS satellite imagery was delivered from GeoEye Incorporated as 4 pan-sharpened, plane-rectified, 1 meter, image files. The four files needed to be ortho-calibrated (to remove terrain distortions) then layer-stacked to create a single 4-band image (BGRN). The resultant ortho-calibrated file was reprojected to WGS84 UTM Zone 42, and then rescaled from 16-bit to 8-bit.

Commercial Imagery (CI) Regional Orthomosaic – this is a pre-processed (pan-sharpened, orthorectified), 3-band (true-color composite) MrSID image mosaic of the entire study area. The images were acquired from NGA. The product was created by the imagery vendors as a countrywide data set. The images are delivered in one-degree cell folders, tiled into 15-minute quarter cells.

Raw commercial imagery datasets from NGA's Unclassified National Information Library (UNIL) were processed (controlled, orthorectified, pan-sharpened, and rescaled) as needed to complete coverage where clouds or snow were present on either of the two other imagery datasets. This was the case primarily for the additional imagery sets in the Paktika Province.

LANDSAT satellite imagery was used to evaluate changes in vegetation over time and evaluate the soil erosion potential of the watershed. 1999 and 2008 were the years that change was evaluated. The images were processed and an USFS Burned Area Reflectance Classification (BARC) algorithm was run to highlight change on each image pair. See the Remote Sensing Appendix A for more details.

Shuttle Radar Topographic Mission (SRTM) elevation data was acquired from NGA. SRTM2f is a level 2 product with elevation posts every arc second (roughly 30 meters). In addition to the SRTM data, a higher resolution DEM was used. This dataset was collected with IFSAR onboard an aircraft to support PROJECT CEDAR/BEECH and has a 5 meter post spacing. Appendix A also includes Processing Guidelines employed on the elevation and imagery files.

The remote sensing data set has been provided to TF Yukon and to AED on external hard drives. A Digital Elevation Model (DEM) is a grid of elevation points that represent the Earth's surface and was used in delineating watershed boundaries, evaluating dam sites, and ortho-rectifying the satellite imagery. The DEM provided on the drive holds the "Limited Distribution" caveats. These datasets can be used only by United States Department of Defense elements and must be protected to prevent misuse. The QuickBird and IKONOS commercial imagery datasets are bound by general license provisions and copyright law and can be shared amongst all US Government entities and their supporting partners. There are no distribution restrictions for the LANDSAT imagery. Below is a partial listing of data.

1. QUICKBIRD Satellite Imagery, 0.6-m resolution (pan-sharpened)
2. IKONOS Satellite Imagery, 1 meter resolution (pan-sharpened)
3. CI Regional Orthomosaic (combination of .6 and 1 meter)
3. 5-m Grid DEM
4. 30-m Grid DEM
5. LANDSAT – 30-m imagery

2.3 Precipitation Data

Precipitation data for Afghanistan can be separated into three categories; historic records, recent records and computed gridded estimates. The search for climate data centered upon locating daily precipitation records that match the period of the daily stream gage records in the five-province study area. The stream gage records generally extend from 1962 to 1980. The purpose of coinciding precipitation and stream gage datasets was to develop unit hydrographs to calibrate hydrologic models of the watersheds. No daily precipitation historic records were located that matched the period of the stream gage records. Collection of daily meteorological data was re-established in 2003.

2.3.1 Historic Data

Much of Afghanistan's historic meteorological records from 1940 to 1980 were lost during the recent years of turmoil. Five different sources of historic climate data were identified. No single source had a complete dataset of precipitation that included all stations or a complete time span. Precipitation data from each source was combined to create one historic dataset and is included in Appendix B. Monthly averages at each meteorological station in southeast Afghanistan is presented in Table 2-1. The meteorological station locations are presented in Figure 2-1 along with the stream gage stations.

The National Oceanic and Atmospheric Administration (NOAA) and their Data Rescue Program have scanned annual meteorological reports that contained monthly precipitation totals. These are original reports prepared by the Afghanistan Ministry of Transportation. The NOAA National Climate Data Center had monthly data for a few major stations. Monthly precipitation totals were also provided by the U.S. Air Force 14th Weather Squadron (14th WS/WXCP, personal communication). A monthly climate dataset was available that predated much of the NOAA information but this included only the major stations, e.g. Khost and Orgun were not included (Guy Fipps, Texas A&M, personal communication). The UN-FAO Climate Impact on Agriculture website contained monthly data for some of the minor stations, link provided below. The "Watershed Atlas of Afghanistan" contained monthly precipitation averages but the length of record was shorter than those in Table 2-1 and did not include minor stations.

The data collection effort included a search of meteorological stations in Pakistan along the Afghanistan border. Data from stations at Parachinar and Miranshah in the Federally Administered Tribal Areas were provided by UN-FAO (Michele Bernardi, UN-FAO, personal communication). The monthly precipitation totals for Parachinar extended from 1962 to 1979 and for Miranshah from 1947 to 1963. Review of both datasets included large gaps in the data with many questionable data points. The precipitation data was not used in the study because of the poor quality but has been provided in Appendix B.

Monthly climate data is available from UN-FAO Climate Impact on Agriculture website below:
http://geonetwork3.fao.org/climpag/agroclimdb_en.php

NOAA Data Rescue Program:
http://docs.lib.noaa.gov/rescue/data_rescue_afghanistan.html

NOAA National Climate Data Center:
http://lwf.ncdc.noaa.gov/oa/ncdc.html

2.3.2 Recent Data

Current meteorological and crop data are being collected and reported by the Afghanistan Agrometeorological (AgroMet) program. Data collection began in January 2003 including precipitation reported on a daily basis. There are 12 AgroMet stations in the five province study area.

In a separate effort, the Corps of Engineers' Cold Regions Research and Engineering Laboratory (CRREL) has organized a meteorological database of Afghanistan to assist PRT personnel operating in country (Daly & Mulherin, CRREL, personal communication). This database includes AgroMet data from 2003 to 2009, a summary report and dataset provided in Appendix B. The AgroMet data is of good quality but there are missing months at many of the recording stations.

2.3.3 Gridded Data

There were two sources for computed gridded climate data: the International Water Management Institute (IWMI) Climate Service Model and the UN-FAO AQUASTAT Climate Information Tool. Both programs use historic climate measurements from stations around the world to develop monthly climate summaries in a 10 minute arc resolution for other locations in the world. The IWMI data closely followed the historic and current precipitation data and the FAO data appeared to overestimate annual precipitation. Other information available from these sources includes temperature, wind and Penman Evapotranspiration. The evapotranspiration data from the IWMI model was used in the irrigation analysis for this study. Table 2-2 includes annual precipitation totals from the IWMI model with complete climate data sheets provided in Appendix B. Internet links are provided below for gridded climate data and details on methodology.

UN-FAO AQUASTAT:
http://www.fao.org/nr/water/aquastat/gis/index3.stm

IWMI Climate Service Tool:
http://www.iwmi.cgiar.org/WAtlas/Default.aspx

Table 2-1 – Monthly Mean Precipitation (mm), Historic Recorded Data

	January	February	March	April	May	June	July	August	September	October	November	December	Annual	Complete Years
Khost	25.5	49.8	59.2	65.7	42.3	21.3	76.5	61.1	31.1	7.3	8.7	19.9	468.5	17
Gardez	36.1	56.9	63.6	50.1	21.3	5.1	15.3	7.6	0.9	5.4	12.0	31.4	305.7	30
Ghazni	42.7	53.1	69.0	48.9	19.3	1.9	15.1	6.3	0.4	3.4	11.8	25.5	297.4	34
Orgun	54.3	64.4	61.0	42.8	29.6	12.9	11.9	14.7	1.4	12.8	14.3	30.7	350.7	8
Sardeh Ghazni	34.0	48.9	63.3	27.0	7.8	1.1	7.6	11.9	1.2	6.7	8.9	19.1	237.6	10
Mokur	49.9	65.0	63.9	27.7	9.6	0.2	3.7	6.2	0.2	6.4	6.1	42.1	281.0	16
Kabul	33.6	55.7	65.9	68.9	34.0	1.5	6.2	1.7	1.6	3.6	18.0	30.6	321.1	27
Okak	44.2	33.8	28.8	23.6	16.3	1.9	11.8	1.6	0.5	0.5	10.8	22.8	196.4	8
Panjab	38.9	60.4	60.0	64.2	26.0	0.8	0.3	0.0	2.0	12.6	12.6	36.0	313.8	12
Logar	29.0	40.8	54.0	44.2	17.7	1.2	1.4	3.4	0.7	3.7	12.0	20.3	228.6	13
Logar Airport	36.8	42.5	31.2	46.8	13.2	0.0	1.1	3.4	0.2	0.2	7.0	13.8	196.3	3
Paghman	59.5	71.6	86.6	74.5	28.4	2.5	8.9	3.9	6.3	9.6	24.6	37.1	413.6	11
Bamiyan	7.3	16.3	27.7	33.0	33.8	5.9	1.0	0.0	2.9	4.6	6.7	6.0	145.0	11
Karizmir	43.8	71.9	96.9	95.1	30.1	2.9	5.5	2.2	3.2	7.1	22.5	30.9	411.8	23
Darullaman	37.9	65.5	72.1	47.1	22.9	1.5	2.3	3.1	2.6	4.6	12.0	23.6	295.2	12

Table 2-2 – Monthly Mean Precipitation (mm), IWMI Climate Summary

	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Khost	18.0	47.1	57.5	51.1	26.5	12.8	49.4	36.1	14.5	4.0	3.5	9.6	330.0
Gardez	28.1	57.4	63.5	48.1	18.2	2.3	6.9	2.9	0.5	2.6	5.5	20.5	256.3
Ghazni	26.9	37.8	47.8	32.7	10.3	0.2	0.9	0.3	0.0	1.1	4.3	13.8	175.9
Orgun	27.8	50.8	60.5	44.5	18.5	3.3	12.8	9.6	0.8	1.6	4.1	17.9	252.2
Sardeh Ghazni	28.4	44.1	53.4	37.7	13.6	0.7	3.2	1.7	0.1	1.1	4.3	16.8	204.9
Mokur	28.4	36.1	43.2	23.5	6.5	0.1	0.5	0.3	0.0	0.3	3.0	13.8	155.5
Kabul	32.1	58.9	77.2	65.2	22.7	1.2	3.4	1.2	0.6	3.4	7.3	21.4	294.5
Okak	35.7	52.6	67.9	60.8	29.2	0.4	0.3	0.1	0.0	1.4	11.1	26.9	286.4
Panjab	31.9	45.4	60.8	54.5	27.8	0.0	0.0	0.0	0.0	0.9	11.5	24.3	257.1
Logar	25.4	48.2	60.2	47.6	15.5	0.9	3.5	1.2	0.4	2.3	4.9	15.6	225.5
Logar Airport	25.4	48.2	60.2	47.6	15.5	0.9	3.5	1.2	0.4	2.3	4.9	15.6	225.5
Paghman	30.7	53.0	69.9	59.7	17.0	0.4	0.8	0.2	0.2	2.2	6.5	19.3	259.9
Bamiyan	30.5	46.1	65.0	67.4	36.2	0.2	0.0	0.0	0.0	2.3	13.9	25.0	286.6
Karizmir	30.7	53.0	69.9	59.7	17.0	0.4	0.8	0.2	0.2	2.2	6.5	19.3	259.9
Darullaman	30.3	53.8	69.9	59.2	19.0	0.6	1.5	0.4	0.2	2.6	6.7	19.9	264.0
Parachinar*	26.5	69.7	98.2	78.7	50.4	25.0	73.8	58.6	29.1	13.1	7.3	14.1	544.5
Miranshah*	14.1	35.8	47.1	39.6	19.9	10.6	47.1	38.6	13.7	2.8	2.2	7.3	278.7

**Station in Pakistan*

Figure 2-1 – Streamflow Gaging and Meteorological Stations

2.4 Stream Gage Data

Afghanistan once operated a network of approximately 160 streamflow gaging stations across the country (Favre, 2004). Some of the earliest gage records date back to the 1940's with the majority of the stations established during the 1960's. The gaging network ceased operation within a year after the Soviet invasion in December 1979 . The last records are from September 1980. Gages have recently been re-established in northern Afghanistan and in the Kabul region but gages have not been re-established in the five province study area or in Paktika.

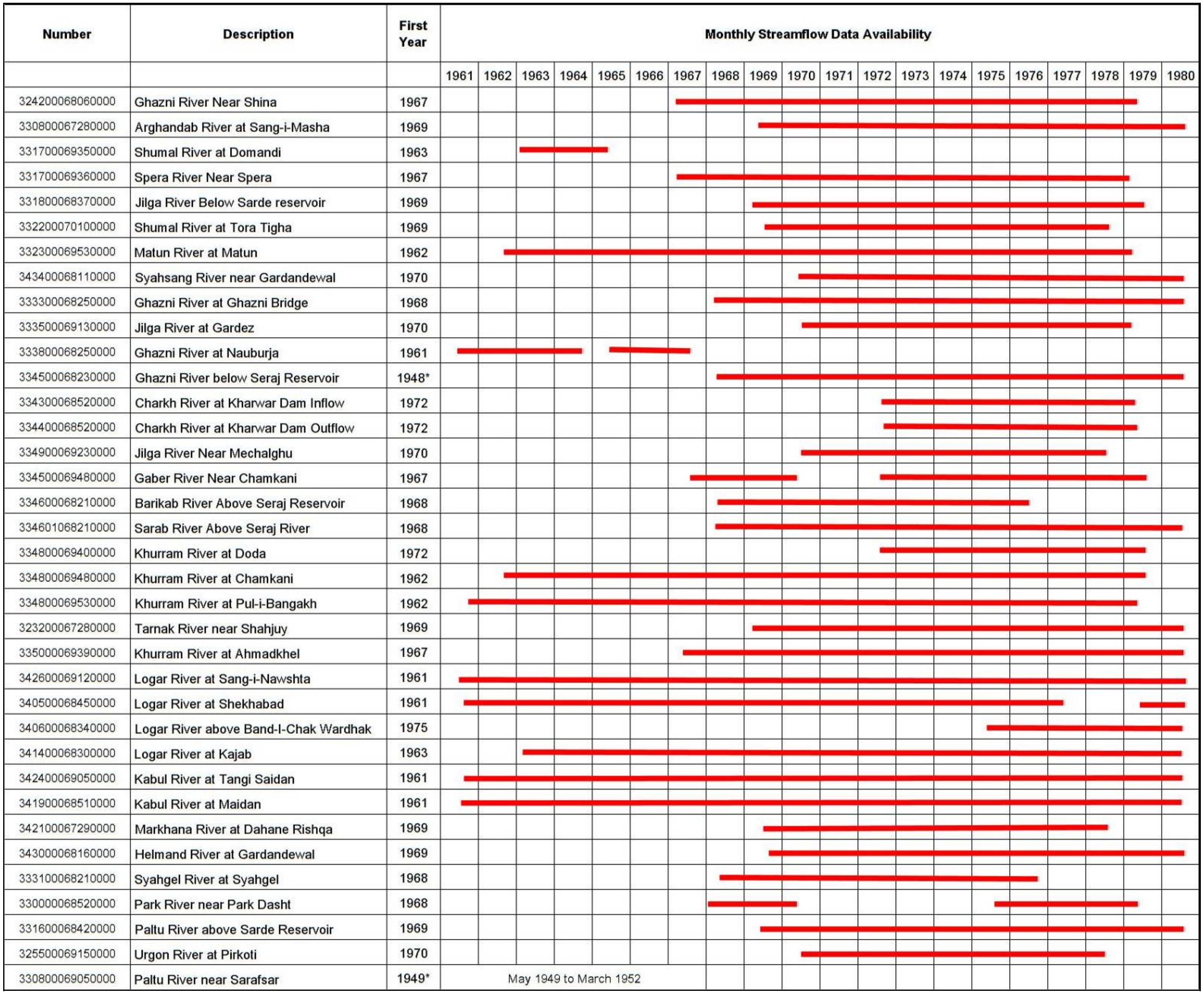
A total of 50 streamflow gage stations have been identified in the five-province study area and Paktika. As part of the SOW, the USGS was tasked with locating the historic stream gage records, entering data into an electronic database and calculating streamflow statistics at each station. The stream gage records were obtained by scanning original paper documents from the Ministry of Energy and Water in Kabul.

The USGS was able to locate original streamflow records for 35 of the 50 stations. The locations of the 35 stations are presented in Figure 2-1. The length and continuity of the streamflow record can be reviewed in Table 2-3. The station at Ghazni River below Seraj (Sultan) Reservoir includes data from January 1948 to May 1948 and from March 1949 to April 1952. Appendix C includes hydrographs of the flow records at each station. Monthly precipitation totals were also plotted on the hydrographs if records from a nearby meteorological station were available.

Appendix C also includes the USGS report "Streamflow Characteristics of Streams in Southeast Afghanistan" and was prepared as a part of this assessment. The report includes station descriptions, monthly and annual statistics, annual peak discharges and probability of occurrence of high or low discharges for the gages. The USGS notes that all the data have been reviewed but the data are provisional and subject to change. The reliability of the statistical data is related to the length of record for a stream. A 10-year record is the recommended minimum for computing flood frequency estimates, 12 stations had records under 10-years.

The Kabul River Valley Development Project Master Plan reviewed much of the same streamflow records presented in this assessment (Montreal, 1980). The Montreal report noted that there were irrigation diversion canals adjacent to many of the gaging stations that bypassed the gage. At a gage on the Logar River, the report states, "Discharge bypassing Sang-i-Naweshta are significant and are equal to or greater than measured river flow during several low flow months of the year." The Montreal study team was able to confirm gage bypassing during field review. Significant gage bypassing was also noted at Kajab, Haijian and Maidan but it is unknown how many gages in Ghazni, Paktya and Khost were affected.

Another difficulty with the streamflow records was determining the impact of hundreds of small scale irrigation diversions along the river upstream of the gaging station. The total amount of water diverted to the fields each year is unknown. Correlating the amount of precipitation over the watershed that turns into runoff by using the gage records will be missing a substantial volume of water. This makes applying records of one river gage to another watershed difficult because the amount of irrigation in each watershed varies. Section 4.1.3 of this report reviews the impact of irrigation diversions on the annual water budget of the major rivers in the study area.



Number	Description	First Year	Monthly Streamflow Data Availability
324200068060000	Ghazni River Near Shina	1967	
330800067280000	Arghandab River at Sang-i-Masha	1969	
331700069350000	Shumal River at Domandi	1963	
331700069360000	Spera River Near Spera	1967	
331800068370000	Jilga River Below Sarde reservoir	1969	
332200070100000	Shumal River at Tora Tigha	1969	
332300069530000	Matun River at Matun	1962	
343400068110000	Syahsang River near Gardandewal	1970	
333300068250000	Ghazni River at Ghazni Bridge	1968	
333500069130000	Jilga River at Gardez	1970	
333800068250000	Ghazni River at Nauburja	1961	
334500068230000	Ghazni River below Seraj Reservoir	1948*	
334300068520000	Charkh River at Kharwar Dam Inflow	1972	
334400068520000	Charkh River at Kharwar Dam Outflow	1972	
334900069230000	Jilga River Near Mechalghu	1970	
334500069480000	Gaber River Near Chamkani	1967	
334600068210000	Barikab River Above Seraj Reservoir	1968	
334601068210000	Sarab River Above Seraj River	1968	
334800069400000	Khurram River at Doda	1972	
334800069480000	Khurram River at Chamkani	1962	
334800069530000	Khurram River at Pul-i-Bangakh	1962	
323200067280000	Tarnak River near Shahjuy	1969	
335000069390000	Khurram River at Ahmadkhel	1967	
342600069120000	Logar River at Sang-i-Nawshta	1961	
340500068450000	Logar River at Shekhabad	1961	
340600068340000	Logar River above Band-I-Chak Wardhak	1975	
341400068300000	Logar River at Kajab	1963	
342400069050000	Kabul River at Tangi Saidan	1961	
341900068510000	Kabul River at Maidan	1961	
342100067290000	Markhana River at Dahane Rishqa	1969	
343000068160000	Helmand River at Gardandewal	1969	
333100068210000	Syahgel River at Syahgel	1968	
330000068520000	Park River near Park Dasht	1968	
331600068420000	Paltu River above Sarde Reservoir	1969	
325500069150000	Urgon River at Pirkoti	1970	
330800069050000	Paltu River near Sarafsar	1949*	May 1949 to March 1952

Table 2-3 – Streamflow Gage Record
(*Note: Ghazni below Sardeh includes data from 1948 to 1952 and Paltu near Sarafsar includes data from 1949 to 1952)

2.5 Literature Search

Scanned versions of documents collected during the literature search are included in Appendix D. Historic documents from the 1950's to the 1980's were continually located during the course of this study and the search for technical data reports continues.

An overview of Afghanistan's climate, river networks and water resources can be reviewed in the UN-FAO's publication "Watershed Atlas of Afghanistan" (Favre, 2004). The Atlas addresses the traditional and particular aspects of water management in Afghanistan. The Atlas is a good primer to those new to water resources in Afghanistan. Useful information obtained from the report includes detailed descriptions of Afghanistan's five major watersheds.

In January 1980, the Montreal Engineering Company published the "Kabul River Valley Development Project, Master Plan Report" (Montreal, 1980). The study was sponsored by the Canadian International Development Agency in cooperation with the Afghan Ministries and UN-FAO. The purpose of this study was to bring together existing water resource studies and identify the best locations in the Kabul watershed for storage dams. The projects addressed in this master plan were large scale, national interest projects. The master plan included the Azrow, Logar and Maidan watersheds addressed in this water resource assessment. Useful information contained in the report included analysis of stream gaging records, measured sediment yield values and irrigation demands. The report evaluated large storage dams at Kajab and Haijian in Wardak Province and Gat Dam in Kabul Province.

Numerous lists and reports addressing individual water resource rehabilitation projects across Afghanistan were identified and are included in Appendix D. Section 4.1.1 reviews the documents utilized in identifying project locations in the Southeast study area.

Appendix D also contains agricultural field guides prepared by the U.S. Department of Agriculture (USDA) Foreign Agricultural Service (Fripp, 2006). Many of the field guides are in Pashtun and Dari and cover items ranging from grazing management and wind breaks to gabion structure construction.

Other useful documents included in Appendix D:

- "Sardeh Irrigation System Condition Assessment", The Louis Berger Group, 2003 The report contained information on the Sardeh Dam in Ghazni.
- "Power System Master Plan", NORPLAN Association, 2003 - This detailed report reviewed the power sector of Afghanistan including hydropower. Data on Chak Wardak dam was obtained from this report.
- "Afghanistan & United Nations Special Fund, Land & Water Resources Survey", 1963 – Maps containing land use, land classification and soil types for the Southeast study area were included in this survey.
- "Watershed Atlas of Afghanistan", Favre, R., and Kamal, G.M., 2004, Afghanistan Information Management Service

3.0 Hydrology and Landscapes of Study Area

3.1 Precipitation Patterns

Southeast Afghanistan receives approximately 70% of the total annual precipitation between January and April. A graph of average monthly precipitation at select locations is provided in Figure 3-1. The heavy snowfalls of winter are followed by rainfall in April. Mean annual precipitation amounts for southeast Afghanistan are presented in Table 2-1. The higher precipitation amounts at Khost and Paktika are the result of summer monsoon rainfall that moves northwest from the Indian sub-continent affecting the eastern border of Afghanistan. Monsoon influences do not extend much further west into Afghanistan than the Gardez Valley. Khost receives over 35% of their annual precipitation from July to September during the monsoon months while Panjab received less than 1% during the same period.

Total annual precipitation amounts vary across the study area. Bamiyan receives 145 mm/yr (5.7 in/yr) while 110 km to the east Paghman receives 414 mm/yr (16.3 in/yr). Both gages are at elevations over 2,000 m but receive very different amounts of precipitation. The difference is likely caused by precipitation shadow effects created by the complex mountainous terrain in Afghanistan. The shadow effects can also be present within adjacent watersheds creating different streamflow characteristics emphasizing the need for well designed and well built dams with the operational flexibility to handle the uncertain conditions.

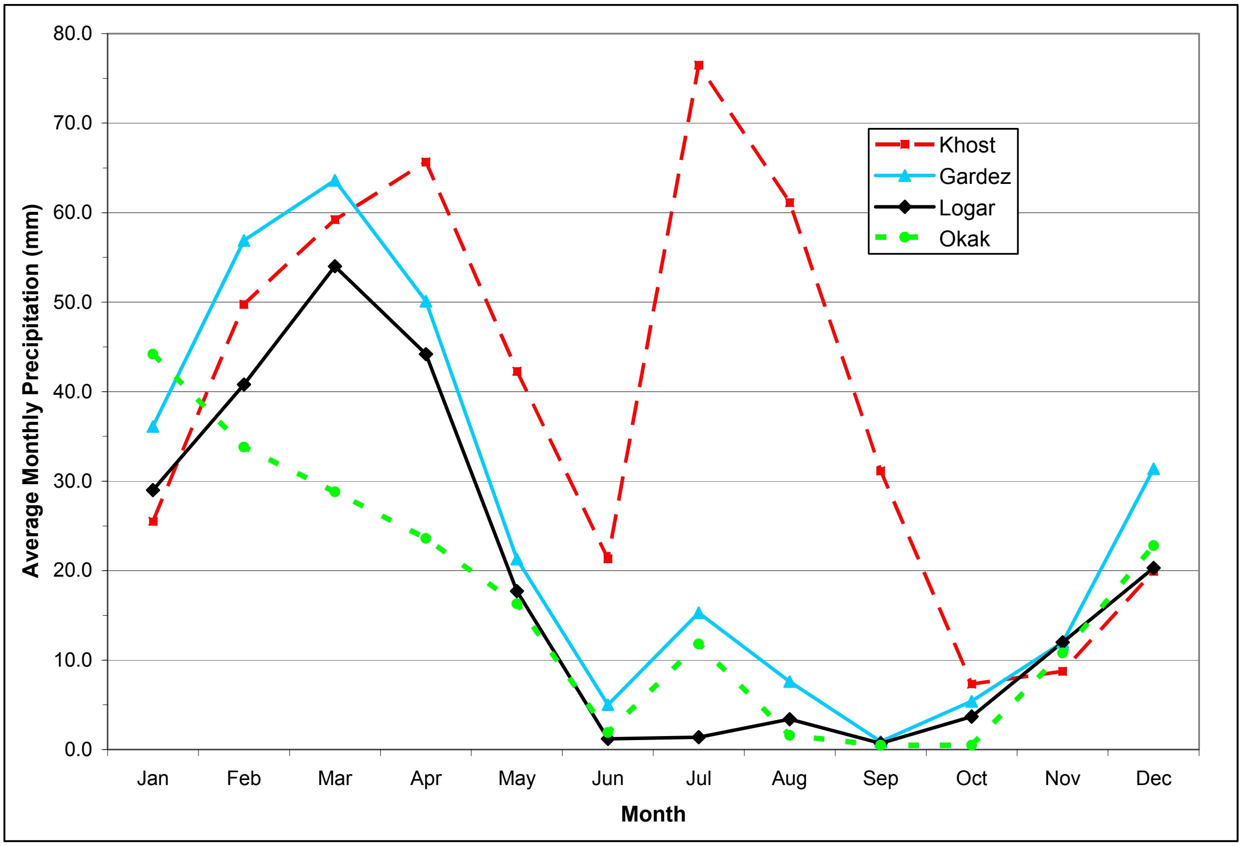


Figure 3-1 – Average Monthly Precipitation at Select Locations

3.2 General Description

The hydrology of a region must be fully understood before attempting to design, build or operate any water resource project. The hydrology of southeast Afghanistan has its own particular characteristics. Not understanding the monsoon effects can lead to undersized dam spillways and potential dam failure. Not knowing a stream's baseflow can lead to an under-utilized hydropower project.

The highest flows for streams in southeast Afghanistan occur during March, April and May. The high flows are associated with coinciding spring rains and melting of the winter's snowpack. The historic floods along the Helmand and Arghandab Rivers occur when higher than normal temperatures coinciding with the spring rains causing rapid snowmelt. Many of the streams in the lower valleys are typically dry from August until the winter precipitation begins in November or December. The summer monsoon can bring heavy rainfall along the eastern border of Afghanistan in July, August and September causing damaging flash floods.

One of the primary ways to understand a region's hydrology is by studying stream hydrographs. A hydrograph is a graph of a stream's flow rate versus time. Flow rates for the hydrographs presented here were obtained from the USGS stream gage records described in Section 2.4 with the gage location identified in Figure 2-1. The hydrographs in Figures 3-2, 3-3 and 3-4 depict three of the major hydrologic characteristics of southeast Afghanistan and are explained in the following paragraphs. Information from the hydrographs was used to evaluate the proposed project sites.

The timing and form of precipitation can dictate the stream flow characteristics and design of the water resource project. Figure 3-2 includes hydrographs of monthly streamflow for the Shamal River gage at Tora Tigha and Helmand River gage at Gardandewal. The Helmand gage is at an elevation of 2,955 m, draining 605 km^2 of the Hindu Kush Mountains. The Shamal gage watershed drains 4,220 km^2 of the low, open Khost valley that borders Pakistan and is at an elevation of 987 m. The timing of the peak spring snowmelt for the Shamal is in April and the peak at Gardandewal is a month later in May extending into June. The Shamal gage has a second peak in July associated with the monsoon rains. For smaller streams further up the Shamal watershed, the monsoon effects are much greater with more pronounced peaks in the hydrograph. Dam spillways and operations must take into account the monsoon flash flooding. A rainfall amount in excess of 60 mm in 24-hours is not uncommon in Khost. The eroded hillsides can lead to damaging flash floods. The baseflow for the Gardandewal gage is constant, thus providing steady flow for a potential hydropower project. The peak monthly runoff of slightly less than 7 m^3/s is very similar at both locations, although the drainage area at Shamal is 7 times the drainage area at Gardandewal.

It is common in Afghanistan for streamflow to decrease as a river travels downstream because of irrigation withdrawals. In addition, in arid regions declining flows are common along low gradient, alluvial stream reaches due to infiltration into the streambed. Groundwater withdrawal can accelerate the process. The impact of irrigation withdrawals from streams can be observed in Figure 3-3. This hydrograph presents monthly mean flow at two stream gages along the Ghazni River. The upstream gage is just below Sultan Dam. The Ghazni bridge gage is 23 km downstream of Sultan Dam. The Sultan gage has a watershed of 1,171 km^2 and the Ghazni bridge gage a watershed of 1,555 km^2. The hydrograph shows that flow is always lower at the Ghazni bridge except for January. The mean annual discharge at Sultan is 1.66 m^3/s and 0.97 m^3/s at Ghazni bridge. The gage records show the impact of water withdrawals for 1,700 ha of irrigated land between the two gages.

Another important hydrologic characteristic that must be considered when planning a water resource project is the stream's baseflow. Building a hydropower project on a stream that is dry for six months of the year is not practical. Figure 3-4 is a hydrograph of monthly flows at the Syahgel River at Syahgel and Jilga River at Mechalghu. The two gages are in different watersheds. The Mechalghu gage has a year round base flow of 0.4 m^3/s and the Syahgel gage has base flow of 0.1 m^3/s. The mean annual flow at Mechalghu is 0.66 m^3/s and 0.19 m^3/s at Syahgel. It should also be noted that the Syahgel gage watershed is twice as large as the Mechalghu gage, 145 km^2 and 65 km^2 respectively. The larger watershed for Syahgel did not result in higher flows than Mechalghu. Groundwater flow is likely contributing to flow at Mechalghu and is a much better location for micro-hydropower. The Syahgel gage is unique in that the peak flow is in July during the monsoon season and not during the April snowmelt.

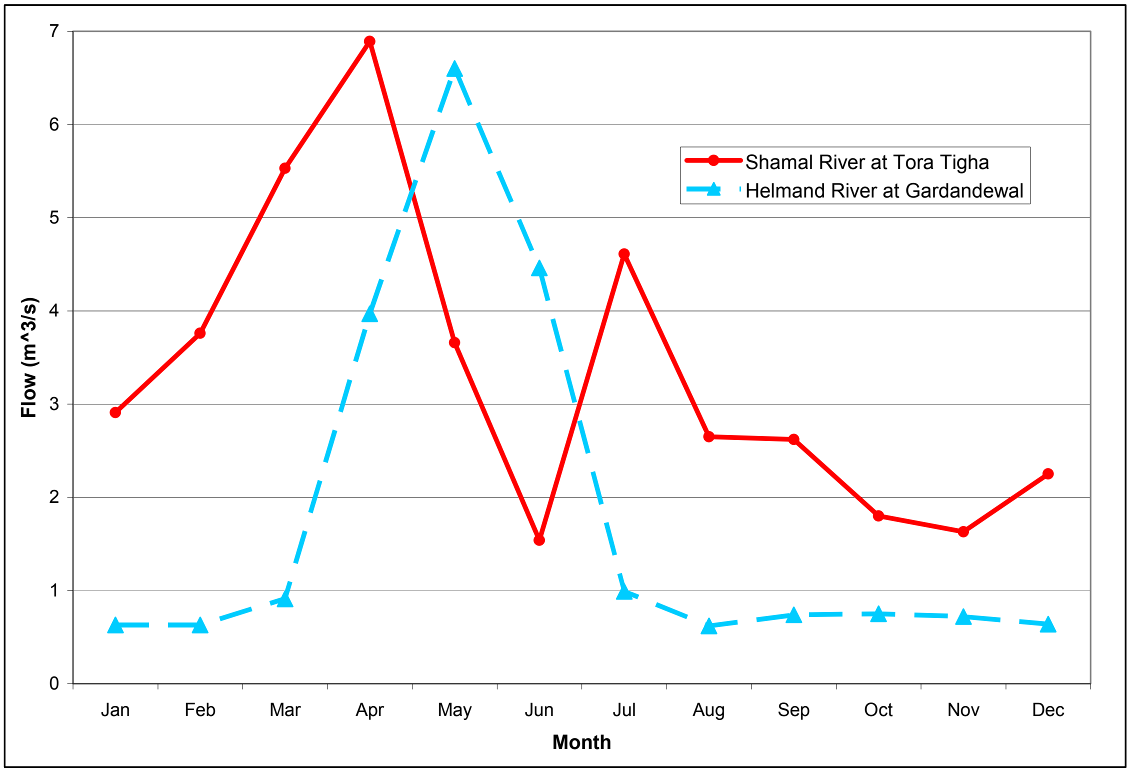


Figure 3-2 – Monsoon and Snow Melt Impacts

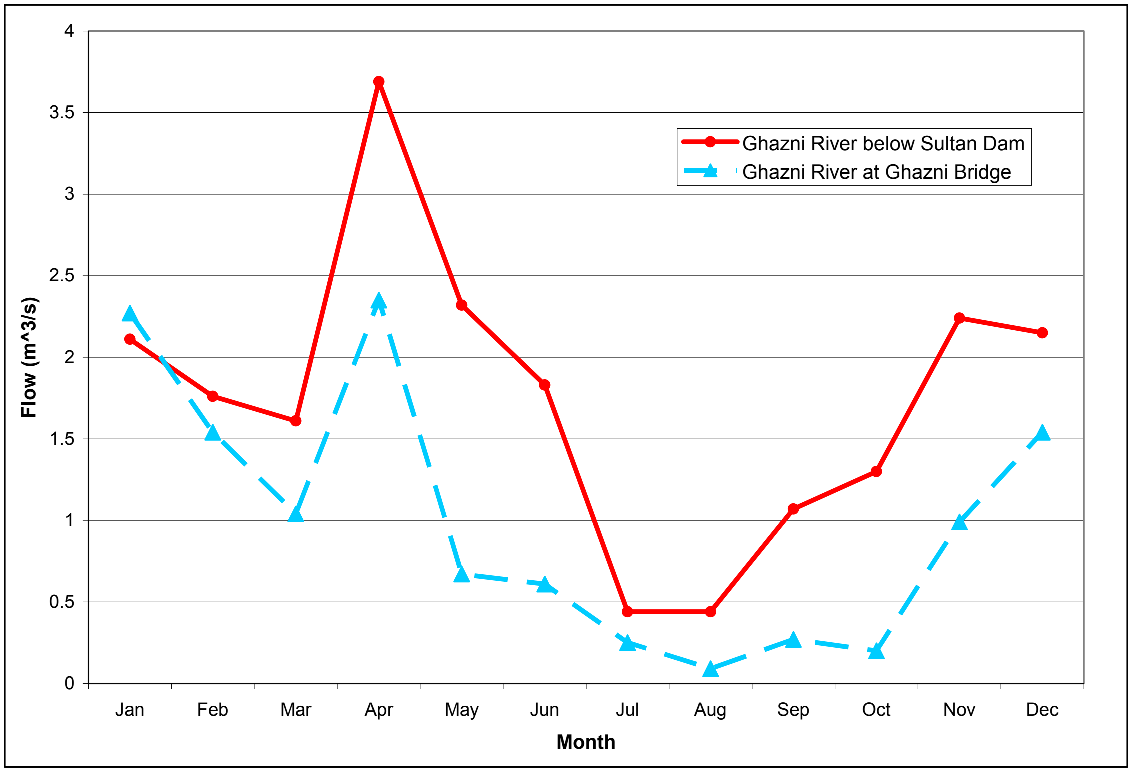


Figure 3-3 – Irrigation Impacts on Ghazni River

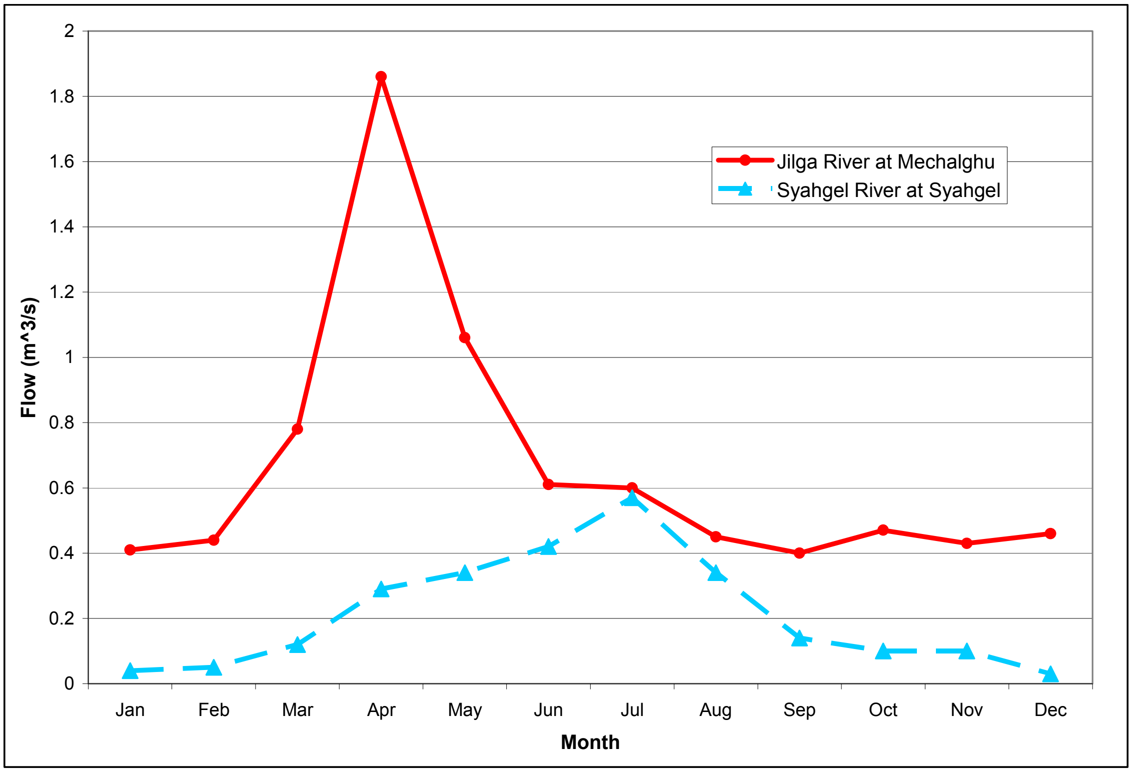


Figure 3-4 – Baseflow Characteristics of Watersheds

3.3 Watershed Sub-Basins Processing

The SOW defined our study area as the five provinces in the TF Yukon area of operations, not by river watershed. Eleven major river systems drain the five provinces. The watersheds for these eleven rivers were delineated at the provincial boundary. If a stream gage was near the province boundary then the watershed was delineated at the gage.

ArcHydro Tool v9 within ArcGIS was used to process the DEM, delineate watersheds and calculate hydrologic properties. Watershed processing began by using the 30 m DEM to delineate the eleven river watersheds and create GIS shapefiles. The watershed shapefiles were then used to cut the higher resolution 5 m DEM into a manageable size for hydrologic processing. The large 5 m DEM file sizes of the Logar and Ghazni (Sardeh-Jilga) watersheds required those to be cut in half. The Ghazni watershed was cut at the existing Sardeh Dam and Logar was cut above a dam at Chak Wardak. The final 13 study watersheds are labeled in Figure 3-5, study watersheds are outlined in black.

The next step was processing the 13 watershed DEMs and calculating the streamlines. Processing included filling sinks, flow direction grids, accumulation grids, catchment polygons along with slope and other attributes. Appendix E includes maps of the major watersheds with a shaded color ramp of elevation and calculated streamlines. Evaluated project locations are also identified on the elevation maps.

The calculated streamlines followed the natural streams and rivers very well when compared to actual imagery. There were errors in the streamlines when following man-made canals and in very flat terrain. Contour lines were also created at 5, 10 and 20 m intervals based on the 5 m DEM. The contours followed the hills and valleys of the terrain well and pick-up small islands within streams. All of the watershed shapefiles, processed DEM and contour data has been loaded onto external hard drives and made available to TF Yukon and AED.

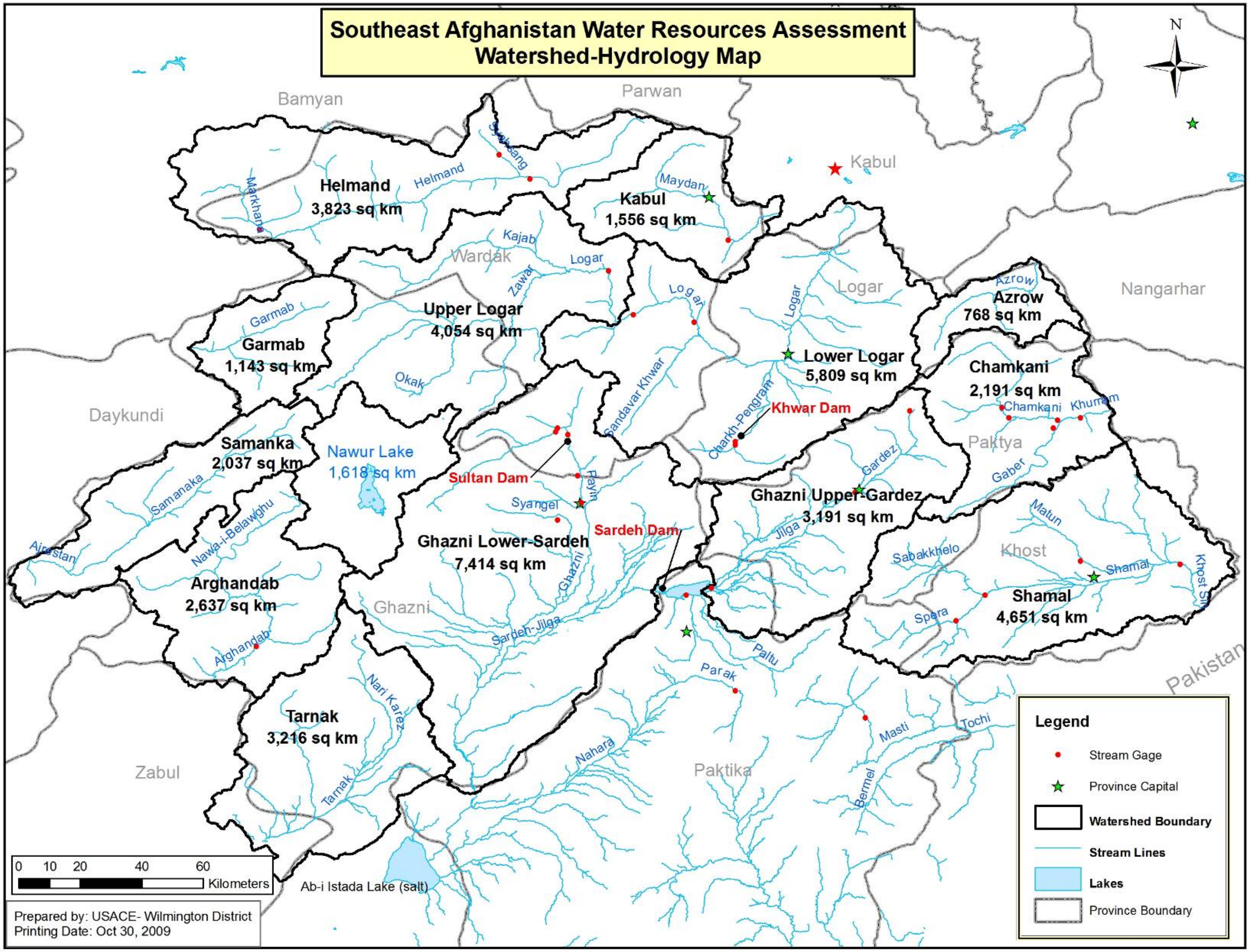
3.4 Study Watershed Descriptions

The following sections include general descriptions of the study watersheds. Figure 3-5 shows areal extent of each study watershed (sub-basin). Names of rivers frequently changed along their course. Maps, gage data and engineering reports often use different names or different spellings for the same stretch of river. An effort was made in this report to use the names established in the Watershed Atlas of Afghanistan (Favre, 2004) and the TLM-100 maps. Alternate names and spellings are provided in parentheses.

Geologic groups for each of the study watersheds are provided in Figure 3-6. Land cover for the study area can be reviewed in Figure 3-7. The majority of the area is classified as rangeland with large areas of rock outcrops or bare soil. Narrow strips of irrigated land follow the river and stream valleys. The only forest cover is in the eastern watersheds. Figure 3-8 includes five different slope classes of the terrain with the steepest slopes in red and the flat valleys in green. Elevation maps for each study watershed are in Appendix E. Printable, large format maps of geology, land cover, soils, and recent deforestation are also in Appendix E.

Land cover for the study area was extracted from a generalized land cover spatial layer for Afghanistan from AIMS (http://www.aims.org.af/ssroots.aspx?seckeyt=295). These data were generated by the United Nations in 2001 and 2002 from LANDSAT imagery. No ground-truth was used in its creation. Geologic spatial data were based on Russian geological mapping, formatted in part by the USGS. Maps of this spatial data are available at (http://afghanistan.cr.usgs.gov/downloads.php).

Character of soils is an important feature of any agricultural planning effort. A soils map is available (http://soils.usda.gov/use/worldsoils/mapindex/afghanistan-soil.html), but is too general for use below the study watershed level. Soil characterization was therefore based on geologic mapping (Figure 3-6), field experience, world-scale maps, and geo-referenced legacy soil maps (Appendix E).



Southeast Afghanistan Water Resources Assessment
Watershed-Hydrology Map

Prepared by: USACE- Wilmington District
Printing Date: Oct 30, 2009

Figure 3-5 – Watersheds and Rivers of Southeast Afghanistan

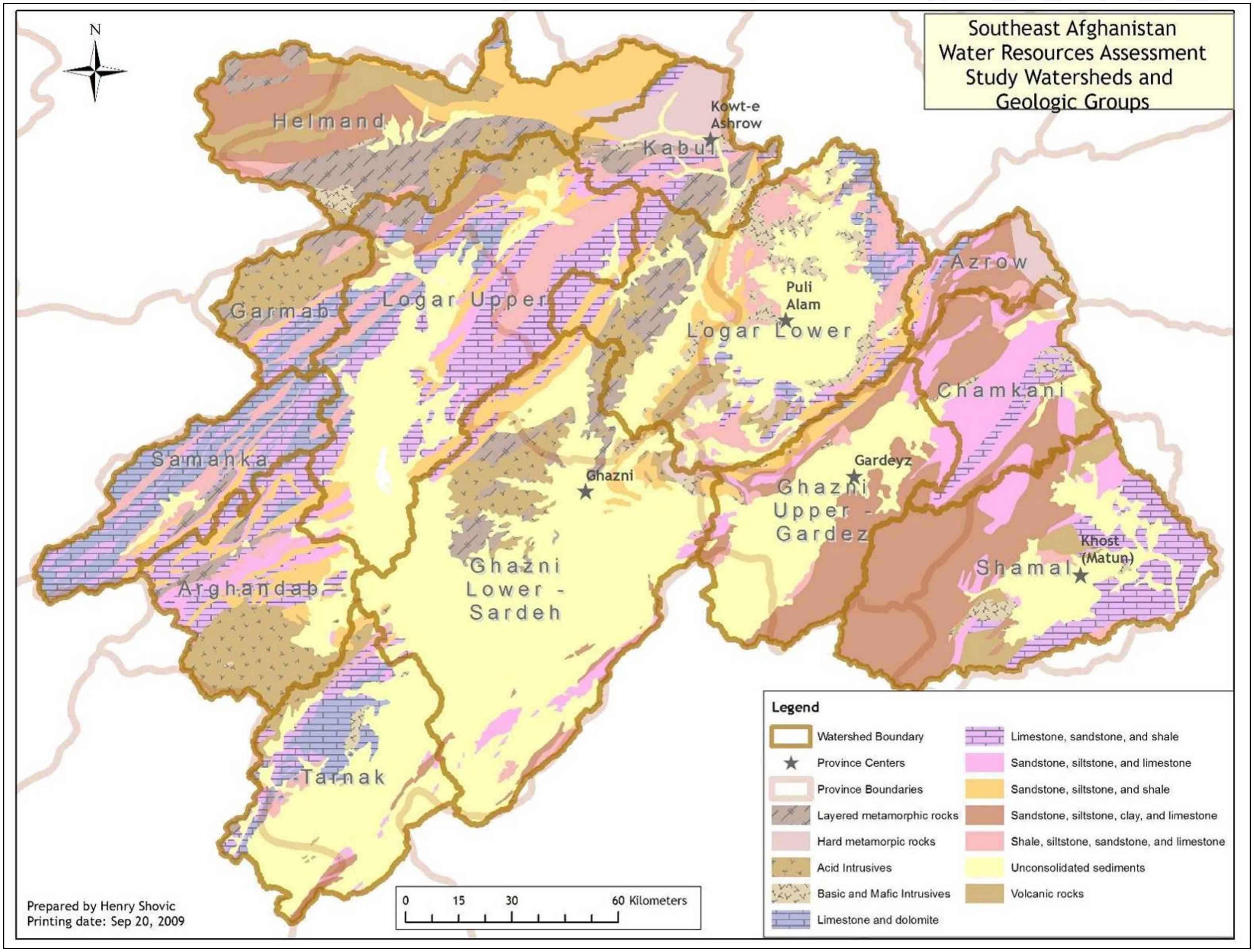


Figure 3-6 – Geologic Groups and Study Watersheds

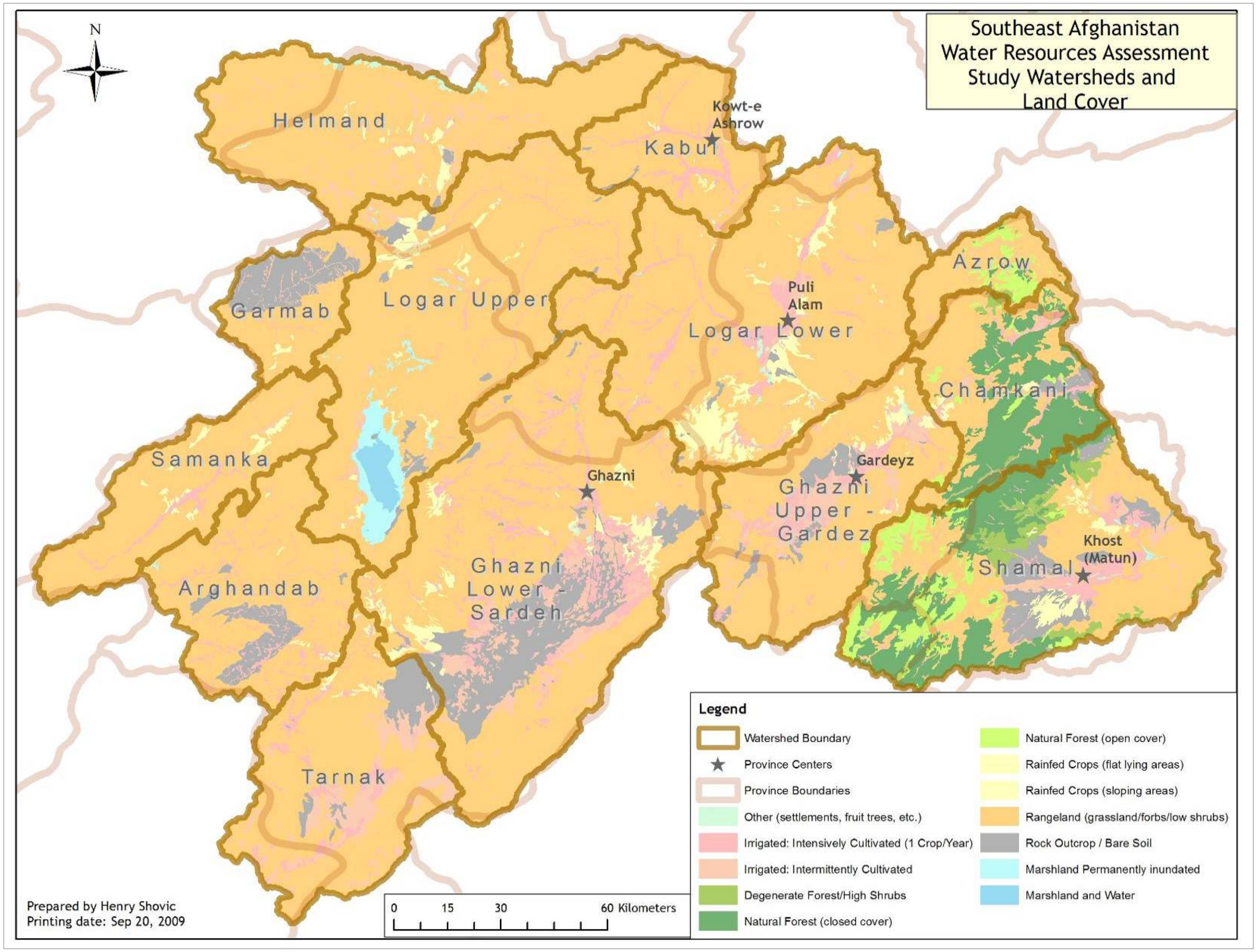


Figure 3-7 – Land Cover and Study Watersheds

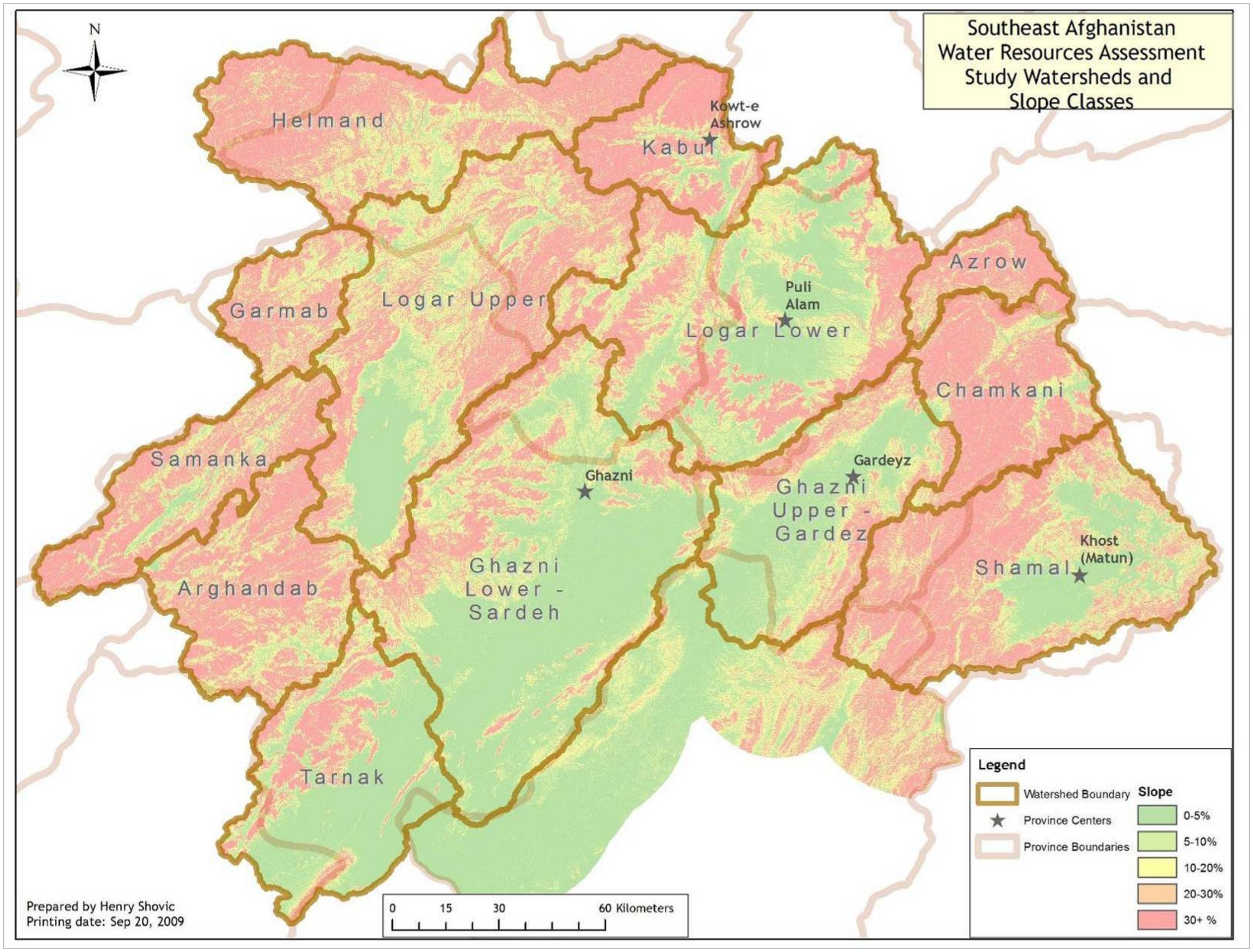


Figure 3-8 – Slope Class and Study Watersheds

3.4.1 Arghandab

The Arghandab River drains 2,637 km^2 of western Ghazni Province. The Arghandab watershed in Ghazni is characterized by mountains over 4,600 m in the northeast corner and a deep river valley that runs generally north to south. Landcover consist of mostly sparse rangeland and bare soil. The river and tributary valleys are not intensively cultivated due to the steep side slopes. The river at Sang-i-Masha has a mean annual discharge of 8.89 m^3/s and a mean annual water budget of 281 M-m^3 (one million cubic meters). Discharge peaks in April with the spring rainfall and snowmelt. There is a continuous baseflow year round with a low flow of 3.98 m^3/s in September. Little summer monsoon influence was noticed in the stream gage data. There are no precipitation gages in the watershed.

Vegetation is low shrub/grassland with some barren land. Geologically, it is largely acid intrusive rocks with some sandstone, siltstone and limestone. There are some deep unconsolidated sediments ranging from gravel to loess. Slopes are steep (>30%) with long narrow, gently sloping valleys.

3.4.2 Azrow

The Azrow (Azra) River drains approximately 768 km^2 of northeastern Paktya Province. The Azrow flows north out of Paktya and into Nangarhar to join with the Nawar River. This river joins the Surkh Rod and continues to flow northeast to join with the Kabul River near Jalalabad. The watershed is characterized by rugged mountains over 4,720 m. Vegetation is open-grown forest at the higher elevations with low shrub and grassland in the remainder. Geologically, it is primarily weathered interbedded sandstone, siltstone, clay, and limestone, with some hard metamorphic rocks in the steep highlands. Slopes are steep (generally over 20%). The deep valleys have narrow strips of irrigated land. The most intense agriculture is centered on the villages of Azra and Mohammad Kheyl. There are no stream or precipitation gages in the watershed. The Azrow does appear to have year round baseflow draining the high mountains. Flows were estimated by using stream gage data from an adjacent watershed with similar characteristics, Khurram River at Ahmadkhel. Where the Azrow joins the Nawar the mean annual discharge is estimated at 3.47 m^3/s with an annual water budget of 110 M-m^3.

3.4.3 Chamkani (Khurram)

The western half of the Chamkani River watershed is characterized by high, rugged mountains with peaks over 4,700 m and narrow strips of agriculture in the deep valleys. Vegetation is primarily forest with some low shrub/grassland. Geologically, it is primarily weathered interbedded sandstone, siltstone, clay, shale, and limestone. Slopes are steep (over 30%), with the exception of long narrow valleys. The eastern half contains wide, heavily irrigated valleys.

The Chamkani drains 2,191 km^2 of eastern Paktya before flowing into Pakistan and joining the Khurram River. The Chamkani River is often referred to as the Khurram River. The watershed is unique in that there are five stream gages with historic records over ten years. There are no precipitation gages in the watershed. The watershed at Pul-i-Bangakh has a mean annual discharge of 4.79 m^3/s and a mean annual water budget of 149 M-m^3. There is a continuous baseflow year round with a low flow of 1.91 m^3/s in September. Monsoon events do affect the basin during the summer months. A record discharge of 50.3 m^3/s was recorded in September 1967.

3.4.4 Garmab

The Garmab River drains approximately 1,143 km^2 of northwest Ghazni Province. The Garmab River flows from east to west joining the Helmand River. The watershed is very rugged with little vegetation and large areas of exposed rock with some low shrub/grassland. Geologically, it is primarily weathered acid-intrusive rock with some limestone. Slopes are steep (over 30%), with the exception of long narrow valleys. The only cultivated areas are the thin strips along the steep valley floors. The watershed is sparsely populated with the highest concentration near the village of Darakhtan. Flows were estimated by using stream gage data from an adjacent watershed with similar characteristics, the Markhana River at Dahane Rishqa. Where the Garmab joins the Helmand, the mean annual discharge was estimated at 8.40 m^3/s with an annual average water budget of 265.7 M-m^3. The watershed is not affected by monsoon events. Damaging flood events usually occur in early May when heavy rainfall encourages rapid melting of the winter snowpack.

3.4.5 Ghazni (Sardeh)

The large Ghazni River watershed had to be divided into two separate watersheds for hydrologic analysis. The watershed was divided at the existing Sardeh Dam. The Upper Ghazni watershed includes the Gardez Valley, which is drained by the Gardez and Jilga Rivers and flows into the Sardeh Dam reservoir. The Lower Ghazni watershed includes the area drained by the Ghazni and Sardeh Rivers up to Sardeh Dam. Vegetation in the Ghazni watershed is primarily low shrub/grassland with large areas of barren rock surrounded by extensive irrigated agriculture. Geologically, it is largely unconsolidated sediments ranging from gravel to loess, with some weathered sandstone, siltstone, and some acid intrusive rocks. Slopes are generally low (less than 10%) with hills on either side of the watershed ranging above 30%.

The 3,191 km^2 Upper Ghazni watershed includes the long, open Gardez Valley bounded by high mountain ridges along the northwest and southeast sides. Hundreds of small tributaries drain the mountainous watersheds into the valley. The Gardez Valley is heavily irrigated by a complex network of canals and diversions along the Jilga River. Many maps refer to the upper Jilga River as the Gardez River. The Jilga River and Paltu River in Paktika drain into the Sardeh Dam with a combined watershed area of 4,376 km^2.

Two stream gages on the Jilga River describe the hydrologic patterns in the Gardez Valley. The Mechalghu gage is located in the upper watershed with an area of 65 km^2. This gage has a mean annual discharge of 0.66 m^3/s with a low flow of 0.4 m^3/s in September. The stream gage at Gardez city has a watershed area of 1,065 km^2 but the low flow in September is only 0.12 m^3/s. Most of the flow from the tributaries and main river channel is diverted for irrigation use. The Gardez city gage has a mean annual discharge of 1.25 m^3/s with an annual water budget of 39.6 M-m^3. Of all the gages analyzed, the Gardez gage had the lowest average annual water yield from the watershed. The average annual value for Gardez was only 3,700 m^3/km^2. The average for all other gages in southeast Afghanistan was 99,100 m^3/km^2. The lower yield is the result of less annual precipitation and large irrigation diversions.

The Lower Ghazni watershed has an area of 7,414 km^2, not including the Sardeh Dam watershed. Elevation changes drastically from over 4,585 m in mountains in the north to 1,987 m on the open plains to the south. The Sultan dam is located approximately 23 km north of Ghazni city. The Sultan Dam has a watershed of 1,171 km^2. The Payin River flows downstream of Sultan Dam and at Ghazni city the Payin joins many smaller tributaries to form the Ghazni River (Favre, 2004). Agriculture is concentrated along Payin and Ghazni Rivers downstream of the Sultan Dam. Approximately 30 km south of Ghazni City, the Ghazni River joins the Sardeh River. The Sardeh becomes heavily braided as it flows southwest into Paktika Province.

The stream gage at Ghazni city has a mean annual discharge of 0.97 m^3/s and an annual water budget of 31 M-m^3. The river is frequently dry during July and August. The river was dry from May to September during the 1980 drought.

3.4.6 Helmand

This study addresses only the upper 3,823 km^2 of the Helmand River watershed located in the Wardak and Bamyan Provinces. This watershed includes the Koh-I-Baba mountain range with elevations over 5,080 m. The heavy winter snowpack slowly melts through spring with peak flows extending into late May and June. The numerous mountain springs provide year-round baseflow for most of the streams in the watershed. Vegetation is almost entirely low shrub/grassland with some barren areas in the northern part. Geologically, it is largely weathered sandstone siltstone, shale, and limestone with some layered metamorphic and acid intrusive rocks in the southern part. Slopes are steep (greater than 30%), with long, narrow valleys and some gently sloping upland in the southern part.

The steep hillsides, narrow valleys and scattered population are not suitable for large-scale irrigation schemes. There are numerous strips of cultivated land with small population centers in the watershed that could benefit from small-scale water resource projects. The steep stream slopes and year round baseflow do offer great opportunity for hydropower in the region. Analysis of the three stream gages in the watershed indicates that the Helmand has the highest water yield of all basins studied. As the Helmand River exits the Wardak Province, the mean annual discharge is estimated at 24.7 m^3/s with an annual water budget of 780 M-m^3.

3.4.7 Kabul

The Kabul watershed includes 1,556 km^2 of northeast Wardak Province. This watershed is drained by the Maydan (Maidan) River, which changes its name to the Kabul River soon after entering the Kabul Province. Even though the watershed includes mountain peaks over 4,500 m the river valley is fairly flat and wide. Vegetation is largely low shrub/grassland with extensive irrigated agriculture in narrow valleys. Geologically, it is largely weathered, hard metamorphic and layered metamorphic rocks, with some unconsolidated sediments in the valleys. Slopes are generally steep (> 30%) with slopes < 5% in the valleys.

The valley along the Maydan River and its tributaries are extensively cultivated with complex irrigation networks. As the Maydan River flows east into the Kabul Province the valley becomes very narrow. MEW has commissioned previous studies for a 110 M-m^3 irrigation storage dam at Haijian along this narrow section of valley (Montreal, 1980).

The Maydan River has a stream gage at Maydan and a second gage 19 km downstream at Tangi Saidan. The impact of irrigation withdraws from the river can be noted in the gage records from the two gages. Maydan has a mean annual discharge of 5.09 m^3/s with an annual water budget of 161 M-m^3. The downstream stream gage at Tangi Saidan has a mean annual discharge of 4.05 m^3/s with an annual water budget of 128 M-m^3. Annual peak flows usually occur in April with the spring rains and melting snowpack. A record peak of 110 m^3/s was recorded in April 1967 at Maydan. Records do show a large flood event at both stations in July 1978, but it is not known if this was monsoon related. Both gages have a year-round baseflow above 0.1 m^3/s most years.

3.4.8 Logar

For this study, the Logar watershed begins at the Sang-i-Naweshta stream gage on the Logar River in the Kabul Province. The Sang-i-Naweshta gage has a watershed of 9,863 km^2. This watershed was too large to process using the 5 m DEM so the Logar watershed had to be cut in half. The watershed was cut at the existing Chak Wardak Dam. For this study, the lower Logar has a watershed area of 5,809 km^2 and the upper Logar watershed has an area of 4,054 km^2.

The Logar watershed is characterized by high mountains over 4,700 m in the upper reaches in the Ghazni and Wardak Provinces. As the Logar River flows east in the Wardak Province the river valley is deep and narrow. Agriculture is concentrated along the valley floor. As the Logar River flows into the Logar Province, the valley opens into a wide floodplain with an extensive network of irrigation diversions and canals. Upper watershed vegetation is largely low shrub/grassland with widespread irrigated agriculture and some rain-fed croplands in the valleys. Geologically, the Logar sub-basins are about a third deep unconsolidated sediments ranging from gravel to loess, with limestone and layered metamorphic rocks, and some shale, siltstone, and sandstone. Logar has a wide range of slopes, with large areas of nearly flat sediments.

There are four streamflow gages along the Logar River. The Kajab gage in the upper reaches of the Logar River has an average annual water yield of 60,200 m^3/km^2. The Sang-i-Naweshta gage at the lower end of the river has a yield of 31,200 m^3/km^2. The yield has been reduced by almost half by the irrigation diversions as the Logar River flows downstream through the heavily cultivated valley.

There are two existing dams in the Logar watershed. The Chak Wardak dam was built in 1938 with an installed capacity of three 1.1 MW units. The Kharwar dam is located in southern Logar Province on the Pengram River. Little information was obtained on Kharwar dam and there are unresolved issues with the streamflow gage data from this site. The dam's outflow gage has significantly higher flow than the inflow gage.

The *Kabul River Valley Development* report evaluated two large storage dams in the Logar watershed (Montreal, 1980). The Kajab dam site is located approximately 22 km upstream of

Chak Wardak near the village of Gowda. The report recommended the Kajab dam with a storage volume of 200 M-m^3 and an irrigation service area of 14,300 ha. The Gat dam site on the lower Logar River is approximately 10 km southeast of Kabul city near the village of Sofla. The Gat Dam was sized to store 105 M-m^3 for municipal water supply and irrigation. Gat dam would have to be increased to 140 M-m^3 for additional water demands of the proposed Logar copper mine and smelter (Montreal, 1980).

3.4.9 Samanka

The 2,037 km^2 Samanka River watershed is located in western Ghazni Province bordering the Daykundi Province. The study area ends at the provincial border with Daykundi. The Samanka River changes its name to the Ajrestan and then to the Tora as it flows through Daykundi to merge with the Helmand River. There are no stream gages in the Samanka watershed. Stream data was taken from the neighboring Arghandab watershed at the Sang-i-Masha stream gage. The watershed was estimated to have a mean annual discharge of 8.39 m^3/s with an annual water budget of 270 M-m^3.

The Samanka watershed is approximately 50 km wide and 200 km long. Vegetation is largely low shrub/grassland with some irrigated agriculture. Geologically, it is composed largely of weathered limestone with some interbedded sandstone and shale. Samanka has generally steep slopes (> 30%) and long, narrow gently sloping valleys.

The river valley is heavily cultivated with irrigation diversions and networks of canals. The amount of agriculture decreases as the river flows downstream and the river valley narrows. Numerous small tributaries drain the surrounding mountains into the spine of the river valley. Because of the numerous streams discharging directly in to the river, the Samanka is susceptible to flash floods.

3.4.10 Shamal

The Shamal (Samal) River drains approximately 4,651 km^2 of Afghanistan before entering Pakistan. The Shamal watershed includes most of Khost province and portions of the Paktika and Paktya Provinces. After entering Pakistan the Shamal is renamed the Kaitu and then merges the Kurram River and eventually joins the Indus River.

The Shamal watershed is bowl shaped with numerous streams draining the surrounding mountains into a large, open valley. Geologically the watershed is primarily weathered, interbedded sandstone, siltstone, clay and limestone, with large areas of deep unconsolidated sediments ranging from gravel to loess. Slopes range from> 30% in the west to 0 to 5% in the east.

The valley is heavily irrigated with networks of irrigation diversions, canals and drains. There are four stream gages in the watershed. All of the gages show the influences of monsoon rains in July and August. The precipitation gage at Khost recorded 63.3 mm of rainfall in 24-hours in July, 1966. The five highest flows recorded at Tora Tigha were measured during summer monsoons. Even with the summer monsoons, the largest percentile of the Shamal annual water budget comes from the spring rains and melting snowpack in March and April. July has the third highest monthly water budget at Tora Tigha.

3.4.11 Tarnak

The 3,216 km^2 Tarnak River watershed is located in southwest Ghazni Province. As the Tarnak River flows west out of Ghazni the river flows through Qalat and eventually joins the Arghandab River near Kandahar. The watershed for this study ends at the Tarnak River stream gage near Shahjuy, Zabul. The gage at Shahjuy has a mean annual discharge of 1.33 m^3/s with an annual water budget of 42.9 M-m^3. The Tarnak watershed has one of the lowest annual runoff yields at 121 m^3/ha. Precipitation data for this watershed was obtained from the Mokur meteorological station. The stream gage data shows a slight increase in flow during the months July and August from monsoon rains.

The northern third of the Tarnak watershed consists of rugged mountains with peaks over 3,760 m. Tributaries draining the mountains flow south into a wide valley creating the Tarnak River. Cultivated land is concentrated near the city of Mokur with much of the valley undeveloped, relatively flat barren land. The remainder is largely low shrub/grassland. Geologically, it is large areas of deep unconsolidated sediments ranging from gravel to loess, with limestone in the steeper western part. Slopes are generally low (< 10%) with exception of the western mountains. There are strips of irrigated land along the tributary streams draining the mountains.

3.4.12 Nawur - Isolated Watershed

The Nawur watershed is located in central Ghazni Province, approximately 70 km west of Ghazni city. Review of the DEM confirmed that the bowl shaped Nawur watershed is isolated and does not drain out of the basin into either the Logar or Helmand-Sardeh watersheds. All precipitation that falls in the 1,618 km^2 watershed remains in the basin and fills the brackish lake in the center. Wetlands contained in the watershed were declared a National Waterfowl and Flamingo Sanctuary in 1974 (Favre, 2004). There is very little agriculture in the watershed. The only agriculture in the basin is concentrated along streams on the western side of the lake. The Gurgkushta irrigation diversion dam was the only project evaluated in this watershed and is included with the results in the Logar-Upper watershed.

4.0 Methodology for Project Evaluations and Prioritization

4.1 Irrigation Storage Dams

4.1.1 Identification of Sites

The first step in the analysis of irrigation storage dams was to identify previously proposed projects. Requests were made to USAID, MEW, MAIL and to UN-FAO for proposed water resource projects in the study area. MEW provided a list of proposed dams in Afghanistan, last updated September, 2008. This list contained 153 dams that ranged in size from small irrigation dams under 5 m high to larger national scale dams over 70 m. The MEW list contains 14 dams in the five province study area. UN-FAO supplied a list of 14 dam sites in the study area, seven of these dams were also included in the MEW list. USAID supplied the "*Afghanistan Water Sector Project Atlas*" and is a collection of projects and needs as expressed by Afghan central and provincial governments. The USAID Atlas and project list are included in Appendix D.

Many of the previously proposed project sites did not include coordinates or a detailed description of their location. Six sites contained coordinates that were far from any water feature. Additional requests to clarify project locations proved unsuccessful so those projects were removed from further investigation. Another problem noted was the same proposed dam having different names on different lists.

The majority of dam sites identified in this study were located by utilizing remote sensing data. Dam sites were identified by reviewing satellite images in ArcMap with elevation contours overlaid. Locations were judged good candidates where a narrow valley minimized dam width and construction cost. The second item required in a good site was available storage upstream of the dam. An open valley with plenty of storage that quickly narrows down at the dam site is ideal. One difficulty encountered was the steep stream gradients. A dam on a steep stream would have to be exceptionally high to store enough water to provide any benefit and may not be economically justifiable. Evaluation of an otherwise good irrigation dam site depends on the presence of irrigated agriculture within a reasonable distance, and on the value (agricultural and social) of the land to be inundated. A great site might be identified with plenty of storage volume but if the downstream area is remote and too rugged for agriculture, the site may not be worthwhile.

A total of 159 irrigation storage dams were evaluated in this assessment. Because of the large number of potential dams identified in this study, a complete list of individual sites has been provided in the results portion of this report, Section 7. This list has been broken down into the 13 study watersheds.

4.1.2 Storage Dam Properties

Engineering properties calculated at each dam site included: watershed area, stage-storage curves, dam dimensions, construction volume, reservoir inundation maps, annual water budgets and irrigation service area estimates.

Watersheds were delineated for each dam site using Arc Hydro Tools in ArcMap version 9.3. Delineation was conducted using the 5 m grid DEM with gaps and sinks filled. Hydrologic characteristics of each watershed were calculated including area, slope, flow direction, longest flow path and sub-catchments.

ArcMap 3D Analyst tools were used to calculate water storage behind each dam. The 5 m DEM was used in the analysis. The stage-storage curves were calculated in 1.0 m increments with cumulative storage volume from the base to the dam crest. When comparing stage-storage curves for two dams of similar size, the site with the flatter curve provides more storage per height of dam and is likely more economical. A comparison of dam stage-storage curves in the Tarnak watershed is provided in Figure 4-1. From the graph it can be noted that for a dam 20 m high the Sengasi site provides about 17 times as much storage volume than at Nala-i-Khurd. Comparing the dam sites does require further study to determine if construction costs, benefits and other factors at Sengasi might outweigh potential at Nala-i-Khurd.

All dams were assumed earthen embankment type dams. Construction volume estimates use a crest width of 6 m with an up and downstream side slope of 3:1. The dam base length (from bank to bank) was measured from satellite images of the river valley. The crest length was measured using contours of the river valley based on the 5 m DEM. The reservoir inundation maps were also based on elevation contours from the 5 m DEM.

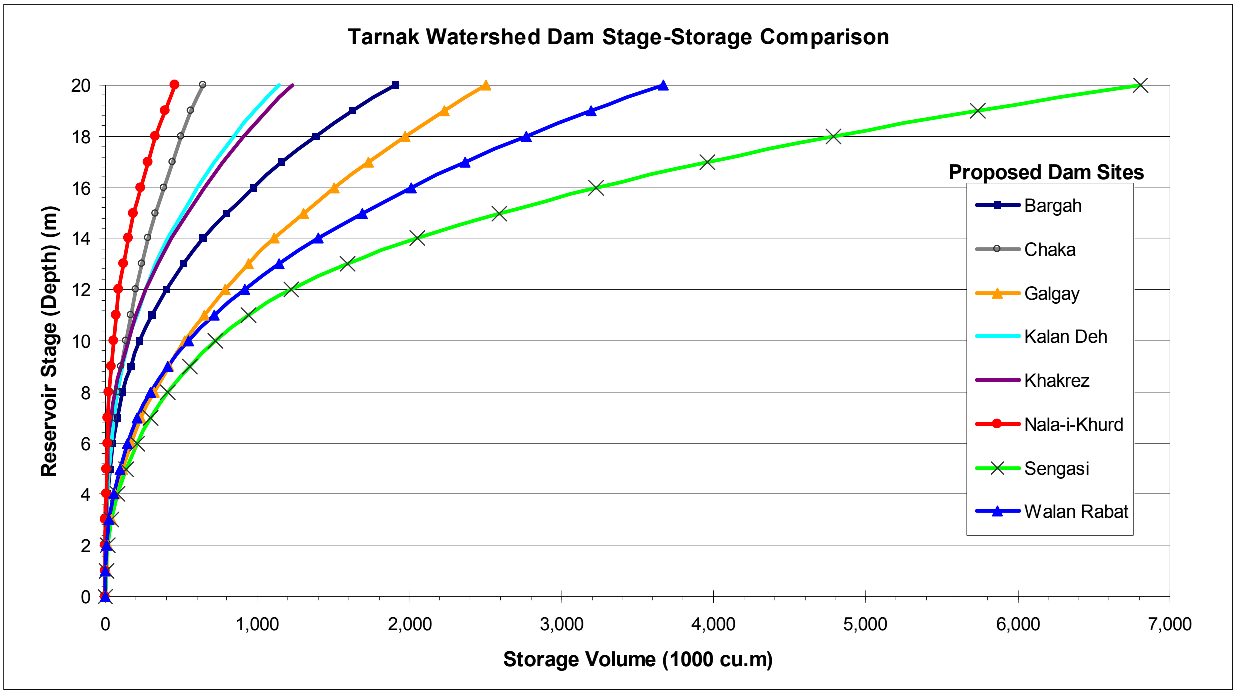


Figure 4-1 – Irrigation Storage Dam Comparison

4.1.3 Water Budget Estimates

Determining the annual water budget at a proposed irrigation storage dam is required to calculate the height of the dam and the potential irrigated service area. Using historic stream gage records is one method to determine the water budget. This would be the best method if each of the 159 proposed dam sites had a nearby gage with a long record. In southeast Afghanistan the average gage record is only 7 years for a complete water year. Another problem was that most of the gage records are for large watersheds but most project sites are on small watersheds. There was concern that multiplying the streamflow records by the ratio of gage watershed area to project watershed area would not be accurate. A small watershed can behave very differently than a small watershed. Smaller watersheds generally yield more total water and have higher peak flow per unit area than a larger watershed.

Hydrologic computer models could be developed to determine the annual water budget from the dam's watershed. It was determined that development of computer models was not possible. Calibrating the models would not have been possible because of the lack of hourly or daily precipitation data to match the available daily streamflow gage data. Only monthly precipitation totals were available for the same period of the recorded streamflow. It would not have been possible to develop unit hydrographs to calibrate the models. There were insufficient data on soil characteristics and channel dimensions. The assumptions used in developing a computer model would have produced results probably no more accurate than less time consuming methods.

Another method in determining the water budget is developing a correlation between the precipitation records and the streamflow records for the watersheds. A correlation or runoff ratio was developed by dividing the volume of water that flowed past a stream gage by precipitation depth that fell over that watershed and by the watershed area. This method usually uses the units of millimeters of runoff per millimeters of precipitation per hectare of watershed. This can also be thought of as a runoff ratio in cubic meters of runoff per millimeter of precipitation over hectare area of watershed (m^3/mm/ha).

The results of the runoff ratio method calculated at each streamflow gage are provided in Table 4-1. The table includes the stream gage watershed area, mean annual discharge, average annual runoff volume per watershed area and the calculated runoff ratio. The average runoff ratio was 3.23 m^3/mm/ha. This can also be viewed as 32.3% of the annual precipitation that fell over the watersheds resulted in runoff flowing past the streamgage. When reviewing the runoff ratios it is important to look at the characteristics of the watershed. The stream gages at Ghazni Bridge, Gardez and Tora Tigha all have values below 1.0 m^3/mm/ha. These gages are in wide valleys with large watersheds and large amounts of upstream irrigation diversions. The gages at Gardandewal and Mechalghu have high runoff values. These gages have small, mountainous watersheds with little upstream irrigation and year-round baseflow from groundwater springs. The runoff ratio should be applied to a proposed dam site that has similar watershed characteristics as the gage watershed it was calculated from. The worksheets used to calculate the runoff ratios are included in Appendix C.

The drawback of this method is that much of the precipitation was in the form of snow and was not converted into runoff until months later in spring, so correlating a monthly value was not completely accurate. Another difficulty was that some of the runoff from the watershed was diverted into irrigated fields before it reached the stream gage. Gaps and errors in the both the precipitation and stream gage records may also present errors.

One benefit of this method is that a runoff ratio calculated from seven years of stream gage data can be used with over 30 years of precipitation records to evaluate the proposed dam site. This may help filter out decade long droughts or flash floods skewing short streamflow records.

The best method to estimate water budgets at proposed water resource projects in Afghanistan might be the methods being developed by the USGS in the Upper Helmand watershed (Vining & Vecchia, 2007). The methods involve using calculated gridded precipitation to extend limited streamflow gage records. This will help to extend the gage records and capture the long-term climatic trends of cyclic droughts and extreme wet years. The scope and schedule for this southeast Afghanistan assessment did not permit the use of this developing technology but might be worth pursuing in designing large dams.

Table 4-1 – Runoff Ratio Summary Table

Stream Gage	Watershed Area	Mean Annual Discharge	Avg Annual Runoff	Runoff Ratio
	(ha)	(m^3/s)	(m^3/ha)	($m^3/mm/ha$)
Arghandab River at Sang-i-Masha	215,500	8.89	1,302	4.97
Barikab River above Seraj Reservoir	16,500	0.16	302	1.10
Gaber River near Chamkani	45,500	0.86	623	1.83
Ghazni River @ Ghazni Bridge	155,500	0.97	197	0.70
Ghazni River @ Nauburja	142,500	2.38	576	2.80
Helmand River @ Gardandewal	60,500	3.90	2,037	8.20
Jilga River @ Gardez	106,500	1.25	37	0.10
Jilga River near Mechalghu	6,500	0.66	3,218	9.60
Kabul River @ Maidan	130,500	5.09	2,126	3.75
Kabul River @ Tangi Saidan	162,500	4.05	1,361	3.09
Khurram River @ Ahmadkhel	73,000	3.30	1,429	4.54
Khurram River @ Chamkani	132,500	3.68	877	2.40
Khurram River @ Doda	101,500	4.04	1,314	3.83
Khurram River @ Pul-I-Bangakh	191,500	4.79	607	1.66
Logar River @ Kajab	378,000	7.41	620	2.90
Logar River @ Shekhabad	482,500	8.08	529	1.82
Logar River above Band-I-Chak Wardhak	441,500	6.66	477	2.60
Logar River @ Sang-i-Naweshta	973,500	9.63	312	1.13
Markana River @ Dahane Rishqa	108,000	7.94	2,317	7.10
Matun River @ Matun	34,000	0.77	695	1.61
Sarab River above Seraj Reservoir	73,000	1.27	550	2.00
Shamal River @ Domandi	75,000	1.45	605	1.30
Shamal River @ Tora Tigha	422,000	3.44	255	0.71
Spera River near Spera	75,500	1.03	448	0.97
Syahang River near Gardandewal	16,000	1.66	2,970	13.12
Syahgel River @ Syahgel	14,500	0.19	846	3.01
Tarnak River near Shahjuy	3,145	1.33	121	0.48

4.1.4 Irrigation Demands

Irrigation demands by crop type were obtained from the FAO publication "Irrigation Water Management" (Brouwer, 1986). Information provided by PRTs in the region indicated that maize and winter wheat were the principle crops in the study area. The crop cycle begins in October when winter wheat is planted. The wheat sprouts during fall and becomes dormant during the winter months. In March, the wheat resumes growth and is harvested in June.

Maize is usually planted following the wheat harvest. It is then harvested in October and the cycle starts over. The planting and harvest dates vary and other crops besides wheat and maize are also grown, but these were used as representatives for irrigation scheduling and volume demands. Wheat and maize were taken as the evaluated crops in the analysis but there are many varieties of grains, legumes and other crop types grown in the area with different rotations, water demands, planting and harvest timing.

Given the many unknowns and assumptions required in this study, a detailed calculation of demands using crop evapotranspiration, crop factors and growth stages was not justified. Therefore, water demand for crops was determined using the total growing demand for wheat and maize found in the FAO publication. Wheat requires 450 to 650 mm of water and maize requires 500 to 800 mm. A residual 50 to 100 mm of equivalent soil moisture is present from winter precipitation at the beginning of the wheat growth in spring. For the spreadsheet calculations, a total seasonal demand of 1000 mm (39.4 in) was used for both crops beginning the 1st of March and ending August 31st. The dams are designed to hold and regulate the release of enough water to irrigate the crops to a depth of 167 mm each month, and would be empty from September through November with filling starting in December.

4.1.5 Evaluation of Dam Sites

An Excel spreadsheet was developed to determine the potential area that could be irrigated by the dam. The main factors driving this were; watershed area, precipitation, dam storage, the runoff ratio and crop irrigation demand. The runoff ratio is essentially how much precipitation over the watershed is converted into runoff entering the dam, calculated from the correlations in Section 4.1.3.

Of the total amount of watershed runoff that enters the reservoir only about 55% is utilized by crops. These losses are from inefficient irrigation practices, releases to meet downstream water demands and reservoir seepage and evaporation losses. To satisfy the water rights of downstream users, 15% of inflow was allowed to leave the dam and by-pass irrigation service areas. Depending on the reservoir surface area, about 5% of the inflow volume was lost in the reservoir itself from evaporation and seepage losses. The irrigation distribution system was estimated to lose 25% of crop demand volume through canal seepage, field drains and overtopped diversion weirs (Brouwer, 1986). Distribution losses of up to 50% is not uncommon in many developing countries with flood irrigation. The loss values can be refined in the spreadsheets during the dam design phase. Proper design and planning should focus on keeping losses to a minimum.

It should be noted that there are benefits from these losses. Seepage at the dam and associated canals can recharge the shallow aquifer benefiting wells and karezes in the area or may add to downstream flows. Trees that grow and take up water along the irrigation canals help prevent wind erosion of soils. Where they serve as windbreaks, crop evaporative losses can be reduced.

The irrigation storage dams were sized in two ways. The first method was to maximize the storage volume to hold as much runoff as possible while at the same time subtracting monthly irrigation demands, releases to downstream users, and other losses. The goal of the "maximized" dam was to have enough water to irrigate wheat in spring and maize through the end of August. These dams tended to be very large and were not feasible at many locations. A maximized dam any higher would contain storage capacity that the watershed could not fill in the average year.

The second method was to evaluate the storage volume provided by a 12, 8 and 5 m high dam. The 5 and 8 m high dam is the typical mid-size irrigation storage dam in Afghanistan. These dams are capable of supplying water to irrigate winter wheat in the spring and in some wetter years, supply water for the first planting of maize. The irrigation depth was reduced to 100 mm per month from March through June. Additional water was supplied to the crops by runoff spilling over the smaller dam. The service area irrigated by the dams was determined by increasing that area until the reservoir went dry in June. In Khost and eastern Paktya these smaller dams will also benefit water users by holding runoff from the summer monsoon.

Optimizing the dam height based on construction cost, long term maintenance and economic benefits was not possible. There was no readily available data on crop production rates and prices for the study. Factoring in transportation, material and security cost in this remote area added more uncertainties. Soil surveys of the irrigated areas would be required to justify construction of any dam.

Estimating the volume of runoff entering the reservoir was difficult because of the lack of precipitation and stream gage data. To offset this difficulty, dam site comparisons were based on storage potential, constructability, irrigation benefits and watershed stability. The amount of area irrigated should be used in preliminary planning purposes only. It should be noted that the dams were evaluated using average annual precipitation amounts and this is considered conservative. Additional storage volume would be desired to hold runoff for above average years and to offer some flood storage during the summer monsoon.

No storage dam project should proceed to construction without first addressing requirements for long-term maintenance. There should be agreements between TF Yukon and local and Ministry officials concerning who will be responsible for maintenance of the dam and reservoir. Initial budget estimates for any project should include training and equipment necessary to ensure a long service life of the project. International experts and assistance from the Natural Resources Conservation Service of the USDA and from the U.S. Bureau of Reclamation can provide guidance on sedimentation issues. Much of the maintenance work will have to be conducted during the dry season from September to November.

4.2 Hydropower Potential

4.2.1 Identification of Sites

Potential hydropower sites in Afghanistan are limited more by available streamflow than by suitable topography. The steep stream slopes and narrow river gorges found in Afghanistan provide excellent elevation change and driving head for turbines to produce electricity. It is the lack of steady, year round baseflow at most sites that is the restraint on hydropower. The best sites tend to be just as the stream exits the mountains and upstream of areas with high irrigation diversions. It is recommended that TF Yukon also investigate other options for small power projects including wind turbine and solar. These projects can be supplemented with banks of batteries to power low-capacity community well pumps.

The evaluation of hydropower in this study will focus on micro and mini-hydropower. Micro-hydropower is rated up to 100 kW and mini between 100 kW and 1MW. Large hydropower projects require years of detailed analysis, planning and design and is beyond this scope of work. This analysis will concentrate on the small scale, run-of-river type project. It is not recommended that TF Yukon pursue hydropower projects that rely on the driving head provided by the small irrigation storage dams. Most irrigation dams in Afghanistan are less than half full for most of the year and will provide little driving head. There would also be conflicts in demands for limited water supplies, either holding water for summer irrigation or releasing water in winter during high power demands. It is recommended that TF Yukon pursue the small scale projects that do not require the extensive design and construction associated with the large, multi-purpose dams.

A schematic of a typical run-of river hydropower system may be reviewed in Figure 4-2. Water is diverted into a headrace channel by a low diversion dam or weir. The low dam will only divert enough water to run the powerhouse with excess flow passing over the dam. The headrace channel runs parallel to the river at a milder slope than the river, increasing the elevation difference between the channel and river. This is where the elevation difference or head will come from that drives the turbines. Headrace canals can extend from a few hundred meters to over 3 kilometers. The headrace empties into the forebay where sediments can settle out. The penstock pipe transfers water under pressure from the forebay to the turbines in the powerhouse. The penstock is usually placed on a very steep slope above the powerhouse with particular effort to keep the pipe length short.

The run-of-river hydropower sites were identified by reviewing the satellite images and elevation contours of the study provinces. A good hydropower site had to have a combination of factors. A location under evaluation in the upper Helmand River watershed may be reviewed in Figure 4-3. The stream needed to have a steep slope to provide driving head for the turbines. The valley side slopes needed to be steep to keep the penstock length short and reduce headloss. The watershed had to be large enough to provide sufficient flow with little irrigation diversions upstream. The hydropower site also needs to be near settlements to keep the cost of transmission and power losses low. The route of the headrace and the diverted flow should have minimum impact on existing irrigation networks.

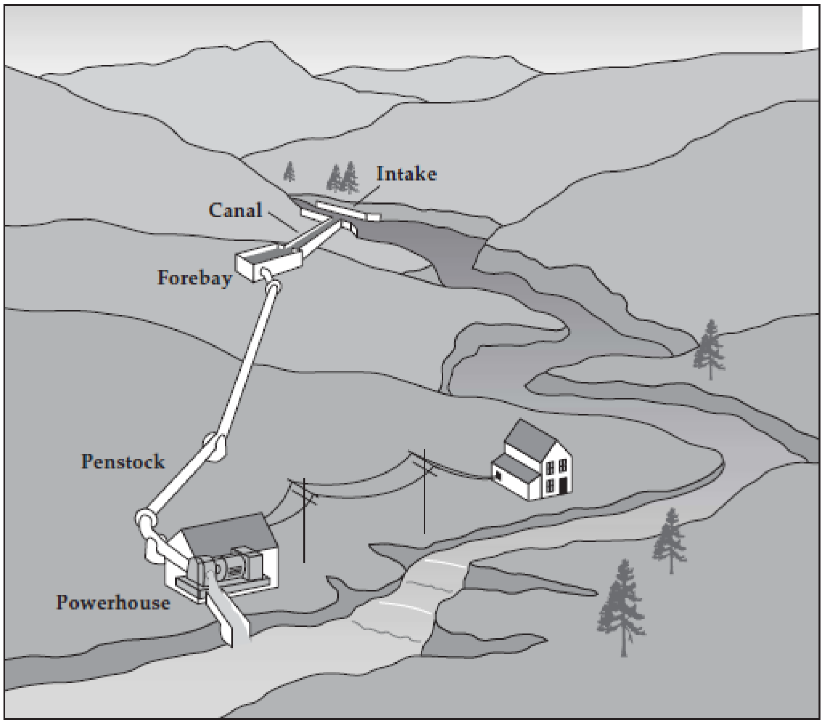


Figure 4-2 – Micro-hydropower System (DOE, 2001)

4.2.2 Water Budget Estimates

The amount of stream flow at each hydropower site was estimated by two methods. The first method used was the runoff ratio method as used in the irrigation storage dam analysis (see Section 4.1.3). The second method involved using streamflow statistics of a nearby streamgage that has similar watershed characteristics as the proposed hydropower site. A ratio of the watershed areas at the streamgage and hydropower site was used to adjust the flow at the proposed site. Monthly streamflow statistics were obtained from the USGS data report (see Section 2.4).

Monthly flows from the runoff ratio method were ultimately not used in the hydropower analysis. This method has difficulty in accounting for the timing of the snowmelt and will overestimate flows in the winter months. This method was useful in evaluating annual kilowatt-hours produced because the runoff method is able to use a longer record of precipitation data than the historic streamgage records.

For the stream gage ratio method, monthly mean flow from the USGS data report was used to estimate power generation for each month. For low flow conditions, the 85th percentile of days flow was equaled or exceeded at the stream gage was used. The 85 percentage was considered conservative enough to provide an idea of low flow conditions and may be used in preliminary estimates of the generating unit size. In the United State the 7Q10 (the lowest streamflow that occurs over 7 consecutive days and has a 10-year recurrence interval period) is frequently used for low flow conditions. Use of the 7Q10 low flow in Afghanistan maybe too conservative. A village may be willing to accept no hydropower each October during low flow conditions.

4.2.3 Potential Power Estimates

Table 4-2 is a sample spreadsheet used to evaluate hydropower potential at the proposed Abbas Koshteh site in the Helmand watershed. This spreadsheet was used to calculate potential power (P) in kilowatts (kW) using the equation below.

$$P = (Q) \times (H) \times (e) \times (g) \times (\rho) \times (c)$$

P = Power in kilowatts (kW)
Q = Flow in cubic meters per second (m^3/s)
H = Head (m)
e = Efficiency (50%)
g = Gravity (9.81 m/s^2)
ρ = Density of Water (1000 kg/ m^3)
c = conversion (1 kW/ 1000 W)

Head (H) is the vertical height of water above the turbine. This would be measured from the water level in the forebay to the turbine exit. For this rough evaluation of so many sites, gross head was used and does not include headloss from friction and contractions. A conservative value of 50% was used for efficiency because of the rugged environment in Afghanistan (RNCan, 2004). The spreadsheet also includes monthly estimates of energy produced in kilowatt-hours (kW-hr). The estimate of energy is artificially high and is used only in comparing different project sites. Energy will have to be recalculated after the turbine and generator are sized.

The upstream elevation in the sample spreadsheet is the streambed elevation at the diversion dam. The diversion dam is 2 m high and directs flow into the headrace channel. The headrace channel continues at a slope of 1 m over 250 m to the forebay. The downstream elevation is at the exit of the turbine with 1 m added to stay above flood flow. Total gross head is calculated by subtracting the downstream elevation from the upstream, subtracting the drop in elevation of the headrace and adding the height of the 2 m diversion dam. The gross head is the vertical drop of the penstock and the head driving on the turbine. It must be noted that elevations were taken from the 5 m DEM and this information should be used for planning purposes only.

4.2.4 Evaluation of Hydropower Project Sites

Proposed hydropower sites were evaluated by their power generating potential, streamflow characteristics and proximity to existing population. The proposed sites were not compared and prioritized with a decision model as used in the irrigation storage dams. There are too many variables and too many assumptions used in the analysis to justify a detailed decision model.

The results of the hydropower analysis are presented in Section 8. The better sites are the ones capable of producing constant power year round. A site producing 300 kW for three months of the year and only 20 kW the other nine is not as good as a site capable of producing 50 kW year round. To keep the design and maintenance to a minimum the generating unit should be sized to the average baseflow at the site. A large baseflow can support a larger generator and more population served. There is the option of a second unit to utilize the higher flows in spring. The better sites are not necessarily the ones with the highest power potential. A smaller but constant baseflow at a location can still produce power to serve a village grain mill or clinic.

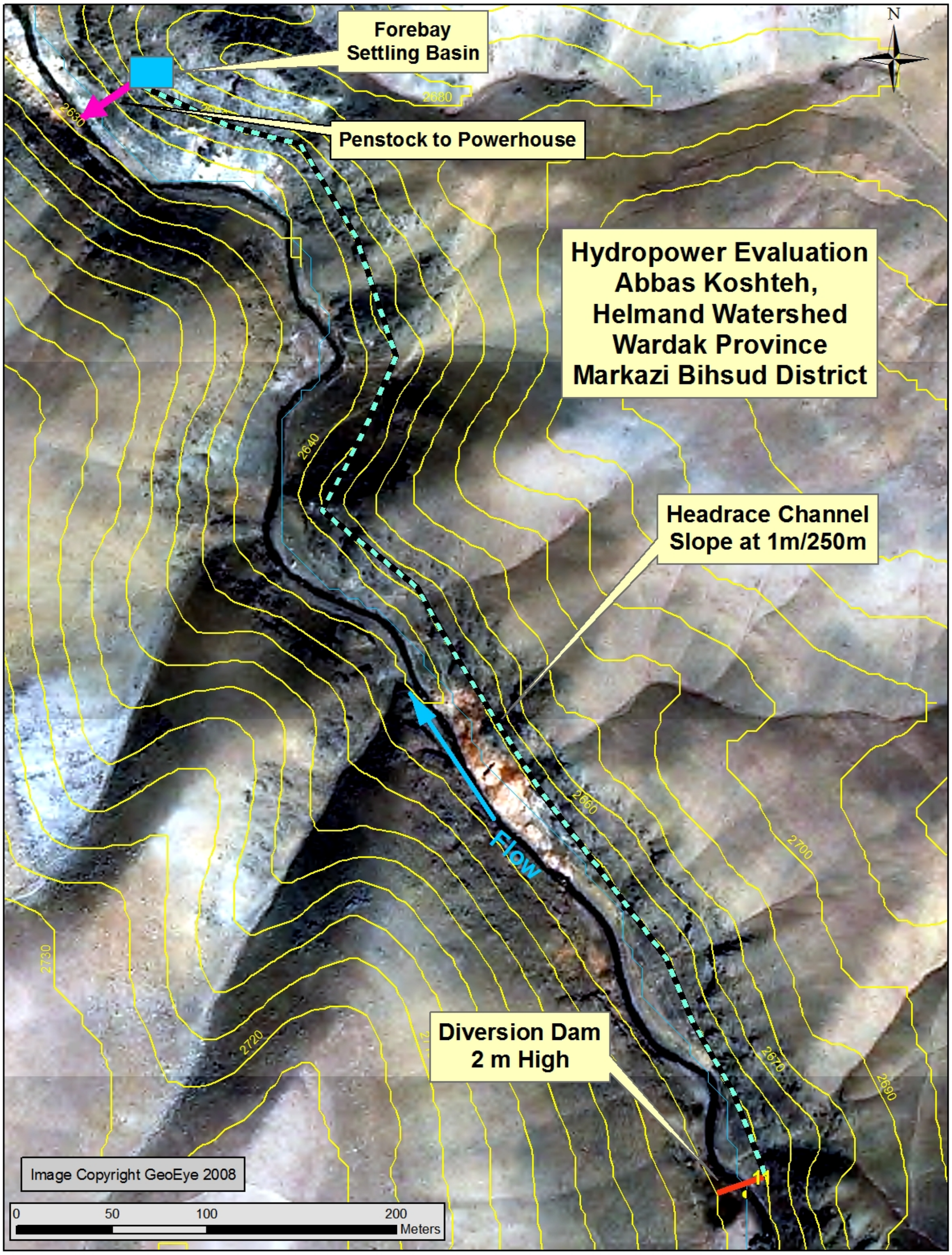


Figure 4-3 – Sample Micro-Hydropower Site Evaluation

Table 4-2 – Sample Hydropower Evaluation Spreadsheet

Abbas Koshteh Hydropower Potential
Helmand Sub-Basin, Wardak Province
Project ID: Helmand #11

Watershed Area = 10,609 ha *Project Site Watershed*
Watershed Runoff Ratio = 7.1 m^3/mm/ha
Upstream Elevation = 2,650 m
Downstream Elevation = 2,624 m
Headrace Length = 745 m
Weir Height = 2 m
Headrace Slope = 0.4%
Potential Head = 25.0 m
Efficiency = 50%
Precip Multiplier = 1.00
Markhana River at Dahane Rishqa = 108,000 ha *Streamgage Watershed Area*

	Power Potential - Runoff Ratio Method					**Power Potential - Stream Gage Ratio Method**							
	Mean Precip (mm)	Monthly Volume Runoff (m^3)	Runoff Ratio Monthly Runoff (m^3/s)	Potential Power (kW)	Kilowatt-Hour (kW-hr)	Mean Dahane Rishqa Gage (m^3/s)	Gage Ratio Monthly Runoff (m^3/s)	Potential Power (kW)	Kilowatt-Hour (kW-hr)	85% Exceed Dahane Rishqa Gage (m^3/s)	Gage Ratio Monthly Runoff (m^3/s)	Potential Power (kW)	Kilowatt-Hour (kW-hr)
Oct	5	347,069	0.13	16	11,832	3.47	0.34	42	31,123	2.46	0.24	30	22,064
Nov	12	902,631	0.35	43	30,770	3.25	0.32	39	28,209	2.40	0.24	29	20,832
Dec	24	1,779,382	0.66	82	60,659	3.04	0.30	37	27,266	2.30	0.23	28	20,629
Jan	38	2,852,458	1.06	131	97,240	2.86	0.28	34	25,652	2.35	0.23	28	21,077
Feb	65	4,930,818	1.97	242	168,090	3.19	0.31	38	26,766	2.28	0.22	27	19,130
Mar	72	5,433,750	2.03	249	185,235	5.91	0.58	71	53,008	2.54	0.25	31	22,782
Apr	47	3,546,597	1.37	168	120,903	18.80	1.85	227	163,180	7.72	0.76	93	67,008
May	23	1,727,814	0.65	79	58,901	27.20	2.67	328	243,960	14.90	1.46	180	133,640
Jun	1	111,248	0.04	5	3,792	13.60	1.34	164	118,045	6.96	0.68	84	60,411
Jul	2	169,768	0.06	8	5,787	6.23	0.61	75	55,878	2.78	0.27	34	24,934
Aug	3	232,345	0.09	11	7,921	3.88	0.38	47	34,800	2.68	0.26	32	24,037
Sep	3	199,319	0.08	9	6,795	3.77	0.37	45	32,723	3.08	0.30	37	26,734
Total =	*295*	*22,233,201*		*87*	*757,924*			*96*	*840,609*			*53*	*463,278*

Power Calculation: P (kW) = Q (m^3/s) x H (m) x e x 9.8 (m/s^2) x 1000 (kg/m^3) x 0.001 (kW/W)
Streamgage data from USGS report "Streamflow Characteristics of Streams in Southeast Afghanistan", 2009.
Streamflow for "Mean" is the simple monthly mean at the recorded streamgage.
Streamflow for "85% Exceed" is the percentage of days discharge equaled or exceeded at the recorded streamgage for the month.

4.3 Irrigation Diversions

4.3.1 Identification of Sites

Irrigation diversions are structures used to redirect flow from a stream and into an irrigation network of canals and ditches that convey water to the fields. Traditional irrigation diversions built for centuries in Afghanistan consist of a low rock dam less than 1 m high and may serve a small village or a single family farm. These traditional diversions are usually temporary structures and are washed out during high flood conditions and are easily rebuilt, an example is in Figure 4-4. Over the past century, more permanent concrete or masonry structures have been built across streams to divert water to larger and more engineered irrigation networks. These permanent structures contain sluice gates that control the flow diverted to the irrigation network and the flow that continues downstream; an example is shown in Figure 4-5. Both types of diversion structure utilize water elevation differences in the range of centimeters to divert flow and transport to the fields.

Many of the irrigation storage dam sites evaluated in this study were rejected because there was little storage potential behind the dam. Some of the rejected dam sites did however have the characteristics of a good diversion site. These characteristics included a natural constriction in the valley walls so that the structure could be narrow in width and easier to build. Another characteristic of a good site is an open, flat valley downstream of the diversion with readily available arable land. The lack of soils data impaired this effort so existing cultivated land was noted.

It should be noted that the best diversion locations are most likely in the already densely populated and heavily farmed areas along the lower river valleys, e.g. Shamal River and Jilga. Because the driving head for these types of projects is in centimeters, our remote sensing tools do not have the resolution to identify and fully evaluate. This study does identify some potential project locations higher up in the watershed where streams draining mountainous watersheds exit into an open valley.

4.3.2 Evaluation of Project Sites

Detailed evaluation of irrigation diversion sites was not possible with the resolution of the remote sensing tools used. For example, while examining existing diversion structures and irrigation canals along the Logar River it was found that the DEM derived contours lines were not accurate enough for use. The wide irrigated valley was too flat for the DEM to accurately follow the route of the canals. The man-made canals were crossing contours and were sometimes flowing in an uphill direction according to the contour lines. Evaluating elevation differences in the range of centimeters was not an appropriate use of the 5 m DEM.

The evaluation of the identified new diversion projects was limited. The watershed area was calculated for each project along with an assessment of the watershed characteristics. The availability of near-by arable land was evaluated by reviewing CIR images of the downstream valley to assess the amount of active cultivated vegetation.

Figure 4-4 – Traditional Irrigation Diversion Structure (Bermel Valley, Paktika)

Figure 4-5 – Concrete Irrigation Diversion with Sluice Gates (Darweshan, Helmand Valley)

4.4 Project Watershed Characterization

The goals of watershed evaluation are to evaluate watershed potential, evaluate present condition, and make management recommendations. These take the form of 1) characterization of features important to watershed management, 2) area-specific management options for watershed improvement, and 3) decision support models that combine the numerous ecological, physical, social, and logistical factors to help guide the allocation of resources and project planning *to maximize chances of success on the ground.*

This section describes methods used in characterization of features important to watershed management and area-specific management options for watershed improvement. These factors are used as criteria in the decision support models used to rate storage dams and watershed restoration potential.

The watershed evaluation part of the SE Water Resources study has the following objectives.

- Estimate deforestation in project watersheds.
- Estimate stream system characteristics in watersheds.
- Estimate stream system characteristics at project sites.
- Estimate active upland erosion in watersheds proposed to feed water resource improvement projects.
- Estimate inundation of dwellings and bridges.
- Downstream presently-irrigated agricultural lands.

The concepts behind these methods were developed in the Paktika Water Resource Assessment completed in 2008. They have been modified for the increased size of the assessment area used here. Only 15 watersheds were evaluated in the former study, and 295 are reviewed in the present one. Therefore, methods had to be changed to keep to the project schedule while maintaining accuracy. Most “ground truth” was obtained from interpretation of high-resolution satellite imagery (0.6 m) draped on detailed elevation models. A color-infrared (CIR) band interpretation provided the most information.

Project watershed results of this analysis are contained in Appendix O. A table describing the location of each factor’s results in that Appendix is at the end of this Section.

4.4.1 Deforestation

One of the SE Afghanistan Water Resource Study's objectives includes estimating watershed condition. Fire and timber harvest affect watersheds and water quality, hence recent disturbances and their environments should be evaluated.

The objective is to show the results of a LANDSAT-based satellite study of the SE Afghanistan Water Resource Assessment Study Area. This study used a U. S. Forest Service classification tool to estimate vegetation change developed initially for wildfire mapping. The model produces a Burned Area Reflectance Classification (BARC) showing degree of vegetation change over time. It is based on a Normalized Differential Vegetation Index (NDVI). Jess Clark (Remote Sensing Applications Center, U. S. Forest Service) applied the model for this assessment. It was ground-truthed using a canvass of CIR (Color Infrared) QuickBird satellite imagery. *All CIR imagery used in this project is © Digital Globe, Inc.*

Initial forested area used for the LANDSAT image acquisition footprint was based on a LANDSAT classification of land use provided by the United Nations in 2001/2002. It is about 70% accurate based on QuickBird (© Digital Globe) CIR imagery interpretation, classifying more land as forested than is probable. It was judged sufficiently precise for limiting the extent of analysis.

The model results show both wildfires and logging occurring in the last nine years. Figures 4-6 and 4-7 show an example area in the western part of the Shamal watershed. Yellow indicates significant vegetation change. This change is almost certainly due to extensive logging, based on the CIR imagery (all imagery is © Digital Globe). Note the regular boundaries, and apparent skid roads. The slope model indicates these lands are steep. They are also apparently at the head of a watershed. There are probably significant watershed effects.

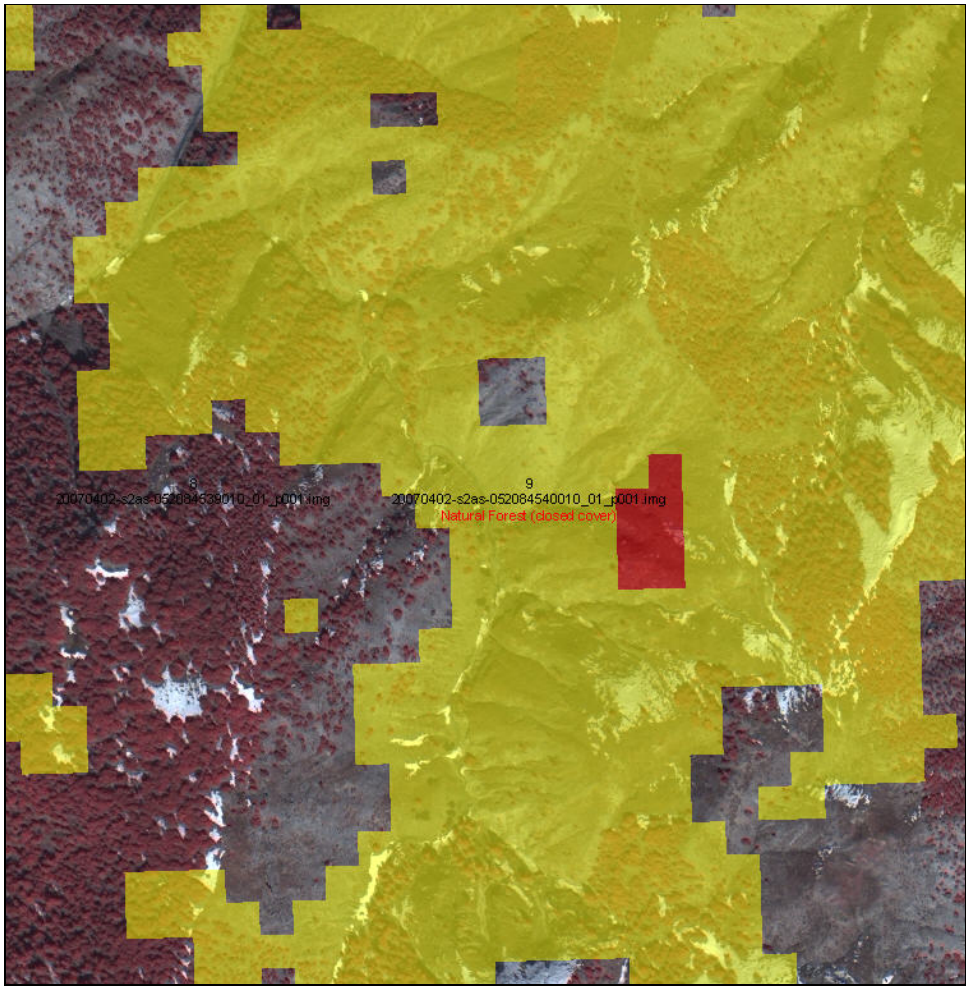


Figure 4-6 Deforestation Estimation – Reflectance Change (© DigitalGlobe)

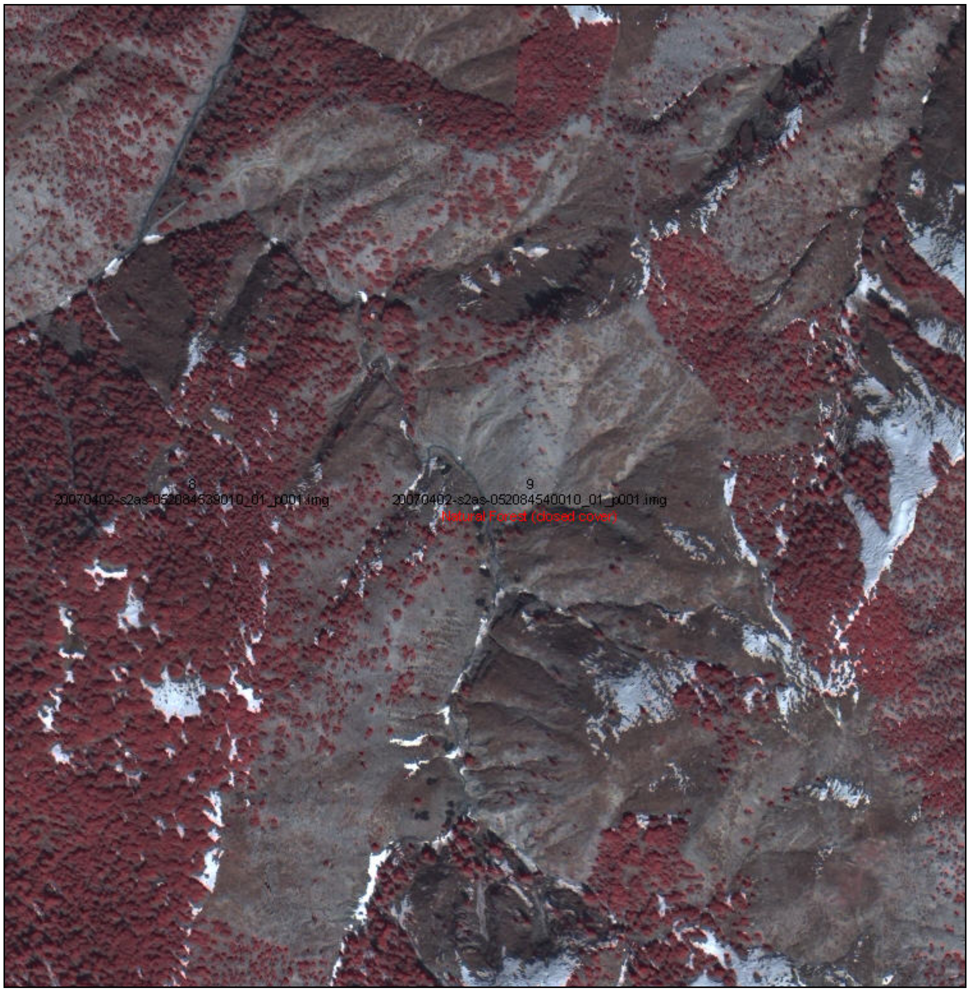


Figure 4-7 Deforestation Estimation- Probable Cause (© DigitalGlobe)

Description of Classes of Disturbance (See Figure 4-8 for mapping)

Initial Estimate of Forested Land: This class shows in light green. This represents the boundaries of the interpretation. It is from the 2001 Land classification map.

Timber Harvest Class: This class (brown polygons on Figure 4-8) is based on both a measured vegetation change using LANDSAT with treeless land and confirmation of harvest indicators using 2007 Quickbird imagery at a scale of 1:2,000. Though only the period of 1999-2008 is measured here, earlier harvests probably make up three times this area. This class also occurs in the test area in Paktika Province. Not all of Paktika has been inventoried.

Burned Area Class: This class (red polygons in Figure 4-8) is based both on a measured vegetation change using LANDSAT, with verification of treeless land, wildfire spatial patterns, and absent harvest indicators at a scale of 1:2,000.

Cloud Class: These white areas are "no data" since cloud cover was present on one or both LANDSAT satellite images.

Other classes (not shown) are a general decrease in vegetative productivity that was widespread over the area, and non-evaluated areas within the forested area (such as settlements, or agricultural areas). No further analysis was made with these areas.

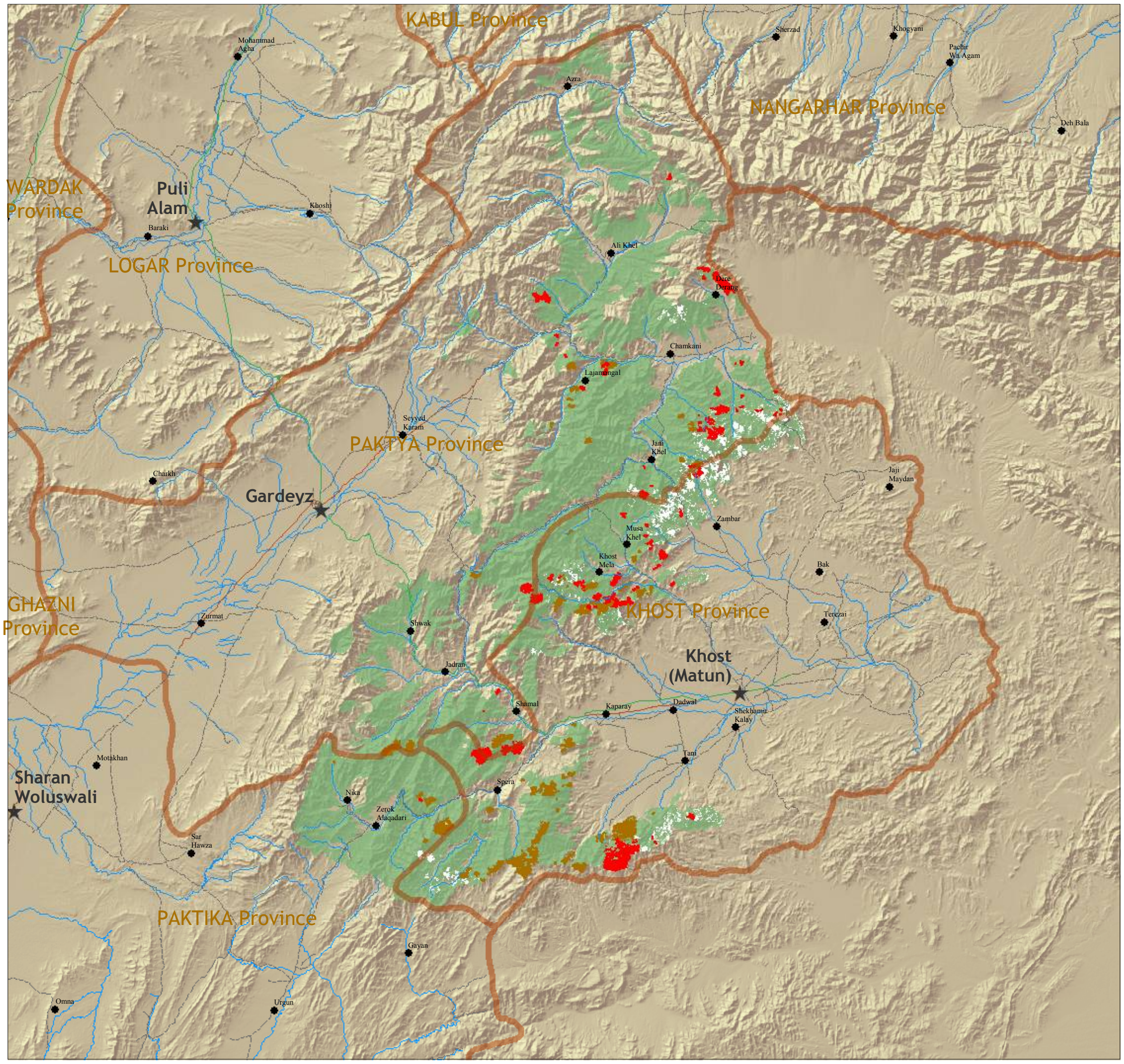


Figure 4-8 – Mapped Deforested Land

Almost all forested land occurs in the eastern Shamal and Chamkani sub-basins (Khost and Paktya provinces) (Figure 4-8). Over 1/2 of each of those watersheds is forested. Timber harvest and burned areas are concentrated in the Shamal sub-basin (88% of harvest and 69% of burned areas).

Fires and harvest tend to occur high in watersheds, on steep land, and without buffering of vegetation near streams (Figure 4-9). This indicates they will likely have related erosion and may increase sediment in streams at lower elevations for a period of years. Burned areas are probably not all wildfires. Many burned areas appear to originate near settlements or in range areas, possibly set to improve forage. Harvested areas may not be commercial operations. Some are probably longer-term fuel wood cutting areas.

The rate estimated here is over a period of nine years. Of forested lands, a total of 4.1 % was burned or harvested in this period. Given the probable poor harvest practices, this is likely to have significant effects on water quality. Limitations: This is a remote-sensing project. It is designed to help focus watershed condition evaluations, planning restoration, and educational efforts and is accurate enough for those purposes. It is not designed to be site-specific or used below a scale of 1:12,000.

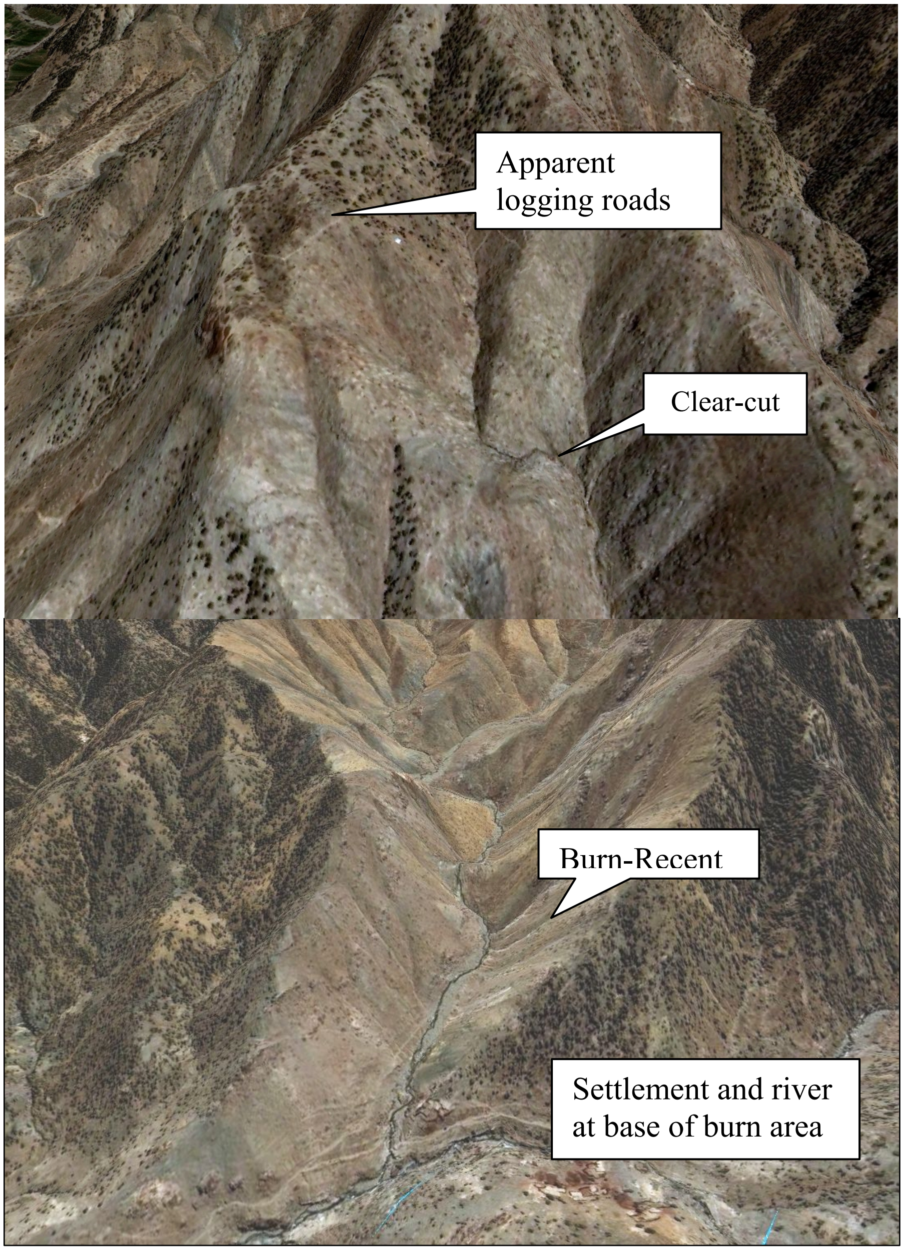


Figure 4-9 – Representative Landscape Context of Burned and Harvested Areas (© DigitalGlobe)

4.4.2 Stream System Characterization

The kinds and density of stream drainage networks help indicate the character of a watershed as well as potential for uses of the transported surface waters. All stream channels digitized for the engineering portion of this project were reviewed and attributed. This includes all major channels (those feeding from watersheds larger than 3 km sq for all watersheds with exception of Ghazni Lower-Sardeh and Logar which used a 12 km sq. minimum watershed). Appendix G shows the entire stream system for each project watershed. Two watersheds had no inventoried streams. These were hand-digitized.

Each stream reach was reviewed at a scale of 1:24,000 with color-infrared satellite imagery (0.6 to 1 m resolution). The same imagery at a scale of 1:2,400 or larger was used to determine bank vegetation, character of flood plain, presence of bedrock banks, live water, and other characteristics at representative points within the reach defined by the smaller scale review.

A “reach” is defined as a relatively-uniform stretch of stream channel and associated floodplain, based on the differentia in the classification described below. Each of 5,147 reaches was rated. Average length of reach was 2,100 m. The differentiating classes were developed from a reconnaissance of the entire watershed study area at a scale of 1:24,000, and supplemented as new kinds of channel systems were identified. The classes rate characteristics important for sediment production, stream bank restoration, and geomorphic stability for this study and were developed based on what occurs in SE Afghanistan. They do not necessarily reflect more generalized classifications designed for other purposes.

The active stream channel and associated floodplain are both components of the stream “system” as used in this study. This system is classified based on flood plain type and size (Table 4-3). A “braided” stream system is classified by the presence of a wide, un-vegetated, multi-channel flood plain, with indicators of a current live or commonly watered stream. This is considered an “unstable” system. An “incised” stream system is one in which stream banks are steep and high (> 10 m) with little associated flood plain and a narrow channel. This system is considered stable. Stream gradients are usually high (<5%).

Stream systems are classed as “normal” if the flood plain is vegetated or other-wise appears relatively stable. The stream channel is well defined and may or may not be vegetated. Based on observations in this study, this class of system is commonly perennial unless dewatered for irrigation. Banks of the flood plain are vegetated.

A “dispersed” stream system has evidence of historical or pre-historical channel development, but no active flow indication. This class is common in drier areas, where past climatic conditions were favorable to stream flow, but current conditions are such that surface flows are extremely uncommon. Active channels are difficult to distinguish on imagery. Figures 4-10 – 4-15 illustrate representative examples of aerial views at about 1:6,000 scale using CIR imagery.

Table 4-3 – Stream System Characteristics

Class	Active flood plain width	Channel Character
1	Large (> 20 m)	Braided
5	Small (<20 m)	Braided
6	Small only (<20 m)	Incised
8	Not rated	Dispersed
9	Large (>20 m)	Normal: vegetated banks, flood plain
10	Not rated	Unknown: Cloud or shade cover
11	Small (<20 m)	Normal: vegetated banks, flood plain

Classes 1 and 5 indicate a geomorphically unstable system. These have high-sedimentation rates and highly variable flow. Though unvegetated and eroding stream banks are very common, the system's instability makes it unlikely streambank restoration would be effective in improving water quality. Sediment loads and peak flows are likely high.

Classes 9 and 11 are reserved for those stream systems that appear to have a "normal" or "stable" channel. Banks and lower hillslopes have convex slopes, with apparent live vegetation, and little braiding is visible. These characteristics indicate a more stable geomorphic environment than those in classes 1 and 5. The system appears well adjusted with an accessible flood plain.

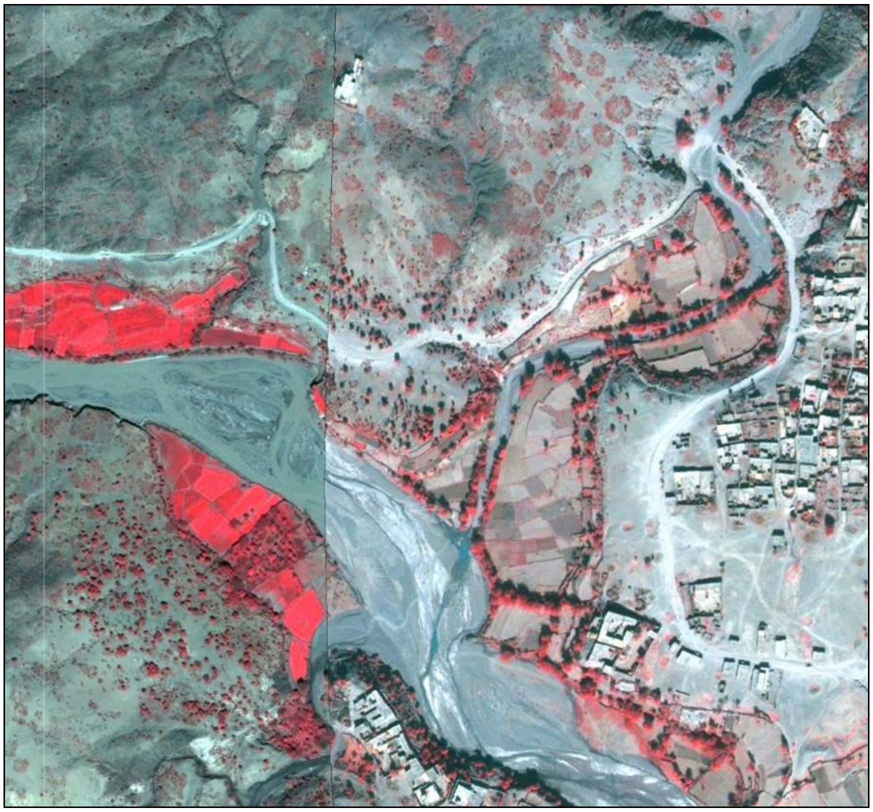


Figure 4-10 – Class 1 Stream (Note two dates of imagery showing flow differences; spring flow is on the left, summer flow is on the right; dark gray on left indicates sediment-laden flow, light gray and white on the right indicate dry alluvium). (© DigitalGlobe)

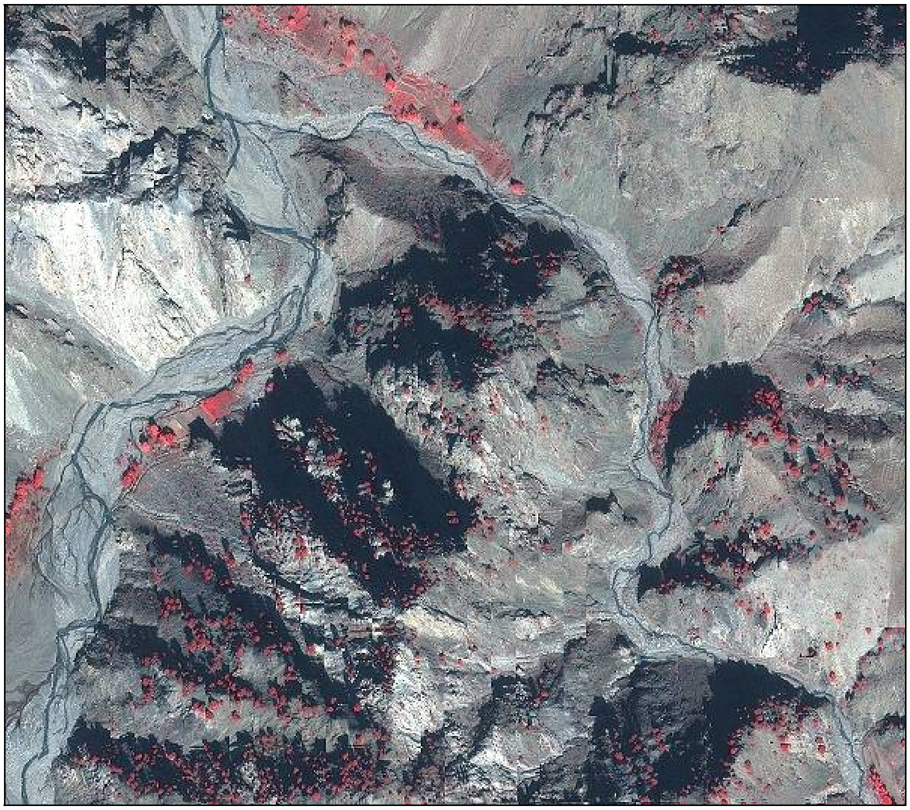


Figure 4-11 – Class 5 Stream (small braided stream system in upper right); Class 1 is on the lower left. (© DigitalGlobe)

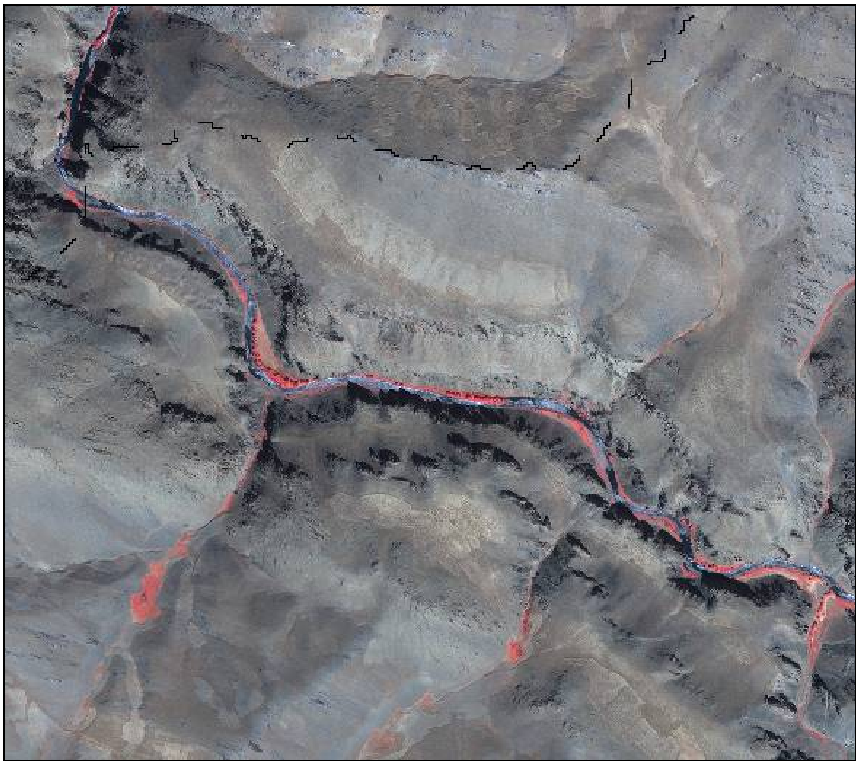


Figure 4-12 – Class 6 Stream (Incised Stream System) (© DigitalGlobe)

Figure 4-13 – Class 8 Stream (Dispersed or Relict – subsurface flow system) (© DigitalGlobe)

Figure 4-14 – Class 9 Stream (Large, stable, meandering stream system) (© DigitalGlobe)

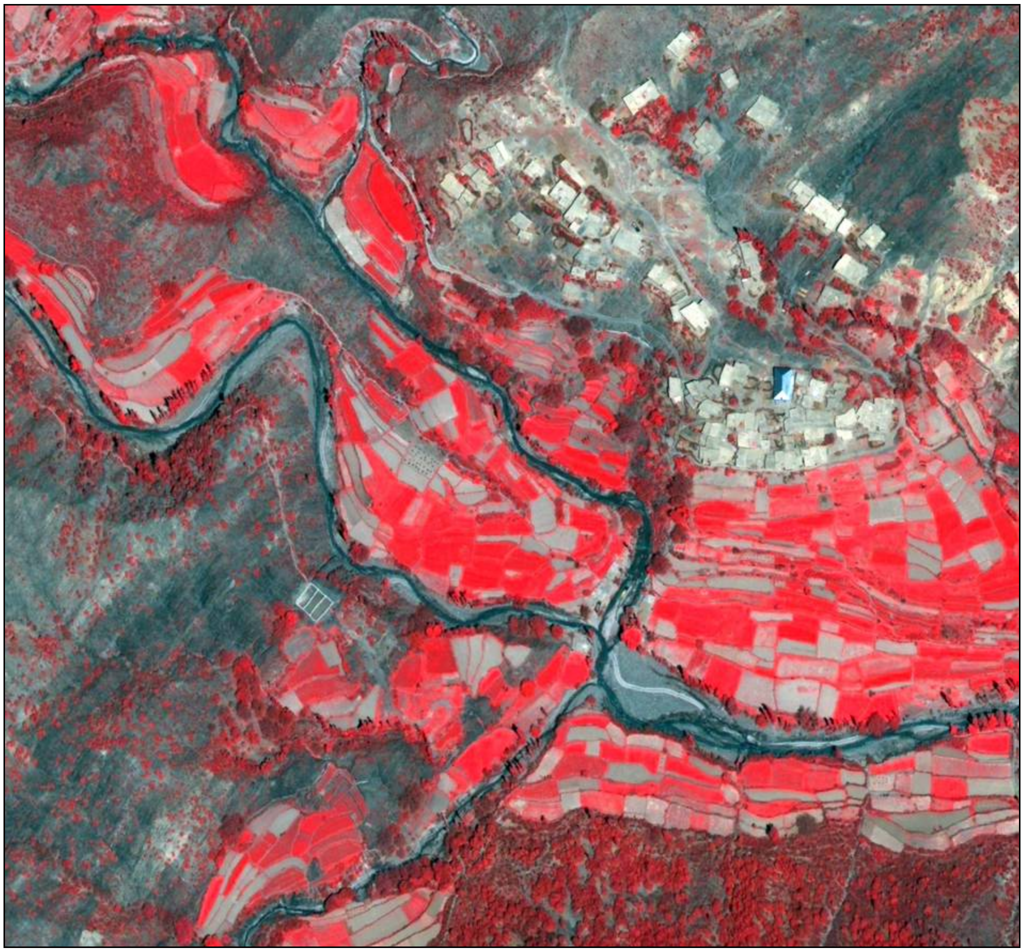


Figure 4-15 – Class 11 Stream (or small stable stream system, note multiple but stable channels and irrigated lands). (© DigitalGlobe)

Based on reviewing multiple imagery dates, most streams in the study area are probably intermittent. Though some relatively stable streams high in the watershed are probably perennial, the available data are not reliable enough to make a definitive determination, other than that given in the classes described above. Furthermore, the term "stable" is relative. It may be more appropriate to say these appear to be in adjustment to their environments. Systems that appear stable, with vegetated banks and little braiding, are still subject to extreme flooding (Figure 4-16 and 4-17). These floods have positive effects, such as creation of new, fertile flood plain deposits, renewal of riparian vegetation, and ground water recharge. However, in these "stable" areas, flooding does not radically affect the stream channel as in more unstable systems (Figure 4-18). These figures are about 1:6,000 scale.

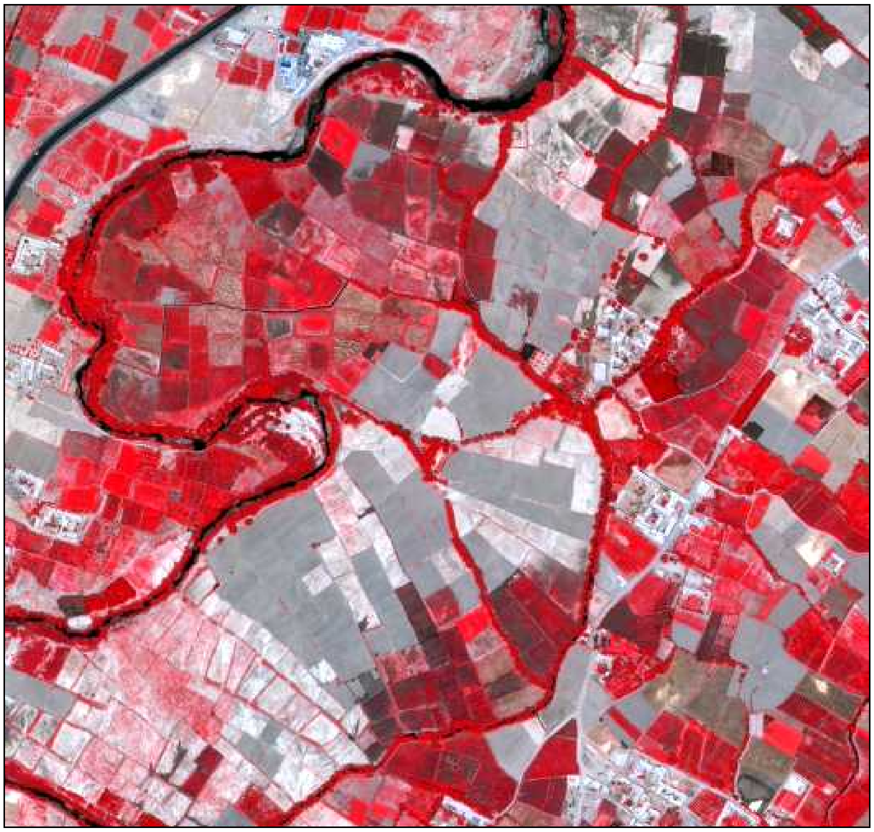


Figure 4-16 – Stable Stream System in July (Lower Logar Sub-basin) (© DigitalGlobe)

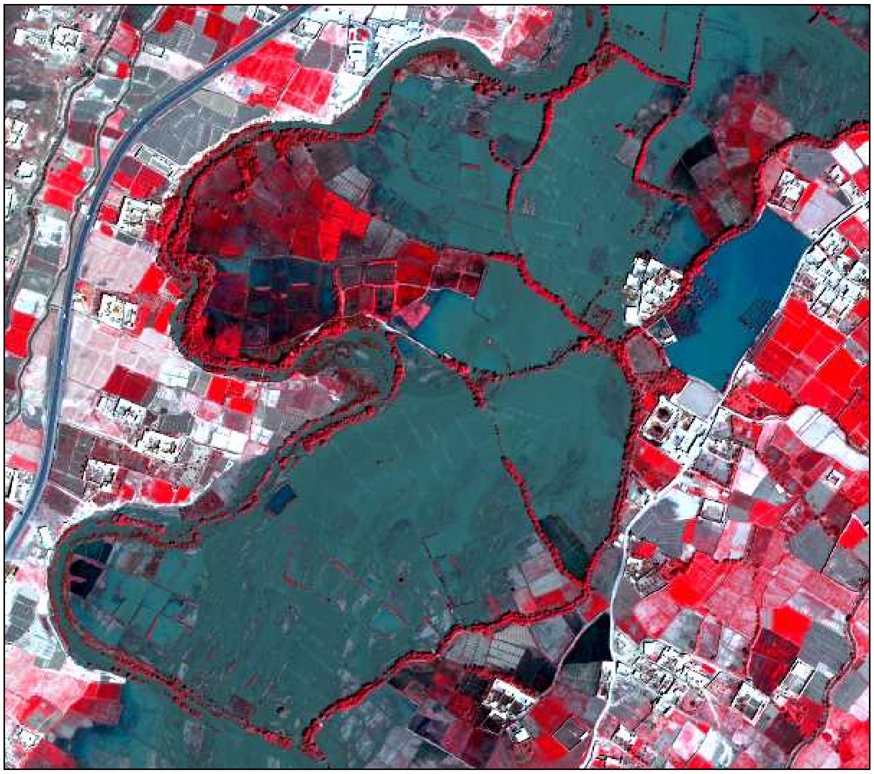


Figure 4-17 – Stable stream system in April (flooding in the Lower Logar Sub-basin) (© DigitalGlobe)

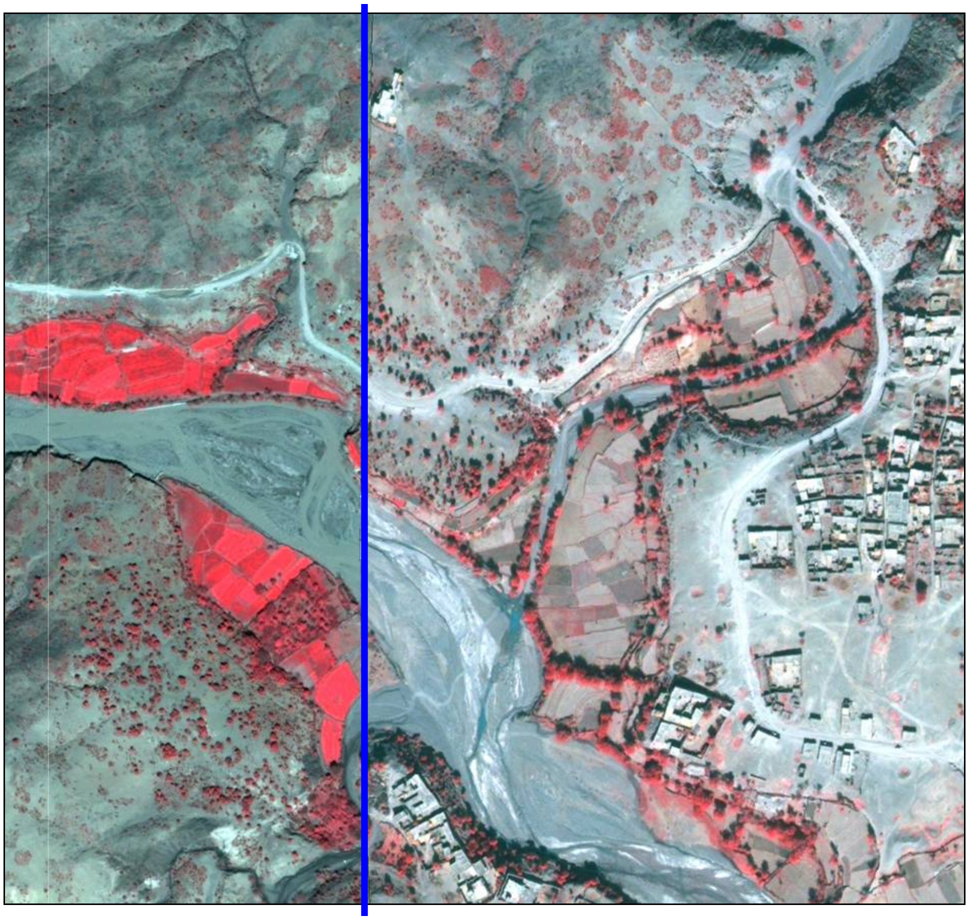


Figure 4-18 – Unstable Stream System in Flood and Dry Period (left is spring flood flow and right is during dry period summer flow) (© DigitalGlobe)

Results were tabulated by project watershed, recognizing the significant overlap in many watersheds. A measure of unstable streams was created by calculating the percentage of classes 1 and 5 over total classified stream length. This percentage was used in the decision support model described below.

4.4.3 Unstable Site at Project Location

Field review and imagery review indicated dams on large, unstable streams likely have high rates of sedimentation, requiring frequent dredging, and potentially severe problems in terms of reservoir maintenance and damage from sediment. See Figure 4-19 for an example of a recently-constructed dam after only three years of use. Figure 4-20 shows the downstream system, a Class 1 (large unstable) stream system.


Figure 4-19 – Reservoir Filling on a Large, Unstable Stream (Oosterkamp, 2009)


Figure 4-20 – Upstream of the Filled Reservoir (Oosterkamp, 2009)

An index of site quality was created to account for this factor. A buffer of 300 m radius was created around each project site. If a large, unstable stream (Class 1) intersected that buffer, it was flagged as an unstable project site.

4.4.4 Active Upland Gully Erosion

Even without considering the relatively unstable stream systems described above, much of Afghanistan's uplands have severe active erosion. Causes range from poor range management, deforestation, climatic extremes, surface expression of erosive geologic materials, to geologic uplift. Some areas have highly-erosive materials exposed in a severe climatic environment, producing "badland" topography. Many areas have gully erosion (Figure 4-21).

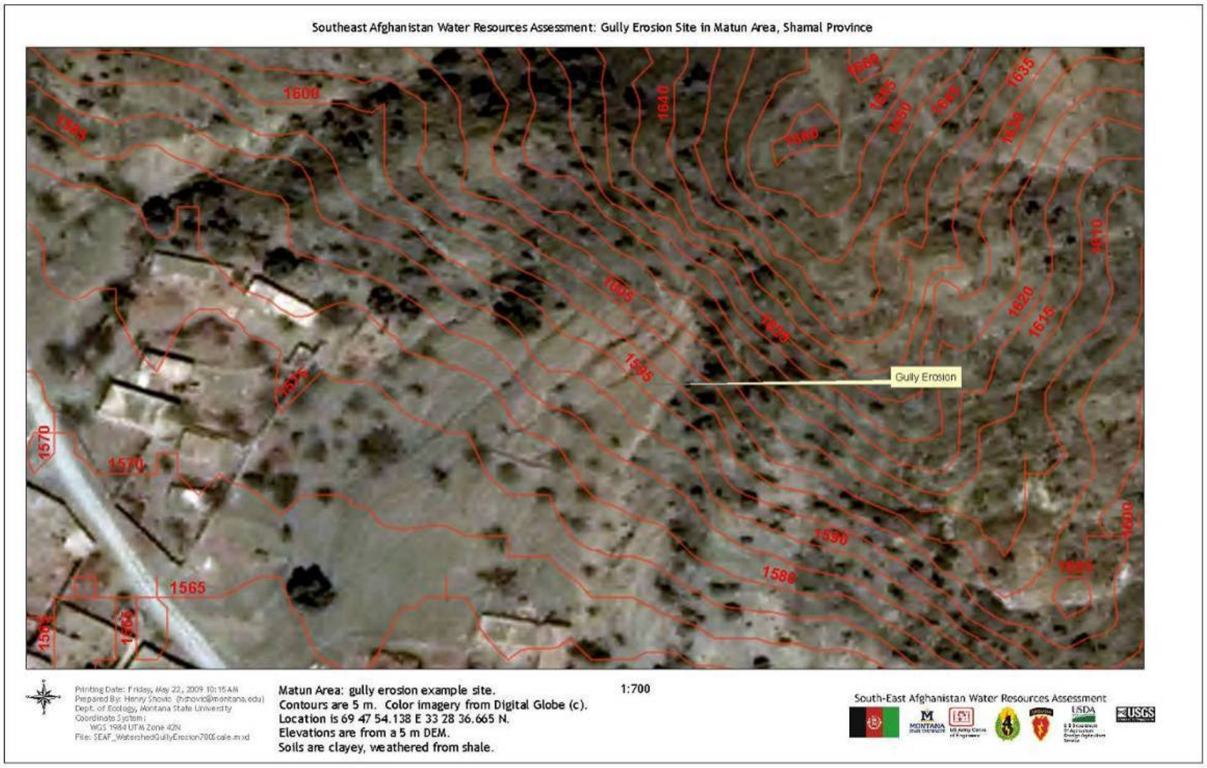


Figure 4-21 – Active Gullying in the Matun Area (Shamal Sub-basin)

The objective of this section was to obtain a spatial, active erosion estimate for each project watershed. Sampling each watershed on the Paktika study was sufficient to differentiate between watersheds. However, with the large number of project watersheds in the current study, an indirect method was needed.

A digital geologic map based on Russian geological mapping and formatted by the USGS was used to create groups of rock types that had generally similar composition. These groups (Table 4-4) were defined to represent rocks that generally have similar erosional characteristics. The rock types from the geologic maps (Appendix E) were classed in these groups.

Though these groups are theoretically different with respect to erosional characteristics, climatic and mapping variations could make them unusable as indicators of active erosion. Therefore, a statistical sample of each group was made to verify differences between them. A random sample of 50 points was made for each stratum (rock type group) in the study area. This was derived from randomly sampling each stratum in the project watershed of the study area (Figure 4-22).

Table 4-4 – Rock Type Groups for Active Erosion

Code	Rock Group Name	Notes
1	Unconsolidated sediments	mixed, recent and Quaternary
2	Basic and Mafic Intrusives	Dunite, Gabbro
3	Acid Intrusives	Granite, Granodiorite
4	Layered metamorphic rocks	Schist, Serpentine
5	Hard metamorpic rocks	
6	Limestone and dolomite	some sandstone and shale
7	Sandstone, siltstone, and limestone	
8	Sandstone, siltstone, clay, and limestone	clayey sedimentary rocks
9	Shale, siltstone, sandstone, and limestone	
10	Sandstone, siltstone, and shale	no limestone
11	Volcanic rocks	acid and mafic, no limestone
12	Limestone, sandstone, and shale	limestone dominates, but others significant

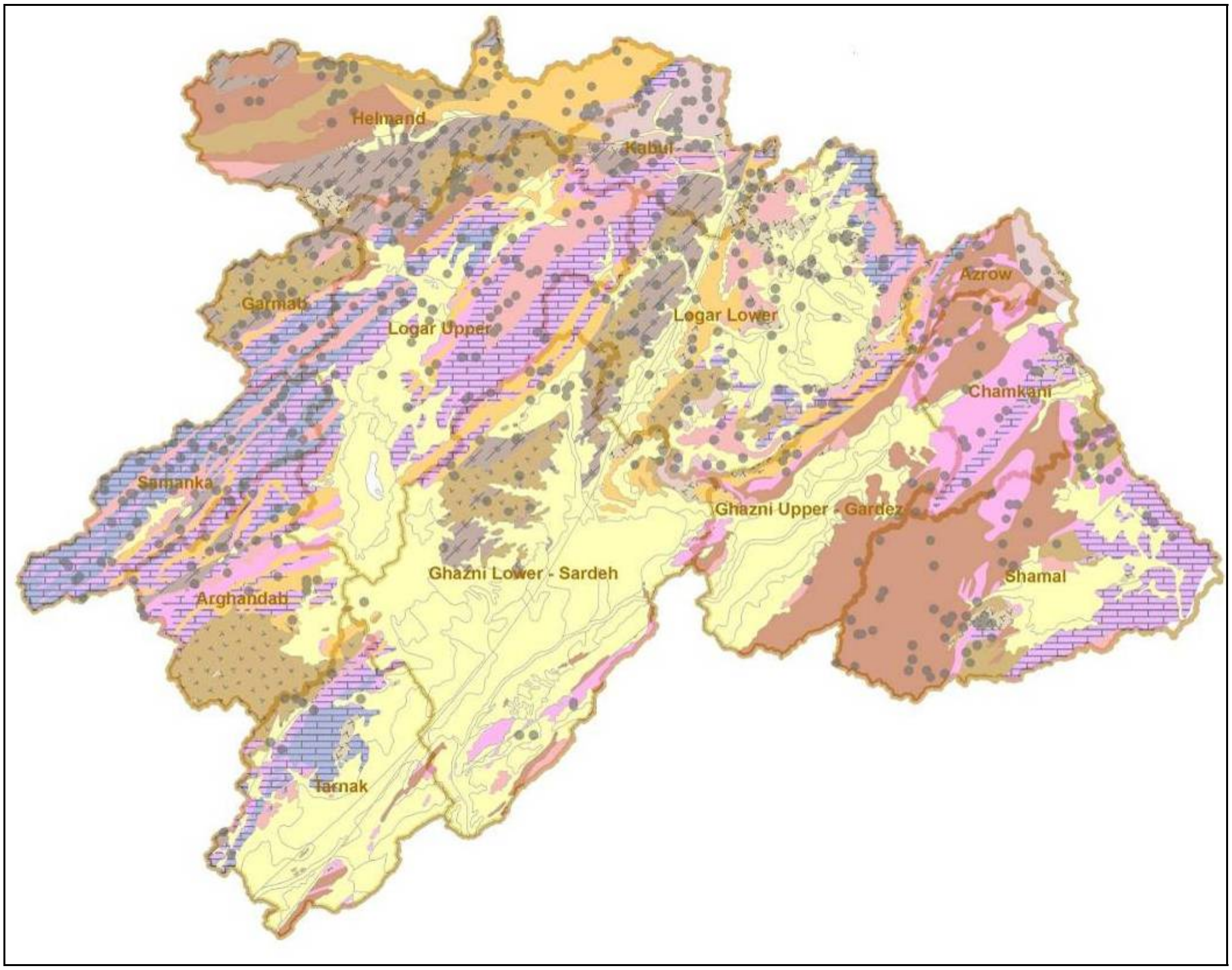


Figure 4-22 – Sampling Distribution on Geologic Groups within the Project Watershed Area

Within a 100 m radius circular plot, presence or absence of gully erosion was described (Figure 4-23). Note a limitation in this study is that only severe gully erosion can be identified on present imagery. The gullies seen below are probably at least 2 m wide. More subtle rill and sheet erosion cannot be detected. This results in a probable under-representation of actual erosion.

Figure 4-23 – Plot Sample - Active Gully Erosion (© DigitalGlobe)

The 50 samples were tabulated to estimate % eroding land in each rock group. Changes in project watershed extent after tally reduced some sample sizes (Table 4-5). Also, up to 4% of some samples were unusable because of cloud cover or gaps in imagery. Using the rock group spatial data, the proportion of each group in each project watershed was used to create a weighted average of active gully erosion for each project watershed. See Table 2 in Appendix O for the distribution of rock types by project watershed.

Table 4-5 – Erosion Rock Groups Sample Size

Rock Group	Sample Size
Acid Intrusives	50
Basic and Mafic Intrusives	50
Hard metamorpic rocks	50
Layered metamorphic rocks	50
Limestone and dolomite	48
Limestone, sandstone, and shale	47
Sandstone, siltstone, and limestone	49
Sandstone, siltstone, and shale	49
Sandstone, siltstone, clay, and limestone	50
Shale, siltstone, sandstone, and limestone	48
Unconsolidated sediments	41
Volcanic rocks	50

4.4.5 Environmental Impacts – Inundation of Dwellings and Bridges

An estimate of the number of dwellings and bridges inundated was made for potential pools representing four potential dam heights (Figure 4-24). Dwellings and bridges within each pool's perimeter were digitized as points at 1:1,500 to 1:3,000 scale (Figure 4-25), and tabulated for each pool polygon. To be considered, dwellings had to be major (generally with a maintained outside wall and inside-buildings). Outbuildings were not counted. See Appendix I for illustrations of each pool set and associated dwellings.

4.4.6 Environmental Impacts – Irrigated land

This is a facet of the proposed method of estimating irrigation project benefits for the proposed irrigation storage projects. All irrigated land visible at a scale of 1:1,500 was digitized on the CIR imagery to a buffer distance of 9 km *downstream only from the project location.* Note these are estimates, to help make decisions as to project feasibility and to assist in dam sizing. They are not site-specific.

Figure 4-26 illustrates the CIR imagery (color Infrared, April and May 2008, © Digital Globe) (1:40,000) with the 9km buffer in gray. The black triangle is the project location (an irrigation storage dam), and violet is the contributing watershed. Reddish hues indicate high plant transpiration. Presently irrigated lands show as very red, but also must have other indicators of intense agriculture (such as field boundaries) for inclusion in our estimate. Other reddish hues are orchards or naturally wet areas, generally on steeper slopes. In areas with Fall imagery, delineations were made using field boundaries and residual crop indicators, such as harvest piles. Figure 4-27 shows supporting landscape data. Slope was used to aid in determining downstream delineations in difficult areas or areas with low slopes, and to determine stream direction. The calculated 200 m buffers were used in determining potentially-irrigable area. Criteria for potential additional land included slopes < 20%, unconsolidated sediments as parent material (generally alluvial fans) and within the 200 m buffer of the stream.

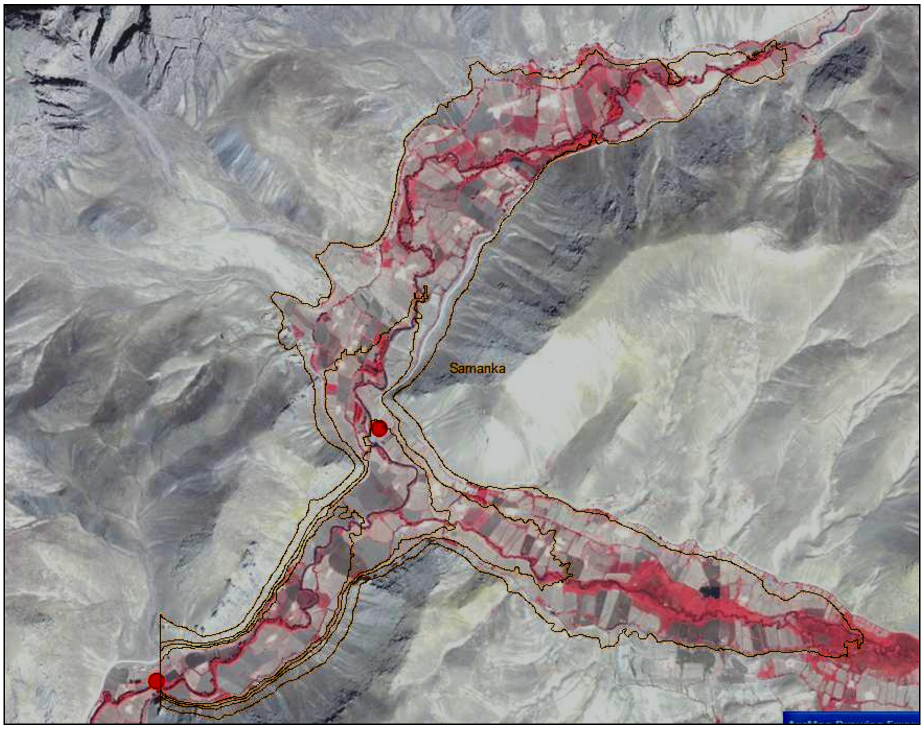


Figure 4-24 – Pool Perimeters for Four Dam Heights (© DigitalGlobe)

Figure 4-25 – Dwelling at Risk - Example Pool (© DigitalGlobe)

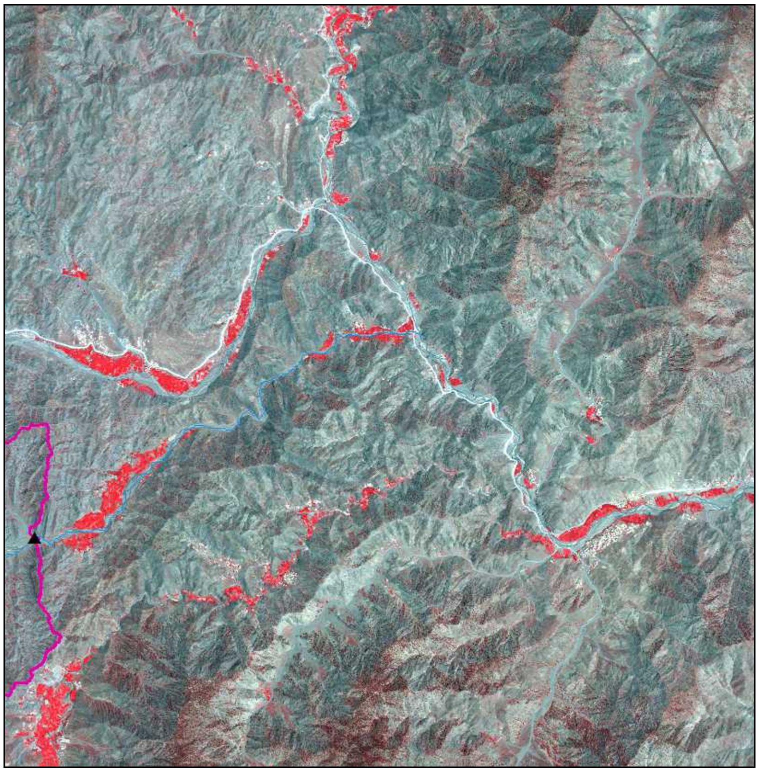


Figure 4-26 – CIR imagery used for irrigated agricultural land (© DigitalGlobe)

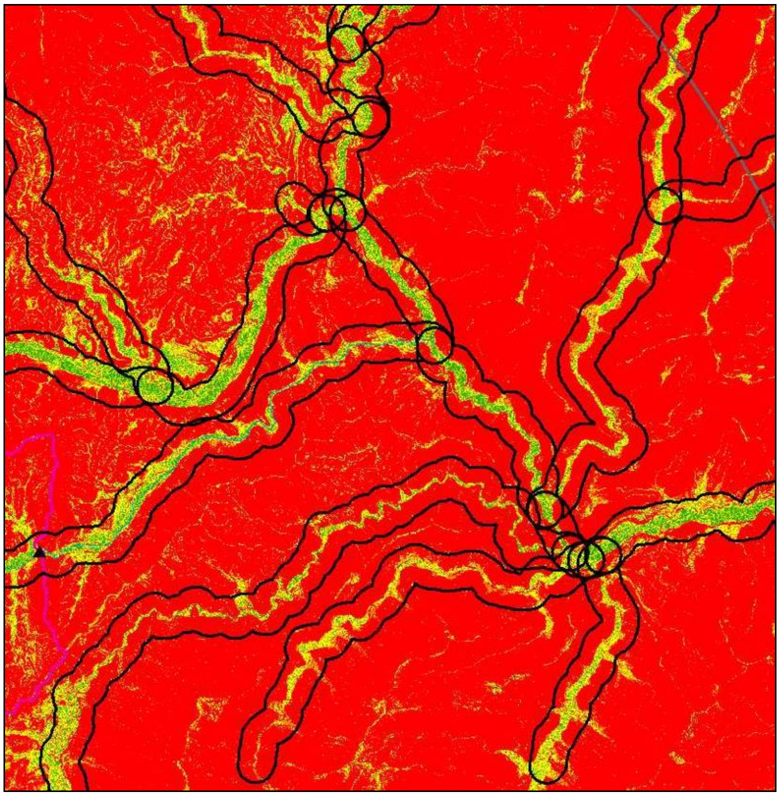


Figure 4-27 – Slope Classification and Stream Buffers. (© DigitalGlobe)

Example results are shown in Figure 4-28. There are 717,000 sq. meters of irrigated land and 107,000 sq. meters of potential irrigated land downstream within 9 km of the illustrated project location. The color green is presently irrigated land, and yellow is potentially-additional irrigable land. Potential additional lands were digitized here as an illustration of the maximum development scenario, and are not inventoried throughout the area. The considerable overlap of project watersheds meant that all or part of digitized irrigated lands could be assigned to more than one project. This was accounted for by multiple queries in a database.

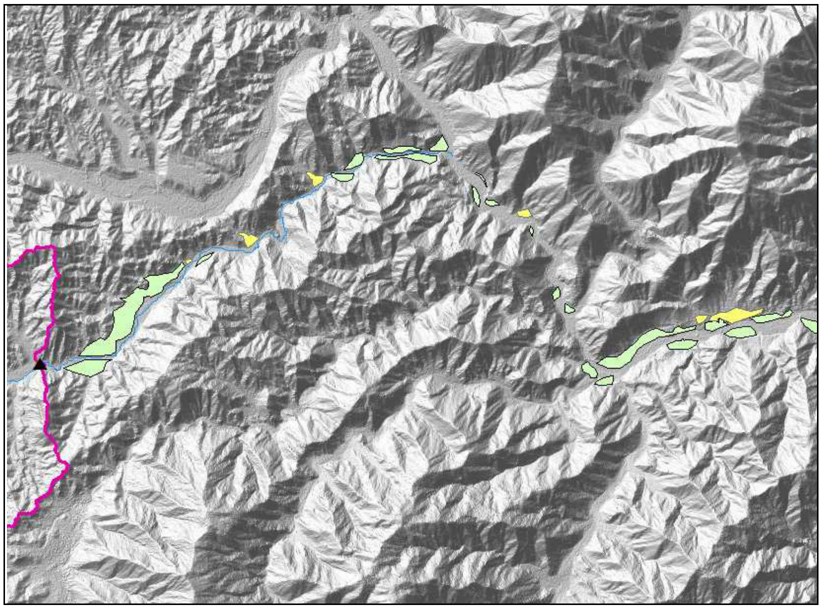


Figure 4-28 – Results of Irrigated Land Inventory (© DigitalGlobe)

4.4.7 Description and Location of Results

Table 4-6 shows the location of results for deforestation, stream system instability, active upland erosion, irrigated lands, and inundation. See Appendix E for spatial data for each.

Table 4-6 – Location of Watershed Evaluation Results

Evaluation	Description	Table in Appendix	Field Name
Deforestation	Total Wildfire +Harvest (% of total land area in watershed)	Appendix O, Table 12	DEFORESTN
Stream System Characterization	Total Unstable Streams (sum of Class 1 and 5) (% of streams in project watershed)	Appendix O, Table 12	UNSTSTRS
Stream System Characterization	Stream Classes by Project Watershed (% of streams in each class)	Appendix O, Table 13	
Unstable Site	“yes” if Class 1 stream within 300 m of project site; “no” otherwise	Appendix O, Table 8	SITEUNST
Active Upland Gully Erosion	Average Gully Erosion (% of land area in project watershed)	Appendix O, Table 12	ERODNGLN
Inundation of Dwellings and Bridges	Total Number of Dwellings and Bridges by Dam Height	Appendix O, Table 7	STTLINUN
Irrigated Agriculture	Total Area Downstream Irrigated Agriculture (Ha by Project)	Appendix O, Table 12	POTAGBNF

4.5 Decision Support Modeling

Preliminary project sites for this assessment were selected through a canvassing process. Because of this, each project has an intrinsic value. Because it was chosen as a proposal already satisfies certain criteria for project feasibility. The location has characteristics favorable for dam construction and reservoir development, watersheds have potential for sufficient delivery, and existing agricultural lands are within a reasonable distance.

Hundreds of sites were vetted through this process, covering a large geographic area. However, after this large initial selection of feasible sites was complete, the evaluation process became more complex. Some projects have better combinations of characteristics than do others. For example, two otherwise promising projects may have very different construction costs, which will influence their prioritization. Also, the degree to which local economies are affected may be quite different, depending on the relationship between impacts and benefits. Finally, some parameters that may affect project effectiveness (such as watershed condition) were not available for the initial canvass for locations.

Where appropriate a prioritization process (decision support model) was developed to help rate the project proposals. The process has some advantages over other methods. The first is the system can consistently rate many alternatives semi-automatically, facilitating client input during the study. A second advantage is that defining the model requires clarification and agreement on the decision support process, an advantage when decision criteria must be justified or communicated.

The process used here is based on a decision support system using the Simple Multi Attribute Rating Technique (SMART) implemented through a software system called CRITERION DECISION PLUS (CDP) from InfoHarvest.com. Additional software from the same company was used in conjunction with a data base management system to rate many alternatives quickly.

The decision support model was applied in two areas: project proposals and watershed management. Within the project proposals, three general categories of projects were considered (storage dams, hydropower facilities, and diversion dams). Of these, only the storage dams had enough data to use this kind of structured model. The projects in other categories were verbally rated. Storage dams were used in the following example to illustrate the process. The application is described in Section 6.2.

The model was also applied in the rating of project watersheds for potential watershed restoration. A subset of the same criteria described below were used to create this model, though weights and rating curves were modified. It is described in Section 10.

The decision support process has the following steps.

- Define objectives and criteria important to the process.
- Define a decision support model hierarchy of factors important to decisions and their relationships with each other.

- Determine relative importance of each factor (weighting).
- Determine data values and scales (rating)
- Rate each project.
- Review and do a reality check.

The most important part of the rating system is setting up the rating parameters (i.e. criteria). In this case, important features in any irrigation storage project evaluation would include costs and efficiency, potential benefits and impacts, and likely longevity. These are discussed below. Project factors such as construction cost are certainly critical. Storage capacity provided would be important, especially when related to dam height and the ability of the watershed to provide sufficient water during the growing season. The condition of the contributing watershed influences reservoir sedimentation, hydrology, potential erosion of fixtures and spillways, and flooding potential. Environmental impacts of reservoir filling should be balanced against the potential benefits to agricultural productivity.

Figure 4-29 shows the conceptual hierarchy for the storage dams decision model showing groups (e.g. Project Efficiency), and criteria (e.g. Storage Efficiency). This is an output from CDP. The hierarchy is developed using a brainstorming method not shown here that includes input from management personnel, resource scientists, and others. The absence of spaces between words in each name is a result of the requirement for using database-compatible nomenclature. These terms are described below.

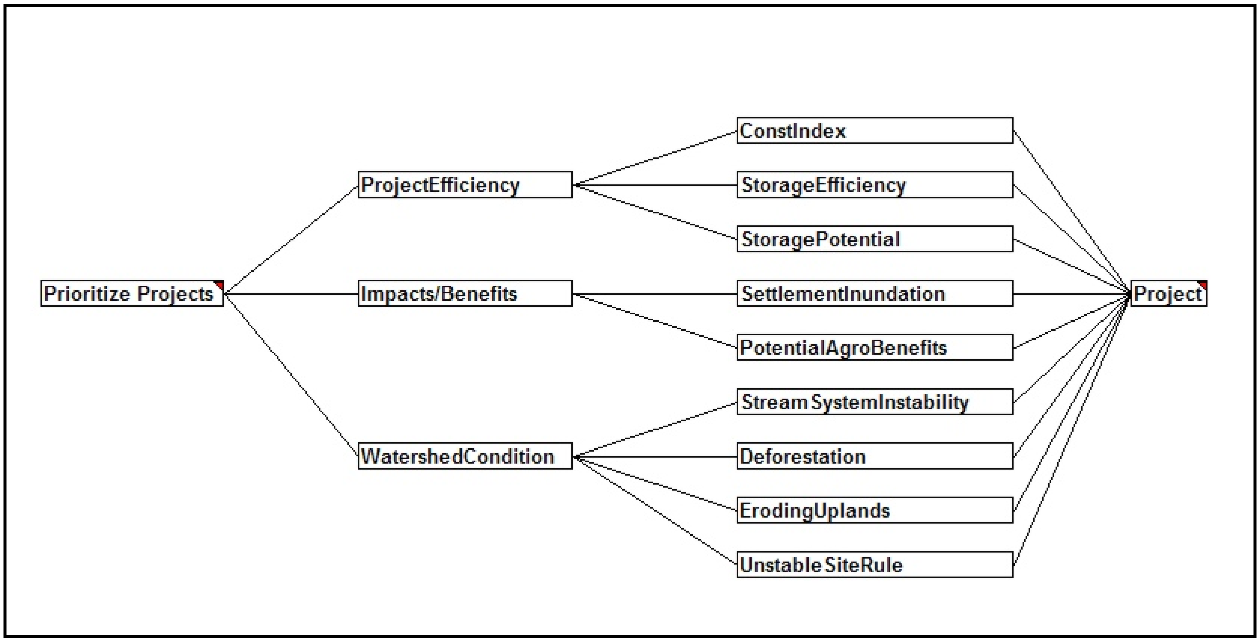
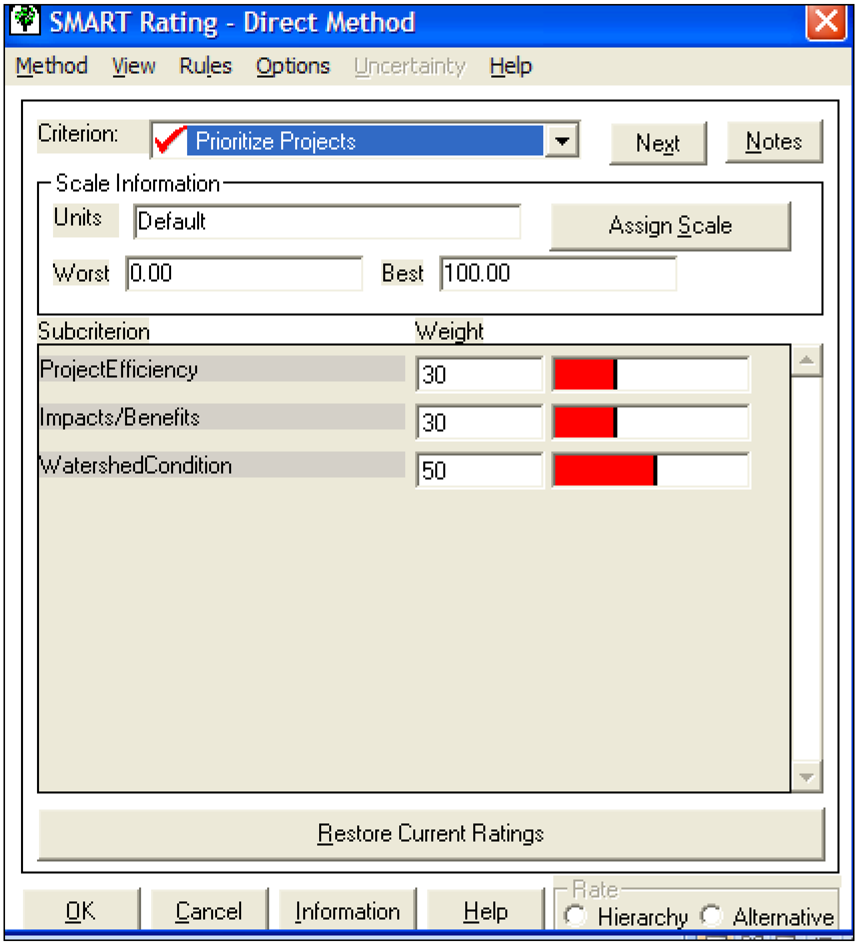


Figure 4-29 – Example Decision Model Hierarchy

The *Project Efficiency* group measures construction and storage parameters, including an indirect index of cost, and efficiency. The *Benefits/Impacts* group measures the potential impact of any projects on local populations. It is a combination of 1) inundation of major bridges and 2) inundation of villages, and 3) potential benefits to affected irrigated lands. The *Watershed Condition* group estimates the likely condition of the watershed, determined by streambank instability, overall active erosion, and degree of deforestation in forested areas. This affects the sedimentation rates behind dams, flood potentials, potential erosion of turbine blades, and overall water quality in streams above the dam.

Given all these factors are important, how should they be compared in terms of relative importance? Intuitively, each group of factors contributes to the priority of a given project, but to what extent? A given political/policy situation may dictate certain factors are critical and others are less so. To account for those situations a relative weighting can be applied either to criteria, groups of criteria, or both. This weighting takes the form of numerical or verbal evaluation, as in Figure 4-30. Here it is applied to the groups of criteria. The watershed group has a higher weight than the others.



Criterion: Prioritize Projects

Units: Default

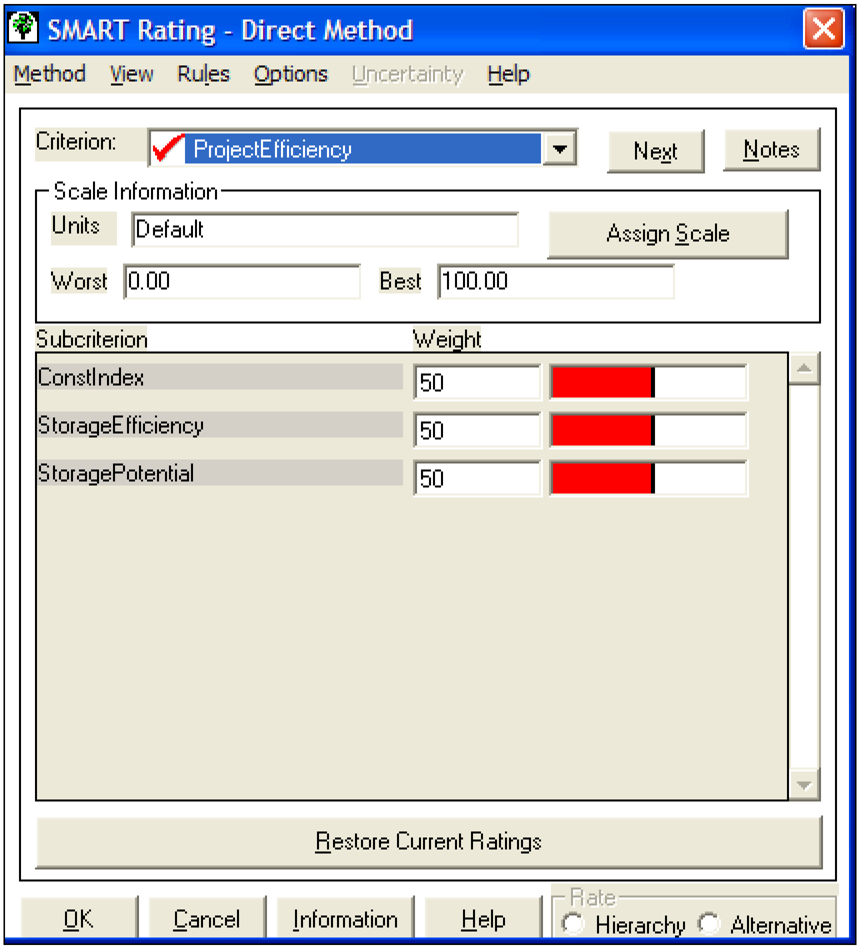
Worst: 0.00

Best: 100.00

Subcriterion	Weight
ProjectEfficiency	30
Impacts/Benefits	30
WatershedCondition	50

Figure 4-30 – Weighting Method for Groups

The criteria themselves are also weighted (Figure 4-31). In this example, each criterion is weighted equally. Changing the weighting numbers adjusts the relative weights. Changing the group weights in Figure 4-30 also influences the final criteria weights. Though the relationship between the criteria weights does not change, their final total will change. All weights on a given level (group or criterion) are adjusted to sum to 1. As an example Figure 4-32 shows the CDP hierarchy with attached weights.



Criterion: ProjectEfficiency

Scale Information

Units: Default

Worst: 0.00

Best: 100.00

Subcriterion	Weight
ConstIndex	50
StorageEfficiency	50
StoragePotential	50

Figure 4-31 – Weighting for Project Efficiency Criteria

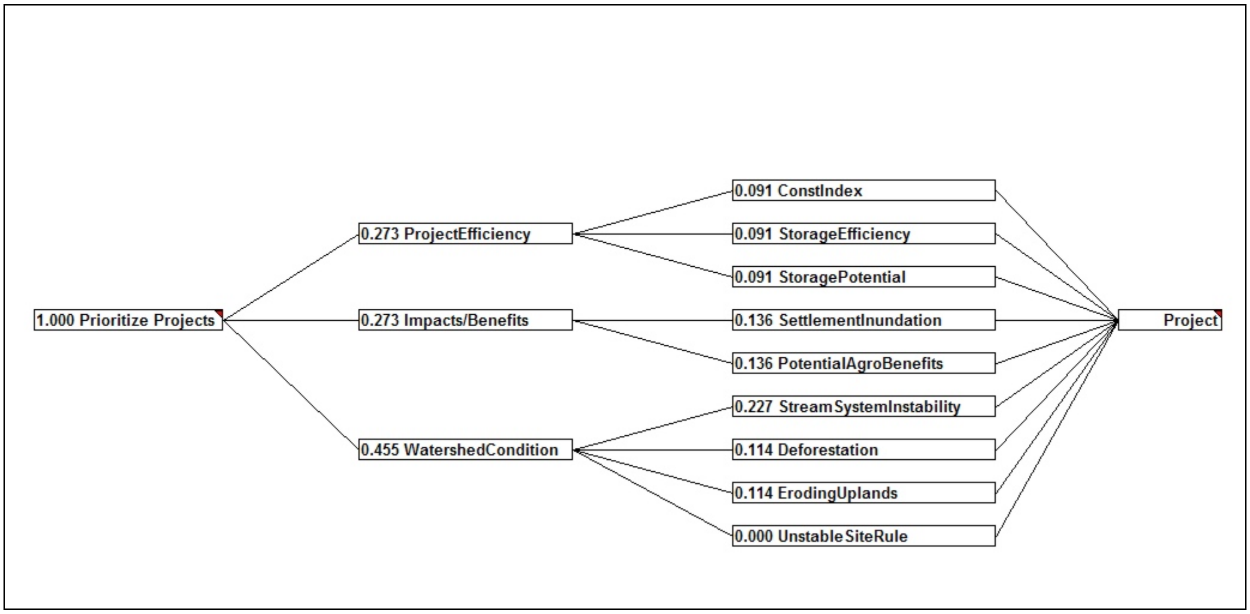
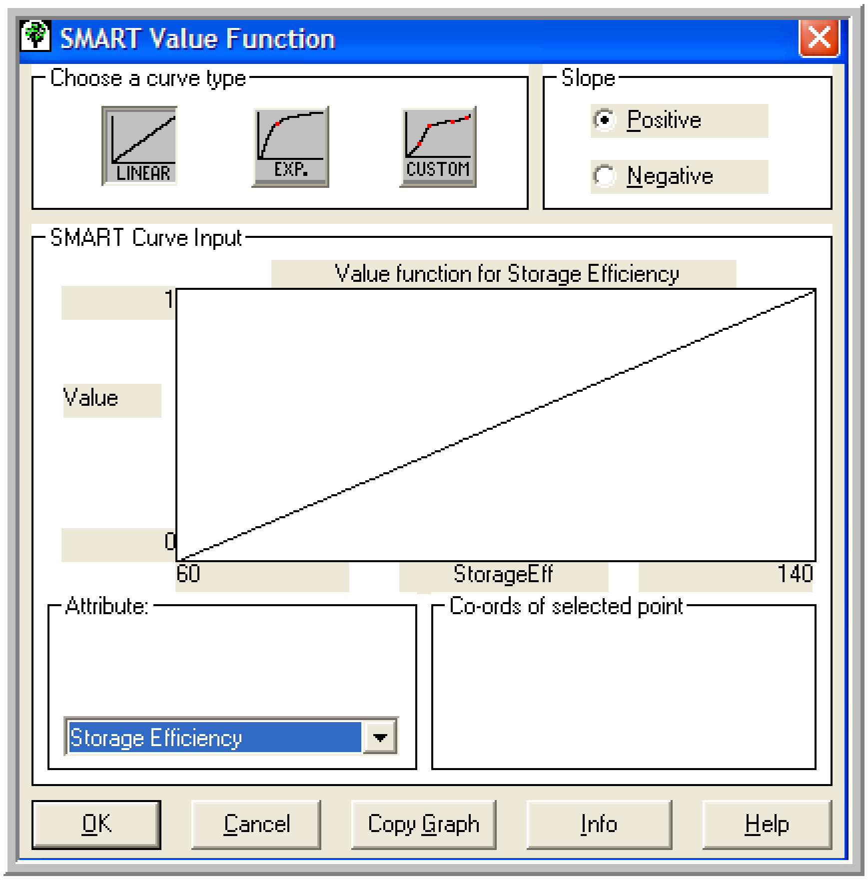


Figure 4-32 – Storage Decision Model Hierarchy with Weights

Finally, there must be a systematic way of rating each project for each of the above criteria. Each group has a number of influencing criteria (Figure 4-32). For example, the group *project efficiency* is rated by a construction cost index, storage efficiency, and storage potential. The values rating each criterion can be numerical or qualitative, with rating values coming from project data.

Rating scales are normalized to a 0 to 1 scale, and can be reversed or standard. That is, a high data value can be rated as either a high or low value in the rating system. For example, Storage efficiency is the available potential storage compared to the size of the dam. Higher ratings indicate a higher volume of storage for a given size of dam, or higher efficiency. This is a ratio, calculated from potential storage volume over total construction volume. Higher values give higher ratings. In another case, e.g. Stream System Instability, higher data values may return lower ratings. This is a reversed scale.

Rating endpoints come from the range of available data. Figure 4-33 shows a standard scale for the criterion Storage Efficiency, with an example data range of 60 to 140 and a resulting scaled value from 0 to 1.0. The shape of the rating curve can be varied, but was left as linear here because no data were available to justify a change.



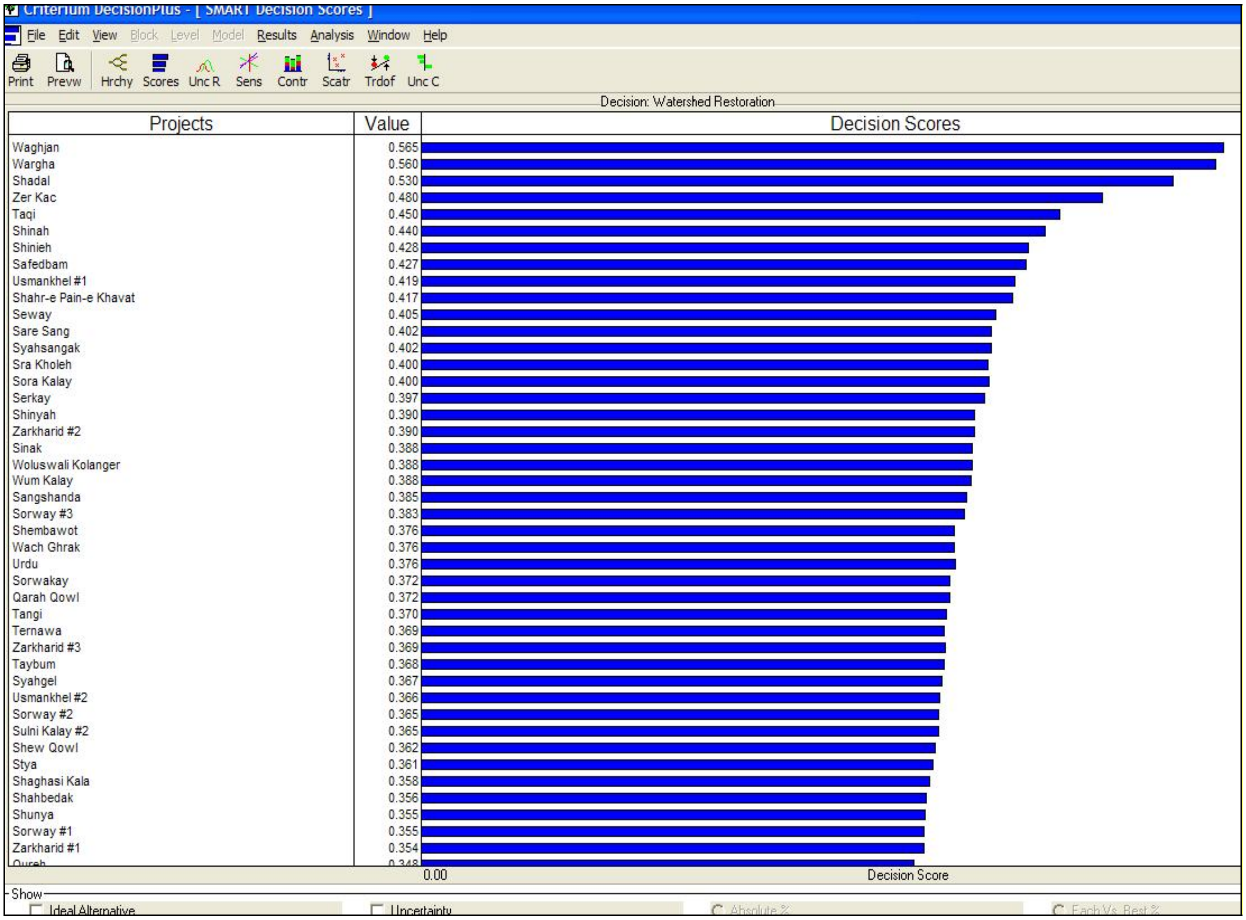
Slope
● Positive
○ Negative

Attribute: Storage Efficiency

Figure 4-33 – Rating value function for Storage Efficiency

The CDP software applies weights, rating functions, and data values; checks for out-of-range data; and rates all projects. Output is in spreadsheet format, which is exported to a database table for analysis and spatial linkage. The process is iterative and can be repeated until results are considered realistic. The CDP software is set up for manual data input. Associated software (IPASTUB © Infoharvest.com) links tabular database criteria values to the model to automate the process.

Each project proposal is rated using the above criteria (Figure 4-34). This figure shows a number of projects, with their associated scores (values) and a visual display of those scores. After review, the criteria weights and scales can be modified depending on the results and needs of the project managers to best reflect current conditions. Uncertainty and sensitivity analysis are also available, but were not formally completed here.



Projects	Value
Waghjan	0.565
Wargha	0.560
Shadal	0.530
Zer Kac	0.480
Taqi	0.450
Shinah	0.440
Shinieh	0.428
Safedbam	0.427
Usmankhel #1	0.419
Shahr-e Pain-e Khavat	0.417
Seway	0.405
Sare Sang	0.402
Syahsangak	0.402
Sra Kholeh	0.400
Sora Kalay	0.400
Serkay	0.397
Shinyah	0.390
Zarkharid #2	0.390
Sinak	0.388
Woluswali Kolanger	0.388
Wum Kalay	0.388
Sangshanda	0.385
Sorway #3	0.383
Shembawot	0.376
Wach Ghrak	0.376
Urdu	0.376
Sorwakay	0.372
Qarah Qowl	0.372
Tangi	0.370
Ternawa	0.369
Zarkharid #3	0.369
Taybum	0.368
Syahgel	0.367
Usmankhel #2	0.366
Sorway #2	0.365
Sulni Kalay #2	0.365
Shew Qowl	0.362
Stya	0.361
Shaghasi Kala	0.358
Shahbedak	0.356
Shunya	0.355
Sorway #1	0.355
Zarkharid #1	0.354
Qureh	0.348

Figure 4-34 – Example Results of the Decision Support Model (Not final results)

The CDP software and its associated spatial components can be used to clearly define priorities, basing them on a rational, documented process. However, its greatest value may be in clarifying the individual factors that influence a given set of priorities, helping managers on-site in their decision-making process.

The process does not generally does not result in final priorities. Final project selection is commonly also based on other factors, e.g. security, administrative structure, or policy. However, it does help define many of the important criteria so those other factors can be overlaid on a base of structured thinking. This can help make better decisions possible in complex situations.

5.0 Groundwater Resources

5.1 Overview

The lack of readily available geohydrologic data and knowledge concerning Afghanistan's aquifers can make utilizing groundwater resources in the study area a risky endeavor. Analysis of the aquifers must be conducted first to determine the amount and quality of groundwater being withdrawn to prevent doing more harm than good. The most appropriate analysis method to evaluate groundwater depends upon the type, amount and quality of existing data. It was determined that the first step the Southeast Afghanistan water resources assessment was to collect and review all available groundwater data. After the data is evaluated, a knowledgeable proposal can be prepared on how best to investigate groundwater resources in future efforts.

Section 5.2 presents a summary of the groundwater data collection effort preformed by the US Geological Survey. Appendix F includes the detailed USGS report "Southeast Afghanistan Water Resources Assessment, Inventory of Groundwater Data".

With knowledge of the existing dataset, the USGS has prepared proposals outlying the strategy for evaluating groundwater resources in Southeast Afghanistan, included in Appendix F. The strategy for evaluation of groundwater resources developed proposes first to process and integrate the historical data identified in this study with other existing geohydrologic data; second, collect specific groundwater data in secure areas; and third, develop capacity building programs with Afghan Ministries and provincial engineers for more widespread groundwater data collection in other areas. In addition to routine groundwater-data collection, compilation, and mapping activities, strategies proposed for evaluation of the region's groundwater resources include geophysical methods to quantify groundwater storage, in areas of potentially thick sediments, and chemical and isotopic sampling of surface and groundwater to assess sources and rates of groundwater recharge.

5.2 Groundwater Data Inventory

Few groundwater data have been collected in the Southeast Provinces, Afghanistan. Records for 93 historical (mostly 1970's) water-supply wells, with detailed hydrologic and lithologic information, are available in the study area. These data have site descriptions but do not have coordinate data. The largest dataset is non-governmental organization (NGO) well data, mostly DACAAR wells, contains approximately 9,000 records in the study area, see Figure 5-1. DACAAR is a Danish humanitarian aid agency that has been active in improving water supply in Afghanistan since 1989. This DACAAR data consists of primarily shallow dug wells with a depth to water at the time of construction. The data indicate that 18 percent of the shallow NGO wells are dry and the average available head, or water column, is 1.9 m. Groundwater levels (and specific conductance) are measured every two weeks at 12 monitoring wells in the study area as part of a national network maintained by DACAAR. As of summer 2009, five FOB water-supply wells, with detailed hydrologic and borehole logs are known to have been recently installed in the study area.

Approximately 200 surface geophysical soundings were collected in the study area in the late 1960's. Some of these surveys provide geohydrologic information including thickness and general aquifer characteristics. Many of these soundings have been obtained but need further analysis to obtain location coordinates. Additional geophysical surveys are believed to be available but would require translation from Dari or Russian and review for quality. Airborne geophysical have recently been collected by the USGS that could be processed to refine aquifer boundary maps.

The groundwater data identified in this inventory provide only some of the information needed to assess and characterize groundwater resources of the study area for current and future needs. Much of the data identified needs processing and integration with additional, targeted data collection to provide a better understanding of the groundwater resources of the Southeast Provinces. Strategies for data collection, processing, and analysis were developed for geohydrologic and groundwater source and quality assessments of the Southeast Provinces, Afghanistan.

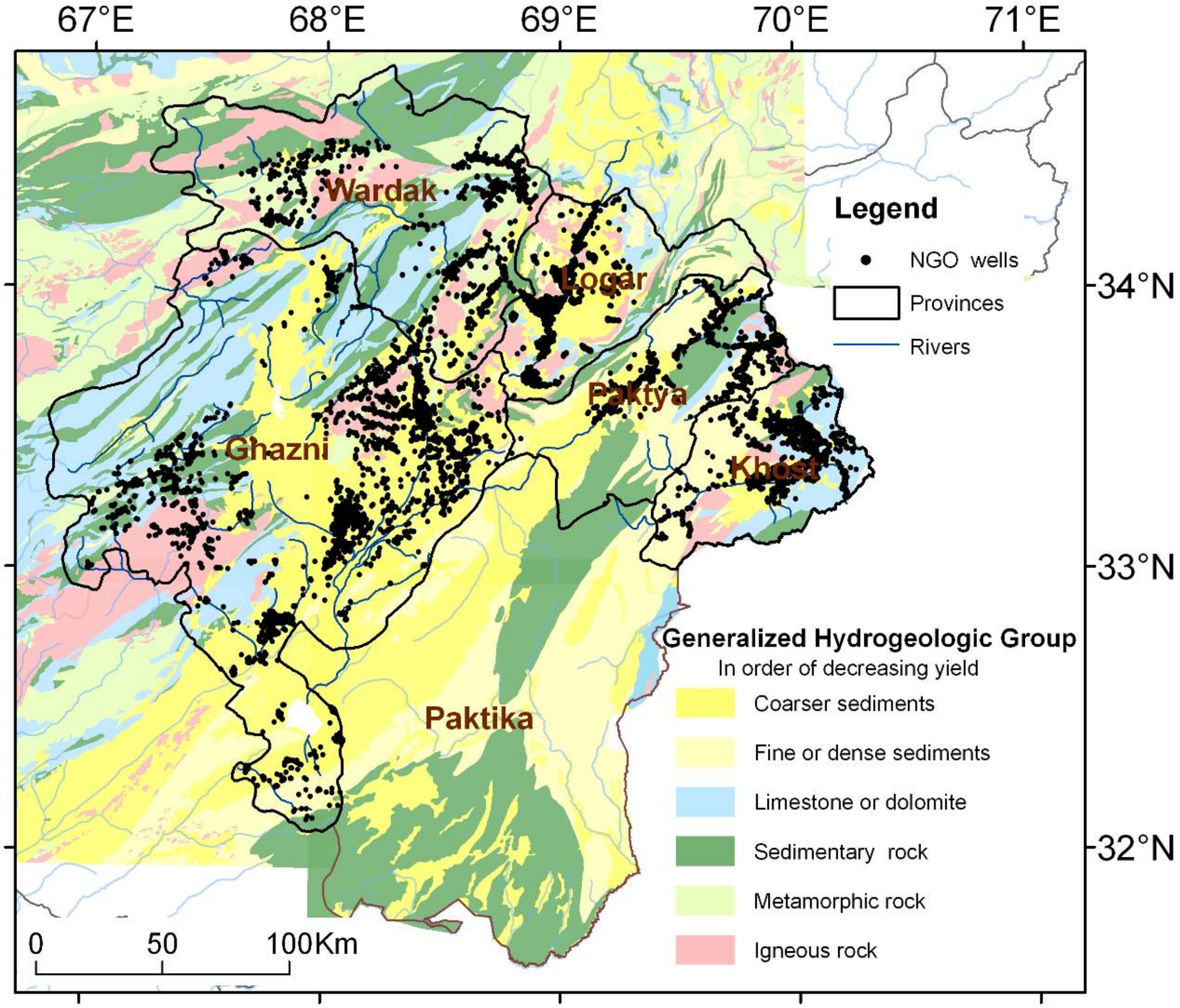


Figure 5-1 NGO well locations and generalized geohydrologic groups in the Southeast Provinces, Afghanistan

6.0 Results – Irrigation Storage Dams

6.1 Overview

Potential irrigation storage dam sites for this assessment were selected through a canvassing process and from previous proposals. Because of this, each project has an intrinsic value. Because it was chosen as a proposal already satisfies certain criteria for project feasibility. The location has characteristics favorable for dam construction, watersheds have potential for sufficient delivery and existing agricultural lands are within a reasonable distance.

Hundreds of sites were vetted through this process, covering a large geographic area. However, after this large initial selection of feasible sites was complete, the evaluation process became more complex. Some projects have better combinations of characteristics than do others. For example, two otherwise promising projects may have very different construction costs, which would influence their subsequent prioritization. In addition, the degree to which local economies are affected may be quite different, depending on the relationship between impacts and benefits. Finally, some parameters that may affect project effectiveness (such as watershed condition) were not available for the initial canvass for locations.

A prioritization process called a "decision support model" was developed to help rate the project proposals. See Section 4.5 "Decision Support Modeling" for a general description and Appendix J for detailed discussion of methods. The rating system was developed in collaboration with TF Yukon. As preliminary results were published, it was modified for a variety of reasons. Since this is an initial study, it is expected criteria and weightings will be modified further to account for changing conditions and priorities.

This section summarizes rating results for 159 storage projects and provides discussion on the relative and absolute merits of the most-highly rated projects using not only model results but also human interpretation using additional data. Considerable interpretation is used in addition to that provided by the decision support model.

Sites are recommended for further investigation and not for immediate design/build. Many outstanding design issues remain that this assessment was not able to address. Some of these issues include cultural and environmental impacts, geotechnical properties of the dam site and soil suitability of the irrigation service area. Resolution can begin on the site-specific issues by having qualified engineers and scientists visit the proposed project location. More important is coordination with local officials and the Afghan Ministries. With the lack of streamflow records, local knowledge can provide information on streamflow characteristics that are valuable for flood spillway design. Many of the proposed project sites are obviously good dam locations and the Ministry engineers have likely investigated them before, either formally or informally.

6.2 Decision Support Model for Irrigation Storage Dams

Ratings are based on a decision support model with the nine criteria shown in Figure 6-1. Ratings of these projects are all *relative.* That is, the system rates from "best" to "worst".

Absolute factors may also influence whether any of these projects are feasible, or “good” or “bad”. These “absolute” factors are not used directly in the rating process, other than “UnstableSiteRule” described below.

Based on feedback from FT Yukon, watershed condition was determined to be the most important criteria to ensure long-term project success. Project watersheds in poor condition have the potential for higher sediment accumulation in the storage dam reservoir, reducing project effectiveness. Therefore, both the Watershed Condition group and the Stream System Instability criterion were weighted twice as heavily as others, resulting in the final weights in Figure 6-1. This was modified to explore other weighting alternatives in Section 6.3.

The criteria are briefly described here. See Appendix J for a detailed discussion of them and how they fit into the model. *ConstIndex (Construction Index)* is a rating of dam construction cost, based on estimated construction volume. It is an indirect rating, since actual costs are not estimable in this study. *StoragePotential* relates to the water balance and storage for the project. *StorageEfficiency* is related to the available potential storage compared to the size of the dam. *SettlementInundation* is a measure of the potential negative impact of reservoir inundation on local populations. *PotentialAgroBenefits* indicates the degree to which there is infrastructure to support increased agricultural operations, and is used to estimate potential affected population.

Deforestation affects watersheds by increasing sedimentation and peak flows, which reduces water quality and downstream benefits. This increase can induce downstream aggradations that cause increased braiding and meander adjustment. *StreamSystemInstability* reflects the instability of stream systems, which influences sediment loads and flooding. *ErodingUplands* are those uplands that have active gully and rill erosion increasing sediment loads. Having unstable stream systems anywhere in the watershed may increase costs and influence the design of a project, the presence of a large, unstable stream system at or near the project site may critically influence the construction and maintenance of a dam. This case is captured by a criterion-based rule (*UnstableSiteRule*). Other criteria, such as security, economics, and proximity to administrative centers were not directly used in the decision model, either due to client agreement or lack of available data.

Four dam heights were rated for each project. Only the 12m dam is shown in most cases, because there is little difference between the overall rating scores for the other three dam heights (Appendix J). This is generally due to the contribution of the higher-weighted watershed criteria that do not vary by dam height, and the potential agro-benefits (existing irrigated area downstream) which also does not vary by height.

The rating value functions (Figure 4-33 in Section 4.5) were defined as linear. This means the range of data provided endpoints and slope for the field value to rating value conversions. Though this is the default, the model could be made more sensitive by varying these conversions. For example, the index of construction cost (constructed dam volume) has a few very large values, and many smaller ones. Using the maximum and minimum as points on a linear curve results in most data points falling in a small range of values. Use of an exponential curve shown in Figure 4-33) which emphasizes the contribution of smaller values would make for better sensitivity. Future versions of the model should consider this modification.

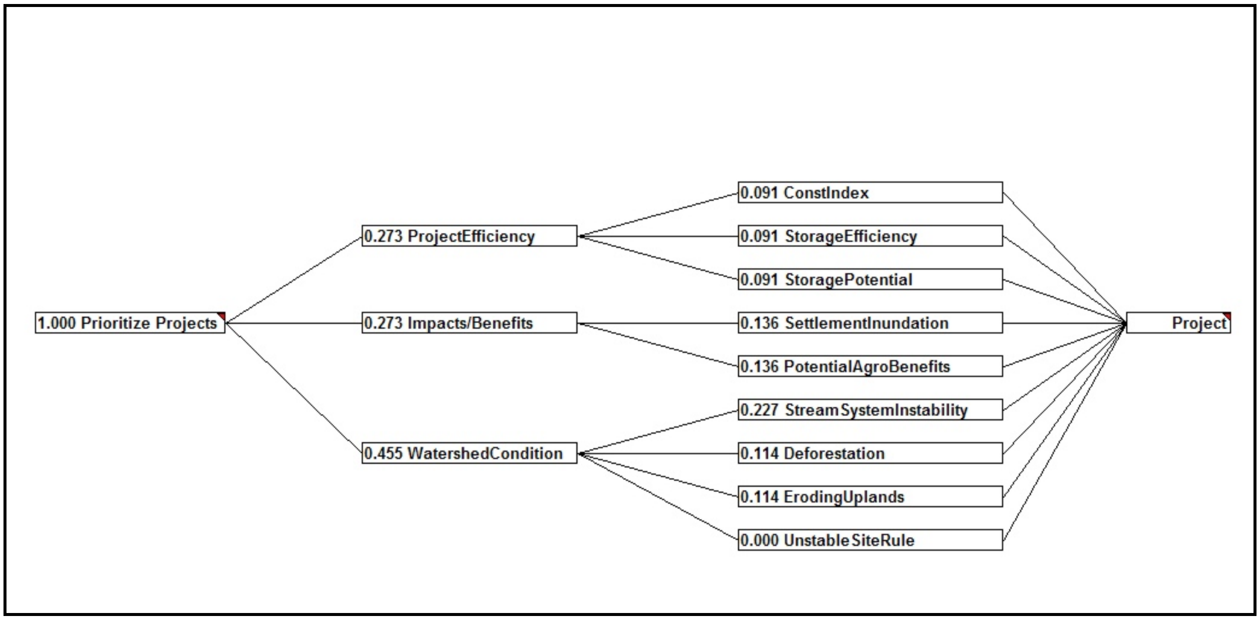
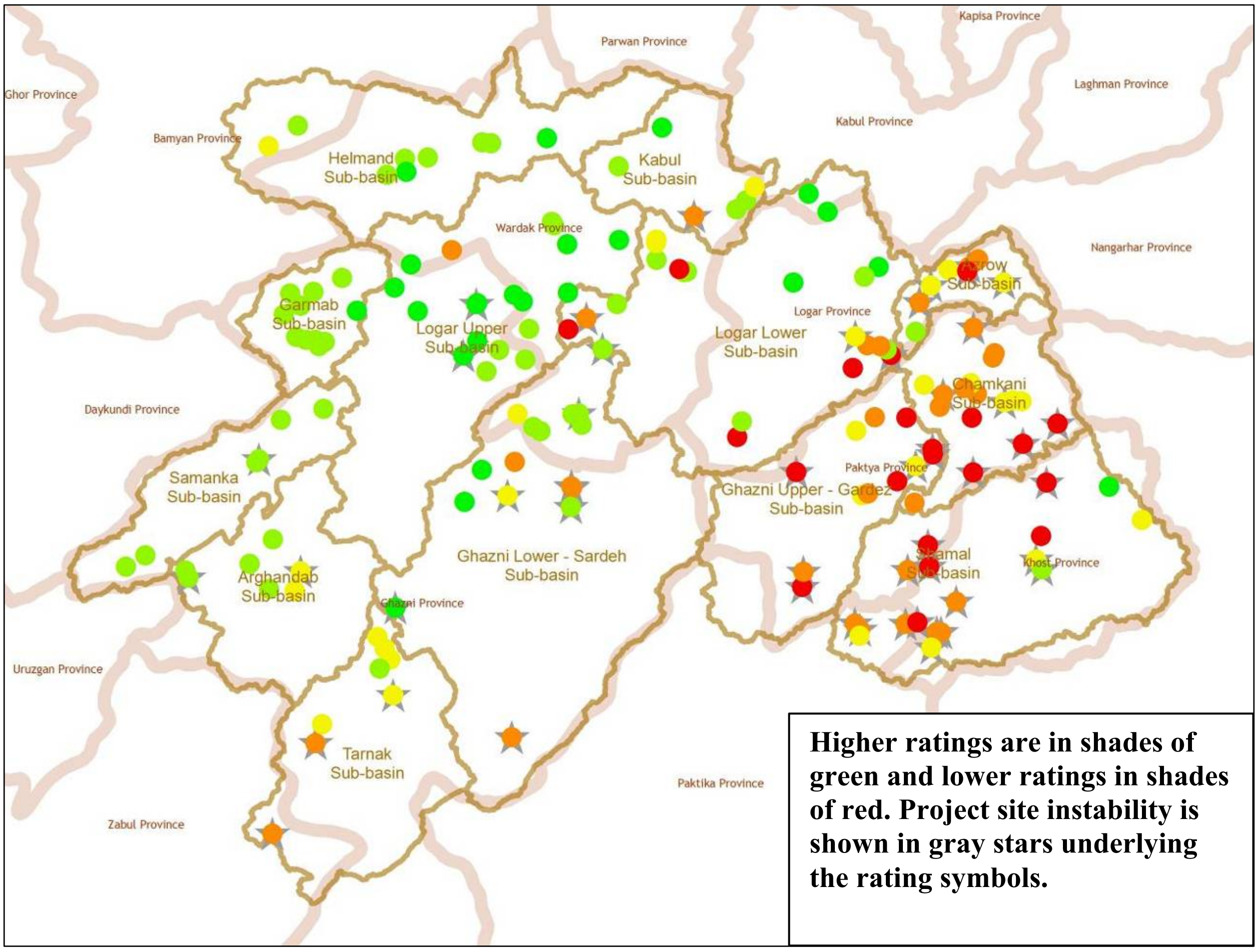


Figure 6-1 Storage Decision Model Hierarchy, Weighted for Watershed Condition

Decision model ratings are symbolized in Figure 6-2 with higher ratings in shades of green and lower ratings in shades of red. Project site instability is shown in gray stars underlying the rating symbols. The northwest region of the study area has most of the higher-rated projects and has the fewest unstable sites as well. The sub-basin watersheds Shamal, Chamkani, and Ghazni Upper appear to concentrate the lowest ratings. The lower-rated watersheds for irrigation storage dams are in eastern Logar, Khost and Paktya Provinces. They were ranked lower because of the poor condition of the storage dam's watershed and higher potential of sedimentation in the reservoir.



Higher ratings are in shades of green and lower ratings in shades of red. Project site instability is shown in gray stars underlying the rating symbols.

Figure 6-2 All 12m Dam Irrigation Storage Dam Ratings.

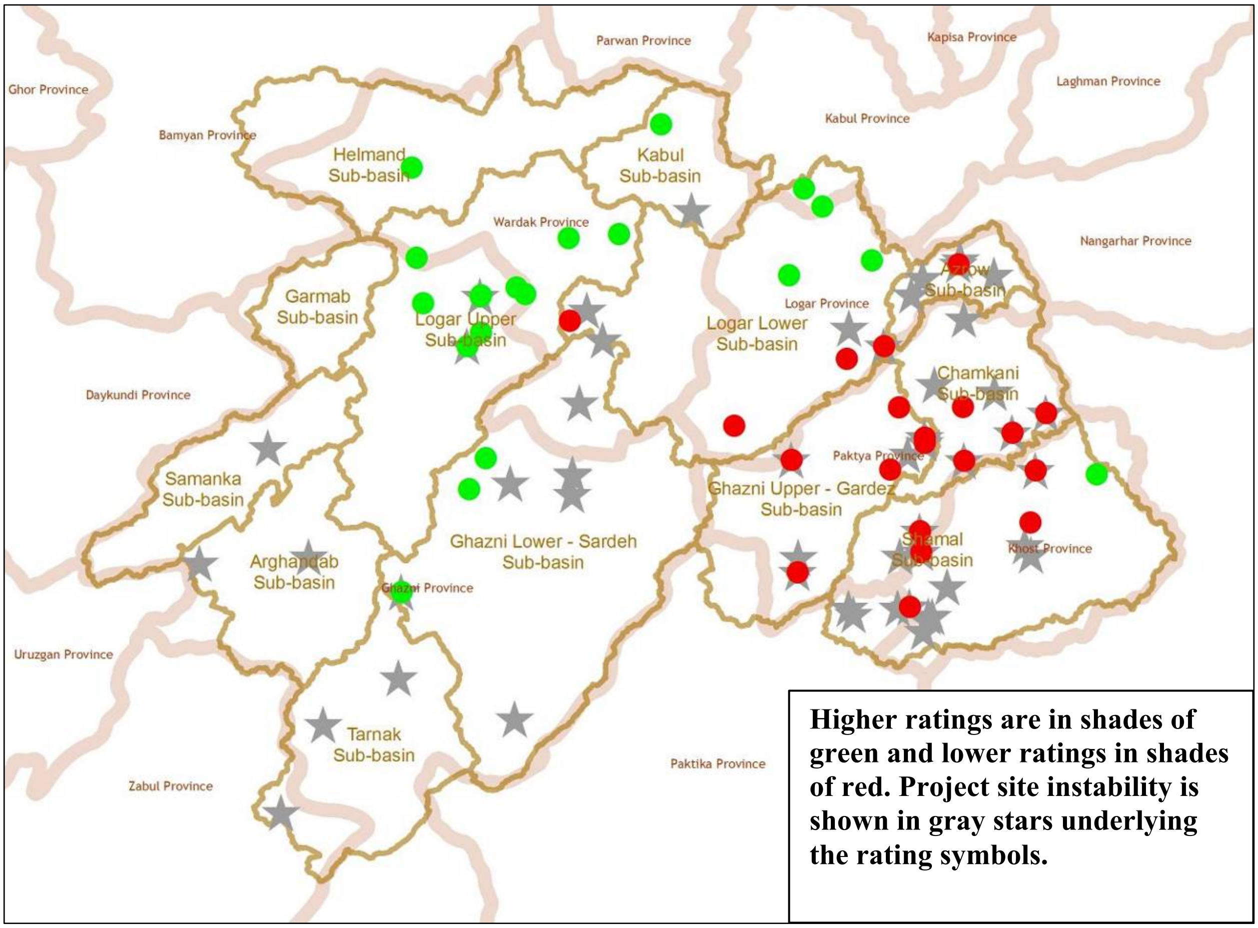
Table 6-1 shows the 20 top-rated projects for a 12 m high dam. This list is used to focus on the best potential projects. Their distribution (green symbols) and that of the bottom 20 (red symbols) are in Figure 6-3. Project site instability is shown in gray stars underlying the rating symbols. Each of the 20 top-rated projects is discussed in Section 6.4 under their respective sub-basin watershed.

Highest ratings are generally in the Logar and Ghazni Lower study watersheds. The lowest ratings are concentrated in the Shamal, Ghazni Upper and Chamkani Sub-basin watersheds. The distribution of ratings in general is quite dependent on watershed criteria, with that criteria being heavily weighted. This relationship is explored further in Appendix J. For comparison purposes, ranking of projects with less weight on watershed condition is provided in Section 6.3.

It may be of interest to discover what projects have the highest rating considering project rating and dam height together, since storage efficiency and other project factors may vary somewhat within a project, depending on pool size, construction volume, and other criteria. See Appendix J for a discussion and tabulation of this.

Table 6-1 Top Twenty 12 m High Irrigation Storage Dams, Watershed Condition Weighted

Rank	Name	Province	Sub-Basin Watershed	Unstable Site	Height (m)	Rating Results
1	Dehbakhshi	Ghazni	Ghazni Lower-Sardeh	yes	12	0.7805
2	Kunj	Kabul	Logar Lower	no	12	0.768
3	Shaghasi Kala	Logar	Logar Lower	no	12	0.745
4	Niw Qal'a #2	Ghazni	Logar Upper	yes	12	0.7005
5	Lashkari	Wardak	Logar Upper	no	12	0.698
6	Ternawa	Ghazni	Logar Upper	no	12	0.679
7	Baak #2	Khost	Shamal	no	12	0.6775
8	Gadagak	Ghazni	Logar Upper	no	12	0.677
9	Syahsangak	Ghazni	Ghazni Lower-Sardeh	no	12	0.6765
10	Niw Qal'a #1	Ghazni	Logar Upper	no	12	0.676
11	Kajab	Wardak	Logar Upper	no	12	0.675
12	Namunyaz	Kabul	Logar Lower	no	12	0.6735
13	Gurgkushta	Ghazni	Logar Upper	yes	12	0.673
14	Bokan	Ghazni	Logar Upper	no	12	0.671
15	Shew Qowl	Ghazni	Logar Upper	no	12	0.6705
16	Sinak	Wardak	Helmand	no	12	0.668
17	Chino Sar #1	Logar	Logar Lower	no	12	0.6645
18	Bazari Sidaqat	Ghazni	Ghazni Lower-Sardeh	no	12	0.656
19	Qal-eh-ye Shah	Wardak	Kabul	no	12	0.656
20	Pitab Saydo	Wardak	Logar Upper	no	12	0.6555



Higher ratings are in shades of green and lower ratings in shades of red. Project site instability is shown in gray stars underlying the rating symbols.

Figure 6-3 Top and Bottom 20 Irrigation Storage Dam Projects.

6.3 Watershed Condition vs. Project Efficiency Weighting

The Decision Support Model can be modified by adjusting the weights of the decision criteria. Figure 6-4 shows a change in weighting with more emphasis on the Project Efficiency group. The weight of the Watershed Condition group has been reduced to have the same value as the Impacts/Benefits groups.

For an irrigation storage dam, project efficiency is driven by how much water the reservoir can hold for the size of dam constructed. A dam built on a steep stream slope has poor efficiency because there is less storage per height of dam compared to a dam on a mild slope. A dam built at a natural constriction in the valley walls can have good efficiency because of the smaller dam size. Dams with the highest efficiencies are located where valley walls rapidly contract just downstream of a flat, open valley. The top twenty rated projects with heavier project efficiency weighting are summarized in Table 6-2 (complete results in Table14, Appendix O).

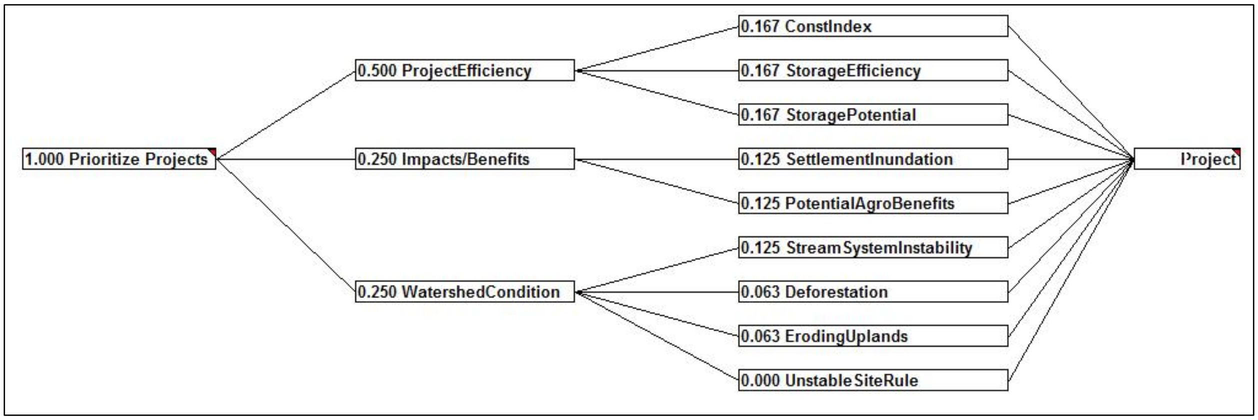


Figure 6-4 Storage Decision Model Hierarchy, Weighted for Project Efficiency

The decision model was initially weighted heavily to the watershed condition because of the concern for rapid sediment accumulation in the reservoirs. Differences are noticeable in the watershed condition ranking in Table 6-1 and ranking for project efficiency in Table 6-2. The dam at Dehbakhshi goes from ranking 1st to out of the top 20, the poor storage efficiency of the dam ranked it 27th overall. Dehbakhshi was initially ranked high because of the good condition of the watershed. Ultimately, Dehbakhshi is not recommended because the steep stream slope offers very little storage per height of dam and very little agriculture benefit. The Dehbakhshi watershed is not free of erosion and effective sediment management also requires a substantial reservoir volume. A table ranking all 159 irrigation dam projects using both weighting methods is available at the end of Section 6.4 in Table 6-16.

Kunj and Kajab are ranked high in both decision models. The terrain at both locations is ideal for dam construction and both were previously proposed by MEW as large scale, National interest projects. These dams would require years of design and are simply too costly for TF Yukon to focus on. An 8 or 12 m high dam at these locations would underutilize a good dam location. This illustrates the need for additional decision criteria and human interpretation for final planning.

Note that Niw Qal'a #2 ranked 4th in the original decision support model, and then 3rd in the modified model. This is largely due to the relatively equal contribution of criteria values for this project. Changing weights did not affect its overall ranking.

The decision support model is working as intended, but all users need to be sure the weightings reflect their priorities. There is an infinite combination of weighting and additional criteria such as local security or ecosystem impacts that could be included, but by client preference were not. The decision model was built as a tool to be used and refined by others and can be expanded to include all proposed projects in Afghanistan.

Results from the decision model were used in the individual project descriptions in Section 6.4. Important outlying factors the decision model was unable to evaluate are included in the descriptions. Projects should not be selected for construction solely based on their ranking. The ranking provides TF Yukon a list of project sites to begin the process.

Table 6-2 Top Twenty 12 m High Irrigation Storage Dams, Project Efficiency Weighted

Rank	Name	Province	Sub-Basin Watershed	Unstable Site	Height (m)	Rating Results
1	Kunj	Kabul	Logar Lower	no	12	0.806
2	Shaghasi Kala	Logar	Logar Lower	no	12	0.761
3	Niw Qal'a #2	Ghazni	Logar Upper	yes	12	0.604
4	Lashkari	Wardak	Logar Upper	no	12	0.602
5	Sinak	Wardak	Helmand	no	12	0.588
6	Av Darreh	Wardak	Kabul	no	12	0.584
7	Gurgkushta	Ghazni	Logar Upper	yes	12	0.577
8	Ternawa	Ghazni	Logar Upper	no	12	0.571
9	Gadagak	Ghazni	Logar Upper	no	12	0.57
10	Bokan	Ghazni	Logar Upper	no	12	0.57
11	Shew Qowl	Ghazni	Logar Upper	no	12	0.568
12	Pitab Saydo	Wardak	Logar Upper	no	12	0.565
13	Baak #2	Khost	Shamal	no	12	0.564
14	Kajab	Wardak	Logar Upper	no	12	0.561
15	Sulni Kalay #2	Khost	Shamal	yes	12	0.561
16	Bazari Sidaqat	Ghazni	Ghazni Lower-Sardeh	no	12	0.56
17	Syahsangak	Ghazni	Ghazni Lower-Sardeh	no	12	0.559
18	Awlaya	Ghazni	Arghandab	no	12	0.558
19	Tar Bulagh	Ghazni	Logar Upper	no	12	0.556
20	Niw Qal'a #1	Ghazni	Logar Upper	no	12	0.556

6.4 Irrigation Storage Dam Descriptions

The following sections provide a brief description and recommendations for the highest ranked irrigation storage dams. In addition, dam sites with high potential benefits but with lower rankings due to poor watershed condition are described. The storage dam descriptions are separated into the 13 study watersheds. Each section begins with a summary table. Below is a key to the table headings and notes on the descriptions with project location in Figure 6-5.

Appendix G contains a variety of maps of the evaluated irrigation dam locations. The maps include large-scale prints (34” x 44”), maps by watershed, maps by province and maps with elevation or satellite image background. Detailed calculations of the dam water budgets, stage-storage graphs and potential irrigation benefits are in Appendix H. Appendix I includes inundation maps for each individual storage dam site. The inundation maps provide a zoomed-in image of the dam site and reservoir. GIS shapefiles of each project site are also available. Further description of each project watershed in terms of slope range, elevation range, land cover, soil, and geology group are in Tables 2, 3, 4, 5, and 6 in Appendix O.

The project descriptions are for the 12 m high dam. A location where a 12 m dam is not practical is explained in the descriptions. Note that the Unstable Site factor is not used directly in the Decision Support Model rating, but *is* used to evaluate projects in the descriptions below. Table 7 and Table 8 in Appendix O contain decision model results also used in the descriptions.

The decision support model results are used as a tool in evaluating project sites. Additional factors are used below to develop final recommendations. The decision model weighting can be adjusted but results should always be used with those additional factors if they are relevant to decisions. Unless noted, the decision support model results below use the watershed-weighted criteria as described above, not the project-weighted criteria.

Descriptions as to the degree of upland erosion and stream stability for the proposed projects are all relative to other projects in the study area. Any water resource project in Southeast Afghanistan will have to contend with sedimentation issues, but some watersheds are worse than others. Good hydropower potential refers to run-of-river type projects that do not utilize head produced by dam height.

Key for Table 6-3 to Table 6-15:

Name: Name of the dam site, taken from local village.

Rank: Results from the decision matrix ranking all 12 m high dams at 159 locations.

Decision Model: Actual rating from the decision model weighting criteria.

Unstable Site: Is the stream at the dam site unstable, is there high potential for stream bank erosion, sedimentation and meandering (used in the criterion UnstableSiteRule in the decision support model).

Watershed Area: The land area that contributes runoff at the dam site, square kilometers.

Reservoir Storage Volume: Volume of water the 12 m high dam holds, in 1,000s of cubic meters.

Annual Watershed Runoff: Annual average runoff volume that enters the reservoir, 1,000s m^3.

Ratio Storage to Runoff: Ratio of reservoir storage volume to annual runoff volume.

Dam Construction Volume: Volume estimate of 12 m high earthen dam (used in the criterion ConstIndex in the decision support model).

Storage Efficiency: Ratio of reservoir storage volume to dam construction volume (used in the criterion StorageEfficiency in the decision support model).

Potential Irrigated Crop Area: Irrigation service area for winter wheat irrigation (used in the criterion StoragePotential in the decision support model).

Ratio Storage to Irrigated Crop Area: Ratio of the reservoir volume to potential irrigated area.

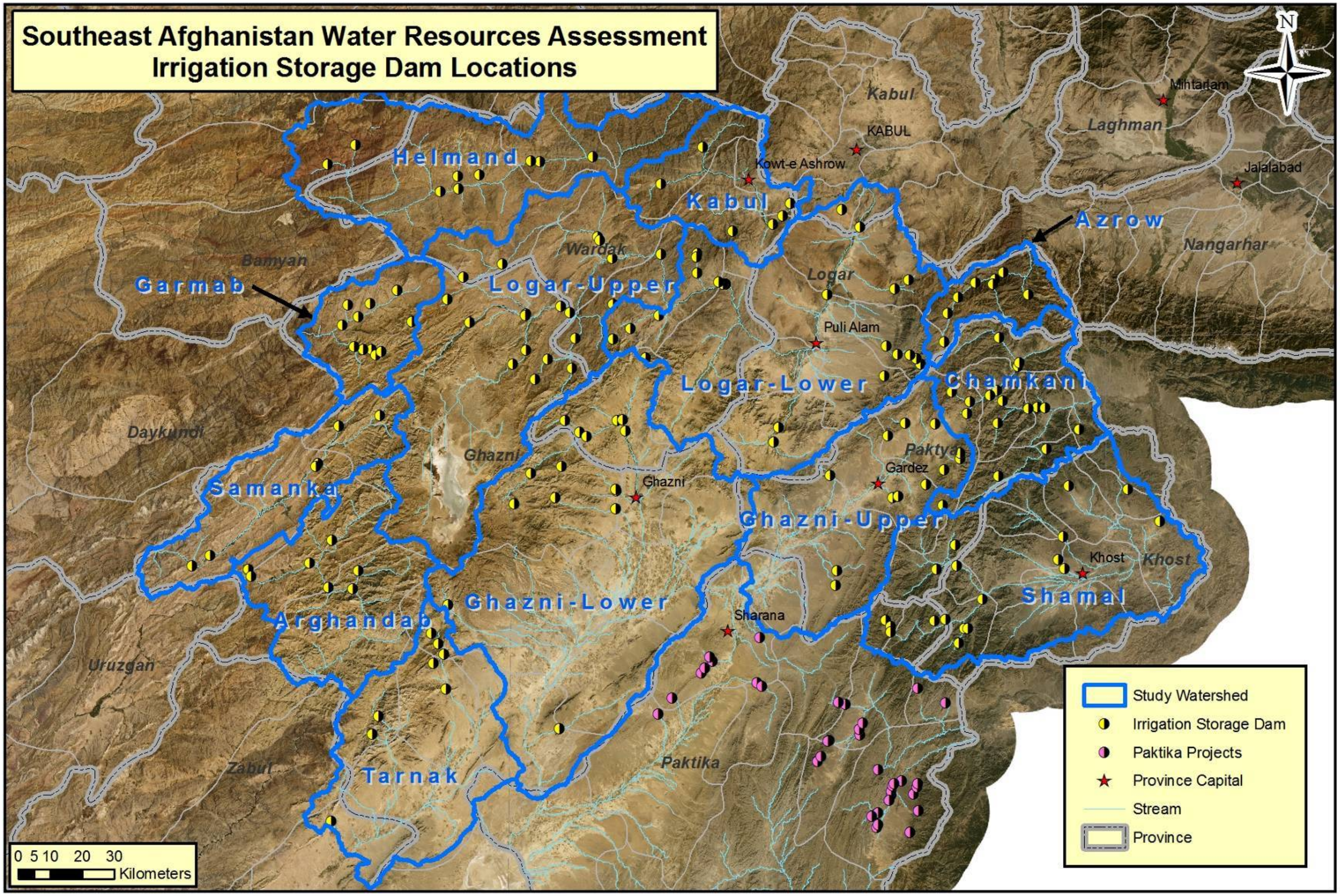


Figure 6-5 Evaluated Irrigation Storage Dams Location

6.4.1 Arghandab

The Arghandab study watershed is located in western Ghazni Province. The watershed is not favorable for irrigation storage dams. The Arghandab River and tributary stream valleys are very narrow with steep steam slopes offering very little storage potential. Agriculture is concentrated along the narrow valleys and most dams would inundate large areas of actively cultivated land, households and roads. Streamgage data from the Arghandab River indicates substantial, year-round baseflow. Irrigation diversion may be more appropriate than storage dams on the main river channel. The tributary streams likely have more fluctuations in flow and the 5 m high storage dams could benefit small agricultural villages.

Table 6-3 Arghandab Irrigation Storage Dam Results

12-m Dam Name	Rank	Decision Model	Unstable Site	Watershed Area (km^2)	Reservoir Storage Volume (1000 m^3)	Annual Watershed Runoff (1000 m^3)	Ratio Storage to Runoff	Dam Construction Volume (m^3)	Storage Efficiency	Potential Irrigated Crop Area (ha)	Ratio Storage to Irrigated Crop Area
Awlaya	26	0.64	no	80.3	3,184	11,242	0.28	17,640	180.50	850	3.75
Malistan	48	0.61	yes	87.8	167	12,291	0.01	28,800	5.80	125	1.34
Sabzak	61	0.59	no	354.4	672	49,681	0.01	31,680	21.21	515	1.30
Tangi	62	0.59	no	324.9	362	45,498	0.01	38,592	9.38	125	2.90
Balaqal	70	0.58	no	988.3	2,892	138,404	0.02	43,848	65.96	2,060	1.40
Barikjoy	78	0.56	no	325.7	474	49,401	0.01	24,480	19.36	365	1.30
Dewkhana	96	0.52	yes	95.3	199	13,347	0.01	31,680	6.28	150	1.33

Awlaya: The project site is located on a tributary stream in the Ajristan District in western Ghazni Province. The Awlaya site ranks 26th overall among the 159 projects evaluated. Awalya offered very good storage volume per height of dam, or good storage efficiency. The stream valley at Awalya transitions rapidly from on open valley with plenty of storage volume to a narrow constriction providing for a small dam size. The watershed has a relatively stable stream system with moderate erosion. The stream channel at the project site is relatively stable and there is existing agriculture 4 km downstream. The major drawback to the site is the relatively small watershed of 80 km^2 and the uncertainty in estimated annual runoff volumes. Additional streamflow information is required to justify the maximized 15 m high dam. Awalya is the best site in Arghandab and the project is worth further investigation.

Malistan: The project is located 2.5 km downstream of Awlaya in the Malistan District of Ghazni Province. It is ranked lower than Awlaya because of the lower storage efficiency and lower stream stability. A storage dam is not recommended but an existing diversion structure could be improved and used in concert with a storage dam at Awlaya. It must be noted that the streambed at this location is unstable increasing design, construction and maintenance costs.

Balaqal: The site offered good storage efficiency but the Kharbed River Valley narrows downstream of the dam offering little arable land. The location has good hydropower potential.

Sabzak: The site ranked low because of the unstable watershed and the steep stream slope resulted in poor storage efficiency. It does have hydropower potential.

Tangi: An irrigation diversion may be more appropriate here, not a storage dam.

Barikjoy: The unstable watershed ranks this location low but it has hydropower potential.

6.4.2 Azrow

The Azrow study watershed is located in eastern Logar Province. The general terrain of the Azrow watershed is not favorable for irrigation storage dams. The main channel of the Azrow River varies from 2% to 5% with major tributaries at slopes over 10%. The steep slopes do not provide much storage volume per height of dam resulting in poor storage efficiency. The project sites in Azrow have watersheds with high percentages of erosive uplands. Sedimentation of reservoirs would be more of a problem in this region.

Table 6-4 Azrow Irrigation Storage Dam Results

12-m Dam Name	Rank	Decision Model	Unstable Site	Watershed Area (km2)	Reservoir Storage Volume (1000 m3)	Annual Watershed Runoff (1000 m3)	Ratio Storage to Runoff	Dam Construction Volume (m3)	Storage Efficiency	Potential Irrigated Crop Area (ha)	Ratio Storage to Irrigated Crop Area
Zer Kac	73	0.58	no	8.23	910	1,238	0.74	26,856	33.88	105	8.67
Kacwal	87	0.53	yes	183.75	944	27,638	0.03	62,064	15.21	1,055	0.89
Usmankhel #2	89	0.53	no	238.44	325	30,285	0.01	20,520	15.84	610	0.53
Dadikhel	104	0.50	yes	46.83	87	7,044	0.01	24,912	3.49	145	0.60
Babar #1	113	0.49	yes	452.30	348	68,031	0.01	35,928	9.69	1,070	0.33
Akbarkhel	114	0.49	no	10.08	69	1,515	0.05	27,504	2.51	24	2.88
Dokanha-i-Gomaran	129	0.45	yes	51.57	355	7,757	0.05	49,104	7.23	360	0.99
Khushhalkhel	140	0.43	yes	182.51	111	27,452	0.00	56,520	1.96	415	0.27

Zer Kac: The project site is located in the Azra District in eastern Logar Province. The site has the highest rank in the Azrow watershed but is 73rd overall of the 159 projects evaluated. A storage dam is not recommended at this location because of the high percentage of erosive uplands. The watershed is also too small to justify a project.

Kacwal: The project site is in the Azra District on the main channel of the Azrow River. A storage dam is not recommended at this site because of the unstable watershed and poor storage efficiency. The low storage efficiency is related to steep stream channel slope, over 3% at the dam site.

Babar #1: The site offers very little storage potential but does have hydropower potential due to the steep stream slope and large contributing watershed.

6.4.3 Chamkani

The Chamkani study watershed is located in the northern half of Paktya Province. The terrain in the watershed offered very good locations for irrigation storage dams. Storage efficiencies were good at many locations. The wide valley floors provided large areas of existing agriculture that could benefit from dependable irrigation sources. The issue that ranked storage dams in Chamkani low was the level of potential sediment problems. Most of the project site watersheds have unstable stream systems and a high percentage of eroding uplands.

Table 6-5 Chamkani Irrigation Storage Dam Results

12-m Dam Name	Rank	Decision Model	Unstable Site	Watershed Area (km2)	Reservoir Storage Volume (1000 m3)	Annual Watershed Runoff (1000 m3)	Ratio Storage to Runoff	Dam Construction Volume (m3)	Storage Efficiency	Potential Irrigated Crop Area (ha)	Ratio Storage to Irrigated Crop Area
Sorway #3	84	0.54	no	1,374.30	1,571	110,245	0.01	162,000	9.70	2,495	0.63
Sorway #2	92	0.52	no	1,298.20	1,646	104,229	0.02	119,664	13.76	2,475	0.67
Sra Kholeh	97	0.52	no	51.80	1,640	7,791	0.21	9,504	172.56	875	1.87
Sorway #1	99	0.52	yes	1,285.60	1,143	103,130	0.01	42,696	26.77	2,090	0.55
Kharzun #2	106	0.50	no	719.70	1,710	108,251	0.02	7,056	242.35	2,660	0.64
Chawnay #2	107	0.49	no	255.10	766	38,370	0.02	47,592	16.10	1,040	0.74
Khangul Kot	112	0.49	no	26.80	450	4,031	0.11	18,648	24.13	310	1.45
Bekaray	115	0.48	no	264.90	456	39,844	0.01	21,240	21.47	830	0.55
Wam Hasankhel	118	0.47	no	1,044.50	754	132,666	0.01	20,088	37.53	2,140	0.35
Ghorushtay	119	0.47	yes	209.20	155	31,466	0.00	39,240	3.95	495	0.31
Ganday Shykhan	120	0.47	yes	88.00	82	13,236	0.01	14,832	5.53	220	0.37
Chawnay #1	122	0.47	no	576.70	994	86,742	0.01	39,600	25.10	1,775	0.56
Salemi Nargay	135	0.44	no	26.80	80	4,031	0.02	17,640	4.54	105	0.76
Rabat	141	0.42	yes	31.40	263	4,723	0.06	32,400	8.12	245	1.07
Pala	146	0.40	yes	38.50	1,463	5,791	0.25	11,304	129.42	730	2.00
Sultak	147	0.40	yes	43.70	109	6,573	0.02	26,856	4.06	155	0.70
Shegaray	153	0.39	no	121.60	116	18,290	0.01	22,464	5.16	310	0.37

Sorway: The proposed project list provided by the Ministry of Energy and Water included a large irrigation storage dam near the village of Sorway in the Chamkani District, Paktya. Three potential dam locations were identified in the area and were evaluated. Sorway #3 is located at the coordinates provided by MEW. All three dam sites ranked high for the Chamkani watershed but ranked between 84th and 99th of all 159 projects evaluated. High reservoir sedimentation potential decreased their ranking. The Sorway sites are within 14 km of the Pakistan border and international water use agreements will be an issue. Only site #1 has good hydropower potential.

All three Sorway sites have significant upland erosion and relatively low stream system stability. All sites are upstream of moderate amounts of existing agriculture. Although sites #2 and #3 have more storage volume, site #1 is the recommended location. Sorway #1 also has less of an impact on existing farmland and infrastructure than the other sites. A dam larger than 12 m at Sorway #1 would affect households at the dam site. If construction cost index were weighted higher, Sorway #1 would rank higher than sites #2 and #3 because of the much smaller dam width and construction volume. Further investigation of Sorway #1 is recommended. Field review should focus on local geology and its suitability for dam construction. Any consideration of building a dam at Sorway will have to include sediment management early in the design process and maintenance planning.

Sra Kholeh: The site ranked third in Chamkani because of high storage efficiency. The narrow valley constriction provides for a small dam size. The site ranked low among the other 159 projects because of the low agricultural benefits and the very highly erosive uplands. The 5 to 8 m high dam is a better size dam for this location. A dam less than 5 m may prove beneficial to the small community downstream but sedimentation will be a continuous maintenance issue.

Kharzun #2: The site is located in the Lija Mangal District in central Paktya Province. The location has good potential given its high storage efficiency and large contributing watershed. The reason the site ranked low was the large number of dwellings and existing development inundated. Similar to the other projects in Chamkani, the project watershed has an unstable stream system and highly erosive upland. The local geology appears favorable for dam construction. This site is recommended for further investigation. The large reservoir volume does make sediment management easier than other smaller sites but will remain an issue at this site. The site also has hydropower potential.

Bekaray: The steep stream slope does not provide good storage efficiency but the site does have hydropower potential.

Wam Hasankhel: The site has moderate storage efficiency but a very high percentage of erosive upland. The site has good hydropower potential but would require a long headrace channel.

Pala: This site has excellent terrain for a storage dam but the watershed is relatively small and the watershed's stream system is highly unstable. Flow characteristics should be investigated to determine if the small watershed could support hydropower.

6.4.4 Garmab

All of the evaluated Garmab project sites are in the Nawur District in northern Ghazni Province. The Garmab River is a tributary to the Helmand and has a relatively good baseflow compared to the ephemeral streams in southern Ghazni. Most of the project site watersheds have stable stream systems and a moderate percentage of eroding upland. The rugged terrain offers little arable land and agriculture is concentrated in small pockets within deep valleys. The steep stream slopes and good baseflow do provide good potential for irrigation storage dams in Garmab.

Table 6-6 Garmab Irrigation Storage Dam Results

12-m Dam Name	Rank	Decision Model	Unstable Site	Watershed Area (km2)	Reservoir Storage Volume (1000 m3)	Annual Watershed Runoff (1000 m3)	Ratio Storage to Runoff	Dam Construction Volume (m3)	Storage Efficiency	Potential Irrigated Crop Area (ha)	Ratio Storage to Irrigated Crop Area
Qureh	23	0.65	no	15.90	720	2,028	0.36	32,256	22.32	275	2.62
Shinyah	37	0.62	no	61.01	277	7,782	0.04	11,736	23.60	210	1.32
Ghawchqol	45	0.61	no	43.58	65	5,559	0.01	14,904	4.36	50	1.30
Nayjoy	49	0.61	no	20.12	187	2,566	0.07	37,872	4.94	130	1.44
Dahane Qol	50	0.61	no	473.61	180	60,409	0.00	15,984	11.26	135	1.33
Kajak	51	0.61	no	580.49	187	74,041	0.00	17,496	10.69	140	1.34
Dame Joy #1	57	0.59	no	174.82	1,001	22,298	0.04	40,320	24.83	600	1.67
Dame Joy #2	63	0.59	no	58.22	231	7,426	0.03	12,240	18.87	180	1.28
Kusha	64	0.59	no	189.23	333	24,136	0.01	53,424	6.23	260	1.28
Argbiru	67	0.58	no	99.13	234	12,644	0.02	24,768	9.45	180	1.30
Tubi	68	0.58	no	325.34	144	41,497	0.00	32,688	4.41	110	1.31

Qureh dam: The site is ranked relatively high (23rd) because of the large reservoir storage potential. However, the project is not recommended because of the small watershed, uncertainties in available flow and lack of existing agriculture downstream.

Shinya: The project watershed is high in stream stability, upland erosion is moderate and the stream channel is stable at the project site. No dwellings would be impacted by inundation but existing farmland would be. The project is located in a narrow valley resulting in a small dam size and low cost index. The site ranks low because of the lack of existing downstream agriculture. The narrow downstream valley provides little terrain for expanding arable land. The site is not recommended for further investigation.

Dame Joy: A series of five storage dams were evaluated on a tributary to the Garmab River near the villages of Tubi and Dame Joy, 30 km west of Doabi. This tributary valley has the largest amount of population and agriculture in the Garmab study watershed. The Dame Joy sites #1 and #2 have good storage efficiencies but at Kusha, Argbiru and Tubi the efficiency is only fair. The factor that reduces the ranking of the five dams is the high potential for upland erosion. High sediment loads would be an issue at these locations.

Kusha: The site does not have good storage efficiency but does have very good hydropower potential.

Tubi: The site does not have good storage efficiency but does have the most hydropower potential in the Garmab study watershed and is worth further investigation.

6.4.5 Ghazni – Lower (Sardeh)

The Ghazni-Lower study watershed is located in eastern Ghazni Province. The watershed has good potential for irrigation storage dams. The project site watersheds have relatively high stream stability and a lower percentage of eroding upland. The degree of sedimentation at the dam sites would be less compared to other regions in the five-province assessment. The decision support model weighted the stable watersheds heavily and a few of the higher ranked project do not have sufficient storage volume in the reservoir to justify construction.

Table 6-7 Ghazni-Lower Irrigation Storage Dam Results

12-m Dam Name	Rank	Decision Model	Unstable Site	Watershed Area (km2)	Reservoir Storage Volume (1000 m3)	Annual Watershed Runoff (1000 m3)	Ratio Storage to Runoff	Dam Construction Volume (m3)	Storage Efficiency	Potential Irrigated Crop Area (ha)	Ratio Storage to Irrigated Crop Area
Dehbakhshi	1	0.78	yes	116.00	108	24,149	0.00	9,720	11.11	80	1.35
Syahsangak	9	0.68	no	55.08	1,706	3,276	0.52	43,632	39.10	400	4.27
Bazari Sidaqat	18	0.66	no	282.04	3,263	33,551	0.10	64,944	50.24	1,780	1.83
Akhunzada Koday	29	0.63	no	751.70	695	44,711	0.02	26,568	26.16	520	1.34
Petawak	36	0.62	no	1188.88	656	70,715	0.01	21,528	30.47	500	1.31
Qalay Wazir	41	0.62	no	634.85	857	37,761	0.02	52,344	16.37	650	1.32
Meserkhel	53	0.60	yes	1166.57	1,457	69,388	0.02	59,040	24.68	1,120	1.30
Syahgel	59	0.59	yes	149.05	483	13,298	0.04	38,160	12.66	335	1.44
Chambarak	74	0.58	no	126.12	334	15,003	0.02	22,392	14.92	255	1.31
Fadzel	80	0.56	no	103.01	136	21,445	0.01	33,120	4.11	100	1.36
Shahbedak	81	0.56	yes	53.20	187	6,329	0.03	33,552	5.57	140	1.34
Qala-I Surkh #1	123	0.46	yes	97.55	299	8,703	0.03	17,712	16.88	225	1.33
Qala-I Surkh #2	124	0.46	yes	96.96	286	8,651	0.03	16,488	17.35	215	1.33
Dehe Ramazi	126	0.46	no	32.14	118	1,912	0.06	99,432	1.19	75	1.57
Wet	128	0.45	yes	294.73	3,521	35,061	0.10	98,208	35.85	1,870	1.88

Dehbakhshi: The site is located in the Qarabagh District in central Ghazni Province. The site ranked first among the 159 locations evaluated. The project site watershed has high stream stability and low upland erosion. Dehbakhshi is ranked high because the stable watershed has less potential sediment yield to fill-in the reservoir compared to the other proposed projects. The reservoir also had no inundation impacts. The site ranked 27th overall with weighted project efficiency (Table 6-16).The project site is also on an unstable stream channel that will increase design, construction, and maintenance costs. The nearest cultivated areas are over 6 km downstream. The reservoir size is only 108,000 m^3 and has poor storage efficiency. Even with the good rating for low upland erosion, sedimentation will remain a problem and there is little available storage volume for accumulated sediment. Dehbakhshi is not recommended as a priority project for construction. The location has a good watershed in terms of low sediment potential but the site does not have enough storage volume to provide much benefit to agriculture.

Syahsangak: This site is located in the Jaghatu District of Ghazni Province. It is the ninth ranked project overall. The watershed has high stream stability and moderately low upland erosion and the project is on a stable channel. There is a moderate amount of existing downstream agriculture. The storage efficiency is below average but this site has higher storage volume and potential irrigation benefits than Dehbakhshi. It was rated lower then Dehbakhshi primarily due to higher upland erosion but the larger reservoir will make managing sediment easier. No dwellings are inundated but large areas of existing farmland would be impacted. The contributing watershed is only 55 km^2 in size so the streamflow characteristics should be confirmed with local knowledge to better estimate the annual water budget. This location is recommended for further investigation.

Bazari Sidaqat: The site is located in the Jaghatu District of Ghazni Province and is ranked 18th overall. The watershed has moderately-high stream stability, moderately-low upland erosion and the project site is on a stable channel. The open valley upstream of the dam site provides a large storage volume. Although the site has good storage efficiency, the dam would be relatively wide at over 200 m. The 12 m high dam would inundate dwellings but the 8 m would not. Large areas of existing farmland would be inundated but there are large areas of existing agriculture downstream that would benefit from dependable irrigation. This location is recommended for further investigation. Dehbakhshi and Syahsangak are ranked higher than Bazari Sidaqat because of less erosive upland, smaller construction volume and inundation impacts. However, the higher storage efficiency, irrigation potential and the larger watershed area make Bazari Sidaqat the better option.

Akhunzada Koday: The project site is located in the Jaghatu District of Ghazni, 4 km upstream of the existing Sultan Dam. The site is an ideal location for a dam given the narrow valley constriction just downstream of an open valley. However, the site is not recommended because the reservoir would inundate large areas of active farmland and there is little arable land between this site and Sultan dam. Either site at Petawak and Merserkhel would be a better location to operate a cascade of dams with Sultan dam. The site does have hydropower potential.

Petawak: This site is 2.5 km downstream of Sultan Dam. The site has good storage efficiency given the small dam size and open valley upstream. A project here would require detailed water management analysis of the Sultan dam and downstream irrigation to ensure the cascading dams operate as an efficient system.

Qalay Wazir: The narrow valley constriction provides for a small dam size at this location but there is little available storage volume behind the dam. There appears to be an existing diversion structure at this location. The site is worth further investigation to determine if a small 5 m dam could improve the existing system.

Meserkhel: This site has good potential but would be a large scale construction project. The Meserkhel project is immediately upstream of the existing Sultan Dam and would require additional water management analysis to determine impacts and water management requirements. The cascade of storage dams could improve water management in the region and will require coordination and planning with MAIL and MEW in Kabul.

Chambarak: The valley constriction provides for a small dam size but the steep stream slope offers little storage potential. There is also little existing downstream cultivation. The site does have good hydropower potential but streamflow characteristics will have to be confirmed.

Wet: The site at Wet has a large reservoir storage volume but the high percentage of unstable streams in its watershed would create sedimentation issues. The soils downstream of the site do not appear arable and would require soil surveys.

6.4.6 Ghazni – Upper (Gardez)

The upper Ghazni study watershed includes all of Gardez Valley in the Paktya Province. The Gardez Valley does not hold good potential for irrigation storage dams for a variety of reasons. The Gardez (Jilga) River channel and floodplain are too wide and flat for a dam to be feasible. The tributary streams that discharge into the Gardez Valley have steep slopes over 5%. The steep streams offer very little storage volume per height of dam, or poor storage efficiency. Dam sites in this watershed had some of the lowest storage efficiencies in the five province assessment. Upland erosion and stream system instability were high for almost all project sites indicating reservoir sedimentation issues. The tributary watersheds tended to be small providing low annual water budgets with increased uncertainties in available water.

Table 6-8 Ghazni-Upper Irrigation Storage Dam Results

12-m Dam Name	Rank	Decision Model	Unstable Site	Watershed Area (km2)	Reservoir Storage Volume (1000 m3)	Annual Watershed Runoff (1000 m3)	Ratio Storage to Runoff	Dam Construction Volume (m3)	Storage Efficiency	Potential Irrigated Crop Area (ha)	Ratio Storage to Irrigated Crop Area
Usmankhel #1	88	0.53	yes	26.48	316	4,047	0.08	25,488	12.40	200	1.58
Darabal Kala #1	94	0.52	no	38.97	331	5,957	0.06	28,440	11.64	165	2.01
Chaparay	102	0.51	no	6.22	87	380	0.23	14,472	6.01	35	2.49
Zundikhel	116	0.48	no	82.13	197	12,554	0.02	53,928	3.65	155	1.27
Bar Deray	117	0.48	yes	105.29	422	16,094	0.03	26,064	16.19	290	1.46
Darabal Kala #2	131	0.45	no	23.39	193	1,430	0.13	16,920	11.41	95	2.03
Shekhan	145	0.41	yes	83.31	109	12,734	0.01	72,792	1.50	115	0.95
Gardedkhwahi	149	0.40	yes	76.12	357	4,654	0.08	41,544	8.59	225	1.59
Kosin #1	151	0.39	yes	6.60	78	1,009	0.08	30,672	2.54	50	1.56
Kosin #2	152	0.39	yes	12.92	97	1,975	0.05	27,576	3.52	75	1.29
Madokhel	155	0.39	no	6.20	157	1,516	0.10	25,416	6.18	85	1.85
Sepahikhel	157	0.36	no	5.58	75	853	0.09	33,120	2.26	40	1.88

Usmankhel #1: The UN-FAO project list included the proposed Usmankhel #1 dam site (Tashnak Reservoir). A recommended dam height was not provided. The site is located in the Sayid Karem District approximately 20 km east of Ghazni City. Usmankhel is the highest ranking dam in the watershed but is ranked 88th overall. The site ranked 89th in the modified decision model. The watershed has only moderate stream stability and upland erosion is high. The stream channel is unstable at the project site. No dwellings would be impacted by the reservoir but an unpaved road would be inundated. A 12 m dam would affect a small amount of existing farmland. This location is the best option for a storage dam in the Gardez watershed but sedimentation will be a long-term maintenance issue. Improving an existing diversion structure at this location may provide benefits but again, sedimentation is an issue.

Darabal Kala #1 and #2: The site is located 6 km southeast of Gardez City. The watershed has only moderate stream stability and upland erosion is high. The project is on a stable stream channel. The steep stream slope provides little storage. Darabal Kala #2 is 2 km upstream and is a smaller sized dam but has significantly less reservoir storage volume. Neither dam inundates existing dwellings or farmland. A dam over 5 m at either site would affect a major roadway to Khost (site confirmation needed). The small potential irrigated service areas for both dam sites do not justify relocating the roadway. Neither dam is recommended.

Chaparay: Chaparay is located 15 km north of Ghazni City in the Sayid Karam District. The watershed has only moderate stream stability and upland erosion is very high. The project is on a stable stream channel. The site had very low storage efficiency and storage potential. The watershed is too small to justify a storage dam. Improvements to an existing irrigation diversion structure and small canal may be the better option for this location.

Bar Deray: This site was evaluated because the narrow valley provided for a very small dam size. The location also has a large watershed compared to other tributaries in the Gardez Valley. The location is ranked low because upland erosion potential is high. The stream slope is over 2% offering little storage volume. A storage dam is not recommended at this site. The location does have good hydropower potential that is worth investigating.

6.4.7 Helmand

The Helmand study watershed is located in northwestern Wardak Province and includes a small portion of Bamyan Province. The study area includes only the upper 3,800 km^2 of the 161,000 km^2 Helmand River watershed. The watershed offers good sites for water resource projects because of high stream system stability and moderate upland erosion potential. Streamflow records from three gaging stations in the watershed indicate high year-round baseflow. The river valley floor is narrow offering little available land for cultivation. Given the high amount of water available and the small amount of arable land, there is little need for irrigation storage dams. The crops can be irrigated by small diversions dams and canals. The terrain and hydrology in the Helmand watershed are excellent for hydropower.

Table 6-9 Helmand Irrigation Storage Dam Results

12-m Dam					Reservoir	Annual	Ratio	Dam		Potential	Ratio
		Decision	Unstable	Watershed	Storage	Watershed	Storage to	Construction	Storage	Irrigated	Storage to
Name	Rank	Model	Site	Area	Volume	Runoff	Runoff	Volume	Efficiency	Crop Area	Irrigated
				(km2)	(1000 m3)	(1000 m3)		(m3)		(ha)	Crop Area
Sinak	16	0.67	no	1953.20	3,808	403,565	0.01	15,408	247.14	2,980	1.28
Zarkharid #1	21	0.65	no	610.54	1,135	126,148	0.01	12,168	93.28	880	1.29
Dahan-e Abdullah	25	0.64	no	1080.19	1,587	223,186	0.01	16,488	96.25	1,230	1.29
Binidaysang	27	0.64	no	2014.44	2,280	416,219	0.01	15,984	142.64	1,770	1.29
Panjasya	28	0.64	no	1101.61	218	227,612	0.00	13,392	16.28	165	1.32
Shinah	56	0.60	no	122.71	850	25,716	0.03	21,168	40.15	660	1.29
Khuskdana	60	0.59	no	106.57	244	22,019	0.01	19,296	12.65	185	1.32
Kuhnaqala	75	0.58	no	165.66	191	34,228	0.01	35,568	5.37	145	1.32
Dewal	98	0.52	no	96.33	313	19,903	0.02	18,072	17.32	240	1.30

Sinak: The site is located in the Markazi Bihsud District of Wardak Province. It is the 16th ranked project out of the 159 project dataset. The watershed has high stream stability and moderate upland erosion with a stable stream channel at the project site. The 12 m high dam would inundate settlements and cultivated land. Therefore, an irrigation storage dam is not recommended at this location. Section 8.8 of this report describes a potential combination hydropower and irrigation diversion project at this location. Sinak has a generation potential of 1.5 MW and 300 ha of irrigated land.

Zarkharid #1: This site is located in the Hisa-i-Awal Bihsud District of Wardak Province. The watershed has high stream stability and moderate to low upland erosion and the stream channel is stable at this location. The Zarkharid #1 location offers the same opportunities as at Sinak. A combination of hydropower and diversion is recommended rather than an irrigation storage dam. There is low downstream agriculture and low population density in the area.

6.4.8 Kabul

The Kabul watershed is in the northeast corner of Wardak Province. The watershed is drained by the Maydan (Maidan) River, which changes to the Kabul soon after entering the Kabul Province. Tributary streams draining into the Maydan River have slopes ranging from 2% to 15% and provide very little storage per height of dam, i.e. poor storage efficiency. The Kabul study watershed was unique in that it did not offer any good quality 5 to 12 m high dam sites but did have excellent locations for 30 m or higher dam sites. The large dam sites are located along the main channel of the Maydan River and would be national-scale projects.

Table 6-10 Kabul Irrigation Storage Dam Results

12-m Dam Name	Rank	Decision Model	Unstable Site	Watershed Area (km2)	Reservoir Storage Volume (1000 m3)	Annual Watershed Runoff (1000 m3)	Ratio Storage to Runoff	Dam Construction Volume (m3)	Storage Efficiency	Potential Irrigated Crop Area (ha)	Ratio Storage to Irrigated Crop Area
Qal-eh-ye Shah	19	0.66	no	32.07	39	5,046	0.01	29,952	1.30	30	1.30
Av Darreh	39	0.62	no	1462.36	10,412	173,784	0.06	42,336	245.94	7,890	1.32
Garmak #1	54	0.60	no	157.91	246	34,537	0.01	23,256	10.58	185	1.33
Hajian	72	0.58	no	1483.20	2,922	173,784	0.02	22,896	127.62	2,280	1.28
Padshakhel	79	0.56	no	1513.32	956	177,313	0.01	15,696	60.91	735	1.30
Dar-e Akhshi	125	0.46	yes	9.20	43	2,012	0.02	31,968	1.35	30	1.43

Qal-eh-ye Shah: This site is located in the Jalrez District in northern Wardak Province. The dam was ranked highest in the Kabul watershed and 19th overall of the 159 projects. Qal-eh-ye Shah ranked high because its watershed had moderate stream stability and low upland erosion. There were also no inundation impacts and it had a low cost index. The major drawback of this site is the very low storage efficiency. The project stream is a tributary to the Maydan River and has a slope of 12%, or 1 m rise over 8.3 m horizontal. The dam offers very little storage per height of dam. This irrigation storage dam is not recommended. This project location is very similar to other tributary streams in the Kabul watershed and in Afghanistan as a whole.

Av Darreh: The site is located on the Maydan River approximately 4 km upstream of the Hajian project site. The watershed has only moderate stream stability and upland erosion is moderately-low. The Av Darreh site offers very high storage efficiency and almost 8,000 ha of potential irrigated crop area. The Av Darreh site is very good but the Hajian site offers better storage efficiency for a large dam. The Hajian reservoir would inundate a dam at Av Darreh so the site is not recommended.

Garmak #1: This site also is located on a steep channel slope and is not recommended.

Hajian: This site is located on the Maydan River in the Nirkh District, Wardak Province. The site is approximately 20 km southwest of Kabul and has previously been investigated for potential irrigation and municipal water supply. The natural constriction in the valley walls and open valley upstream make the Hajian site an ideal location for a large storage dam. The recommended dam at this site would have a live storage of 110 M-m^3 (Montreal, 1980) and would be over 70 m high. The World Bank evaluated Hajian as part of a long-term, integrated water resources strategy for the Kabul River Basin (World Bank, 2008). The location would be under-utilized with a 12 or 30 m high dam and a 70 m dam is beyond the mission objectives of TF Yukon. Engineering data and watershed characteristics developed in this work will be useful on future development of Hajian dam.

6.4.9 Logar – Lower

The lower Logar watershed has good potential for irrigation storage dams. Most of the project watersheds have moderately stable stream systems and moderate upland erosion potential. Reservoir sedimentation rates are likely to be less than sites in the Shamal or Chamkani study watersheds. The rivers and tributaries have wide valleys with large areas of existing agriculture that could benefit from dependable irrigation supplies. The flat stream slopes and some narrow valley constrictions offer excellent dam sites with high storage efficiencies.

Table 6-11 Logar-Lower Irrigation Storage Dam Results

12-m Dam Name	Rank	Decision Model	Unstable Site	Watershed Area (km2)	Reservoir Storage Volume (1000 m3)	Annual Watershed Runoff (1000 m3)	Ratio Storage to Runoff	Dam Construction Volume (m3)	Storage Efficiency	Potential Irrigated Crop Area (ha)	Ratio Storage to Irrigated Crop Area
Kunj	2	0.77	no	9,618.92	40,623	408,847	0.10	79,344	511.99	24,505	1.66
Shaghasi Kala	3	0.75	no	8,579.00	32,839	364,646	0.09	86,040	381.67	19,890	1.65
Namunyaz	12	0.67	no	25.90	507	2,398	0.21	50,544	10.03	220	2.30
Chino Sar #1	17	0.66	no	59.59	55	5,449	0.01	15,480	3.55	40	1.38
Godan	38	0.62	no	4,766.16	1,552	217,916	0.01	32,976	47.06	1,195	1.30
Urdu	40	0.62	no	111.24	111	10,172	0.01	19,008	5.84	85	1.31
Girdab	43	0.62	no	4,751.53	1,599	217,247	0.01	49,176	32.52	1,235	1.29
Koday	44	0.62	yes	7.59	108	1,215	0.09	20,880	5.17	65	1.66
Mulla Sayed Baba	47	0.61	no	23.25	255	3,721	0.07	13,896	18.35	185	1.38
Durwo	52	0.61	no	157.83	436	14,432	0.03	35,352	12.33	335	1.30
Takhtak	71	0.58	no	572.40	76	52,342	0.00	13,968	5.44	55	1.38
Bum Wardak	77	0.57	no	203.45	440	18,604	0.02	36,000	12.22	340	1.29
Khushi	85	0.54	yes	145.61	2,651	12,378	0.21	15,480	171.25	1,310	2.02
Soja #2	86	0.54	no	72.12	103	6,503	0.02	33,480	3.08	75	1.37
Soja #1	93	0.52	no	64.88	70	10,382	0.01	19,296	3.63	50	1.40
Shali	110	0.49	yes	31.29	276	5,007	0.06	22,896	12.05	210	1.31
Tangay	121	0.47	no	96.43	592	8,197	0.07	15,480	38.24	425	1.39
Nyazikhel	130	0.45	no	31.29	62	5,007	0.01	14,112	4.39	45	1.38
Gerdab	139	0.43	no	45.20	89	4,133	0.02	32,616	2.73	65	1.37
Khwajakhel	142	0.41	no	26.51	203	4,242	0.05	34,920	5.81	150	1.35
Karakat	148	0.40	no	21.68	151	3,469	0.04	54,792	2.76	115	1.31
Abchakan	150	0.40	no	32.45	130	2,967	0.04	26,208	4.96	100	1.30
Zinak	156	0.37	yes	9.44	24	2,036	0.01	31,896	0.75	18	1.33

Kunj: This site is located on the Logar River near the border of Logar and Kabul Provinces, 30 km southeast of Kabul City. A dam at Kunj would inundate a large number of households but there are significant irrigation and water supply benefits. The site has the highest storage efficiency of all the dams evaluated. The watershed has moderate stream stability and moderately-low upland erosion. The previous proposed and evaluated Gat Dam is located 12 km upstream of Kunj. The proposed Gat Dam would have a live storage volume of 140 M-m^3 and would supply water to Kabul and irrigate 9,000 ha (Montreal, 1980). Gat Dam would also supply 2.0 m^3/s of water to the proposed Aynak Copper Mine and Smelter, Kunj could also serve this purpose. A dam at Kunj or Gat is highly recommended but the +20 m high, multi-purpose dam does involve water management issues on a National scale and may be beyond the scope of TF Yukon. Four existing downstream hydropower plants rely on water from the Logar River. Water regulation and water rights will be a major issue. The Gat Dam location was outside of the SOW study area and was not fully evaluated but data is available.

Shaghasi Kala: This site is located 25 km upstream of Kunj in the Puli Alam District of Logar. The site is ranked third of the 159 projects evaluated. The watershed has moderate stream stability and moderately-low upland erosion and the stream channel is stable at the project site. The Shaghasi Kala site is ideal for a storage dam. The valley constriction provides for a small dam construction volume and the open valley upstream provides plenty of storage. The site ranks second only to Kunj in storage efficiency and has a low cost index (equivalent to a high cost index rating). The reservoir would inundate a significant number of households, farmland and a major roadway but the potential irrigation benefits are high. This is project is recommended but it will require careful planning in water management as discussed with the Kunj and Gat dam.

Namunyaz: The site is located in the Chahar Asyab District of Logar Province. It is the third ranked project in the study watershed and 12th overall. Although the watershed is small, it does have high stream stability and low upland erosion. The stream at the project site is stable. This location ranked highly because of the stable watershed and no inundation impacts. The site ranked lower at 26 when storage efficiency was weighted heavier in the decision support model. The project site has a watershed of only 26 km^2. A dam at this location is not recommended as a priority project, since there are better locations in Logar Province. If any dam is pursued at this location soil surveys should be conducted first to confirm downstream agricultural benefits.

Chino Sar #1: This site is located in the Muhammad Agha District of Logar Province. The project is ranked 17th overall because of the stable watershed and no inundation impacts. This site is not recommended because of the very low storage efficiency and low agricultural benefits.

Godan and Girdab: These two sites have similar characteristics and are located within 1 km of each other on the Logar River. They are located in the Saydabad District in southern Wardak Province. Their watersheds have moderate-high stream stability and moderate upland erosion. The stream channels are stable at both sites. There are inundation issues for both projects with Girdab having slightly higher impacts. The reservoir storage volumes are high but the construction volumes for both dam are also high, which result in moderate storage efficiencies. There are large areas of existing agriculture downstream. Godan is the better site of the two and is recommended for further investigation. Both sites have good potential for hydropower and could be combined with a storage dam. Previous studies evaluated the proposed Tangi Wardak dam, approximately 3 km upstream of Girdab. This could be the Girdab site but the exact location was not provided. The Tangi Wardak was determined to have a storage volume of 123.1 M-m^3 (World Bank, 2008).

Urdo: Urdo is located in the Chak District in central Wardak Province. The dam is on a tributary to the Logar River and would serve a small village. This dam is much smaller in scale than the dams described above. The watershed has moderate stream stability and moderately-low upland erosion. The watershed is large and there appears to be good baseflow. The project site is on a stable stream channel. The stream slope is steep offering little storage. A smaller 5 m dam may be more practical here and could serve as a diversion structure.

Khushi: The site is located in the Khushi District in eastern Logar Province. The watershed has low stream stability and moderate upland erosion, and the project site is on an unstable stream channel. The site does offer good storage efficiency and the valley constriction would make for a small dam size. There are no inundation impacts and there is existing agriculture downstream. This site and Godan are the very few sites evaluated that contain a combination of irrigation storage and hydropower potential with head from the dam height. Further investigation of Khushi is recommended with particular attention focused on sediment management.

Bum Wardak: This site has potential for a small 5 m dam. It has a relatively large watershed and moderate storage efficiency.

Durwo: The stream slope at Durwo is steep offering little storage but is a good site for an irrigation diversion structure. The location has a large watershed and baseflow.

Takhtak: The stream slope is too steep to provide any storage but the site has good hydropower potential.

6.4.10 Logar – Upper

The upper Logar study watershed contained most of the top-ranked irrigation storage dams. The watershed stream systems are relatively stable. The potential for eroding upland is moderate to moderately low. These two factors indicate reservoir sedimentation may be less of an issue compared to the rest of the assessment area. The river valleys of the Logar, Chak and Kajab Rivers are wide with flat stream slopes offering very good storage potential. There are numerous constrictions along the river valleys that offer locations to build dams with small construction volumes. One potential issue with many of the dam sites is the local geology. The valley hillsides appear to consist of loose, alluvial fill and may not be suitable for dam construction.

Table 6-12 Logar-Upper Irrigation Storage Dam Results

12-m Dam					Reservoir	Annual	Ratio	Dam		Potential	Ratio
		Decision	Unstable	Watershed	Storage	Watershed	Storage to	Construction	Storage	Irrigated	Storage to
Name	Rank	Model	Site	Area	Volume	Runoff	Runoff	Volume	Efficiency	Crop Area	Irrigated
				(km2)	(1000 m3)	(1000 m3)		(m3)		(ha)	Crop Area
Niw Qal'a #2	4	0.70	yes	532.10	5,107	41,810	0.12	26,496	192.75	2,930	1.74
Lashkari	5	0.70	no	2411.74	4,775	137,389	0.03	29,808	160.19	3,730	1.28
Ternawa	6	0.68	no	1477.33	1,511	84,159	0.02	15,624	96.71	1,165	1.30
Gadagak	8	0.68	no	1500.37	2,641	85,471	0.03	31,536	83.75	2,060	1.28
Niw Qal'a #1	10	0.68	no	361.33	715	28,392	0.03	24,984	28.62	550	1.30
Kajab	11	0.68	no	3799.92	816	216,470	0.00	20,232	40.33	620	1.32
Gurgkushta	13	0.67	yes	345.33	3,692	19,684	0.19	17,136	215.45	1,745	2.12
Bokan	14	0.67	no	408.00	3,784	23,242	0.16	27,864	135.80	1,965	1.93
Shew Qowl	15	0.67	no	288.38	2,729	22,659	0.12	15,984	170.73	1,600	1.71
Pitab Saydo	20	0.66	no	33.31	3,820	4,580	0.83	18,720	204.06	470	8.13
Tar Bulagh	22	0.65	no	75.12	3,382	10,329	0.33	17,928	188.64	1,125	3.01
Pay Kotal	24	0.64	no	13.47	85	1,058	0.08	14,040	6.05	55	1.55
Sangshanda	30	0.63	no	346.07	1,676	27,192	0.06	36,360	46.09	1,305	1.28
Dahane Bum	32	0.63	no	100.85	288	7,924	0.04	31,824	9.05	220	1.31
Bodak	33	0.63	no	864.46	955	49,246	0.02	33,120	28.83	740	1.29
Gidargu	34	0.63	no	1080.08	1,062	61,529	0.02	29,880	35.54	820	1.30
Awdara	35	0.62	no	14.19	221	1,115	0.20	25,992	8.50	90	2.46
Taybum	76	0.57	no	147.66	283	11,602	0.02	14,400	19.65	215	1.32
Sar-e Tup	111	0.49	no	321.67	2,158	25,275	0.09	65,160	33.12	1,435	1.50

Niw Qal’a #2: This site was included in the MEW project list and is ranked fourth overall in this assessment. The watershed has high stream stability and low upland erosion. No dwellings are impacted by reservoir inundation for the 12 m dam though a small amount of existing farmland would be flooded. There are large areas of existing agriculture downstream. The Niw Qal’a #2 is an ideal site for a storage dam. The river valley contracts down to 110 m wide as it passes through a rock ridgeline. The rock outcrops are over 50 m above the valley floor. Upstream of the constriction is a natural depression area providing over 5 M-m^3 of storage with a 12 m high dam. The maximized dam height was 24 m high with 20 M-m^3 storage volume The 12 m dam had a better rating than the 24 m high dam. The 532 km^2 watershed does not provide enough runoff to justify a dam larger than 24 m unless storage for downstream flood reduction is a function. This is should be one of the priority projects for field review and additional analysis. There is little hydropower potential at the site. Even with the relatively stable watershed, there will be sediment entering the reservoir. Any proposed dams in Afghanistan will have to address sediment management in the early stages of planning and design.

Lashkari: This site is located in the Day Mirdad District in central Ghazni Province and is ranked 5th overall of the 159 dams evaluated. The watershed has high stream stability and moderately-low upland erosion. The stream channel is stable at the project site. The site has high storage efficiency and a large potential storage volume. Inundation impacts to dwellings are low but large areas of farmland would be affected. The valley hillsides appear to consist of loose, alluvial fill and are not very suitable for a dam. The site has very good potential as an irrigation storage dam but field review is recommended to confirm the geology before pursuing this project.

Ternawa: This site is located in the Nawur District in northern Ghazni Province. The best feature of the Ternawa site is the narrow valley constriction through a rock ridgeline. The site offers a small dam size with a potentially good rock foundation. It is the 6th rated project overall out of the 159 project dataset. The watershed has high stream stability and moderately-low upland erosion. Few dwellings would be affected by inundation but areas of farmland would be. An 8 m high dam would have no inundation impacts. One drawback of this location is the valley downstream is very narrow with little existing agriculture. Further investigation of this site is recommended to determine potential benefits. There is an existing irrigation diversion at this location and one option is to improve the diversion dam and canal.

Gadagak: This site is located in the Nawur District in Ghazni Province near the border with Logar. The site ranks 8th overall because of the stability of the stream system, moderately-low upland erosion and high storage potential. The Gadagak site may have foundation issues because of the alluvial fill on the south riverbank. The dam construction volume is larger than most dams in upper Logar. There is little existing agriculture downstream of the dam because of the narrow river valley. A dam at Gadagak may have lower priority than other projects in the upper Logar study watershed but is worth further investigation.

Niw Qal'a #1: The site is located in the Nuwar District in central Ghazni Province and is ranked 10th overall of the 159 projects evaluated. The watershed has high stream stability and moderately-low upland erosion, but the project site is near an unstable stream channel. Existing farmland will be impacted by inundation but no dwellings are in the pool perimeter. The site is located downstream of a natural depression area providing a large amount of potential storage. The small dam size provides for one of the higher storage efficiencies. The project would have to be constructed with a diversion canal uphill of an existing canal to serve downstream agriculture. The site is located on a tributary to the Chak River and has a much lower annual water budget than Lashkari or Niw Qal'a #2. Further investigation of this project is recommended but Niw Qal'a #2 is the better site.

Kajab: Kajab is located in the Day Mirdad District in central Wardak Province. The local geology and watershed characteristics at Kajab are one of the better locations in southeast Afghanistan for a large scale dam. The site is ranked 11th overall of the 12 m high dams. Previous engineering studies have evaluated the project site and it is a priority project for MEW. The recommend dam has a height of approximately 70 m and a live storage of 200 M-m^3 for irrigation purposes (Montreal, 1980). Kajab is a National scale project and will require years of design and water management planning before construction could begin. It is recommended that TF Yukon focus on smaller scale projects and rehabilitation of existing infrastructure.

Gurgkushta: This project is located in the Nawur District in northeastern Ghazni Province. It is the 13th of the 159 projects. It is ranked high because of the high stream stability, low upland erosion, small dam size and good reservoir storage efficiency. The narrow downstream valley offers very little arable land. The poor agricultural benefits were outweighed by the very good watershed conditions and good storage efficiency. This site is not recommended.

Bokan: Bokan is located in the Nawur District in northern Ghazni Province, 7 km downstream of the Gurkushta site. Bokan ranked just below Gurkushta but is much closer to existing cultivated land. The site still has low potential agricultural benefits. The watershed has high stream stability, low upland erosion and the stream at the site has a stable channel. No dwellings or farmlands are impacted by inundation. Rough estimates of annual runoff volumes had to be used because of the lack of nearby streamflow gage data. The Bokan site is recommended for further investigation but local knowledge of flow patterns should be one of the first items obtained and the site re-evaluated. Bokan also holds some hydropower potential but additional flow data is needed.

Shew Qowl: This site is located in the Nawur District in northeastern Ghazni Province. The site is ranked 15th overall because of the stable watershed and good storage efficiency. The watershed has high stream stability and low upland erosion. Upstream of the dam site the river valley is flat and open providing good storage volume and good storage efficiency. There is not a large amount of existing agriculture downstream. Shew Qowl is 20 km upstream of Niw Qala #2. The 12 m high dam Niw Qala #2 should be priority over Shew Qowl but a small 5 m high dam is worth investigating at this location. In this region of Ghazni, the analysis used rough estimates of watershed runoff volumes. Local knowledge of streamflow characteristics should be collected before pursuing for design. This site also has hydropower potential. Another potential dam location is located less than 1 km downstream of Shew Qowl.

Pitab Saydo: This site is located in the Markazi Bihsud District in southwestern Wardak Province and is ranked 20th overall. The reservoir is located in an existing depression area with no impacts to dwellings and small impacts to existing farmland. The watershed has high stream stability but moderate upland erosion. The dam site is in a narrow valley constriction making for a small dam size and the stream channel is stable. There is a moderate amount of existing agriculture downstream that would benefit from the storage dam. The terrain at Pitab Saydo is very good for a storage dam but the watershed has an area of only 33.3 km^2. A 5 or 8 m high dam at this location is recommended for further investigation.

Tar Bulagh: The small dam size and larger reservoir storage make for an efficient dam site but there is little existing downstream agriculture. At 75 km^2 the watershed is not very large but a 5 or 8 m dam is worth further investigation to confirm downstream benefits.

Pay Kotal: The site is ranked 24th and is not recommended due to the small watershed and lack of benefits.

Sangshanda: The site is ranked 30th and is not recommended because the very narrow downstream valley offers little irrigation benefit. The site does hold some hydropower potential.

Bodak: This is a good site for a 5 or 8 m high dam but there is little arable land downstream in the narrow valley. There is good hydropower potential.

Gidargu: The site is located 1 km downstream of Bodak but Bodak is a much better storage dam site.

Dahane Bum: The stream channel slope is steep at this location offering little storage potential.

6.4.11 Samanka

The Samanka study watershed is located in western Ghazni Province. The watershed does have some favorable sites for irrigation storage dams but all the locations tend to impact large areas of existing agriculture and infrastructure. The project watersheds have moderate stream stability and low upland erosion. The potential for reservoir sedimentation would be less than most areas in Khost and Paktya.

Table 6-13 Samanka Irrigation Storage Dam Results

12-m Dam Name	Rank	Decision Model	Unstable Site	Watershed Area (km2)	Reservoir Storage Volume (1000 m3)	Annual Watershed Runoff (1000 m3)	Ratio Storage to Runoff	Dam Construction Volume (m3)	Storage Efficiency	Potential Irrigated Crop Area (ha)	Ratio Storage to Irrigated Crop Area
Chaqmaq	42	0.62	no	1,729.67	6,780	91,233	0.07	48,600	139.51	4,355	1.56
Baraki	46	0.61	no	1,617.59	1,748	85,321	0.02	59,904	29.18	1,350	1.29
Qategha	55	0.60	no	88.77	711	4,682	0.15	23,544	30.20	345	2.06
Baba Wali	58	0.59	no	644.08	2,900	33,973	0.09	51,768	56.02	1,730	1.68
Nawrak	65	0.59	yes	579.88	1,827	30,586	0.06	79,488	22.98	1,260	1.45
Madras	69	0.58	no	84.11	1,369	4,436	0.31	34,272	39.95	550	2.49

Chaqmaq: Chaqmaq is located in the Ajristan District in southwestern Wardak Province. The site is ranked 42nd overall of the 159 sites evaluated. The watershed has moderate stream stability and low upland erosion. The narrow valley constriction at Chaqmaq is just upstream of a large, natural depression area providing excellent terrain for a storage dam. The storage efficiency is higher than any other site in Samanka and has potential to irrigate a large area. The reservoir would inundate large areas of existing farmland and at least eleven dwellings. From the inundation map, it should be noted that even the 5 m high dam inundates over 50 ha. The cost index is low for the small dam but there is limited existing agriculture or arable terrain downstream that could benefit. Chaqmaq is recommended for further investigation but downstream agriculture benefits will need to be addressed. The site also holds hydropower potential.

Baraki: This site is located in the Markazi Bihsud District in southwestern Wardak Province and is ranked 46th overall. The watershed has moderate stream stability but low upland erosion. Baraki is not recommended because of the low storage efficiency and the local geology does not appear to be favorable for dam construction.

Qategha: The watershed is in relatively good condition but the site has moderate storage efficiency because of the steep stream slope. The site is recommended for further evaluation for a dam under 5 m.

Baba Wali: The site offers good storage efficiency and the watershed is in relatively good condition but the local geology needs to be evaluated before pursuing design.

Nawrak: This site is upstream of Baba Wali but is on a steeper stream slope offering less storage potential. The dam would also be exceptionally large (over 170 m wide) and is not recommended.

Madras: The Madras site holds some potential for a dam under 5 m but would inundate existing farmland. The location is worth further investigation.

6.4.12 Shamal

The Shamal study watershed does not have high potential for irrigation storage dams. Most of the project site watersheds contributing streamflow are in poor condition. All of the dams in Shamal will have to be designed and maintained to handle high sedimentation rates in the reservoirs. The project watersheds generally consist of erodible soils and there is widespread active gully and rill erosion. The stream systems are also unstable resulting in high sedimentation potential and flash flooding. A significant amount of recent deforestation has exacerbated the sediment problem.

Table 6-14 Shamal Irrigation Storage Dam Results

12-m Dam											
Name	Rank	Decision Model	Unstable Site	Watershed Area (km2)	Reservoir Storage Volume (1000 m3)	Annual Watershed Runoff (1000 m3)	Ratio Storage to Runoff	Dam Construction Volume (m3)	Storage Efficiency	Potential Irrigated Crop Area (ha)	Ratio Storage to Irrigated Crop Area
Baak #2	7	0.68	no	18.26	426	7,434	0.06	38,520	11.06	505	0.84
Sulni Kalay #2	31	0.63	yes	48.52	845	3,664	0.23	28,728	29.41	370	2.28
Nika #2	90	0.53	no	25.22	128	1,904	0.07	31,536	4.06	135	0.95
Acarkhel	100	0.52	yes	131.00	455	9,830	0.05	17,280	26.33	610	0.75
Khan Kala #2 *	103	0.51	no	29.41	299	2,221	0.13	6,746	44.32	205	1.46
Sulni Kalay #1	105	0.50	yes	23.96	350	1,809	0.19	32,472	10.78	180	1.94
Mana	108	0.49	yes	224.98	1,710	16,988	0.10	13,032	131.22	1,455	1.18
Sorwakay	132	0.45	yes	764.46	608	57,724	0.01	26,064	23.33	1,990	0.31
Nika #1	133	0.44	yes	79.13	151	5,975	0.03	39,528	3.82	270	0.56
Ghorka Kalay	134	0.44	yes	108.59	282	8,200	0.03	26,424	10.67	425	0.66
Kala	136	0.44	yes	18.39	163	1,389	0.12	17,424	9.35	120	1.36
Bazak	137	0.43	yes	40.51	195	3,059	0.06	30,744	6.34	210	0.93
Khatinkhel	138	0.43	yes	70.49	233	5,290	0.04	12,672	18.39	315	0.74
Paktak	143	0.41	no	312.57	212	23,602	0.01	26,136	8.11	765	0.28
Ghorma	144	0.41	yes	44.34	244	3,348	0.07	14,904	16.37	245	1.00
Nasirkhel	154	0.39	yes	33.89	87	2,559	0.03	27,504	3.16	130	0.67
Sur Gori	158	0.36	yes	21.73	92	1,641	0.06	25,704	3.58	110	0.84
Zambar	159	0.35	yes	43.58	301	3,291	0.09	37,656	7.99	260	1.16

* 7 m high dam at Khan Kala #2.

<u>Baak #2</u>: This site is located in the Baak District in northeast Khost Province. The site is the highest ranked project in the Shamal watershed and ranked seventh overall of the 159 dam sites evaluated. This site had the best watershed condition of all the Shamal project sites. The watershed has high stream stability, moderate upland erosion and the project is located on a stable stream channel. The combination of stable watershed, no inundation impacts and small dam size resulted in the high ranking. Baak #2 ranked 13th with the modified decision model weighted towards project efficiency. The closest existing cultivated area is over 6 km downstream. Even with the high ranking, the Baak #2 site is not recommended because of little potential agricultural benefit.

<u>Sulni Kalay #2</u>: The project site is located in the Nadir Shah Kot District in central Khost Province. The watershed has low stream stability and moderate upland erosion and was ranked 31st overall. The project site is located on a wide, unstable stream channel that will increase design, construction and maintenance costs. There are no inundation impacts on dwellings or existing agriculture. There is a moderate amount of downstream irrigation. The dam has good storage efficiency compared to other sites in Shamal. The 48 km^2 watershed area is not large enough to supply runoff to justify a 12 m dam; a 10 m dam was the calculated maximized dam size. This site is recommended for further investigation. Field review of the local geology should be conducted to confirm the hillsides are favorable to dam construction before pursuing design.

Nika #2: The site is not recommended because of the small contributing watershed, small storage efficiency and the highly erosive upland.

Acarkhel: Acarkhel is located in the Spera District in western Khost Province. A constriction in the stream valley provides for a small dam size and the site has good storage efficiency compared to other locations in Shamal. The watershed has moderate stream stability but upland erosion potential is very high and the relatively high deforestation only increases the stream sediment load. There are pockets of existing agriculture that could benefit from a dam but the overall benefit rating is low. Satellite images show an existing irrigation diversion at the evaluated site. The local geology appears very favorable for a dam so further investigation into this site is recommended. A smaller 5 m dam or improvements to the existing diversion structure and canal may be a better option than a 12 m dam.

Khan Kala #2: This site is in the Tere Zayi District in eastern Khost Province. The site has a relatively small watershed of 29 km^2. The small watershed does not have enough annual runoff to justify building a 12 m dam; the maximum sized dam is 7 m. The site has good storage efficiency but there is little existing agriculture downstream to benefit. The watershed has low stream stability and moderately erosive uplands. The location is worth further investigation but sedimentation will be an issue and a diversion canal maybe required to convey water to nearby arable land.

Sulni Kalay #1: This project is located in the Nadir Shah Kot District in central Khost Province. The site is 4 km upstream of the Sulni Kalay #2 site. Sulni Kalay #2 is the better site because it provides over twice the storage volume for a smaller size dam. This site is not recommended.

Mana: This site is located in the Spera District in western Khost Province. The watershed has moderate stream stability but the upland erosion potential is very high. The poor watershed condition and high deforestation rates resulted in ranking this site 108th overall. The stream channel at the project site is unstable. The site has the highest storage efficiency of the Shamal projects but has one of the lowest potential agricultural benefits. The downstream valley is too narrow to provide much arable land. The location does hold some hydropower potential but there is little population in the immediate area to utilize its benefits. Mana has higher potential than many other sites in Shamal mainly do to its storage potential. If a dam at Mana is pursued the dam will have to be carefully designed to handle the high sediment loads.

Sorwakay: The site offers good storage volume with a small size dam but sediment will be a serious issue at this location. The large watershed and steep downstream slope does offer good potential for a run-of-river micro-hydropower project.

Nika #1: This location was evaluated during the Paktika assessment. A dam at this location would inundate a large area of existing farmland with little downstream potential benefit. The upland is highly erosive, creating sediment issues.

Ghorka Kalay: The topography of this site appeared very favorable for an irrigation storage dam but the watershed at this location is one of the worst for sediment potential. This site should be avoided.

<u>Paktak</u>: This site was initially thought to hold good potential for a storage dam. Analysis determined that the site offered very little storage per height of dam because of the steep 2.5% stream channel slope. Uplands are also highly erodible, presenting a sedimentation problem in a dam with little storage. The site is not recommended for irrigation storage but the location does hold hydropower potential.

6.4.13 Tarnak

The Tarnak watershed is located in southwestern Ghazni Province. This region had the lowest annual precipitation amounts of the five province study area. This watershed does not hold much potential for irrigation storage dams. The steep slopes of the stream valleys do not provide much storage volume per height of dam (i.e. poor storage efficiency).

Table 6-15 Tarnak Irrigation Storage Dam Results

12-m Dam		Decision	Unstable	Watershed	Reservoir Storage	Annual Watershed	Ratio Storage to	Dam Construction	Storage	Potential Irrigated	Ratio Storage to
Name	Rank	Model	Site	Area	Volume	Runoff	Runoff	Volume	Efficiency	Crop Area	Irrigated
				(km2)	(1000 m3)	(1000 m3)		(m3)		(ha)	Crop Area
Chaka	66	0.59	no	36.01	202	2,024	0.10	27,648	7.31	80	2.53
Khakrez	82	0.55	no	111.52	268	6,267	0.04	43,992	6.09	125	2.14
Nala-i-Khurd	83	0.54	no	13.93	92	783	0.12	18,648	4.93	30	3.07
Kalan Deh	91	0.52	no	147.22	265	8,273	0.03	23,184	11.43	140	1.89
Sengasi	95	0.52	yes	309.55	1,226	17,396	0.07	99,072	12.37	515	2.38
Bargah	101	0.52	no	177.75	402	9,989	0.04	51,408	7.82	195	2.06
Walan Rabat	109	0.49	yes	80.59	916	4,529	0.20	82,584	11.09	305	3.00
Galgay	127	0.46	yes	108.88	788	6,119	0.13	81,648	9.65	310	2.54

<u>Chaka</u>: Chaka is located in the Moqur District in southwestern Ghazni Province. The watershed has moderately-high stream stability and moderate upland erosion. The stream channel slope at the project site is over 2% but offers the best potential for a storage dam in the Tarnak watershed. The limited benefits do not justify a storage dam at this location.

<u>Khakrez</u>: This site is located in the Qarabagh District in southwestern Ghazni Province. The watershed has moderate stream stability and moderate upland erosion and the project is located on a stable channel. The site has very low storage efficiency because of steep stream channel slopes. A storage dam is not recommended here. The location is favorable for an irrigation diversion structure and canal to serve existing downstream agriculture.

Table 6-16 is a summary of all the projects described above. Those recommended for further study are indicated, along with the main reasons for that recommendation. The decision support model results are ranked for each, broken down by the groups Watershed Condition and Project Efficiency described in Section 6.2 (Figure 6.1). This table illustrates the results of using the decision support model information *with* additional factors. Scanning down the table shows that most of the high rankings in both groups correlate well with "yes" recommendations. The correlation is not perfect, but that merely indicates the importance of those additional factors in final recommendations.

Table 6-16 All Irrigation Storage Dam Projects Evaluated

Name	Study Watershed	Province	Rank Watershed Condition	Rank Project Efficiency	Recommend	Notes
Dehbakhshi	Ghazni Lower	Ghazni	1	27	No	Poor storage efficiency & benefit, small watershed
Kunj	Logar Lower	Kabul	2	1	Yes	National interest scale project, excellent storage
Shaghasi Kala	Logar Lower	Logar	3	2	Yes	But 25 km upstream of Kunj (Gat)
Niw Qal'a #2	Logar Upper	Ghazni	4	3	Yes	Good site previously proposed dam
Lashkari	Logar Upper	Wardak	5	4	Yes	Good site but local geology should be confirmed
Ternawa	Logar Upper	Ghazni	6	8	Yes	Confirm downstream potential benefits
Baak #2	Shamal	Khost	7	13	No	6 km from nearest arable land, small watershed
Gadagak	Logar Upper	Ghazni	8	9	Yes	Good site but local geology should be confirmed
Syahsangak	Ghazni Lower	Ghazni	9	17	Yes	Small watershed, confirm flow characteristics
Niw Qal'a #1	Logar Upper	Ghazni	10	19	Yes	Worth investigating but Niw Qal'a #2 better
Kajab	Logar Upper	Wardak	11	14	No	Large scale, National interest project
Namunyaz	Logar Lower	Kabul	12	26	No	Small watershed, questionable crop soils
Gurgkushta	Logar Upper	Ghazni	13	7	No	Little observed downstream benefits
Bokan	Logar Upper	Ghazni	14	10	Yes	Confirm downstream benefits and streamflow
Shew Qowl	Logar Upper	Ghazni	15	11	Yes	Upstream of Niw Qal'a, small 5 m dam maybe better
Sinak	Helmand	Wardak	16	5	No	Good location for hydropower & diversion
Chino Sar #1	Logar Lower	Logar	17	30	No	Very poor storage efficiency, little benefit
Bazari Sidaqat	Ghazni Lower	Ghazni	18	16	Yes	Large dam, inundation impacts
Qal-eh-ye Shah	Kabul	Wardak	19	21	No	Very poor storage efficiency, steep stream slope
Pitab Saydo	Logar Upper	Wardak	20	12	Yes	Small watershed, small 5 or 8 m dam
Zarkharid #1	Helmand	Wardak	21	23	No	Good location for hydropower, little population
Tar Bulagh	Logar Upper	Ghazni	22	20	Yes	Need to confirm downstream benefits
Qureh	Garmab	Ghazni	23	36	No	Small watershed, lack of downstream agriculture
Pay Kotal	Logar Upper	Wardak	24	40	No	Small watershed and little storage
Dahan-e Abdullah	Helmand	Wardak	25	25	No	Good hydropower potential
Awlaya	Arghandab	Ghazni	26	18	Yes	Best in Arghandab, small watershed
Binidaysang	Helmand	Wardak	27	24	No	Little downstream arable land
Panjasya	Helmand	Wardak	28	41	No	Good hydropower potential
Akhunzada Koday	Ghazni Lower	Wardak	29	31	No	Large inundation impacts but good hydropower
Sangshanda	Logar Upper	Wardak	30	33	No	Little downstream benefit, confirm
Sulni Kalay #2	Shamal	Khost	31	15	Yes	10 m dam, confirm local geology, small watershed
Dahane Bum	Logar Upper	Ghazni	32	37	No	Small watershed and little storage
Bodak	Logar Upper	Wardak	33	39	Yes	Small dam and hydropower potential
Gidargu	Logar Upper	Wardak	34	35	No	Bodak site better location
Awdara	Logar Upper	Ghazni	35	49	No	Small watershed and little storage
Petawak	Ghazni Lower	Wardak	36	28	Yes	Water regulation with Sultan Dam, large project
Shinyah	Garmab	Ghazni	37	48	No	Lack of downstream agriculture
Godan	Logar Lower	Wardak	38	29	Yes	Good storage, near Girdab site
Av Darreh	Kabul	Wardak	39	6	No	A good site but Hajian is the better site
Urdu	Logar Lower	Wardak	40	34	Yes	Little storage, 5 m dam maybe practical
Qalay Wazir	Ghazni Lower	Wardak	41	42	Yes	Improve existing diversion w/ small dam
Chaqmaq	Samanka	Ghazni	42	22	Yes	Large inundation impacts but good hydropower
Girdab	Logar Lower	Wardak	43	32	Yes	Good storage, near Godan site
Koday	Logar Lower	Wardak	44	47	No	Small watershed and little storage
Ghawchqol	Garmab	Ghazni	45	60	No	Poor storage efficiency
Baraki	Samanka	Ghazni	46	38	No	Local geology maybe an issue
Mulla Sayed Baba	Logar Lower	Logar	47	58	No	Very good hydropower potential
Malistan	Arghandab	Ghazni	48	50	No	No storage, possible diversion
Nayjoy	Garmab	Ghazni	49	64	No	Poor storage efficiency
Dahane Qol	Garmab	Ghazni	50	62	No	Poor storage efficiency
Kajak	Garmab	Ghazni	51	63	No	Poor storage efficiency
Durwo	Logar Lower	Logar	52	53	No	Steep stream, potential diversion or hydropower
Meserkhel	Ghazni Lower	Wardak	53	44	Yes	Water regulation with Sultan Dam, large project

Table 6-16 Continued, All Irrigation Storage Dam Projects Evaluated

Name	Study Watershed	Province	Rank Watershed Condition	Rank Project Efficiency	Recommend	Notes
Garmak #1	Kabul	Wardak	54	45	No	Poor storage efficiency
Qategha	Samanka	Ghazni	55	57	Yes	Small dam possible, remote location
Shinah	Helmand	Wardak	56	51	No	Good hydropower potential
Dame Joy #1	Garmab	Ghazni	57	61	No	On the border as a good project, best in Garmab
Baba Wali	Samanka	Ghazni	58	52	Yes	Small dam and hydropower potential
Syahgel	Ghazni Lower	Ghazni	59	56	No	Poor storage efficiency
Khuskdana	Helmand	Wardak	60	70	No	Good hydropower potential
Sabzak	Arghandab	Ghazni	61	66	No	Has hydropower potential
Tangi	Arghandab	Ghazni	62	67	No	No storage, possible diversion
Dame Joy #2	Garmab	Ghazni	63	69	No	Poor storage efficiency, small watershed
Kusha	Garmab	Ghazni	64	74	No	Poor storage efficiency, good hydropower potential
Nawrak	Samanka	Ghazni	65	65	No	Large dam with little benefits
Chaka	Tarnak	Ghazni	66	78	No	Confirm downstream benefits, <5m small dam
Argbiru	Garmab	Ghazni	67	72	No	Poor storage efficiency, small watershed
Tubi	Garmab	Ghazni	68	77	No	Good hydropower potential, poor storage
Madras	Samanka	Ghazni	69	68	Yes	Diversion structure possible
Balaqal	Arghandab	Ghazni	70	55	No	Little downstream arable land, hydropower potential
Takhtak	Logar Lower	Logar	71	43	No	Hydropower potential
Hajian	Kabul	Wardak	72	46	Yes	A large scale dam, National interest project
Zer Kac	Azrow	Logar	73	80	No	Small watershed
Chambarak	Ghazni Lower	Wardak	74	71	No	Poor storage efficiency
Kuhnaqala	Helmand	Bamyan	75	83	No	Little downstream arable land
Taybum	Logar Upper	Ghazni	76	76	No	Small dam maybe possible, narrow valley
Bum Wardak	Logar Lower	Wardak	77	75	Yes	Potentially good site but poor watershed
Barikjoy	Arghandab	Ghazni	78	84	No	Unstable watershed, hydropower potential
Padshakhel	Kabul	Wardak	79	81	No	A good hydropower, Hajian is better for storage
Fadzel	Ghazni Lower	Wardak	80	87	No	Poor storage efficiency, small watershed
Shahbedak	Ghazni Lower	Ghazni	81	86	No	Poor storage efficiency, small watershed
Khakrez	Tarnak	Ghazni	82	88	No	Possible irrigation diversion
Nala-i-Khurd	Tarnak	Ghazni	83	90	No	Poor watershed condition, little storage
Sorway #3	Chamkani	Paktya	84	59	Yes	Sorway #1 is a better site, smaller size
Khushi	Logar Lower	Logar	85	54	Yes	Potentially good site but poor watershed
Soja #2	Logar Lower	Wardak	86	95	No	Very poor storage efficiency
Kacwal	Azrow	Logar	87	91	No	Poor watershed condition, unstable site
Usmankhel #1	Ghazni Upper	Paktya	88	89	Yes	High sedimentation will be an issue
Usmankhel #2	Azrow	Logar	89	92	No	Poor watershed condition
Nika #2	Shamal	Paktika	90	96	No	Very poor storage efficiency and poor watershed
Kalan Deh	Tarnak	Ghazni	91	102	No	Poor watershed condition, little downstream benefit
Sorway #2	Chamkani	Paktya	92	79	Yes	Sorway #1 is a better site, smaller size
Soja #1	Logar Lower	Wardak	93	101	No	Very poor storage efficiency
Darabal Kala #1	Ghazni Upper	Paktya	94	98	No	Small watershed, poor watershed condition
Sengasi	Tarnak	Ghazni	95	103	No	Poor watershed condition, little downstream benefit
Dewkhana	Arghandab	Ghazni	96	100	No	No storage and poor watershed condition
Sra Kholeh	Chamkani	Paktya	97	85	Yes	Smaller 5 m dam more practical, small watershed
Dewal	Helmand	Bamyan	98	105	No	Little downstream arable land
Sorway #1	Chamkani	Paktya	99	82	Yes	Near Pakistan border, large project
Acarkhel	Shamal	Khost	100	99	Yes	Small 5 m dam maybe better option, unstable site
Bargah	Tarnak	Ghazni	101	107	No	Poor watershed condition, little storage, unstable site
Chaparay	Ghazni Upper	Paktya	102	93	No	Small watershed, poor watershed condition
Khan Kala #2	Shamal	Khost	103	108	Yes	Small 7 dam, sediment will be a issue
Dadikhel	Azrow	Logar	104	111	No	Poor watershed condition and storage efficiency
Sulni Kalay #1	Shamal	Khost	105	97	No	Site worth review for small dam, sediment issues
Kharzun #2	Chamkani	Paktya	106	73	Yes	Hydropower potential, sediment an issue

Table 6-16 Continued, All Irrigation Storage Dam Projects Evaluated

Name	Study Watershed	Province	Rank Watershed Condition	Rank Project Efficiency	Recommend	Notes
Chawnay #2	Chamkani	Paktya	107	106	No	Poor watershed condition and storage efficiency
Mana	Shamal	Khost	108	94	No	Downstream valley has little arable land, confirm
Walan Rabat	Tarnak	Zabul	109	109	No	Poor watershed condition, little downstream benefit
Shali	Logar Lower	Wardak	110	110	No	Unstable project site, small watershed
Sar-e Tup	Logar Upper	Wardak	111	104	No	Poor watershed condition
Khangul Kot	Chamkani	Paktya	112	118	No	Small watershed and poor watershed condition
Babar #1	Azrow	Logar	113	112	No	Poor watershed condition and storage efficiency
Akbarkhel	Azrow	Logar	114	119	No	Small watershed and poor watershed condition
Bekaray	Chamkani	Paktya	115	116	No	Hydropower potential
Zundikhel	Ghazni Upper	Paktya	116	124	No	Poor storage efficiency, poor watershed condition
Bar Deray	Ghazni Upper	Paktya	117	123	No	Unstable site, poor watershed condition
Wam Hasankhel	Chamkani	Paktya	118	115	No	Hydropower potential
Ghorushtay	Chamkani	Paktya	119	113	No	Poor watershed condition and storage efficiency
Ganday Shykhan	Chamkani	Paktya	120	125	No	Poor watershed condition and storage efficiency
Tangay	Logar Lower	Logar	121	120	No	Good storage, poor watershed, little agriculture
Chawnay #1	Chamkani	Paktya	122	117	No	Good site for a dam but very poor watershed
Qala-i Surkh #1	Ghazni Lower	Ghazni	123	121	No	Poor watershed condition
Qala-i Surkh #2	Ghazni Lower	Ghazni	124	122	No	Poor watershed condition
Dar-e Akhshi	Kabul	Wardak	125	114	No	Very poor storage efficiency, steep stream slope
Dehe Ramazi	Ghazni Lower	Ghazni	126	128	No	Poor storage efficiency, small watershed
Galgay	Tarnak	Ghazni	127	129	No	Poor watershed condition, little storage, unstable site
Wet	Ghazni Lower	Ghazni	128	126	No	Poor watershed condition
Dokanha-i-Gomaran	Azrow	Logar	129	131	No	Poor watershed condition and storage efficiency
Nyazikhel	Logar Lower	Logar	130	136	No	Very poor storage efficiency
Darabal Kala #2	Ghazni Upper	Paktya	131	130	No	Small watershed, poor watershed condition
Sorwakay	Shamal	Khost	132	127	No	Good location but sediment issues, hydropower
Nika #1	Shamal	Paktika	133	133	No	Very poor storage efficiency and poor watershed
Ghorka Kalay	Shamal	Paktya	134	137	No	Poor watershed condition
Salemi Nargay	Chamkani	Paktya	135	140	No	Poor watershed condition and storage efficiency
Kala	Shamal	Paktika	136	142	No	Very poor storage efficiency and poor watershed
Bazak	Shamal	Paktika	137	138	No	Very poor storage efficiency and poor watershed
Khatinkhel	Shamal	Khost	138	141	No	Poor watershed condition
Gerdab	Logar Lower	Wardak	139	134	No	Very poor storage efficiency
Khushhalkhel	Azrow	Logar	140	143	No	Poor watershed condition and storage efficiency
Rabat	Chamkani	Paktya	141	135	No	Poor watershed condition and storage efficiency
Khwajakhel	Logar Lower	Logar	142	144	No	Very poor storage efficiency
Paktak	Shamal	Khost	143	147	No	Poor watershed condition
Ghorma	Shamal	Paktika	144	148	No	Poor watershed condition
Shekhan	Ghazni Upper	Paktya	145	150	No	Poor storage efficiency, poor watershed condition
Pala	Chamkani	Paktya	146	132	No	Good site for a dam but very poor watershed
Sultak	Chamkani	Paktya	147	139	No	Poor watershed condition and storage efficiency
Karakat	Logar Lower	Wardak	148	151	No	Very poor storage efficiency
Gardedkhwahi	Ghazni Upper	Paktya	149	153	No	Poor storage efficiency, poor watershed condition
Abchakan	Logar Lower	Logar	150	154	No	Very poor storage efficiency
Kosin #1	Ghazni Upper	Paktya	151	145	No	Poor storage efficiency, poor watershed condition
Kosin #2	Ghazni Upper	Paktya	152	146	No	Poor storage efficiency, poor watershed condition
Shegaray	Chamkani	Paktya	153	152	No	Poor watershed condition and storage efficiency
Nasirkhel	Shamal	Paktya	154	155	No	Very poor storage efficiency and poor watershed
Madokhel	Ghazni Upper	Paktya	155	149	No	Poor storage efficiency, poor watershed condition
Zinak	Logar Lower	Logar	156	156	No	Very poor storage efficiency, unstable site
Sepahikhel	Ghazni Upper	Paktya	157	159	No	Poor storage efficiency, poor watershed condition
Sur Gori	Shamal	Khost	158	158	No	Very poor storage efficiency and poor watershed
Zambar	Shamal	Khost	159	157	No	Very unstable watershed, avoid

7.0 Sedimentation

7.1 Background

One of the most important issues to consider when proposing a water resource project in Afghanistan is how to manage sediment. The swift moving streams draining the barren watersheds carry a high amount of suspended sediment and moving bedload. When a stream reaches a dam and slows down the suspended sediment settles out and will eventually fill the reservoir. The physics of sediment transport from the land surface and along waterways is complex with a multitude of influencing factors. Sediment load can vary drastically between adjacent watersheds, along the same river and be highly variable over time. Project handover to include operation and maintenance procedures related to sediment should be determined during the early planning and design stages.

Figure 7-1 is a picture of Surkhab irrigation storage dam in Logar Province, viewed looking from top of dam downstream at the reservoir. Accumulated sediment in Surkhab's reservoir has reduced its storage volume and irrigation potential. Figure 7-2 is a view of the newly constructed Hezarak irrigation storage dam in Nangarhar, view along dam along the crest. Figure 4-19 and 4-20 are also pictures of Hezarak dam. Construction on the 10 m high Hezarak dam began in 2006 and was completed in June 2008. As of July 2009, the reservoir is almost completely filled of sediment with only 1 m of storage left (Oosterkamp, 2009). Larger size gravel is also entering the reservoir and will be difficult to pass through the dam's lower sluice gate.

Oosterkamp describes three major issues that led to the dam filling with sediment. These should be understood before pursuing dams in Afghanistan. The dam was built with only one 1.4 m wide sluice gate at its base. There is potential that two or three larger gates could be operated to encourage scour behind the dam and pass sediment downstream during flood conditions. The second issue was that the dam was built on a stream with a slope of 3%. A flatter stream slope allows water to back up further providing more storage volume for water and sediment.

The third issue is the condition of the Hezarak watershed that contributes the sediment. The surficial geology of this particular watershed may be of the type that naturally contributes a very high sediment load or yield. With this type of geology, a watershed restoration effort or a network of check-dams may not be successful in reducing the high sediment yield. The watershed assessments conducted in this study will help identify those watersheds that have lower sediment yields or offer an opportunity to reduce the yield by restoring vegetation, improving grazing practices, check dams or other hillside stabilization techniques. The assessments will also identify watersheds with naturally high sediment yields that cannot be repaired and should be avoided. The local farmers noted that the stream at Hezarak always flowed 'muddier' than others so local knowledge of stream characteristics should be collected during the early planning stages (Oosterkamp, 2009).

Figure 7-1 – Surkhab Dam, Logar, View from Top of Dam Downstream at Reservoir

Figure 7-2 – Hezarak Dam, Nangarhar View along Top of Dam (Oosterkamp, 2009)

7.2 Sediment Yield Data

The most comprehensive study of sediment yield for the study area was identified in the master plan “Kabul River Valley Development Project” prepared by Montreal Engineering Company (Montreal, 1980). This study estimated sediment yields at proposed dams sites on the Logar, Maidan, Panjshir, Ghorband and Kabul rivers. This study calculated sediment yields based on data collected over a two-week period by Montreal and data collected at established stream gage stations by Afghan Ministries in the 1960s and 1970s. The study did not specifically state how bedload amounts were accounted for; values should be used with caution. Data from this report and other sources is provided in Table 7-1. The units for sediment yield for a river is given as tonne of sediment per square kilometer of watershed area per year. The yield can be converted to a volume by using a specific weight of 1,300 kg/m^3 for sediment as measured by Montreal.

Sediment yield data was also obtained from the World River Sediment Yields Database maintained by the UN-FAO (UN-FAO, 2009). The US Bureau of Reclamation determined a sediment yield of 250 t/km^2/yr at the Arghandab Dam (Mort, 1973). A yield of 200 t/km^2/yr was calculated at the Kajakai reservoir by the USGS (Perkins, 1970).

Table 7-1 – Sediment Yields for Afghanistan

River	Location	Sediment Yield	Data Source
Panjshir	Panjshir I	275	(a)
Panjshir	Baghdara	455	(a)
Ghorband	Totumdara	420	(a)
Maidan	Hajian	250	(a)
Logar	Kajab	250	(a)
Logar	Gat	150	(a)
Kabul	Tangi Gharu	148	(a)
Kunar River	not provided	780	(b)
Arghandab	Arghandab Reservoir	250	(c)
Helmand	Kajakai	200	(d)
Ghorband	Pul-i-Ashawa	420	(e)
Hari Rud	Tagau Gaza	270	(e)
Kabul	Naghlu	410	(e)
Kabul	Tangi Saidan	280	(e)
Logar	Kajau	190	(e)
Pajshir	Mouth	455	(e)
Pajshir	Gulbahar	750	(e)
Shakhar Darya	Ak Sahai	273	(e)
Kabul	Nowshera, Pakistan	288	(f)

Sediment Yield Units = tonnes/sq km/year
(a) - Montreal (1980)
(b) - Electrowatt (1977)
(c) - Mort (1973)
(d) - Perkins (1970)
(e) - UN-FAO on-line database, Tkachev et al.
(f) - UN-FAO on-line database (no source, location:33.9967, 72.0131)

7.3 Sedimentation Analysis Results

An attempt was made to quantify the impact of sedimentation on the proposed irrigation storage dams using very limited sediment data. Sediment yield was used to calculate the number of years it would take for the proposed storage dams to become half-full of sediment. Assumptions had to be used in the sediment analysis and the results provided here should be used with caution. The major assumption used was sediment load. The sediment data presented in Section 7.2 and used in this analysis was calculated at stream locations with watersheds over 1,000 km^2. Many of the project watersheds evaluated in this assessment are under 20 km^2 and the sediment transport processes are expected to behave differently for the large watersheds. For this analysis, a sediment load of 200 t/km^2/yr was used for all projects in the Helmand and Garmab watersheds and a value of 250 t/km^2/yr for all other project watersheds and is considered conservative.

A sample of sedimentation results of the storage dams in the Shamal watershed are provided in Table 7-2. A complete set of results for each of the 13 study watersheds are provided in Appendix K. The spreadsheets include the watershed area, reservoir volume and number of years for the reservoir to be half-full of sediment. Results are provided for the maximized, 12 m, 8 m and 5 m high dams. The results are used in dam site evaluations contained in Section 6.0.

Even with the limits in sediment yield data, certain key conclusions can be observed from the analysis. One key point is the rapid filling of reservoirs located on steep stream slopes. For a 12-m high dam at Nika #1, the reservoir will be half-full of sediment in 5 years and in 20 years for a dam at Mana. The stream slope at the Mana dam is much flatter than at Nika #1 and will have a much larger storage volume to hold and manage accumulated sediment.

The size of the watershed influences sediment in the reservoir. A small dam on a very large watershed will fill rapidly because there is more land area to contribute sediment. An 8 m high dam at Ghorka Kalay and Khan Kala #2 has about the same reservoir storage volume but the watershed at Ghorka Kalay is over three times as large. The Ghorka Kalay reservoir will be half-full in 2 years and Khan Kala #2 in 10 years. As a rule of thumb, Oosterkamp recommends that a reservoir should have enough storage volume to hold at least one-year runoff volume.

The results presented in this section should be used with the recommendations from the watershed characterization in Section 10. The characterization will identify individual project watersheds with very high potential for large sediment yields. These types of watersheds are typically described as badlands. Dams at these locations should be avoided.

The results from this rough analysis help to illustrate the hard lessons learned at the sediment filled Hezarak Dam. Irrigation storage dams should not be located on steep stream slopes that provide little storage volume. The condition of the watershed should be reviewed to avoid landforms with exceptionally high sediment yields. Design and construct the dam appropriately to manage the stream sediment load. Irrigation and hydropower diversion structures can also be designed to pass sediment loads. The high sediment load of Afghanistan's streams should not prevent the construction of water resource improvement projects. Sedimentation should be appropriately considered in the site selection, design, operation and maintenance of the project.

Table 7-2 – Example Table of Estimated Reservoir Sedimentation Rates

Shamal Irrigation Storage Dams
Sedimentation Rate Estimates

Sediment Yield =	250	(tonne/km2/yr)
Specific Weight =	1.3	(tonne/m^3)

Name	**Watershed** Area (km2)	Maximized Dam Size			12-m High Dam		8-m High Dam		5-m High Dam	
		Height (m)	**Reservoir Storage Volume (1000 m3)**	**Years to Half Full (Yr)**	**Reservoir Storage Volume (1000 m3)**	**Years to Half Full (Yr)**	**Reservoir Storage Volume (1000 m3)**	**Years to Half Full (Yr)**	**Reservoir Storage Volume (1000 m3)**	**Years to Half Full (Yr)**
Acarkhel	131.00	22	1,670	33	455	9	205	4	81	2
Baak #2	98.45	19	1,218	32	426	11	168	4	56	1
Bazak	40.51	17	498	32	195	13	64	4	17	1
Ghorka Kalay	108.59	22	1,360	33	282	7	100	2	29	1
Ghorma	44.34	18	589	35	244	14	110	6	46	3
Kala	18.39	14	240	34	163	23	56	8	16	2
Khan Kala #2	29.41	7	79	7	299	26	108	10	36	3
Khatinkhel	70.49	22	940	35	233	9	91	3	34	1
Mana	224.98	17	3,034	35	1,710	20	884	10	383	4
Nasirkhel	33.89	21	420	32	87	7	25	2	6	0
Nika #1	79.13	21	940	31	151	5	44	1	10	0
Nika #2	25.22	17	317	33	128	13	51	5	19	2
Paktak	312.57	30	3,880	32	212	2	71	1	23	0
Sorwakay	764.46	30	5,030	17	608	2	228	1	65	0
Sulni Kalay #1	23.96	11	282	31	350	38	131	14	41	4
Sulni Kalay #2	48.52	10	574	31	845	45	359	19	122	7
Sur Gori	21.73	20	290	35	92	11	36	4	12	1
Zambar	43.58	15	544	32	301	18	104	6	30	2

Sediment yield data obtained from "Kabul River Valley Development Project, Vol. 2", Montreal Engineering Co., 1980.
The spreadsheet estimates the number of years for the reservoir to be half full of sediment deposited from the contributing watershed.
US Army Corps of Engineers - Wilmington District, Update Aug 21, 2009

8.0 Hydropower Results

8.1 Overview

Hydropower potential in southeast Afghanistan is limited more by the lack of available streamflow than from suitable terrain. The steep streams in the study area offer large elevation changes over short distances providing excellent driving head for hydropower turbines. The issue was that most of the streams are dry for many months of the year and irrigation demands divert large amounts of water out of the streams. A good hydropower site requires a constant baseflow year round to efficiently size the turbines and generators. Another issue encountered in evaluating hydropower sites was that many of the best locations that had both sufficient streamflow and steep elevation change were in very remote locations away from population centers. Additional analysis will be required to determine the maximum length the transmission lines can be without too much power loss and remain economically feasible.

All of the hydropower projects evaluated are run-of-river type and do not rely on head provided by dam height. A full explanation of the hydropower analysis is available in Section 4.2. The limited amount of available streamflow records has required many assumptions in the calculations in this assessment. Before any hydropower project is pursued in southeast Afghanistan, local knowledge of the streamflow characteristics should be obtained. Local Mirabs should be interviewed to determine if the project stream flows year round, what the minimum flows are and how high the annual and extreme flood elevations are.

Of the 295 water resource projects investigated in this assessment, hydropower was evaluated at 120 locations. A complete list of all 120 hydropower projects evaluated is provided in Table 8-14 at the end of this section. Appendix L contains satellite images of each of the 120 project sites and includes planning layout of the low diversion dam, headrace channel, penstock and powerhouse. Detailed analysis of each of the 120 sites is provided in Appendix L and includes spreadsheets with head calculations, streamflow and power generation in monthly time steps.

The following sections include a brief description and summary table of the 62 hydropower projects that have the most potential for success. The sections are separated into the 13 study watersheds. It should be noted that the kilowatts of power provided assumes all available streamflow is utilized by the powerhouse turbines and generators. Actual power provided will be less and will depend on the size and number of generator units in the powerhouse and the available streamflow. Sizing the units to efficiently utilize the high streamflows of spring and the low flows of fall will be a design issue. Field review of potential sites should include an assessment of impacted irrigated land. Agriculture should always have priority over hydropower but there may be options of cooperating with and compensating the impacted or relocated farmers. The planning phase should include a milestone that indentifies impacts to existing irrigation.

8.2 Arghandab

Most of the streams in the mountainous Arghandab watershed offer year round baseflow along very steep stream slopes to provide good hydropower potential. Of the ten sites evaluated in the Arghandab watershed, the four below offer the best potential. The population in the Arghandab study area is scattered along the narrow valley floors and none of the sites evaluated were near exceptionally dense population centers. Long transmission lines may be required to utilize all the power potential at the Balaqal site. The Dewkhana site has a watershed of only 95 km^2 so the streamflow characteristics should be confirmed with local knowledge to ensure sufficient flow to support hydropower. The Sabzak and Barikjoy sites will require long headrace channels that will have to be excavated along steep mountain slopes increasing their construction cost.

Table 8-1 Arghandab Hydropower Potential

Name	Longitude	Latitude	MGRS	Headrace Length	Potential Head	Generation Potential	
				(m)	(m)	(kW)	(kW-hr/yr)
Sabzak	67.3966	33.4199	42S UB 5092 9898	2,770	14.9	107	938,607
Balaqal	67.3871	33.2868	42S UB 4980 8424	1,850	27.6	551	4,837,054
Barikjoy	67.4693	33.2828	42S UB 5746 8368	2,000	23.0	164	1,438,757
Dewkhana	67.4871	33.3354	42S UB 5920 8949	1,240	40.0	77	676,693

8.3 Azrow

The recommended hydropower sites in the Azrow watershed all have good year round baseflow from the high, mountainous terrain. The Zera site has high power generation potential but its location in a deep, remote valley will require transmission lines over 4 km to the nearest population. The Khushhalkhel site has a small watershed of only 183 km^2 and the streamflow characteristics should be confirmed with local knowledge. The headrace channel for the Babar #1 site may negatively affect local irrigation diversions but offers good hydropower potential.

Table 8-2 Azrow Hydropower Potential

Name	Longitude	Latitude	MGRS	Headrace Length	Potential Head	Generation Potential	
				(m)	(m)	(kW)	(kW-hr/yr)
Babar #1	69.6313	34.1626	42S WC 5818 8036	2,015	36.9	371	3,253,889
Zera	69.7451	34.1807	42S WC 6866 8244	1,740	44.0	669	5,872,295
Khushhalkhel	69.6240	34.1501	42S WC 5752 7897	760	32.0	129	1,135,985

8.4 Chamkani

The steep stream slopes and year round baseflow provide good opportunity for hydropower in the Chamkani watershed. The Wam Hasankhel site has a large watershed providing year round flow and there should be enough flow not to interfere with existing irrigation. Construction cost for the Wam Hasankhel would be high because of the 4,600 m long headrace and transmission lines will have to be over 6 km long. The Kharzun #2 site is a good candidate for hydropower with little impacts to existing irrigation and short transmissions lines to serve nearby settlements. The Ghorushtay project has a large settlement nearby to serve but the watershed is only 209 km^2

so streamflow characteristics should be confirmed with local knowledge. Chawnay #1 site has good hydropower potential with nearby settlements but the headrace channel may affect existing irrigation. The Bekaray site requires a long headrace channel but there would be little impact to existing irrigation and there are settlements nearby that can utilize the power. The Sorway #1 site is the location for a large irrigation storage dam but is also a very good location for a smaller run-of-river hydropower project. The Sorway #1 headrace would be long but the high baseflow should provide enough water to prevent impacts to existing irrigation along its route.

Table 8-3 Chamkani Hydropower Potential

Name	Longitude	Latitude	MGRS	Headrace Length	Potential Head	Generation Potential	
				(m)	(m)	(kW)	(kW-hr/yr)
Wam Hasankhel	69.6524	33.8197	42S WC 6037 4235	4,600	30.9	663	5,816,905
Kharzun #2	69.6340	33.8490	42S WC 5865 4559	1,055	16.8	268	2,351,921
Ghorushtay	69.6428	33.9990	42S WC 5935 6223	1,180	26.3	122	1,070,696
Chawnay #1	69.7053	33.9184	42S WC 6519 5333	1,590	17.6	226	1,981,198
Bekaray	69.6117	33.8361	42S WC 5659 4415	2,700	66.2	389	3,415,224
Sorway #1	69.7366	33.7957	42S WC 6863 3999	3,810	31.8	543	4,775,678

8.5 Garmab

The Garmab watershed offers streams with good baseflow and steep gradients providing good hydropower potential. The problem with hydropower projects in this watershed will be the lack of concentrated population centers that can utilize the power. Long transmission lines will be required for the small settlements scattered along the narrow valleys. The Kusha, Tubi and Chamandi sites are all along the same tributary that discharges into the Garmab River. Even though the Tubi site has the longer headrace it is the better site because it offers the highest power generation potential. Tubi is also centrally located in the sparsely populated valley reducing power losses from long transmission lines.

Table 8-4 Garmab Hydropower Potential

Name	Longitude	Latitude	MGRS	Headrace Length	Potential Head	Generation Potential	
				(m)	(m)	(kW)	(kW-hr/yr)
Kusha	67.4929	33.9583	42S UC 6075 5855	1,925	35.3	241	2,115,423
Tubi	67.4616	33.9657	42S UC 5786 5941	2,415	52.3	614	5,392,667
Chamandi	67.4013	33.9870	42S UC 5234 6187	995	30.0	443	3,897,772

8.6 Ghazni – Lower (Sardeh)

The lower Ghazni watershed does not hold much potential for hydropower. Many of the streams in this watershed are dry for many months of the year and much of the streamflow is diverted to large irrigated areas. The site with the greatest potential is Akhunzada Koday and is located upstream of the existing Sultan Dam. Transmission cost should be low with the large nearby population but the headrace channel is almost 2,000 m long. The Paywandkushta, Qeshlaghak and Merzaka sites are all along the same 8 km length of stream near the village of Merzaka. The Paywandkushta site is the better of the three with the higher head and shorter transmission line distance. The Chambarak and Bum sites hold potential but the watersheds are relatively small so the streamflow characteristics should be investigated before pursuing.

Table 8-5 Ghazni-Lower Hydropower Potential

Name	Longitude	Latitude	MGRS	Headrace Length	Potential Head	Generation Potential	
				(m)	(m)	(kW)	(kW-hr/yr)
Chambarak	68.2273	33.7308	42S VC 2841 3257	985	20.1	22	193,009
Akhunzada Koday	68.3526	33.7653	42S VC 4004 3632	1,950	14.2	93	814,320
Paywandkushta	68.0550	33.3520	42S VB 1207 9071	3,050	76.8	84	736,169
Qeshlaghak	68.0424	33.3680	42S VB 1092 9248	2,015	52.9	56	494,340
Merzaka	68.0120	33.3777	42S VB 0809 9359	3,100	73.6	74	645,288
Bum	67.8183	33.2130	42S UB 8989 7551	540	10.1	11	94,064

8.7 Ghazni – Upper (Gardez)

The upper Ghazni watershed holds a moderate amount of hydropower potential. The better sites are on the steep tributaries draining the mountainous watersheds just before they empty into the wide Gardez-Jilga River Valley. The streamgage at Mechalghu has a watershed of 65 km^2 with a year round baseflow of 0.5 m^3/s. A recently completed micro-hydropower project is downstream of the Mechalghu gage. Other watersheds with similar characteristics to Mechalghu were identified. The site at Zundikhel has good hydropower potential with nearby population but streamflow characteristics need to be confirmed. The sites at Shekhan, Gardedkhwahi, Sepine Takhte and Bar Deray have hydropower potential but each site is relatively far from population centers requiring long transmission lines. The Liwan site is downstream of the existing Mechalghu hydropower site and is a good candidate. The headrace channel for the Liwan site may negatively affect existing irrigated land.

Table 8-6 Ghazni-Upper Hydropower Potential

Name	Longitude	Latitude	MGRS	Headrace Length	Potential Head	Generation Potential	
				(m)	(m)	(kW)	(kW-hr/yr)
Zundikhel	69.3235	33.7585	42S WC 2995 3542	1,020	27.9	115	1,008,704
Shekhan	69.0709	33.6123	42S WC 0657 1917	2,000	58.0	242	2,125,552
Gardedkhwahi	69.0900	33.3021	42S WB 0837 8477	1,740	20.0	76	671,032
Sepine Takhte	69.1876	33.4045	42S WB 1744 9614	850	27.9	115	1,008,704
Liwan	69.3760	33.7972	42S WC 3481 3973	2,120	29.5	109	953,535
Bar Deray	69.0941	33.3435	42S WB 0874 8938	2,100	25.6	135	1,185,697

8.8 Helmand

Of the 13 study watersheds, the Helmand watershed held the best promise for hydropower projects. The mountainous watersheds provided year round stream baseflow and the steep stream slopes provided driving head for the turbines. Cold temperatures will be an issue at this high elevation but properly trained staff can keep the project operating year round.

The Sinak site had the largest power generation potential of all the sites investigated. The headrace channel was very long at over 4,800 m but there are possibilities of a shorter configuration on the opposite stream bank. With the large amount of available flow from the Helmand River, the Sinak headrace channel could also serve as an irrigation diversion channel. The valley at Sinak opens into a wide plain and agriculture could be improved and expanded by increased irrigation.

The sites at Qala-i-Haydar, Otopur and Zarkharid #1 and #2 have good hydropower potential but are in areas of low population. The Dahan-e Abdullah and Panjasya sites are along the same 5 km section of the Helmand River but the Dahan-e site has higher power potential. The Gardandeh site has high power potential with a very short headrace but is far from population. The Abbas Koshteh site is within 3 km of the populated agriculture centers of Siah Zamin and Nawarha but the site has a watershed of only 106 km^2. The sites at Khuskdana and Shinah are good project locations but distribution to the scattered population may be an issue.

Table 8-7 Helmand Hydropower Potential

Name	Longitude	Latitude	MGRS	Headrace Length	Potential Head	Generation Potential	
				(m)	(m)	(kW)	(kW-hr/yr)
Zarkharid #1	68.2641	34.5074	42S VD 3243 1866	1,540	13.8	267	2,349,642
Zarkharid #2	68.2396	34.5127	42S VD 3019 1926	1,050	20.8	223	1,963,241
Qala-i-Haydar	68.1715	34.5839	42S VD 2402 7210	1,040	17.8	121	1,061,689
Dahan-e Abdullah	68.0839	34.4933	42S VD 1589 7239	2,855	23.6	806	7,082,643
Sinak	67.8089	34.4137	42S UD 9054 0866	4,813	24.7	1,529	13,441,206
Panjasya	68.0539	34.4946	42S VD 1314 7402	1,950	6.2	216	1,899,201
Abbas Koshteh	67.6401	34.3353	42S UD 7490 0017	745	25.0	96	840,609
Gardandeh	67.7161	34.4108	42S UD 8222 0795	480	55.1	682	5,991,393
Otopur	68.1532	34.5996	42S VD 2235 2896	1,155	35.4	223	1,963,241
Khuskdana	67.8785	34.4530	42S UD 9698 1295	1,410	31.4	120	1,058,384
Shinah	67.8049	34.4492	42S UD 9022 1261	1,495	37.0	164	1,438,629

8.9 Kabul

Most of the Kabul River Valley located in the assessment study area was too wide and flat to be suitable for run-of-river hydropower. Two locations were identified on the lower end of the river as the valley narrows and steepens just before entering the Kabul Province. The Padshakhel and Av Darreh sites both have very good hydropower potential but will require transmission lines over 10 km to reach the population center near Sur Pol. The Surkhgelak site is located on a tributary to the Maidan River and has over 44 m of head but the small watershed will require confirmation of streamflow characteristics. The Garmak site is also on a tributary and will require confirmation that there is enough streamflow to support hydropower. There are population centers up and downstream of the Garmak site.

Table 8-8 Kabul Hydropower Potential

Name	Longitude	Latitude	MGRS	Headrace Length	Potential Head	Generation Potential	
				(m)	(m)	(kW)	(kW-hr/yr)
Surkhgelak	68.7311	34.5983	42S VD 7534 2852	1,730	44.1	133	1,167,871
Padshakhel	68.9369	34.3784	42S VD 9420 0411	2,510	19.0	550	4,819,376
Av Darreh	68.8780	34.3188	42S VC 8877 9751	4,300	11.8	335	2,939,703
Garmak	68.4963	34.4327	42S VD 5372 1025	1,815	20.7	104	910,688

8.10 Logar – Lower

The sites at Chalakhel and Takhtak would both utilize flows released from the existing Kharwar Dam on the Charkh River. The Charkh River drops steeply downstream of the dam, offering very high potential head at the two hydropower sites. Chalakhel has a head of 182 m but the headrace is almost 3,500 m long. Both sites would serve the heavily populated areas near Nawshad in the Charkh District of Logar.

The Godan and Girdab sites are located along a section of the Logar River with a mild slope offering little potential head. The sites make up for little head by having a relatively high minimum baseflow of 3 m^3/s and are close to dense population along the valley. The Durow and Khushi sites are located on tributaries to the Logar River with watersheds of 158 and 146 km^2 respectively. These two sites are also located upstream of population centers. The flow characteristics of these smaller watersheds will need to be confirmed to ensure they can support hydropower.

Table 8-9 Logar-Lower Hydropower Potential

Name	Longitude	Latitude	MGRS	Headrace Length	Potential Head	Generation Potential	
				(m)	(m)	(kW)	(kW-hr/yr)
Chalakhel	68.8732	33.7303	42S VC 8824 3225	3,470	182.1	685	6,020,879
Godan	68.7189	34.1504	42S VC 7408 7887	2,140	11.4	449	3,935,461
Girdab	68.7081	34.1499	42S VC 7308 7881	3,465	14.1	553	4,849,354
Durwo	69.2913	34.1376	42S WC 2685 7740	1,820	39.7	314	2,757,689
Takhtak	68.8980	33.7489	42S VC 9049 3422	1,290	34.8	132	1,161,713
Khushi	69.2617	33.9761	42S WC 2418 5952	325	45.7	334	2,927,210

8.11 Logar – Upper

The Kajab site has been investigated in previous studies for a large irrigation storage dam over 70 m in height. The Kajab site also has potential for a run-of-river hydropower project without a large dam in place. The site would require a relatively long headrace channel but there is good baseflow and dense population along the river valley that could utilize the power with short transmission lines. The long headrace could affect local irrigation networks but there should be sufficient flow in the Logar for the headrace to also supply water to irrigated land in the valley.

The Bodak and Gidargu sites are both located along a section of the Logar River where the valley narrows downstream of heavily cultivated areas. The mild stream slope provides little potential head but there is good year-round baseflow to provide a moderate amount of power. The Shew Qowl and Sangshanda sites are located on tributaries to the Logar and are good hydropower sites but may be too far from populated areas to be practical.

Table 8-10 Logar-Upper Hydropower Potential

Name	Longitude	Latitude	MGRS	Headrace Length	Potential Head	Generation Potential	
				(m)	(m)	(kW)	(kW-hr/yr)
Kajab	68.4987	34.2346	42S VC 5383 8828	3,810	22.8	834	7,317,125
Bodak	68.2822	34.2828	42S VC 3392 9375	1,200	11.2	93	819,137
Gidargu	68.2890	34.2734	42S VC 3455 9269	1,430	10.3	107	939,383
Shew Qowl	67.8512	34.0388	42S UC 9395 6705	460	31.2	78	685,527
Sangshanda	68.2112	33.9949	42S VC 2715 6187	1,285	16.9	51	445,127

8.12 Samanka

The Gule Badam site is located on a steep section of the Samanka River offering high potential head and good year round baseflow. Gule Badam is a very good site but is over 30 km from the densely populated area near Usmankhel and Ajrestan. Further analysis will be required to determine if the cost of transmission lines and the power losses along those long lines justify the Gule Badam project. The sites at Chaqmaq and Qala-i-Qoli are closer to population centers but have less than one forth of the power generation potential as Gule Badam. The Baba Wali site is located on the upper Samanka and is a good site but the long headrace channel may not justify supplying power to the sparsely populated area.

Table 8-11 Samanka Hydropower Potential

Name	Longitude	Latitude	MGRS	Headrace Length	Potential Head	Generation Potential	
				(m)	(m)	(kW)	(kW-hr/yr)
Chaqmaq	66.9283	33.3392	42S UB 0722 9079	1,145	11.4	399	3,502,953
Gule Badam	66.8509	33.3797	42S UB 0010 9544	2,500	43.0	1,648	14,461,322
Qala-i-Qoli	67.0727	33.4163	42S UB 2080 9911	3,300	8.8	272	2,384,872
Baba Wali	67.3398	33.6272	42S UC 4600 2206	2,310	19.8	257	2,257,001

8.13 Shamal

The limiting issue for hydropower in the Shamal watershed is lack of continuous streamflow. The Dowa Manda site provided the best opportunity for hydropower in the Shamal watershed. Dowa Manda has a relatively large watershed of 1,550 km^2 but the streamgage records at Domandi indicate flows less than 1.0 m^3/s for five months of the year. At 1.0 m^3/s the Dowa Manda site could only produce 140 kW. The 3,610 m long headrace channel may not justify the low power output. The Sorwakay site is approximately 5 km upstream of Dowa Manda but has a smaller watershed of 765 km^2. The Sorwakay site has good potential head but the Dowa Manda site should be pursued instead because the larger watershed will have a more reliable streamflow.

The Kamkay Mazghar and Paktak sites are along the Matun River and have good potential for producing a moderate amount of power. Population centers for both are nearby reducing transmission cost. The headraces for both sites are along valleys with little cultivated land so there should be little impacts to existing irrigation diversions. The Matun streamflow gage has a mean annual discharge of 0.77 m^3/s and low flow of 0.3 m^3/s in October.

The Ghorka Kalay site in the Jadran District is a good location for a diversion dam and the stream has a steep slope but there is little population to serve in this remote area. The small Ghorka watershed may not be able to supply enough flow to justify a project, streamflow characteristics should be confirmed with local knowledge. The Mana site also has great terrain for a hydropower project but the lack of nearby population may not justify a project. Field review should investigate power demand in this service area and streamflow characteristics.

Table 8-12 Shamal Hydropower Potential

Name	Longitude	Latitude	MGRS	Headrace Length	Potential Head	Generation Potential	
				(m)	(m)	(kW)	(kW-hr/yr)
Dowa Manda	69.6130	33.2909	42S WB 5707 8370	3,610	28.6	311	2,732,462
Tange Sultankhel	69.3632	33.2037	42S WB 3385 7392	1,335	38.7	69	606,250
Ghorka Kalay	69.4276	33.3467	42S WB 3979 8980	1,385	32.5	25	218,741
Mana	69.5195	33.1805	42S WB 4843 7141	315	31.7	50	440,208
Kamkay Mazghar	69.8770	33.4030	42S WB 8105 9697	1,500	31.0	115	1,013,058
Paktak	69.8552	33.4365	42S WC 7949 0000	1,340	24.6	88	772,117
Sorwakay	69.5825	33.2610	42S WB 5425 8036	2,190	28.2	151	1,330,842

8.14 Tarnak

The Tarnak watershed does not hold much potential for hydropower. The low annual precipitation and high rate of evaporation in this region of Afghanistan limits the amount of streamflow available year round. The Khakrez and Kalan Deh sites may be possible but streamflow characteristics should be investigated before pursuing.

Table 8-13 Tarnak Hydropower Potential

Name	Longitude	Latitude	MGRS	Headrace Length	Potential Head	Generation Potential	
				(m)	(m)	(kW)	(kW-hr/yr)
Khakrez	67.7578	33.1312	42S UB 8413 6652	1,710	24.2	19	169,022
Kalan Deh	67.7773	33.1014	42S UB 8591 6319	1,270	33.9	36	313,268

Table 8-14 – Hydropower Evaluations

								Potential Power			
Project	Study			Invert Elevation		Headrace	Potential	Mean		85% Exceeded	
Name	Watershed	Province	Watershed	Upstream	Dnstream	Length	Head	Streamflow		Streamflow	
			(km^2)	(m)	(m)	(m)	(m)	(kW)	(kW-hr)	(kW)	(kW-hr)
Awlaya	Arghandab	Ghazni	80.27	3,019	2,981	1,500	34	55	483,991	28	249,117
Malistan	Arghandab	Ghazni	87.76	2,950	2,914	1,830	31	54	477,482	28	245,767
Tangi	Arghandab	Ghazni	324.87	2,726	2,700	1,380	23	148	1,295,123	76	666,619
Diwal	Arghandab	Ghazni	101.63	3,115	3,090	1,335	22	44	390,378	23	200,933
Balaqal	Arghandab	Ghazni	988.25	2,640	2,607	1,850	28	551	4,837,054	284	2,489,703
Pay Tangi	Arghandab	Ghazni	70.44	2,780	2,727	1,200	50	71	627,087	37	4,335,254
Dewkhana	Arghandab	Ghazni	95.30	2,683	2,640	1,240	40	77	676,693	40	348,304
Barikjoy	Arghandab	Ghazni	352.74	2,545	2,516	2,000	23	164	1,438,757	85	740,550
Sabzak	Arghandab	Ghazni	354.42	2,828	2,804	2,770	15	107	938,607	55	483,115
Namdar Kala	Azrow	Logar	87.48	2,360	2,301	1,660	54	105	926,120	49	427,808
Khushhalkhel	Azrow	Logar	182.51	2,411	2,378	760	32	129	1,135,985	60	524,752
Kacwal	Azrow	Logar	183.75	2,716	2,673	1,795	38	154	1,353,406	71	625,186
Babar #1	Azrow	Logar	452.30	2,356	2,313	2,015	37	371	3,253,889	171	1,503,086
Zera	Azrow	Logar	684.67	2,112	2,063	1,740	44	669	5,872,295	309	2,712,620
Dadikhel	Azrow	Logar	46.83	2,493	2,458	665	34	36	313,187	16	144,672
Khangul Kot	Chamkani	Paktya	26.80	2,872	2,859	950	11	7	58,456	3	27,003
Wech Peray	Chamkani	Paktya	53.90	2,740	2,708	1,375	29	34	299,166	16	138,196
Pala	Chamkani	Paktya	38.50	2,422	2,369	460	53	45	398,589	21	184,122
Stya	Chamkani	Paktya	45.00	1,712	1,693	375	20	19	170,894	9	78,942
Ganday Shykhan	Chamkani	Paktya	88.00	2,254	2,226	745	27	53	463,071	24	4,920,107
Sra Kholeh	Chamkani	Paktya	51.80	2,620	2,537	580	83	95	834,083	44	385,293
Shawat	Chamkani	Paktya	36.50	2,188	2,137	710	50	41	356,558	19	164,707
Ghorushtay	Chamkani	Paktya	209.20	2,327	2,298	1,180	26	122	1,070,696	56	494,592
Bekaray	Chamkani	Paktya	264.90	2,062	1,987	2,700	66	389	3,415,224	180	1,577,613
Shegaray	Chamkani	Paktya	121.60	2,095	2,071	760	23	62	543,732	180	1,577,613
Wam Hasankhel	Chamkani	Paktya	1044.50	1,889	1,843	4,600	31	663	5,816,905	332	2,914,232
Kharzun #2	Chamkani	Paktya	719.70	1,953	1,934	1,055	17	268	2,351,921	124	1,086,435
Chawnay #1	Chamkani	Paktya	576.70	2,088	2,066	1,590	18	226	1,981,198	104	915,185
Sorway #1	Chamkani	Paktya	1285.60	1,778	1,733	3,810	32	543	4,775,678	154	1,355,112
Gardan Deh	Garmab	Ghazni	261.44	2,927	2,898	1,125	27	250	2,194,069	138	1,209,200
Shinyah	Garmab	Ghazni	61.01	2,998	2,956	725	41	90	794,100	50	437,646
Dahane Qol	Garmab	Ghazni	473.61	2,698	2,658	2,045	34	577	5,072,557	318	2,795,598
Garmak	Garmab	Ghazni	65.47	2,660	2,604	660	55	131	1,147,812	72	632,585
Kajak	Garmab	Ghazni	580.49	2,529	2,502	1,525	23	479	4,209,812	264	2,320,120
Dame Joy #1	Garmab	Ghazni	174.82	2,880	2,853	2,175	20	128	1,123,879	70	619,395
Kusha	Garmab	Ghazni	189.23	2,847	2,806	1,925	35	241	2,115,423	133	1,165,856
Tubi	Garmab	Ghazni	325.34	2,780	2,720	2,415	52	614	5,392,667	338	2,972,018
Chamandi	Garmab	Ghazni	409.99	2,596	2,564	995	30	443	3,897,772	244	2,148,148
Chambarak	Ghazni-Lower	Ghazni	126.12	2,550	2,528	985	20	22	193,009	8	69,753
Fadzel	Ghazni-Lower	Ghazni	103.01	2,680	2,655	1,175	22	20	175,245	7	63,333

Table 8-14 continued – Hydropower Evaluations

								Potential Power			
Project	Study			Invert Elevation		Headrace	Potential	Mean		85% Exceeded	
Name	Watershed	Province	Watershed	Upstream	Dnstream	Length	Head	Streamflow		Streamflow	
			(km^2)	(m)	(m)	(m)	(m)	(kW)	(kW-hr)	(kW)	(kW-hr)
Akhunzada Koday	Ghazni-Lower	Ghazni	751.70	2,395	2,375	1,950	14	93	814,320	34	294,293
Khwajagan	Ghazni-Lower	Ghazni	71.03	2,489	2,459	1,120	28	1	8,053	0	1,168
Qala-i Surkh #2	Ghazni-Lower	Ghazni	96.96	2,286	2,274	660	11	8	69,098	2	14,155
Syahgel	Ghazni-Lower	Ghazni	149.05	2,243	2,230	1,235	10	11	94,064	2	19,269
Paywandkushta	Ghazni-Lower	Ghazni	152.80	2,460	2,373	3,050	77	84	736,169	17	150,807
Qeshlaghak	Ghazni-Lower	Ghazni	148.85	2,528	2,469	2,015	53	56	494,340	12	101,267
Merzaka	Ghazni-Lower	Ghazni	139.76	2,630	2,546	3,100	74	74	645,288	15	132,189
Bum	Ghazni-Lower	Ghazni	138.73	2,516	2,499	540	10	11	94,064	2	19,269
Wach Ghrak	Ghazni-Upper	Paktya	22.29	2,608	2,580	975	26	29	255,916	16	137,583
Kosin #2	Ghazni-Upper	Paktya	12.92	2,788	2,747	925	39	25	223,358	14	120,079
Darabal Kala #1	Ghazni-Upper	Paktya	38.97	2,427	2,399	1,290	25	49	425,822	26	228,926
Shekhan	Ghazni-Upper	Paktya	83.31	2,460	2,396	2,000	58	242	2,125,552	130	1,142,717
Bar Deray	Ghazni-Upper	Paktya	105.29	2,271	2,239	2,100	26	135	1,185,697	73	637,442
Sepine Takhte	Ghazni-Upper	Paktya	65.66	2,435	2,400	850	28	115	1,008,704	62	542,289
Liwan	Ghazni-Upper	Paktya	73.43	2,658	2,622	2,120	30	109	953,535	58	512,629
Gardedkhwahi	Ghazni-Upper	Paktya	76.12	2,340	2,315	1,740	20	76	671,032	41	360,753
Zundikhel	Ghazni-Upper	Paktya	69.39	2,670	2,640	1,020	28	115	1,008,704	62	542,289
Zarkharid #1	Helmand	Wardak	610.54	2,957	2,939	1,540	14	267	2,349,642	153	1,349,776
Zarkharid #2	Helmand	Wardak	213.70	2,953	2,930	1,050	21	223	1,963,241	117	1,029,875
Otopur	Helmand	Wardak	126.79	3,108	3,070	1,155	35	223	1,963,241	117	1,029,875
Qala-i-Haydar	Helmand	Wardak	134.74	3,057	3,037	1,040	18	121	1,061,689	63	556,940
Panjasya	Helmand	Wardak	1101.61	2,837	2,825	1,950	6	216	1,899,201	124	1,091,016
Sinak	Helmand	Wardak	1953.20	2,660	2,618	4,813	25	1,529	13,441,206	878	7,721,442
Kuhnaqala	Helmand	Bamyan	165.66	2,827	2,797	1,175	27	163	1,432,230	90	789,333
Abbas Koshteh	Helmand	Wardak	106.09	2,650	2,624	745	25	96	840,609	53	463,278
Gardandeh	Helmand	Wardak	343.48	2,650	2,595	480	55	682	5,991,393	376	3,301,989
Khuskdana	Helmand	Wardak	106.57	2,770	2,735	1,410	31	120	1,058,384	66	583,299
Shinah	Helmand	Wardak	122.71	2,729	2,688	1,495	37	164	1,438,629	90	792,860
Dahan-e Abdullah	Helmand	Wardak	1080.19	2,871	2,838	2,855	24	806	7,082,643	462	4,068,699
Surkhgelak	Kabul	Wardak	95.28	2,747	2,698	1,730	44	133	1,167,871	76	670,896
Garmak	Kabul	Wardak	157.91	2,570	2,544	1,815	21	104	910,688	59	523,155
Av Darreh	Kabul	Wardak	1462.36	2,112	2,085	4,300	12	335	2,939,703	113	991,000
Padshakhel	Kabul	Wardak	1513.32	2,039	2,012	2,510	19	550	4,819,376	186	1,624,654
Chino Sar	Logar Lower	Logar	59.59	2,429	2,378	1,435	47	141	1,238,835	76	666,010
Bum Wardak	Logar Lower	Wardak	203.45	2,305	2,267	1,995	32	54	470,197	29	251,674
Soja #1	Logar Lower	Wardak	64.88	2,490	2,460	810	29	36	313,416	12	105,655
Godan	Logar Lower	Wardak	714.19	2,104	2,086	2,140	11	449	3,935,461	241	3,546,452
Girdab	Logar Lower	Wardak	699.56	2,112	2,086	3,465	14	553	4,849,354	296	2,595,631
Shaghasi Kala	Logar Lower	Logar	4527.03	1,878	1,868	2,140	4	186	1,625,159	98	859,370
Urdu	Logar Lower	Wardak	111.24	2,300	2,276	790	23	49	426,755	16	143,863

Table 8-14 continued - Hydropower Evaluations

								Potential Power			
Project	Study			Invert Elevation		Headrace	Potential	Mean		85% Exceeded	
Name	Watershed	Province	Watershed	Upstream	Dnstream	Length	Head	Streamflow		Streamflow	
			(km^2)	(m)	(m)	(m)	(m)	(kW)	(kW-hr)	(kW)	(kW-hr)
Soja #2	Logar Lower	Wardak	72.12	2,460	2,403	1,890	51	70	614,489	24	207,150
Durwo	Logar Lower	Logar	157.83	2,263	2,218	1,820	40	314	2,757,689	169	1,482,560
Takhtak	Logar Lower	Logar	572.40	2,239	2,201	1,290	35	132	1,161,713	78	684,279
Tangay	Logar Lower	Logar	96.43	2,509	2,478	385	32	152	1,334,496	82	717,438
Khushi	Logar Lower	Logar	145.61	2,368	2,323	325	46	334	2,927,210	179	1,573,696
Chalakhel	Logar Lower	Logar	567.52	2,420	2,226	3,470	182	685	6,020,879	404	3,546,452
Kajab	Logar Upper	Wardak	5417.92	2,339	2,303	3,810	23	834	7,317,125	508	4,451,399
Bokan	Logar Upper	Ghazni	2026.00	2,880	2,858	700	21	83	731,796	51	445,190
Jawqul	Logar Upper	Wardak	69.76	2,982	2,939	1,195	40	89	780,189	51	448,188
Sare Sang	Logar Upper	Wardak	76.07	2,930	2,866	2,130	58	138	1,215,854	79	698,460
Bodak	Logar Upper	Wardak	864.46	2,533	2,519	1,200	11	93	819,137	57	498,325
Gidargu	Logar Upper	Wardak	1080.08	2,521	2,507	1,430	10	107	939,383	65	571,477
Taybum	Logar Upper	Ghazni	147.66	2,836	2,803	1,735	28	36	316,091	13	114,235
Dahane Bum	Logar Upper	Ghazni	100.85	2,916	2,865	1,930	45	40	348,373	14	125,901
Ternawa	Logar Upper	Ghazni	3095.33	2,655	2,638	1,375	14	192	1,687,349	117	1,026,505
Sare Bed	Logar Upper	Ghazni	217.64	3,081	3,053	2,200	21	40	351,995	14	127,210
Shew Qowl	Logar Upper	Ghazni	288.38	2,967	2,936	460	31	78	685,527	28	247,748
Sangshanda	Logar Upper	Wardak	346.07	2,725	2,705	1,285	17	51	445,127	18	160,868
Gurgkushta	Logar Upper	Ghazni	1963.53	2,970	2,934	1,355	33	98	858,813	35	310,373
Kareze Gholak	Logar Upper	Ghazni	234.08	2,752	2,710	4,395	26	60	523,228	36	318,308
Madras	Samanka	Ghazni	84.11	3,075	3,035	2,030	34	58	505,354	30	260,113
Qategha	Samanka	Ghazni	88.77	2,919	2,907	535	12	21	186,705	11	96,100
Baba Wali	Samanka	Ghazni	644.08	2,755	2,728	2,310	20	257	2,257,001	133	1,161,712
Chaqmaq	Samanka	Ghazni	1729.67	2,370	2,356	1,145	11	399	3,502,953	206	1,803,022
Gule Badam	Samanka	Ghazni	1896.42	2,990	2,239	2,500	43	1,648	14,461,322	850	7,443,456
Qala-i-Qoli	Samanka	Ghazni	1528.19	2,469	2,449	3,300	9	272	2,384,872	140	1,227,529
Tange Sultankhel	Shamal	Paktika	254.38	2,131	2,089	1,335	39	69	606,250	13	117,119
Mana	Shamal	Khost	224.98	1,792	1,761	315	32	50	440,208	10	85,042
Khatinkhel	Shamal	Khost	70.49	1,865	1,816	670	48	24	209,972	5	40,564
Kamkay Mazghar	Shamal	Khost	325.97	1,335	1,300	1,500	31	115	1,013,058	27	237,739
Paktak	Shamal	Khost	312.57	1,420	1,381	1,340	25	88	772,117	21	181,196
Kanay	Shamal	Khost	82.38	1,617	1,583	830	31	29	253,049	7	59,384
Khargoray	Shamal	Khost	445.14	1,757	1,730	1,570	23	71	623,465	14	120,445
Acarkhel	Shamal	Khost	131.00	1,949	1,919	1,190	27	25	219,981	5	42,497
Ghorka Kalay	Shamal	Paktya	108.59	1,980	1,944	1,385	33	25	218,741	23	204,816
Dowa Manda	Shamal	Khost	1551.99	1,478	1,437	3,610	29	311	2,732,462	60	527,874
Sorwakay	Shamal	Khost	764.46	1,547	1,512	2,190	28	151	1,330,842	29	257,100
Nika #1	Shamal	Khost	79.13	2,466	2,415	1,575	50	28	242,440	5	46,836
Khakrez	Tarnak	Ghazni	111.52	2,427	2,398	1,710	24	19	169,022	4	34,837
Kalan Deh	Tarnak	Ghazni	147.22	2,355	2,318	1,270	34	36	313,268	7	64,567

9.0 Results - Irrigation Diversion Structures

9.1 Overview

It was not possible to fully evaluate irrigation diversion structures using the remote sensing dataset and techniques. Irrigation diversions are structures used to redirect flow from a stream and into an irrigation canal. The structure can either be a low dam diverting all flow into the irrigation canal or a weir that allows some streamflow to pass over the structure. The water elevation differences used to drive the diverted flow are in the range of a few centimeters or less. The accuracy of the digital elevation model can be as much as +/- 3.0 m but is usually within +/- 0.5 m. More detailed analysis was possible with the irrigation storage dams and hydropower projects because those dam heights and the elevation differences were well above the 3.0 m tolerances.

Even with the limits of the remote sensing dataset, the analysis was able to identify many potential diversion project locations. These locations were deemed to have good potential based on available streamflow, stream channel configuration and downstream terrain favorable to agriculture. These sites will require further investigation on the ground to confirm suitable soil types. A topographic survey will ultimately be required to properly evaluate the diversion.

9.2 Results

Appendix M includes a complete list of 110 potential irrigation diversion projects. A large-scale map of the five province study area with diversion locations is also provided in Appendix M. This list includes 26 existing irrigation structures. Many of the existing structures are located along the extensively irrigated Logar River Valley. The existing diversions identified are permanent structures and are likely in need of repair or improvement. The list also includes 16 locations that could operate as a combination micro-hydropower and irrigation diversions. These 16 locations will require further investigation to determine if the hydropower headrace bypasses irrigated land. Agriculture water demands should have priority over hydropower demands.

The potential irrigation diversion projects were given a simple rating of 1 to 5. A good project worth further investigation was given a rating of 5. A project with a lower potential of success was given a rating of 1. Decision support models were not used for diversions because of the limited amount of analysis that was possible. The limited elevation dataset and satellite images were used to evaluate each diversion site. Factors considered in the rating were streambed stability, existing nearby agriculture, watershed size, stream baseflow and downstream terrain suitable for cultivation.

Diversion structures along the major rivers tended to be better sites than those on the tributary streams. The major river sites tended to have more stable streambeds, year-round baseflow and suitable terrain for cultivation in the open valleys. The exception to this was tributary streams draining mountainous watersheds that were stable and had good baseflow. The majority of the tributary streams have unstable meandering channels with high sediment loads. Diversions built on these unstable streams would likely have sedimentation issues.

As with the irrigation storage dams, the best sites for the diversions tended to be in the Logar-Upper and Ghazni-Lower watersheds. These watersheds are located in the Logar, Wardak and northern Ghazni Provinces. Many of the streams in these provinces drained mountainous areas and have a higher likelihood of continuous baseflow. Many of the sites in the Shamal, Chamkani and Ghazni-Upper watersheds would have sedimentation issues with the unstable streambeds and highly erosive uplands.

Afghan farmers have solved the sediment problem of diversion on unstable streambeds by building temporary small rock dams across the streams each spring. The rock diversions can easily be re-built after spring floods. On the smaller unstable streams, the temporary rock dam is more appropriate than a permanent concrete structure for most locations.

It is recommended that TF Yukon focus efforts on existing diversion structures. Existing structures ranked high because they are generally built in good locations. Most of these existing structures are along the well defined and stable river channels in heavily cultivated valleys. The structures are likely in need of repair and can be improved with sluice gates or completely rebuilt.

One result of the limited ability to evaluate new project sites was the development of map books of heavily irrigated river valleys that have existing diversion structures. The map books consist of a series of 11” x 17” map sheets at a scale of 1:10,000. A sample sheet from the Logar River map book is provided in Figure 9-1. The maps include 20-m contours and a map sheet key is provided for orientation. A draft copy of the complete Logar River map book is provided in Appendix M. Each map sheet has been exported as a high resolution *.pdf image and can be zoomed in for higher detail.

One problem PRT personnel have noted was the inability to locate existing diversion structures from the roadway because of heavy vegetation blocking the view. The PRTs were receiving requests from local farmers for assistance in repairing existing diversion structures. With the map book, the PRTs will be able to plan routes in the office and carrying printed versions of the map books in the field while navigating along the valley. The map books are being prepared under a separate scope of work. Existing diversions will be noted on the maps. Because the maps may cover sensitive locations, the map books will be designated For Official Use Only with TF Yukon and AED responsible for its distribution.

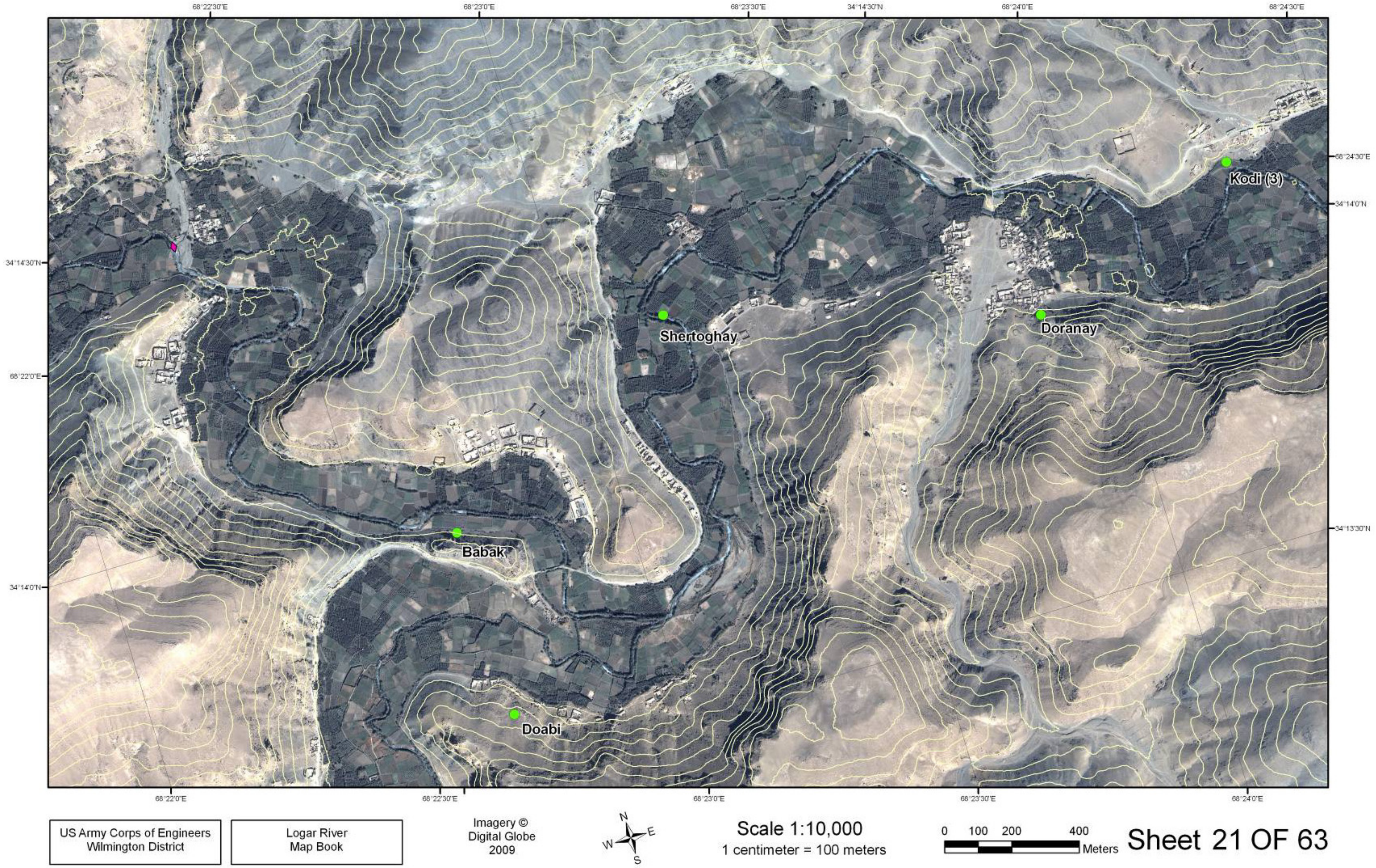


Figure 9-1 – Example Panel from Logar River Map Book

10.0 Watershed Management

Potential for watershed restoration is influenced by the condition of the watershed stream system, overall active erosion, and degree of deforestation in forested areas. Watersheds with favorable conditions may be stronger candidates for resource allocation. A higher proportion of actively-eroding upland provides more opportunities for upland restoration and more potential for reforestation projects at higher elevations. A relatively stable stream system increases the opportunities for streambank restoration projects, and increases chances of their success. Finally, local population and existing agricultural infrastructure make any project more beneficial. *Subject to other considerations (such as security, access, vegetative condition, and remoteness) watersheds with these characteristics are the likely places where watershed restoration would be successful.*

To remotely prioritize the 295 proposed project watersheds we developed a structured decision support model, based on data gathered in the assessment. Since it is based on consistently measured watershed properties, it can be used to help guide watershed restoration efforts on the ground. It is not site-specific. The advantages of using it include systematic and consistent rating for each of many projects, repeatability and documentation, the ability to modify the rating system as circumstances change, and the ability to include subjective weights to modify the objective data in the rating system. The conceptual background of the decision support model is described in detail in Section 4.5. Methods for the watershed restoration application and a detailed discussion of results are in Appendix N.

Ratings are based on a decision support model with four criteria. Figure 10-1 shows the decision support model with attached weights for each criterion. For this model each of the main criteria (Deforestation, Stream System Instability, Potential Agro-benefits, and Upland Erosion) are weighted equally. Each criterion and the rating system for it are described below.

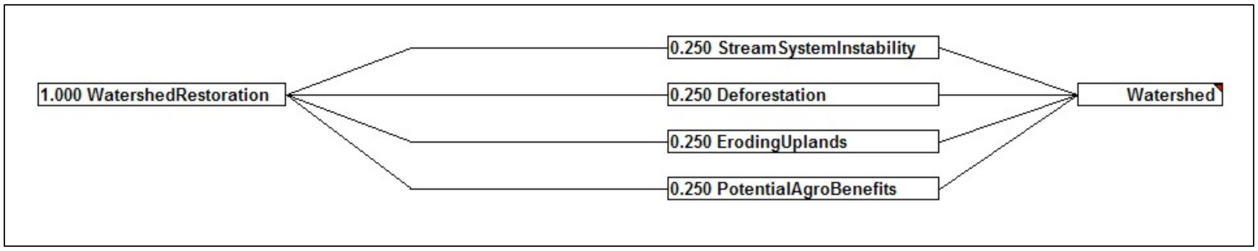


Figure 10-1 Decision Support Model for Restoration

StreamSystemInstability: This rating reflects the instability of stream systems, which influence sediment and flooding, as well as bank vegetation and channel character. See Section 4.4.2, Stream System Characterization for details on evaluating this factor. See Figure 10-2 and Figure 10-3 for an example of unstable and stable systems, respectively. Note in Figure 10-2 two dates of imagery showing large flow differences between spring and summer flows and the wide, unstable flood plain. See Section 4.42, Figure 4-10, Figure 4-15, and associated discussion for more details.

This variation limits the success and increases the scope of any proposed streambank restoration projects. Projects in areas similar to Figure 10-3 may have greater success. This criterion uses an inverse scale with lower values of instability indicating a higher likelihood of conditions favoring successful stream system restoration.

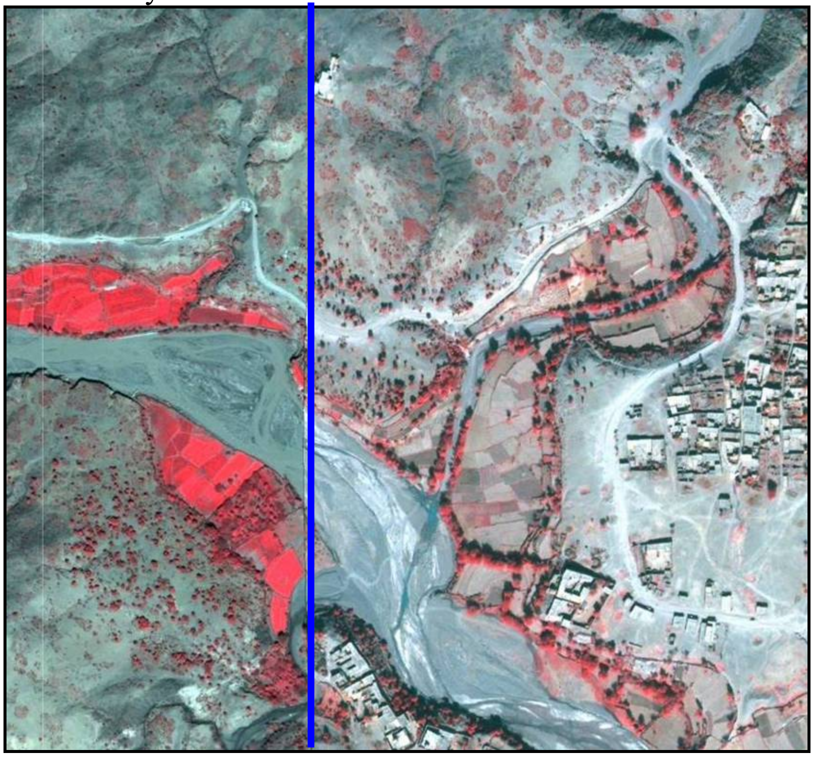


Figure 10-2 Unstable Stream System (flood season left and dry on right) (© DigitalGlobe)

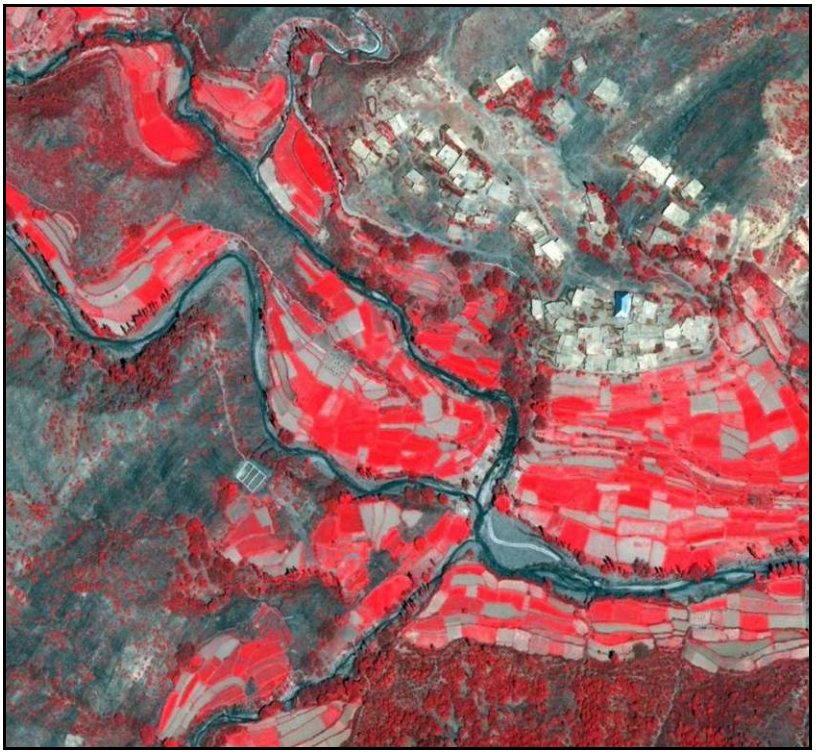


Figure 10-3 Example of Stable Stream System (© DigitalGlobe)

Deforestation: Deforestation affects watersheds by increasing sedimentation and peak flows, reducing the probable success of streambank restoration projects. However, since deforestation also increases the chances of reforestation opportunities, it is used here as a positive indicator. See Section 4.4.2, Stream System Characterization for details on evaluating this factor. See Figure 10-4 for an example. The scale is standard, i.e. higher values result in higher ratings. Rating endpoints come from the range of available data.

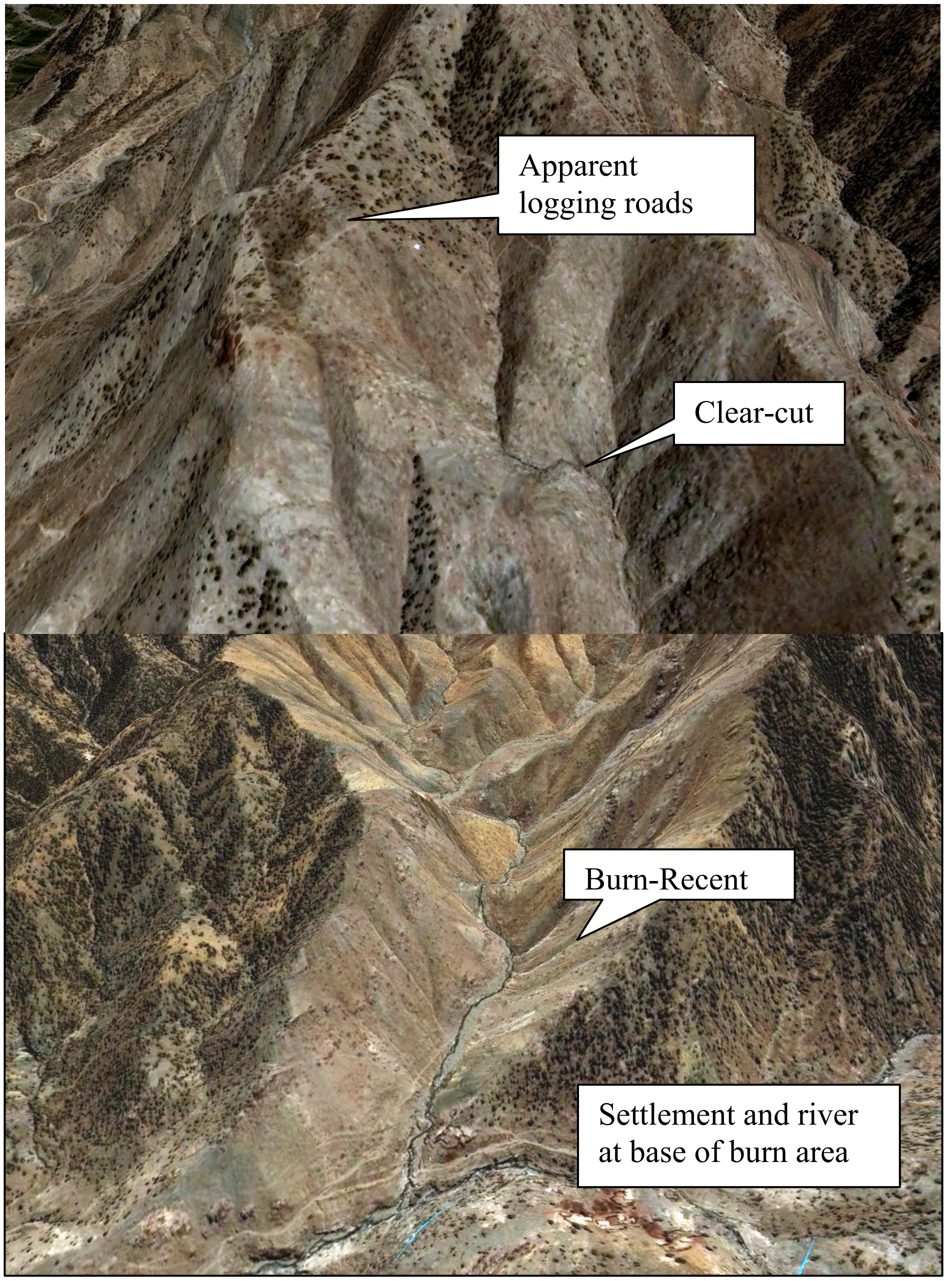


Figure 10-4 Illustrations of Deforestation (© DigitalGlobe)

ErodingUplands: Eroding lands are those uplands that have active gullying and rill erosion. They are related to relatively erodible soils, slope, climate, and poor land use practices. See Section 4.4.2, Stream System Characterization for details on evaluating this factor. See Figure 10-5 for an example. A higher proportion of eroding lands probably gives more opportunity for upland restoration projects. The scale is standard, with higher values giving higher ratings.

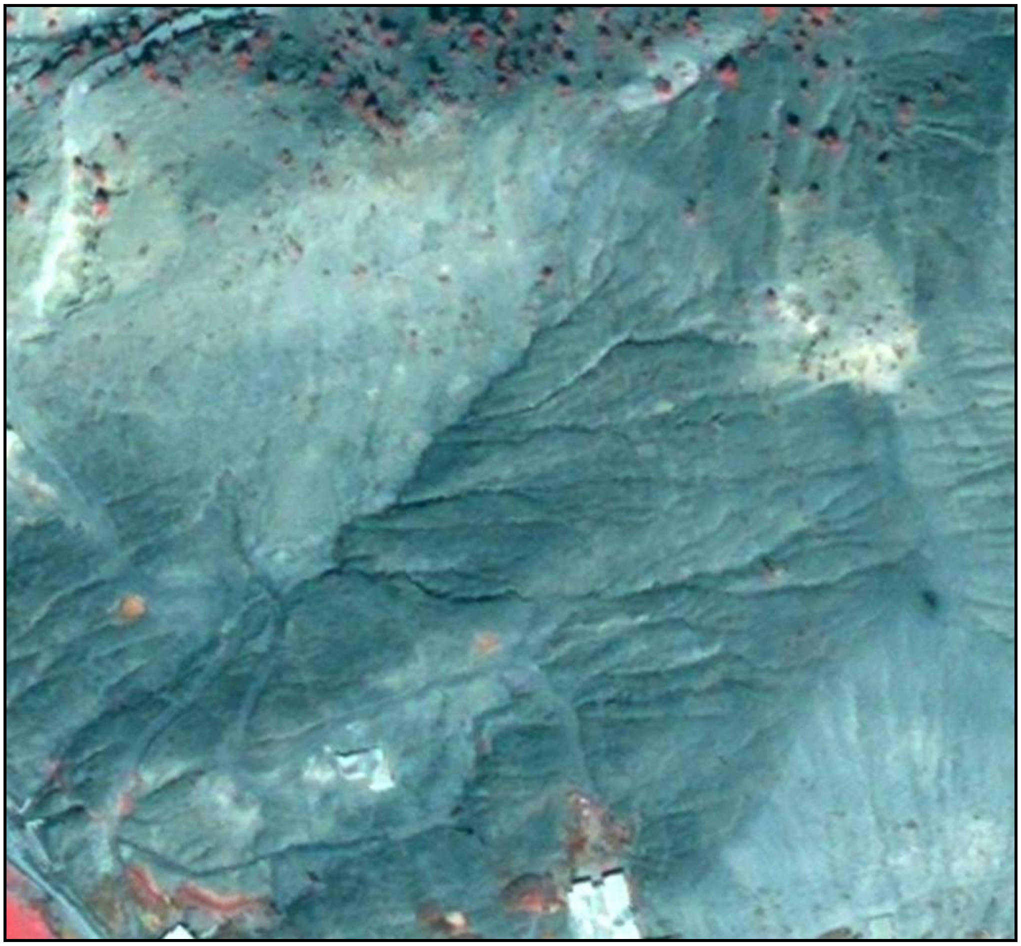


Figure 10-5 Active Gully Erosion (scale about 1:3000) (© DigitalGlobe)

PotentialAgroBenefits: This rating indicates the degree to which there is infrastructure to support increased agricultural operations, and is used to estimate potential affected population. It is rated by the area of presently-irrigated land less than 9 km downstream from the project. The 9 km limit was estimated as the largest distance practical over which benefits could be developed. See Project Watershed Characterization - Section 4.4 for details on evaluating this criterion. See Figure 10-6 for an example. Reddish areas low in valleys are irrigated lands. A higher area of irrigated land indicates a higher benefit.

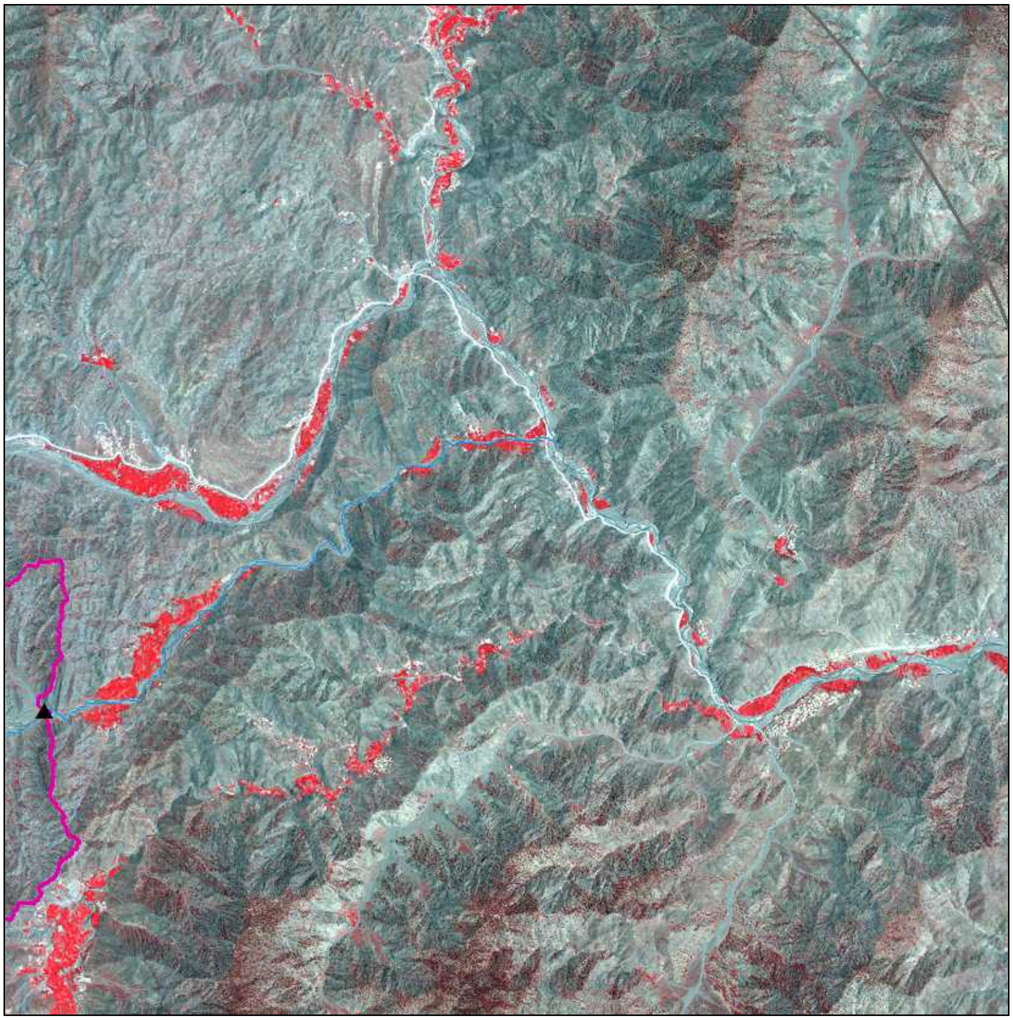


Figure 10-6 Example of Irrigated Agriculture (scale about 1:40000) (© DigitalGlobe)

Project locations symbolized by watershed restoration rating are in Figure 10-7. See Appendix N for details. The color green indicates the highest potential, and the color red indicates the least potential. Ratings of these projects are all relative. That is, the system rates from “best” to “worst”. Most of Afghanistan has challenges respective to watershed condition. It would be hard to find a watershed in “good” condition as is defined over most of the world. However, this rating system can still help focus efforts to improve the situation.

Shamal, Helmand, and Logar Upper sub-basin watersheds appear to have the greatest potential in terms of opportunities for restoration. However, there are some limitations to this evaluation. Watersheds were evaluated only if they had a prospective project associated with them, which biases the spatial distribution of results. Though the display can show trends, a better usage may be to use these data to select the best watersheds for further evaluation, as described below.

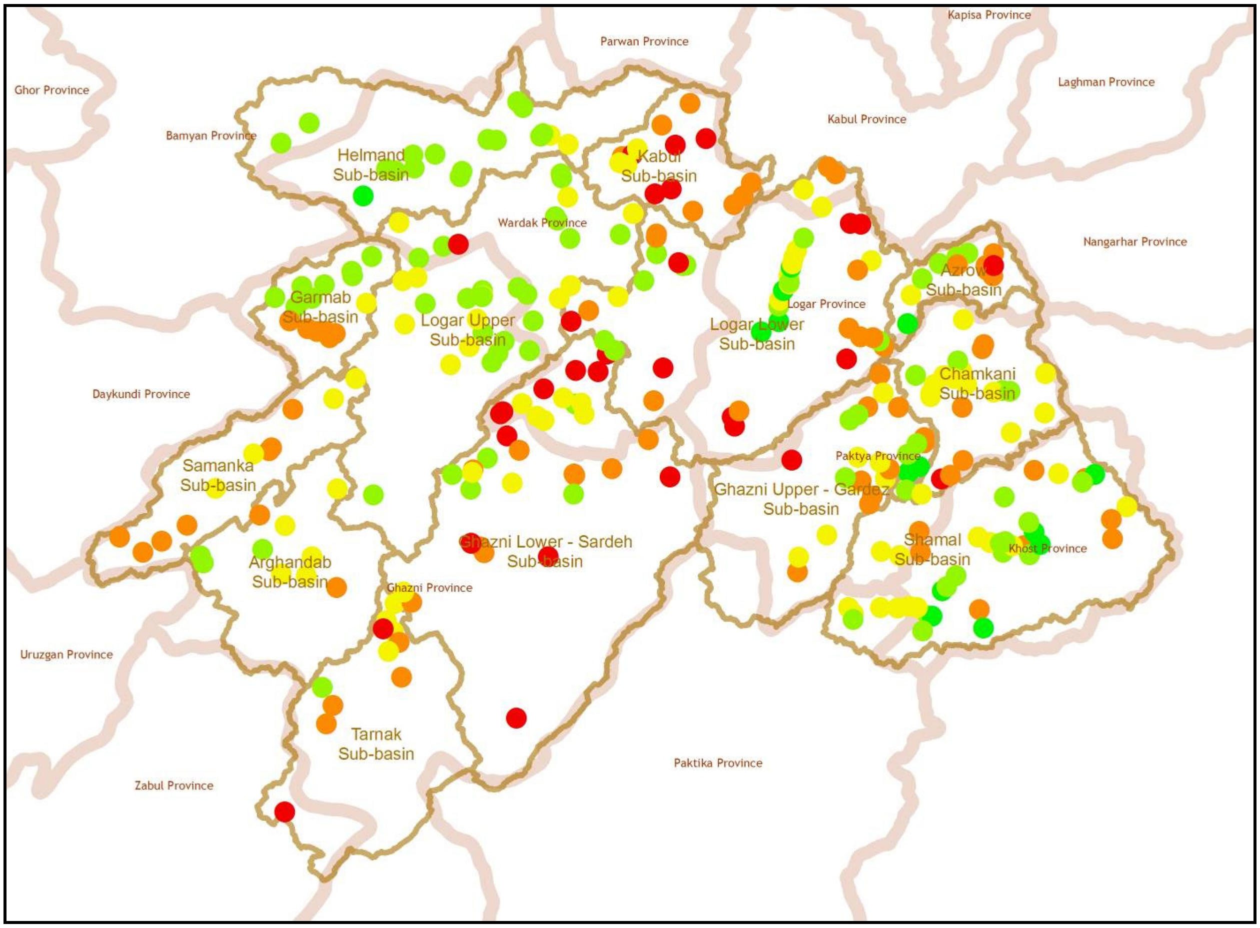


Figure 10-7 Watershed Restoration All Ratings

Table 10-1 shows just the top 20 rated project watersheds, and the values of the criteria used to rate them. This list is used to focus on the best project watershed restoration areas. Table 10-2 shows the 20 project watersheds having the least potential for restoration, based on this model.

Table 10-1 Top 20 Watersheds for Restoration Potential

Name	Province	Sub Basin	Stream System Instability	Eroding Uplands	Deforestation	Potential Agro Benefits	Rating
Kamkay Mazghar	Khost	Shamal	0.494	0.904	0.159	0.709	0.567
Waghjan	Logar	Logar Lower	1	0.79	0	0.471	0.565
Wargha	Khost	Shamal	0.486	0.894	0.152	0.709	0.56
Shadal	Khost	Shamal	0.439	0.9	0.717	0.063	0.53
Khatinkhel	Khost	Shamal	0.78	0.846	0.378	0.038	0.51
Abbas Koshteh	Wardak	Helmand	1	0.98	0	0.017	0.499
Narezah	Khost	Shamal	0.3	0.673	0.976	0.047	0.499
Dam	Paktya	Ghazni Upper-Gardez	1	0.845	0	0.137	0.495
Ghunday	Paktya	Ghazni Upper-Gardez	1	0.901	0	0.075	0.494
Zer Kac	Logar	Azrow	1	0.911	0	0.011	0.48
Puli Alam	Logar	Logar Lower	0.451	0.464	0	1	0.479
Baak #2	Khost	Shamal	1	0.619	0	0.22	0.46
Qal'eh-ye Khwaja	Logar	Logar Lower	1	0.419	0	0.405	0.456
Taqi	Logar	Logar Lower	0.629	0.514	0	0.658	0.45
Mana	Khost	Shamal	0.705	0.883	0.154	0.035	0.444
Shinah	Wardak	Helmand	0.911	0.767	0	0.083	0.44
Acarkhel	Khost	Shamal	0.76	0.896	0.058	0.033	0.437
Dawlatzi	Paktya	Ghazni Upper-Gardez	0.894	0.75	0	0.086	0.433
Laki Babakhel #1	Wardak	Ghazni Lower-Sardeh	1	0.7	0	0.029	0.432
Nayjoy	Ghazni	Garmab	1	0.698	0	0.016	0.429

Table 10-2 Bottom 20 Watersheds for Restoration Potential

Name	**Province**	**Sub Basin**	**Stream System Instability**	**Eroding Uplands**	**Deforestation**	**Potential Agro Benefits**	**Rating**
Aynak	Logar	Logar Lower	0	0.012	0	0	0.003
Baha'ijan Kor	Logar	Logar Lower	0	0.091	0	0	0.023
Qolak	Wardak	Kabul	0	0.037	0	0.193	0.057
Sar-e Tup	Wardak	Logar Upper	0	0.162	0	0.108	0.068
Dara-i Zyarat	Wardak	Kabul	0	0.1	0	0.237	0.084
Shotan	Ghazni	Ghazni Lower-Sardeh	0	0.433	0	0.045	0.12
Mohammad-Khel #2	Logar	Azrow	0.374	0.1	0	0.021	0.124
Wet	Ghazni	Ghazni Lower-Sardeh	0.069	0.394	0	0.043	0.127
Dahana	Wardak	Ghazni Lower-Sardeh	0	0.494	0	0.024	0.129
Nyazullah	Ghazni	Ghazni Lower-Sardeh	0	0.428	0	0.097	0.131
Ampurak	Wardak	Ghazni Lower-Sardeh	0	0.486	0	0.074	0.14
Chambare Warqa	Ghazni	Tarnak	0	0.501	0	0.06	0.14
Babur	Wardak	Ghazni Lower-Sardeh	0	0.537	0	0.026	0.141
Abchakan	Logar	Logar Lower	0	0.58	0	0.012	0.148
Khwajakhel	Logar	Logar Lower	0	0.555	0	0.065	0.155
Chalakhel	Logar	Logar Lower	0.215	0.316	0	0.093	0.156
Karakat	Wardak	Logar Lower	0	0.599	0	0.04	0.16
Mayana	Wardak	Ghazni Lower-Sardeh	0	0.585	0	0.082	0.167
Tangi Kholeh	Wardak	Kabul	0.088	0.384	0	0.2	0.168
Merzaka	Ghazni	Ghazni Lower-Sardeh	0.228	0.407	0	0.051	0.171

Figure 10-8 shows distribution of the top and bottom rated watersheds in the Study Area. There is some overlap in watershed area, but the image still shows the best areas to focus restoration efforts and the areas that may have lower opportunities for success. Best opportunities for further watershed evaluation or focus of resources may be in Shamal, Helmand, and Logar

Lower, with less opportunity in Ghazni Lower. See Table 10-1 and Table 10-2 to review each criterion's influence on the final rating. Examples for individual watershed rating parameters and a sensitivity discussion on the effects of changing (or leaving out) criteria are in Appendix N.

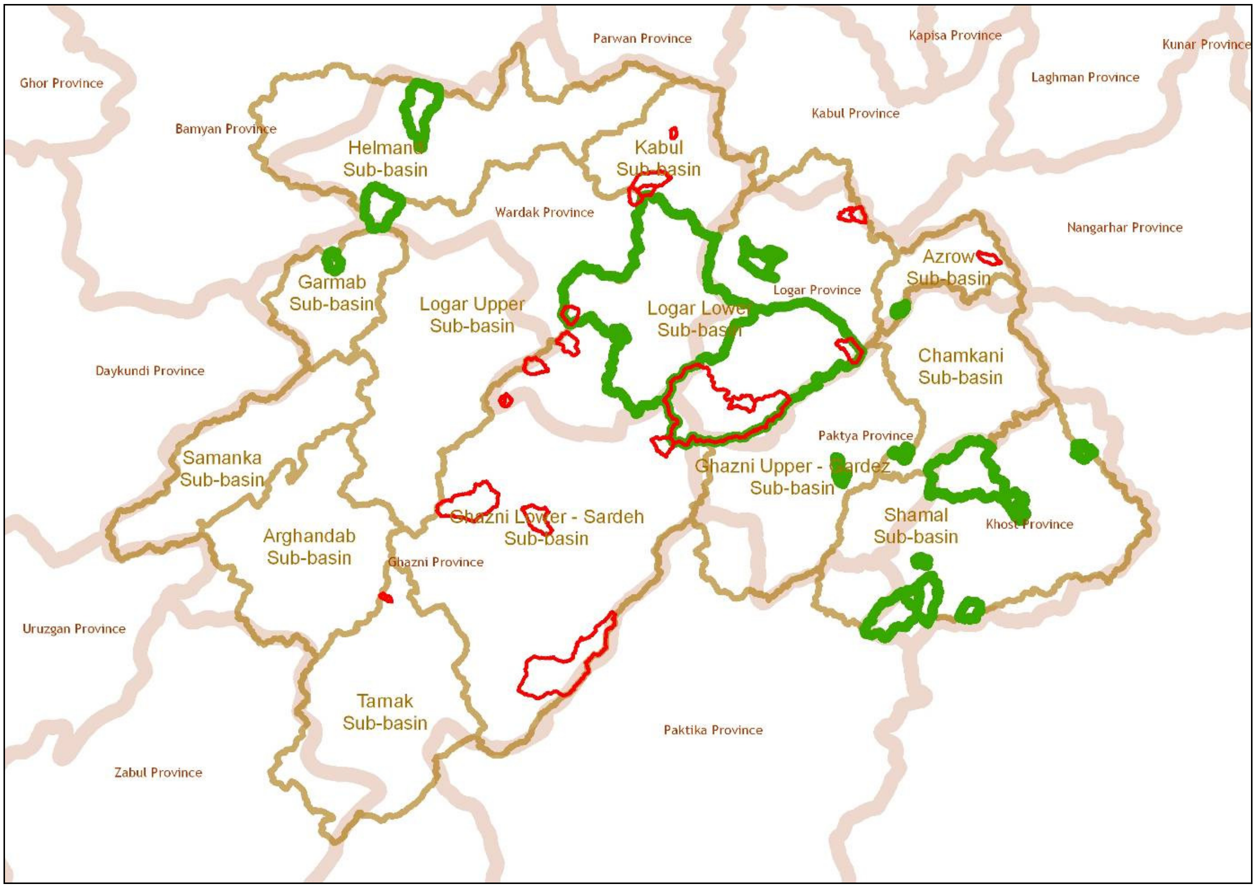


Figure 10-8 Top and Bottom Rated Watersheds for Restoration Potential

Though this decision support model shows general areas that may benefit from watershed restoration, project planning also requires the use of other factors. For example, existing vegetation was not directly evaluated in this rating. This is because only a low resolution, medium-accuracy vegetation map was available (see Section 3). The general category of "Rangeland" includes a wide range of vegetative types, and does not include vegetative condition. Use of the high-resolution CIR imagery is needed to further rate restoration effectiveness and specify location of projects.

Specification of restoration projects depends on many factors, and many cannot be quantified as was done in the decision support model. These may include security, proximity to labor sources, values-at-risk in project areas, logistical concerns, and local priorities. These could be included as data becomes available. However, using the above model can help focus potential areas, and show the effects of important criteria, freeing up decision makers to use those "other" factors more clearly, rather than just "shooting in the dark" when prioritizing expensive and potentially dangerous field work.

11.0 Conclusions and Recommendations

This assessment includes the provinces of Khost, Paktya, Logar, Wardak and Ghazni in southeast Afghanistan. This semi-arid region has an agrarian-based economy and most farmers rely on irrigation for their crops. The people of this region face serious water resource problems, including lack of safe household water supplies, an existing irrigation system in disrepair and lack of dependable water for agriculture. Some of the problems with flash flood damage, sedimentation and loss of productive rangeland can be directly related to poor land management in the deteriorating watersheds, while others are related to the extreme climatic and geologic situation.

The purpose of this assessment was to identify and evaluate potential water resource projects that Task Force (TF) Yukon can implement to benefit the people of this region in cooperation with local governing bodies and Ministries within the Islamic Republic of Afghanistan. This assessment also discusses the nature of landscape and hydrologic patterns in the study area and the fundamental causes of the water resource challenges, including the constraints put on any proposed project by the natural environment of Afghanistan.

A large component of this assessment was the data collection effort. During the past years of turmoil, streamflow and precipitation records, soils and geological maps, engineering reports and even general knowledge of the region's hydrology have been lost. As part of this effort, the USGS was tasked with collecting and organizing available historic streamflow records into a publically accessible database. Analysis of the stream gage records revealed large influences of irrigation withdrawals.

Only monthly historic precipitation data was located that matched the 1960 to 1980 period of the streamflow records. There was insufficient streamflow and precipitation data to calibrate hydrologic or hydraulic computer models of the watersheds and rivers. A simple correlation was used to establish a relationship between precipitation over a watershed and the resulting runoff recorded at the stream gage. This relationship was used to estimate flows at water resource project sites with similar watershed characteristics. This method does have limitations and it is recommended that streamflow characteristics at a project be confirmed with local inhabitants.

The study was primarily based on analysis of high-resolution satellite images, digital elevation models, available land-cover and soils spatial data, assistance of experts familiar with the region, the authors' in-country experience, observations by on-site personnel and publications. Remote sensing methods have the advantage of being able to investigate the hydrologic, social, land use and geologic patterns of southeast Afghanistan without the expense and effort of actually being on the ground in an un-secured environment. Disadvantages of remote sensing include the unwieldy size of the dataset, large effort required to process the data and the limitation of analysis scale, e. g. not being able to accurately evaluate small-scale features such as irrigation canals, check dams, rill and sheet erosion.

To address small-scale village improvement projects in this assessment, a hands-on workshop for military and civilian personnel was delivered by the USDA Foreign Agricultural Service. The four-day workshop at FOB Salerno, Khost reviewed soil assessments, water supply, watershed restoration, irrigation methods and erosion control. The participants recommended that a similar, expanded workshop be provided to those working on water related projects before deployment to Afghanistan.

Groundwater is the primary and safest source for household water supply in southeast Afghanistan. The lack of available hydrogeologic data and knowledge of aquifers can make utilizing groundwater resources a risky endeavor. Installing a high capacity well can negatively affect surrounding wells and karezes, ultimately being counter-productive in efforts to help the community. The best technique in evaluating an aquifer is dependent on the available hydrogeologic data. As part of this assessment, the USGS conducted an extensive data gathering effort and appraisal to determine the best technique in evaluating groundwater resources. It is recommended that TF Yukon utilize the dataset collected by the USGS and proceed with their strategy for evaluating and utilizing groundwater resources.

Hydropower potential in southeast Afghanistan is limited more by the lack of available streamflow than from suitable terrain. The steep stream slopes in the study area offer large elevation changes over short distances, providing excellent driving head for hydropower turbines. The issue was that many streams are dry for months each year. This assessment team evaluated hydropower at 120 locations. Of these, 61 sites had generating potential over 100 kW and two sites over 1.5 MW. Many locations were in remote areas with low population density requiring long transmission lines. The most promising project was at Sinak on the upper Helmand River. Because of the high streamflows at Sinak, the headrace channel may be able supply enough flow to support both hydropower and irrigation demands in the open valley. Installing hydropower capabilities at the irrigation storage dams in southeast Afghanistan is not recommended. Irrigation has the higher priority for limited water and relying on the head produced by the dam would be sufficient only a few months of the year. All hydropower in this assessment utilized the more reliable head produced by the steep stream slopes for run-of-river type projects.

This assessment utilized the remote sensing dataset to identify locations for potential irrigation diversion structures. However, limitations in the remote sensing dataset resolution hindered the analysis. The diversions rely on centimeters of elevation differences to drive water out of the streams and into the canals and irrigated crops. The elevation dataset did not have the resolution to appropriately evaluate potential sites and estimate benefits. It is recommended that TF Yukon focus efforts on existing diversion structures along stable river channels that do not show severe sedimentation issues. Many of the existing structures need replacement of sluice gates or complete replacement of the structure. TF Yukon should avoid building new permanent structures on the unstable streams with high sediment loads. The traditional, temporary structures that are re-built each spring may be more appropriate on sediment-laden streams. One result of the diversion analysis was the development of individual map books of irrigated river valleys. With an organized and portable collection of high resolution images in *.pdf format, TF Yukon or PRT personnel can use the maps in the field to zoom-in on diversion structures that may be hidden from the roadway by vegetation.

In terms of irrigation storage dams, the terrain and condition of the watersheds in southeast Afghanistan are generally unfavorable. However, through an intensive canvassing process 159 potentially successful locations were identified and described. These project sites and associated watersheds were intensively analyzed to discover their true potential for further investigation.

To make sense of the complex criteria and large number of potential projects, structured decision support models were developed to help prioritize the 159 irrigation storage dams for further investigation and all 295 project watersheds for restoration potential. The criteria and factor weightings were developed in consultation with TF Yukon, and they can be easily modified as situations change. The list of ranked projects included in this report (Table 6-16) is only a tool. Final recommendations were not only based on these rankings, but also on additional information and professional interpretation. Some factors were consciously excluded, e.g. local security or cultural relationships.

Results showed the majority of the sites had little reservoir storage potential or the dam's watershed condition presented serious sedimentation issues. The mountainous terrain in Afghanistan results in streams with very steep gradients. Therefore, the reservoirs have little storage per height of dam. Many sites had a dam construction volume over 20% of the reservoir storage volume and were judged infeasible. Many watersheds had large areas of relatively-high active gully erosion and deforestation with unstable stream systems. Some sites, though favorable from an engineering standpoint, were located on wide-unstable streams that present significant challenges in design, implementation, and maintenance.

Sediment accumulation in reservoirs will be a continuous, long-term maintenance issue for dams in southeast Afghanistan. The high sediment load of Afghanistan's streams should not prevent the construction of all storage dams. Sites have to be carefully selected to avoid steep stream slopes and watersheds in poor condition. It is recommended that TF Yukon consult with international experts on appropriate outlet designs to encourage sediment passage through dams.

However, these negative factors also present opportunities in watershed restoration. Areas having relatively high erosion and deforestation also present potential for gully control and reforestation. In areas having relatively stable streams, bank stabilization may be effective in reducing sediment and improving water quality. This potential was spatially reviewed using a decision support model similar to the irrigation storage model, to identify the best candidates for restoration efforts. These watersheds must be further investigated, as not all potentially important factors were considered, e.g. vegetation condition.

There are indeed challenges in water resource development in southeast Afghanistan. However, there are also many opportunities. The terrain, climate and hydrology vary greatly across the five-province assessment area. The appropriate type of water resource improvement project will also vary across the area. Each province has a different potential and different challenge. The type of projects recommended for further investigation depend on those unique characteristics.

Irrigation storage dams are not recommended in the Helmand River watershed in northern Wardak Province. Impounded water is not needed given the high year-round streamflows and small amount of arable land in the valley. Hydropower and irrigation diversions are recommended.

The Shamal, Chamkani and Ghazni Upper (Gardez) River watersheds in the Khost and Paktya Provinces are not favorable for irrigation storage dams. The evaluated sites had little storage and high potential for sedimentation. The watersheds of Shamal and Chamkani do have one unique resource in Afghanistan and that is the forest and orchards. Efforts should concentrate on their conservation and restoration. Gardez has a few recommended dams and had high potential for successful watershed restoration.

The Logar River watershed in Wardak and Logar Province has many recommended irrigation storage dams. It is also recommended that the series of existing irrigation diversions along the Logar and tributaries be high priority projects for rehabilitation. There are also existing dams at Chak Wardak and Khwar that should be prioritized high for repairs.

Western Ghazni Province included the study watersheds of Garmab, Samanka, Arghandab and Tarnak. Only Samanka had recommended irrigation storage dams. All watersheds except Tarnak included recommended locations for hydropower and irrigation diversions.

Southeastern Ghazni Province included the Ghazni Lower (Sardeh) watershed. The watershed does not hold much potential for hydropower, but includes four storage dams recommended for further investigation. There is a series of existing irrigation diversions below the Sultan Dam that should be priority projects for rehabilitation.

The greatest uncertainty in the evaluation of project sites was in the estimation of streamflow water budgets and design flood flows. The uncertainty was a result of the short length of streamflow and precipitation gage records. Another issue was the estimation of flows on streams without gages. Additional streamflow characteristics should be obtained from local Mirabs. Dam structures and spillways should be carefully designed with constant quality control inspection during construction to help compensate for the uncertainties in flood flows. The level of analysis in this assessment was unable to address geotechnical and seismic conditions at the project sites and require further investigation. There are also uncertainties in quantifying the benefits of watershed restoration programs and reducing soil erosion, especially if improved local grazing practices are not included.

Afghanistan is indeed a land of challenges. Anecdotal information abounds on its poor watershed conditions and irrigation water supply problems. In addition, recommendations for past improvement projects are often based on poorly defined parameters, or are too generally defined to implement. This study was based on remote sensing data, with limited direct ground-truth. As in the previous Paktika Water Resource Assessment, it provides a consistent and systematic evaluation of “where, when, who, how much, and why”. Both studies emphasizes specifically locating projects using well defined criteria, with its accuracy based on *what is known,* both directly and indirectly. The studies give some specific recommendations on irrigation supply structures as well as for longer-term watershed management improvement. Both together should help continue to focus future efforts on cost-efficient solutions in developing safe and productive water supplies for the people of Afghanistan.

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