CHAPTER

3

HOW SHOULD WATER SOURCE RIVERS BE UNDERSTOOD?

Before starting a PMS method irrigation project, from what point of view do we need to know the water source river?

Before planning and implementing a PMS method irrigation project, it is first necessary to study the characteristics of the river which will serve as the water source. Rivers are constantly changing, and phenomena such as floods and droughts occur. To construct irrigation facilities that can stably take water from the river during both floods and droughts and to properly operate and maintain them, it is necessary to first know the river conditions during floods and droughts. Therefore, existing data, information and documents related to the target river basin and river channels are collected and studied. Interviews and observations are locally conducted, and river surveys are also conducted for the planning and designing of irrigation facilities. It is further essential to genuinely visit the site and observe it. Through these activities, the specific conditions of the target river are confirmed as follows:

- Check river channel movement (stable streamway, flow direction, riverbed fluctuation) and sand bar fluctuations (stable sand bar, erosion/sedimentation), and recognize a location where water can be easily taken.
- Observe the river flow condition during floods and droughts, and identify locations where floods are likely to occur, in particular where the flood force is likely to be concentrated and estimate how much water can be extracted for irrigation purpose during droughts.
- Understand the water level, velocity and discharge of the river during flood and drought in order to prevent overtopping and facility destruction due to floods and to allow irrigation water to be extracted even during droughts.

The series of survey methods necessary for understanding these river conditions are explained in the following pages.

3.1 Why Should We Understand the River Conditions?

Before global warming effects became evident in river basins of Afghanistan, where rivers originate from mountains below 4,500 m in altitude, snowfalls near the summit did not disappear even in summer, snowmelt gradually recharged groundwater during spring, and rivers and groundwater at the foot of mountains remained moist and saturated even in winter (during the drought period). Farmers used such river water and groundwater as water source to irrigate farmlands by traditional irrigation facilities such as *Jui* (small irrigation canals from small and medium-sized rivers) and Karez (underground drain which conveys water from ground canals to the surface). However, since the 1990s, global warming has become remarkable, and snow cover regularly disappears in summer, causing precipitation to flow all at once without underground being recharged. As a result, some rivers run out of water in summer, groundwater level dropped significantly, and water intake by *Jui* and *Karez* became difficult, which has in turn become a matter of life and death for the farmers (See Figure 3.1). The only way to deal with these problems was to deepen and restore the *Karez*, or construct dams/reservoirs. When these measures are not possible, farmers have to focus on agriculture at a certain period during the year.
On the other hand, in large river basins headed by mountains with elevations above 4,500 m, the snowline does not disappear in summer and a certain amount of water still flows in rivers during winter. In these situations, irrigation water can still be taken at the gate. The snowline gradually rises in summer (the flood season) and the melting snow result in flows into rivers. However, due to the impact of global warming, the snowline suddenly rises in summer, and sudden snowmelts can cause serious floods. Therefore, when targeting large rivers as water sources, it has become an important issue to anticipate and minimize flood damage, while still ensuring a stable water intake.
In order to safely and stably take the necessary irrigation water from the rivers during both flood season and drought season, it is necessary to have an intake weir which raises the water level of the river, and an intake gate. To protect these structures and farmlands from floods, levees, revetments, and flood control works are also necessary. Such irrigation facilities and flood control facilities are constructed in river channels or adjacent to rivers. Therefore, in order to plan and design safe and stable structures, it is essential to understand the river conditions during flood and drought periods. In addition, when a structure is constructed in the river, the river flow on the left and right banks upstream and downstream of the structure will be affected, and the river conditions will change. Furthermore, when water is extracted from rivers, flow conditions downstream change. The decrease of discharge especially in winter may in turn affect downstream water use.
Based on the above, the river conditions which should be comprehended in the PMS method irrigation project and the method of grasping them are as summarized in Table 3.1. Firstly, the existing information is collected, organized, and analyzed. Then, interviews and observations are conducted on-site, to understand the river conditions. Finally, river surveys for planning and designing the facilities are conducted. When conducting the above observations and surveys, it is important to consider the ways to utilize the obtained information and data, for planning, designing, constructing and maintaining the irrigation projects.

Table 3.1 River Conditions to be Comprehended and How to Grasp Them[1)]

River Conditions to be Comprehended	How to Grasp River Conditions
•**River basin conditions** Flood and drought runoff characteristics and groundwater recharge conditions are analyzed by understanding the topography and visitation, etc. in the river basins. In addition, what kind of water resources are being used, such as the existence of irrigated areas, cities and villages in the river basin, and land use conditions are grasped. •**River channel conditions** Necessary information is obtained for facility planning and designing, such as checking river channel fluctuations (stable streamway, flow direction, riverbed fluctuations) and sandbar fluctuations (stable sandbars, sediment erosion / sedimentation), and grasping sites where water intake is easy. •**River flow conditions (flood and drought conditions)** By grasping water level, velocity, and discharge of the river during floods and droughts, the river flow conditions are clarified. It is analyzed where flooding is likely to occur, where the flood force is likely to concentrate, and how much water can be taken during droughts. It is utilized for facility planning and designing. The sediment transport volume and particle size and water quality are grasped. •**Impact of river structure construction on river flow and channel** The impact on the structures located on the upstream / downstream and left and right banks, river channels and landside areas of the newly constructed river structures in the PMS method irrigation project is analyzed. In particular, the new generation of flood inundation occurrence due to backwater (rise of water level) at the upstream by weir construction are carefully assessed. •**Impact of irrigation water extraction on downstream water use** Investigate the water rights registered with The National Water Affairs Regulation Authority (NWARA) Water Rights Bureau, grasp the current water use situation near the water intake point, and plan new irrigation water intake above the water intake point. Carefully consider whether it will affect water use on the downstream and left and right banks, especially on the downstream side, and coordinate with relevant parties. The water rights registered in the Department of Water Right of NWARA are investigated and the present water use situation near the intake site is grasped. Then, the planned new water intake for irrigation is carefully studied, specially whether it affects the water use on the upstream/downstream and the left/right banks. It is coordinated with the stakeholders.	•**Collection and organization of existing information** The existing information such as satellite images such as Google Maps, existing topographic maps, digital elevation models, geological maps, hydromet information, water rights, and river structures is collected and organized. •**Interview survey among residents** Be sure to go to the site and interview at the site. For local situations and flood conditions, record interview information along with location information (latitude and longitude, etc.) and local photos. In addition, various information is collected and organized. Then, their consistency is confirmed, and the accuracy of interviews is confirmed. •**Observation and measurement of river conditions and their arrangement** Existing information and interviews are often inadequate, and field observations and measurements are especially important for understanding river conditions. In order to grasp the constantly changing river conditions, it is necessary to visit the site on a regular basis and grasp the situation at that time. In particular, it is important for the person in charge of the project to visit and observe the river and flow conditions both during floods and droughts. Results of observations and measurements are organized using photos and sketches. •**River survey and survey study** The cross-sectional survey, the profile survey, and the topographic survey of rivers are performed, and drawings are created. A riverbed material survey is also important for understanding river channel characteristics. Based on these materials, the hydraulic parameters of rivers are examined by non-uniform flow calculation.

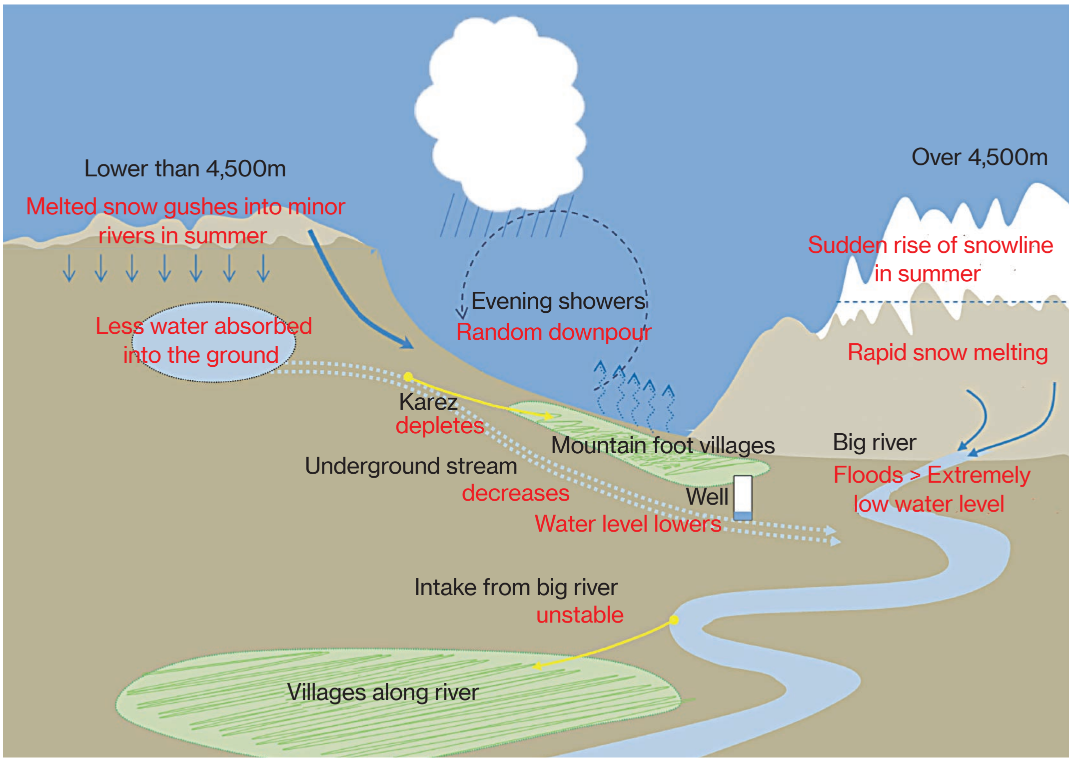


Figure 3.1 Water Cycle in River Basins After Severe Climate Change in Afghanistan[3)]

3.2 Collection and Organization of Existing Information

3.2.1 | River Basin Condition

The conditions of the subject river basin are investigated. The characteristics of flood runoff in the flood season, the baseflow runoff in the drought season, and the conditions of the recharge of precipitation to groundwater are all analyzed and used as essential data for planning, designing, constructing and maintaining the irrigation projects. The survey target elements and main survey contents are as follows:

[**Topography**] Mountains, collapsed areas, valley plains, fans, floodplains, old river meanders, etc., are all categorized topographically based on satellite images such as Google Maps, existing topographic maps 4) and digital elevation models (DEM). Then, high potential areas of natural disaster risks (such as flood inundation and landslides) are identified and this information is used as essential data for water intake site identification. In addition, the basin boundaries of the main river and major tributaries, basin area, major mountain ranges and elevations, water sources, water systems (main rivers and major tributaries), etc. within the target river basin are investigated. These fundamental data are required for hydrological cycle and river flow analysis to be described in the following survey element [hydrometeorology]. In addition, the information on cities, villages, access roads, etc., near the target river, all of which are necessary for the field survey, are confirmed.

[**Geology**] The geology of the target river basin is roughly reviewed and a preliminary survey on water retention in the basin is conducted based on the existing geological maps of the United States Geological Survey (USGS)[5)], Afghanistan Geological Survey (AGS), Department of Geo-Engineering and Hydrogeology (DGEH), etc., and field surveys. In general, river basins containing many geological features such as highly permeable igneous rocks and conglomerates have high water retention capacity, which can replenish ground water with precipitation, and one can expect more abundant river runoff during the drought season (which can be used as irrigation water source). In the case of constructing an irrigation reservoir in the river basin with high water retention capacity, it has been seen that it facilitates groundwater recharge around the reservoir which helps to expand vegetation coverage. Furthermore, it can be expected to lead to the functional recovery of many *Karezes* which have become unusable due to the decline of groundwater.

[**Hydrometeorology**] The hydrometeorological parameters and data such as temperature, precipitation, and snowfall in the target river basin are established. Based on the above-mentioned topography and geological information, the headwaters of the target river basin and the direction of river flow and groundwater recharge, conditions are analyzed to grasp the outline of the hydrological cycle in the target river basin. In addition, runoff characteristics such as the manner how the river flow responds to rainfall in the river basin and how the river flow responds to snowmelt and temperature is understood. If necessary, runoff analysis and runoff model formation is performed and analyzed. Furthermore, understanding meteorological conditions such as precipitation is useful for setting work schedules and safety management for irrigation projects. The meteorological data required for analysis are available from three agencies: 1) The Afghanistan Meteorological Department under the Afghanistan Civil Aviation Authority (AMD); 2) The Ministry of Agriculture, Irrigation and Livestock (MAIL); and 3) The National Water Affairs Regulation Authority (NWARA). NWARA has the leading role as data source for river flows.

[**Vegetation**] According to Dr. Tetsu Nakamura of PMS, due to the climate change in Afghanistan, the natural forest of cedar and walnuts which had spread like a belt near the snowline was thinned, and the number of Sheesham (the evergreen broad-leaved tree of the legume family that grows naturally in South Asia) which was seen in a small plain along the river has drastically decreased. This is contributing to the land becoming arid. In respect for such situation, the time series vegetation change of the target river basin is confirmed based on the Landsat satellite images and the 1/500,000 map of the Provincial Landcover Atlas of Afghanistan (FAO).

[**River Water Quality**] Regarding river water quality, it is important to confirm the effects of upstream domestic effluent and irrigation drainage containing chemicals such as pesticides, etc., and it is also important to confirm whether water suitable for irrigation can be obtained at the intake site. In particular, if there is a concern that water quality deteriorates due to the development of towns and industries in the upstream and

neighboring areas, the present and future river water quality is thoroughly examined.
[**Irrigation Facility**] In Afghanistan, there are two main irrigation intakes: there is the *Jui* (small irrigation canals from small and medium-sized rivers) and then there is a large-scale irrigation intake weir, reservoir, dam, and pumping stations which were constructed with assistance from Russia, China, and the United States before the 1970s. In addition, there are *Karezes* which bring groundwater to the surface. If these facilities exist in the target river basin, the current usefulness of these facilities is confirmed. The necessity and suitability of a new PMS method irrigation project is evaluated. Furthermore, it is confirmed that the PMS method irrigation project should not reduce the effective functioning of existing irrigation structures.
[**Flood Control Facility**] In Afghanistan, there are flood control facilities such as dikes and revetments constructed by existing projects. The existence of flood control facilities point to the fact that the area was exposed to the threat of floods and thus flood control facilities were constructed. Therefore, the presence of these facilities is confirmed, to assess the risk of flood inundation and the efficacy is verified. On the basis of that, the necessity and appropriateness of measures for the PMS method irrigation project are evaluated.
[**Land/Water Resource Use**] The existence of irrigated areas, cities/villages and other land use conditions in the target river basin is confirmed. In addition, it is verified what kind of water resources' use there is. Lands' titles, etc., are confirmed from 1/5,000 public maps and land ownership survey maps of the Afghan Geodesy and Cartography Head Office (AGCHO).

3.2.2 | River Channel Condition

(1) Classification and Characteristics of River Channel

Rivers can be classified into sections having similar characteristics, as shown in Table 3.2. Generally, rivers have larger discharges, deeper water depths, gentler slope, and smaller bed materials particles in the downstream sections. With these as reference, it is important to imagine in advance the characteristics of the target river channel and its flow conditions. Afghanistan's river basins, which tend to be mountainous, are roughly classified into mountainous areas and valley plains and the segments are under M, 1 and 2-1 in the following table. For accurate classification, it is necessary to understand the characteristics of the target river channel from river surveys and bed material surveys.

Table 3.2 River Channel Categories and Characteristics [2), see 6)]

	Segment M	Segment 1	Segment 2		Segment 3
			2-1	2-2	
Terrain classification	← Mountainous →	← Alluvial fan →	← Valley bottom plain →	← Natural levee →	← Delta →
Representative particle size of riverbed material dR	Various	2cm or more	3cm～1cm	1cm～0.3mm	0.3mm or less
Riverbank constituent materials	Often rocks on the banks of the riverbed	Sand and silt may ride on the surface layer, but it is thin and is occupied by the same substance as the riverbed material.	A mixture of fine sand, silt and clay. However, the lower part is the same as the riverbed material		Silt, clay
Gradient guide	Various	1/60～1/400	1/400～1/5,000		1/5,000～flat
Meandering	Various	little bending	Meandering is intense, but 8 character meandering or islands occur where the river width / depth ratio is large		Some have large meanders, others have small meanders
Riverbank erosion	Very intense	Very intense	Medium (The larger the riverbed material, the better river channel moves)		Weak (Most river channel do not move.)
Average depth of river channel	Various	0.5～3m	2～8m		3～8m

Green: Many Afghanistan river channels are categorized here.

(2) Understanding River Condition at Planned Sites of River Structure

Using topographic maps, Google maps, satellite images, etc. while referring to the characteristics of river channels, the historical changes in meandering conditions and bank erosion are clarified. It should be checked whether the river flow outside of the curved part is fixed, whether the river has changed from the recent past to the present, whether the structures' site is with the bedrock at the back, whether there is a stable sandbar in the river, and whether the river is wide or narrow. In particular, the present location of the streamway and changes in the past streamway are confirmed. These are important elements in determining the site of intake weirs and intake gates.

When looking across the river channel, the deepest part is the streamway, which is the part where the majority of the river water flows. The transition of the streamway in the Kunar River is shown in Figure 3.2 as obtained from a satellite image. This figure shows the site of the weir constructed under the existing PMS irrigation project. It can be said that the streamway at the Marwarid I and II weirs and the Kama I and II weirs are stable with little changes over time and are suitable for water intake. On the other hand, at the Miran Weir, the streamway moved frequently, so that maintenance works, such as riverbed excavation is essential for stable water conveyance to the intake.

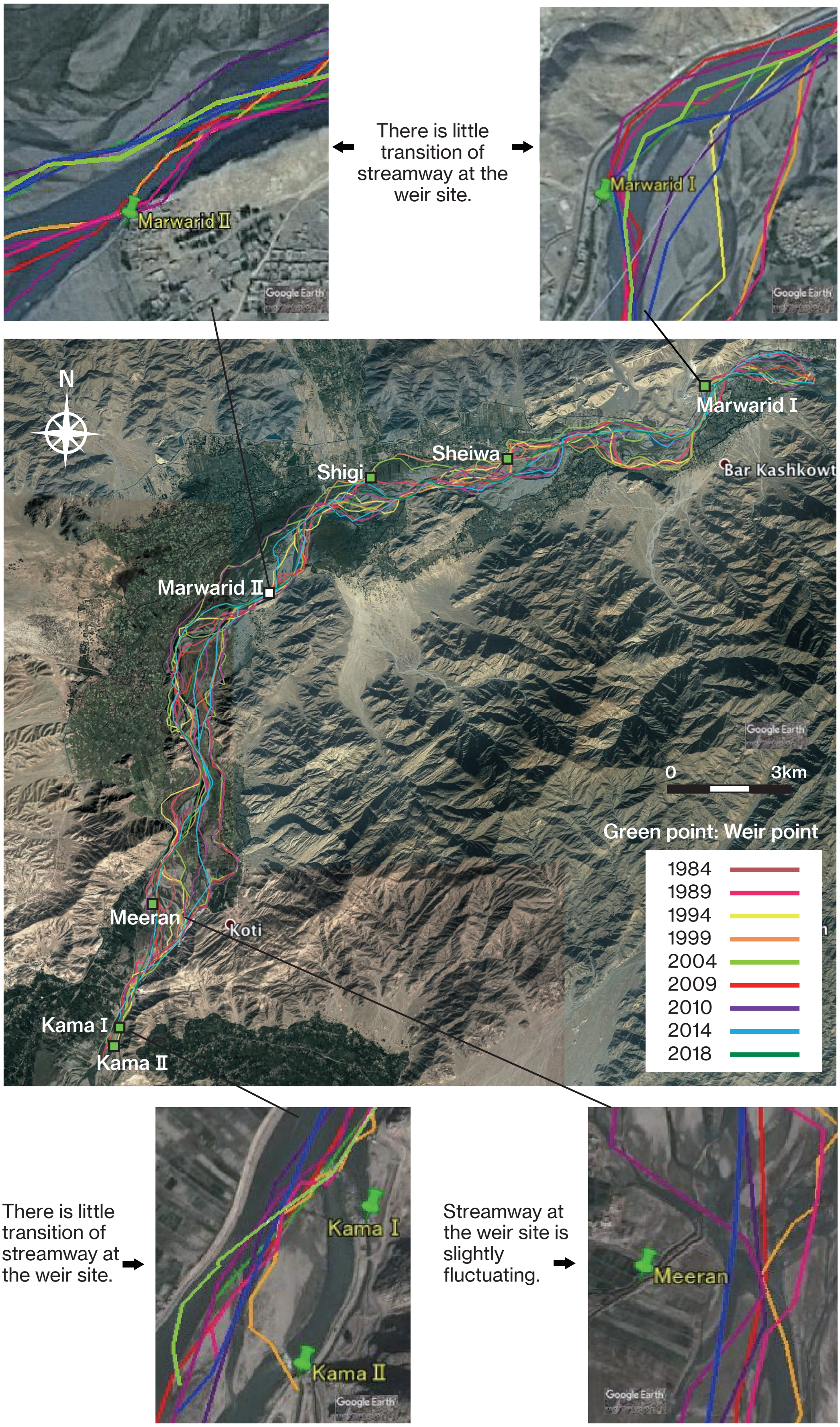


Figure 3.2 Transition of Streamway 2)

3.2.3 | River Flow Conditions during Flood and Drought

Information on river flow conditions during floods and droughts are collected and confirmed to ensure that river structures can safely perform their full functions during floods and droughts. In addition, impacts of the intake of irrigation water on the river flow conditions at the upstream and downstream, both along left and right banks are analyzed and identified.

(1) Collection and Organization of Existing Hydrometeorological Data

Hydrometeorological data recorded at observation stations near the target area of the irrigation project are collected and organized to check the flood and drought discharges. The parameters of hydrometeorological data collected are precipitation, temperature, river water level, river discharge, etc. The agencies for collection are as follows:

- Data such as daily precipitation and river discharges, as yearbooks of precipitation and discharges, issued by NWARA. For reference, Figure 3.3 shows an example of the river flow chart and annual fluctuation of the discharge graph. It includes statistical values such as annual maximum/minimum/average/specific discharge. NWARA also organizes and summarizes the results of frequency analysis of precipitation and discharge. Through the Project for Capacity Enhancement on Hydrometeorological Information Management by the Japan International Cooperation Agency (JICA-HYMEP)[7] and the Irrigation Restoration and Development Project by the World Bank (WB-IRDP) [8], NWARA has developed hydromet stations throughout Afghanistan, stored data, conducted hydrometeorological analysis, and established systems for observation, storage and disclosure of hydrometeorological data. Moreover, the water levels for estimating the discharges have been measured.
- Meteorological data recorded at agromet stations under the control of MAIL and the weather stations under the control of AMD.
- Past discharge data and hydrological frequency analysis results are available from USGS website [9]. Specifically, it should be noted that the discharge data up to the 1970s (maximum/minimum/average monthly, discharge frequency analysis results, etc.) is old and may differ from the present situation.

A hydromet station near the target area of the irrigation project means the station closest to the planned intake site. It is preferable that the station is within the same river basin. If there is no observation station in the river basin, the data of observation stations in nearby basin is used, but attention is paid to the difference in runoff characteristics in the river basins. As a general rule, the discharge at the planned intake site is calculated from the discharge data at the observation station based on the river basin area ratio at both sites, i.e., the discharge at the planned intake site is estimated from the specific discharge at the observation station. The longest period of hydrometeorological data is collected as possible, at least, for the last 10 years or more. If the discharge data is not in the vicinity, measuring the discharge for about one year is required (see Subsection 3.4.2 for discharge observation). If the downstream locations which may affect water use at irrigation water intake are distant or there is a confluence such as a tributary between them, the discharge data at the downstream affected locations also is surveyed and estimated.

River basin	Kabul	Code 1- 0.000		Water year 2018
River	Kunar	Code 1- 4. L00		Elevation 558 m+m.S.I
Station	Pul-i-Kama	Code 1- 4. L00 -1A		Dranage Area 26005 Km²
Gage	Staff	Location Lat. 34.46870556 N		Long. 70.55703056 E

Discharge daily means m³/sec

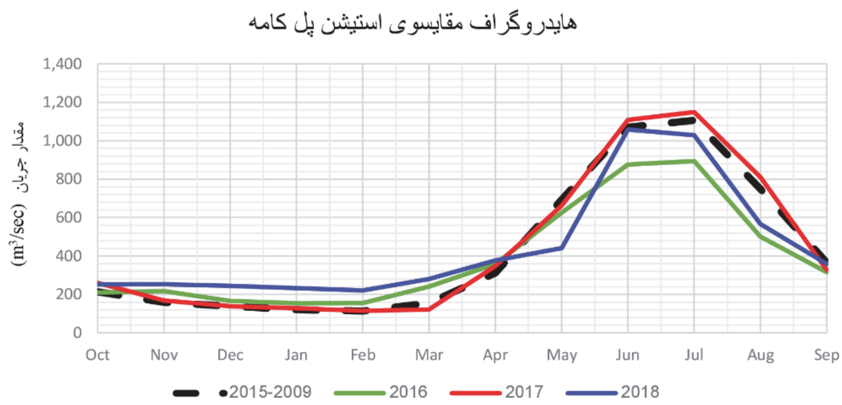
Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.
		2017								2018		
1	259	251	259	243	227	259	327	385	622	960	622	457
2	251	251	251	243	219	285	350	420	643	1045	622	513
3	251	251	251	243	219	330	414	414	622	1130	608	464
4	251	251	251	243	219	305	396	375	618	1028	615	426
5	243	251	251	243	219	285	376	375	770	977	601	402
6	243	251	243	243	219	267	375	345	994	1028	629	396
7	251	251	243	243	219	243	380	370	1113	1011	622	390
8	251	251	235	235	219	243	420	360	1181	960	608	385
9	259	251	243	243	219	251	526	360	1232	977	594	380
10	251	251	243	243	227	243	471	385	1164	1552	594	380
11	243	251	243	243	227	227	385	457	1130	1062	636	375
12	251	251	251	243	227	235	340	580	1215	977	574	380
13	259	251	251	243	227	325	330	513	1283	1011	594	375
14	251	251	251	235	219	370	325	544	1249	994	574	375
15	251	259	243	227	219	345	315	538	1045	1011	615	365
16	251	251	243	219	219	325	331	513	1181	1198	608	365
17	251	251	243	219	219	285	396	464	1130	1181	594	365
18	251	295	243	219	219	280	444	478	1181	977	562	360
19	251	251	243	219	219	267	450	499	1045	1011	594	360
20	251	251	243	219	219	259	426	492	1412	1096	550	355
21	251	251	251	227	219	243	390	432	1384	1096	562	350
22	251	251	243	227	219	243	365	402	1412	1164	556	345
23	259	251	243	227	219	267	340	375	1384	1249	562	339
24	251	259	235	227	211	280	340	375	1266	1130	580	337
25	259	251	235	227	227	267	340	385	1266	1079	370	334
26	251	251	243	227	211	280	365	380	1130	1011	587	325
27	259	251	243	227	219	295	350	390	922	1045	513	290
28	259	251	251	227	259	305	345	426	587	846	464	243
29	251	259	243	227		305	355	513	694	884	444	189
30	259	251	243	227		295	360	544	884	618	450	159
31	251		243	227		290		601		580	450	

Monthly summary

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.
Date	5	1	8	16	24	11	15	6	28	31	25	30
Min.	243	251	235	219	211	227	315	345	587	580	370	159
Mean	252	253	245	232	222	281	378	442	1059	1029	566	359
Max.	259	295	259	243	259	370	526	601	1412	1552	636	513
Date	1	18	1	1	28	14	9	31	20	10	11	2
Time												
Mm³	675.7	656.5	656.4	622.5	536.0	751.6	978.5	1183	2744	2755	1517	931.3

Tot.	Runoff	14007	Mm³				Record	Available	Jan.1967
Q - m³/sec	Min	159	Mean	443	Max	1552	Peak on Record	Q:2350	Jul.18.1973
q-L/sec Km²	Min	6.11	Mean	17.0	Max	59.7	Lowest on Record	Q:45.0	Feb.26.1975

Example of River Flow Yearbook



Example of Annual Fluctuation Figure of River Flow

Figure 3.3 Example of River Flow Yearbook and Changes in Water Level and Discharge of Rivers Over a Year [10)]

Based on the long period daily discharges yearbook at the planned intake sites, an annual fluctuation figure of river discharge is created, as shown in Figure 3.3, aimed to understand the annual fluctuation characteristics of river discharge. That is, it is necessary to understand when and how much the river flow increases, when it stops increasing and starts to decrease and how much it decreases. Furthermore, it is necessary to check how much the discharge changes from year to year.

It is important to consider the mechanism of changes in water levels and discharges over a year. By carefully and continuously observing rivers in the mountainous area, at the upstream of the river basin and the surrounding areas, a hypothesis should be made which can explain the structure of water level and flow changes over the year. It should be verified with data provided by public agencies and project-monitoring findings. It is also necessary to pay attention to the effects of climate change, such as rising of the snowline in the mountains during summer and the decreasing rainfalls. It is important to verify the hypothesis of the mechanism of annual water levels and flows changes in the river, through existing data and continuous cycle of observation and monitoring.

For example, in the Kunar River Basin, the accumulated snow in winter thaws from early spring to summer. The Kunar River has abundant flow, and the river water level and flow from spring to summer can be roughly predicted by observing the snowfall in winter. Through repeating these observations and verifications, it became known that the Kunar River stabilizes the river flow when there is a lot of snowfall during the severe winter season, and floods easily occur in the spring when there is much snowfall in late winter. Furthermore, it is known that floods easily occur when the temperature is high.

On the other hand, a scientific approach based on measurement data is also important. It is possible to estimate river discharges under various weather conditions and climate changes by performing runoff simulations with computers, with modeling river basins and rivers. In this way, it is necessary to grasp the river conditions by integrating local observation and monitoring with scientific knowledge.

To carry out the runoff simulation, it is necessary to establish rainfall, snowfall, and temperature data in the basin. It is also necessary to estimate, not only the runoff of rainfall, but also the snowmelt runoff model, based on the temperatures. If a runoff model including such snowmelt can be assembled, it is possible to deepen the understanding of floods and droughts in the river basin. Future research is expected to improve this approach.

(2) Organization of River Flow Condition

To know the fluctuation of the river flow and the profusion of water volume for one year, a flow duration curve is created as shown in Figure 3.4. The flow duration curve is a sequence of discharge data for 365 days observed in a river, sorted in descending order. In Japan, there are the following four indicators which represent river flow conditions. Globally, 75% (Q75) and 95% (Q95) of the horizontal axis of the flow duration curve are often used as indicators of low and drought flow.

- High discharge: Discharge which occurs during less than 95 days (26%) through the year
- Normal discharge: Discharge which occurs during less than 185 days (51%) through the year
- Low discharge: Discharge which occurs during less than 275 days (75%) through the year
- Drought discharge: Discharge which occurs during less than 355 days (97%) through the year

From such river flow regime indices, it is understood how much (or less) a certain amount of discharge is flowing in a certain river for a certain number of days, when a certain amount of irrigation water is taken, and how much it is affected downstream. Similarly, by plotting the river water level data for one year in descending order, it is possible to grasp the highwater level, normal water level, low water level, and drought water level.

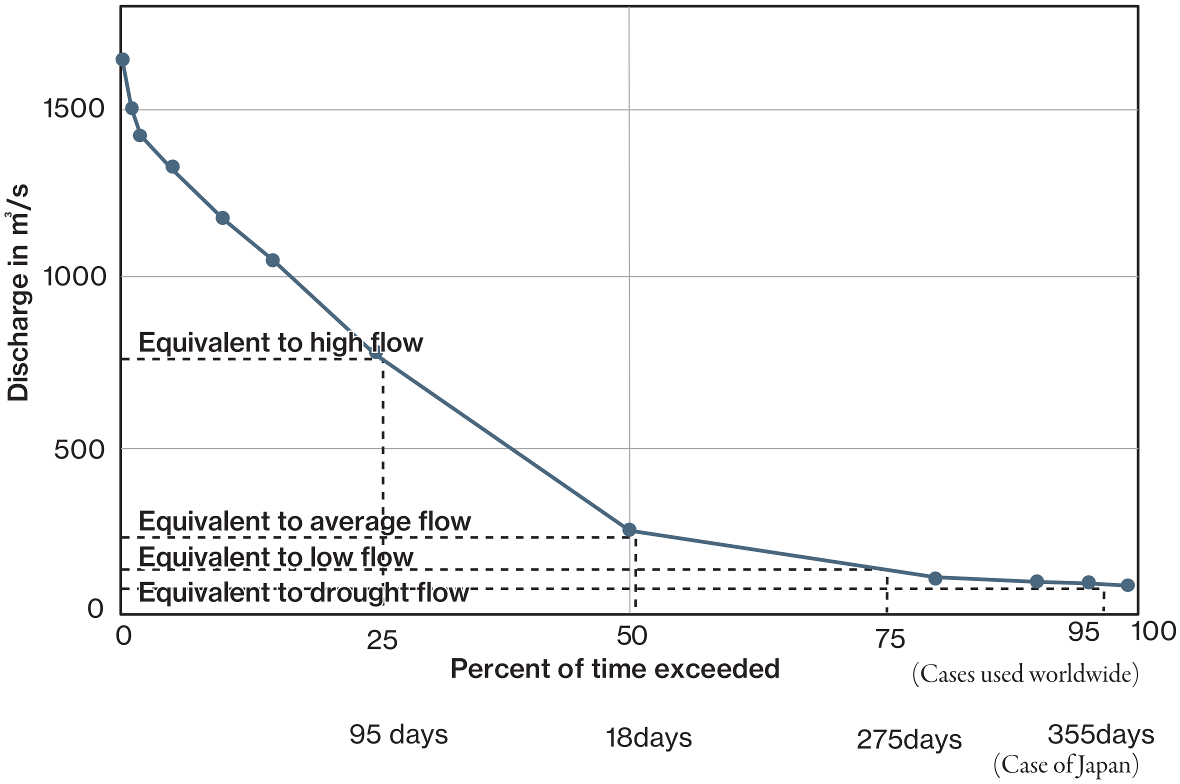


Figure 3.4 River Flow Duration Curve 2)

(3) River Flow at the Time of Flood

How often (once in how many years) and how much flood flow will likely occur in the target area can be understood by performing frequency analysis of river flood flow. As shown in Figure 3.5, the relation between flood discharge and return period can be graphed to show flood discharge against the probability scale. The lower horizontal axis shows the probability of occurrence, the upper one shows the return period, and the vertical axis shows the flood discharge. In the figure, the flood discharge with a 10-year return period (once in 10 years) is approximately 2,000 m^3/s. If the slope of this line is steep, it means that the flood discharge varies greatly depending on the return period. Also adverse, if the slope is gentle, it indicates that the flood discharge does not change so much depending on the return period. In general, large rivers have a gentle slope, and small/medium rivers have a steep slope of the flood duration curve.

When a long period of hydrometeorological data is available, generally, a target return period is set to determine the design flood discharge. Then, flood control facilities and structures are planned and designed. However, if there are very few data, the probable flood discharge obtained as above is not reliable. Therefore, in the PMS method irrigation project in Afghanistan, in situations where hydrometeorological information has not been sufficiently recorded, the water level and discharge at the time of maximum flood are confirmed based on interview with residents regarding the maximum flood and the flood marks from the past. Then, planning and designing river structures is performed in such a way that the system would be flood resilient, able to withstand high floods which occurred at the river in the past. Even if there is a little flood data, it is possible to get a rough indication as to what year the probability of the past maximum flood was by drawing a probabilistic flood discharge graph as shown in Figure 3.5.

As described above, when using probabilistic flood discharges for planning and designing, it is necessary to fully consider the number and accuracy of data obtained, and the possibility of flood characteristics which differ from past trends due to climate change and human influences.

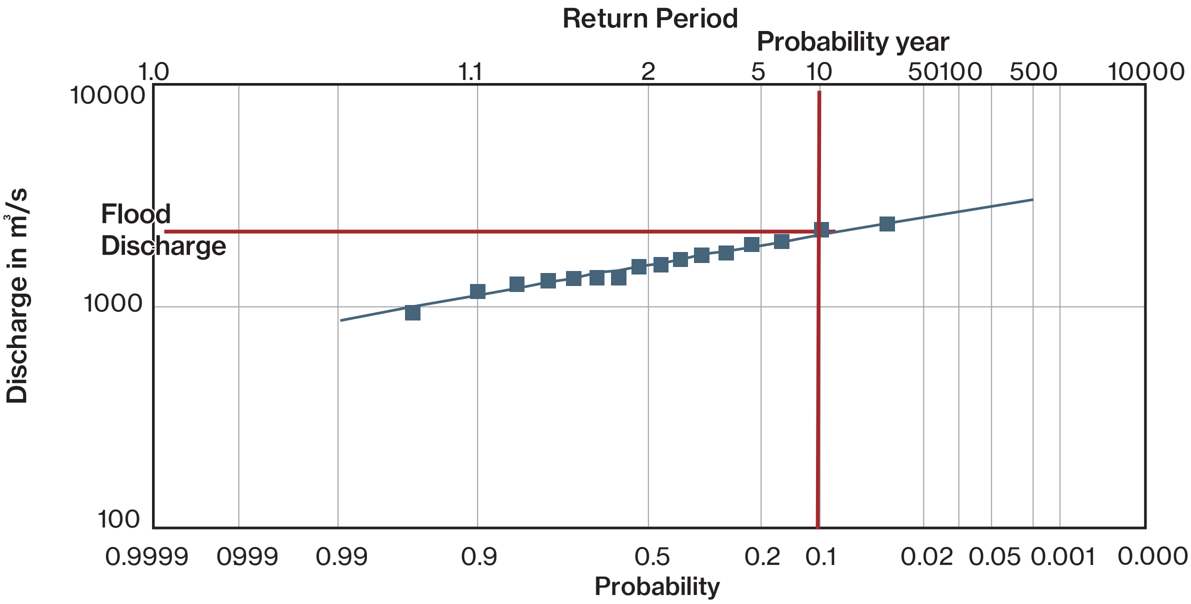


Figure 3.5 Estimation of Probabilistic Flood Discharge[2)]

(4) River Flow at the Time of Drought

River flow at the time of draught is grasped as to how often (once in how many years) and how much discharge may decrease in the target area by conducting a frequency analysis of drought discharge. Similar to the river flow during floods described above, the drought discharges for each probability scale is calculated by graphing the relationship between drought discharge and return period as shown below. The drought discharge (which occurs once in five years) is approximately 80 m^3/s in this case.

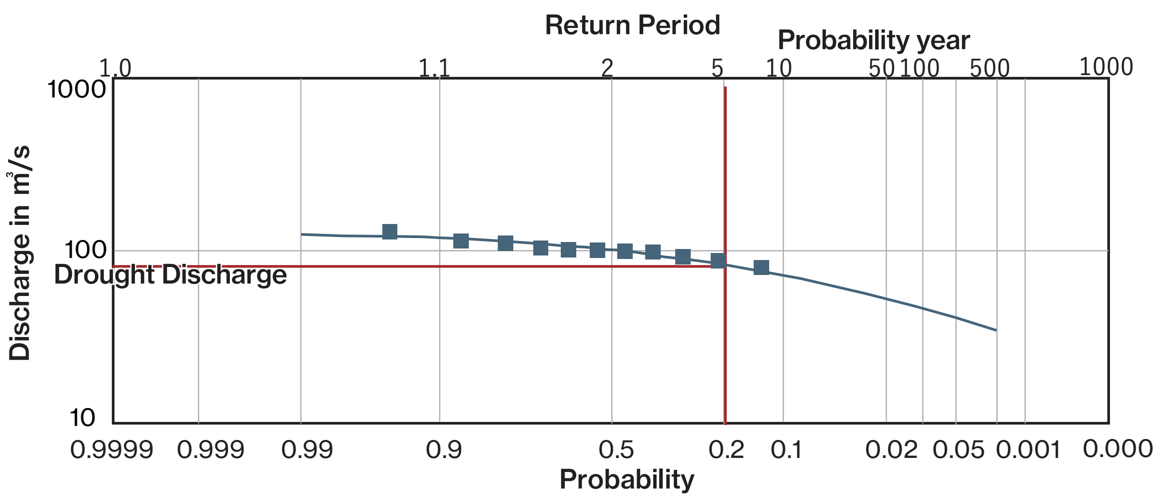


Figure 3.6 Estimation of Probabilistic Drought Discharge [2)]

(5) Impacts of New River Structures on River Channels and River Flows

When river structures, such as intake weir and spur dikes are constructed, they affect riverbanks and river flows, more or less, somewhere on the left/right banks, or upstream/downstream stretches. Therefore, the situation related to the following structures, river channels and landside areas located on the left and right banks, upstream and downstream of the PMS method irrigation facility planned site are understood and arranged in advance:

- Existing or planned river structures (irrigation facilities, intake gates, spur dikes, dikes, revetment works, etc.).

- Topography, geology and land use conditions of river channels and landside areas which are considered vulnerable during floods.

Based on this information, the impact on other structures, river channels and landside areas of the newly constructed river structures in the PMS method irrigation project is analyzed. For example, the possibility of increasing the water level on the left and right banks/upstream and downstream, changing the flow, and promoting erosion with the construction of intake weirs and spur dikes are examined. In particular, the new generation of flood inundation occurrence due to backwater (rise of water level) at the upstream by weir construction are carefully assessed.

3.2.4 | Impact of New Water Intake on Downstream Water Use

When irrigation water is abstracted, the discharge downstream of the intake always decreases. In addition, if the upstream water use increases, the water intake of the irrigation project may be affected. To understand such impacts, firstly, the water rights registered in the Department of Water Right of NWARA are investigated and the present water use situation at upstream/downstream and left/right banks (who, where and how much water is taken) is grasped. Then, the planned new water intake for irrigation is carefully studied, specially whether it affects the water use on the upstream/downstream and the left/right banks. Furthermore, the fluctuation of river flow over the year is grasped to confirm whether the intake is relatively small, compared to the river flow. Specifically, studies are conducted, and the results evaluated as described below. The reduction of water volume should be evaluated by making a diagram such as shown in Figure 3.7 which indicates the planned drought discharges and the planned water intake volumes, inflow of tributaries, and return flows from irrigation canals and irrigated farmland, etc. If new water use has a large impact on the downstream flow, the local situation is carefully checked and adjusted based on laws and customs with coordination among representatives of downstream water users and relevant government agencies (NWARA, MAIL, MRRD, etc.). In some cases, it is necessary to take flexible measures such as reducing the amount of new water intake, increasing the number of reservoirs, or incorporating downstream water use into the project. The PMS method irrigation project does not assume new water resources development, such as dams and large-scale reservoirs.

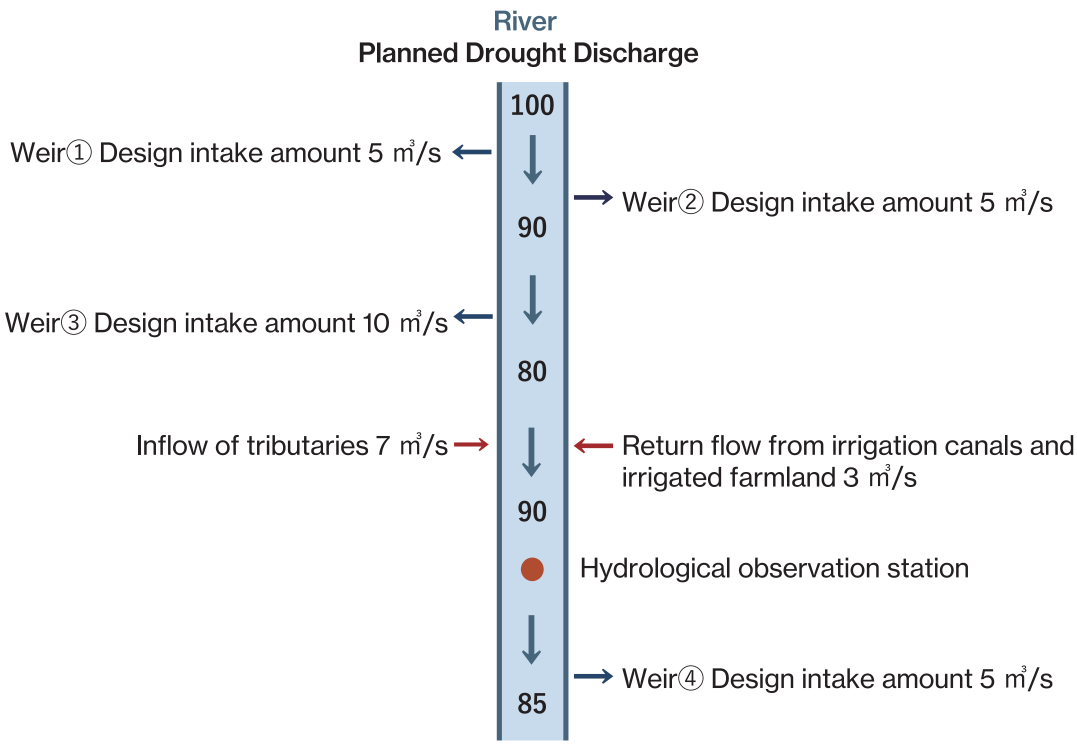


Figure 3.7 Assessment of Impacts of New Water Intake on Downstream Water Use[2)]

3.3 Interview Survey with Residents

Residents living near the target area often know the river condition during floods and droughts. Therefore, interview survey with residents is conducted to collect and organize various river information useful for the PMS method irrigation project, such as river water levels and depth of fluctuations, flow and water levels during floods and droughts, and flood inundation situations.

3.3.1 | Methods of Interview with Residents

Interviews are conducted with as many residents as possible by targeting the village heads, elders, residents and boatmen near the planned construction site, intake weir, intake gate, flood control facilities, and the beneficiary village heads, elders and representatives of *Mirab* and WUA (IA) who are familiar with the past and present local and river conditions. Table 3.3 shows the interview survey target areas, target persons, recording methods and survey items required for such interviews with residents. Table 3.4 gives an example of a survey form of the interview with residents which can be used when conducting an interview survey.

Table 3.3 Methods and Utilization of Interviews Survey with Residents [2)]

Interview survey target area	Vicinity of beneficially irrigation areas and planned construction sites for intake weirs, intake gates, flood control facilities, etc.	
Target persons for interview survey	Village heads, elders, *Mirab*s, WUA (IA) representatives, residents, boatmen, etc. who are familiar with past and present local and river conditions	
Recording methods of interview survey	• Be sure to go to the site and interview at the site and write the results of the interviews in the answer column. • Record the latitude and longitude of the interviewed sites and river survey sites with GPS, etc. • Take photos or draw diagrams to keep a record that allow you to check the local situation and what you interviewed. In particular, be sure to record photos and figures of water levels, traces of erosion, and changes in river channels and sandbars due to past floods. • It is also necessary to obtain photos of river conditions, floods and droughts that the interviewee has.	
Interview survey items	Detailed items	Utilization methods
River conditions	Annual fluctuations of rivers, water level, discharge, and water quality during floods and droughts	Understanding the water level required for facility design and selecting water intake sites
	Location and stability of river channels, fluctuations in sandbars, sedimentation and scouring situation	Understanding the ease of water intake such as the stability of river channels and sandbars, and selecting water intake sites
	Recent changes in precipitation, temperature, floods, droughts (frequency, scale, timing, etc.)	Understanding the impact of climate change
Flood situation	Flood date, river water level at the time of flood	Understanding the flood water level required for facility design
	Flood inundation location, inundation extent (area, latitude / longitude coordinates, ratio), inundation depth, inundation duration	Confirming the need for dikes and spur dikes by grasping the flood situation
	Damage situation etc.	Understanding the flood damage situation
Drought situation	Drought date, water level, location, stability of river during drought	Understanding the drought water level required for facility design
	Affected extent (area, latitude / longitude coordinates, ratio), damage situation, etc.	Understanding the drought damage situation
Existing structures and water intake situation	Existing structures and river use situation on the upstream and downstream / left and right banks of new river structures	Examining the impact of new facility construction and water intake, and selecting water intake sites

Table 3.4 Example of Interview Survey Form with Residents [2)]

Date and Time：	Interview Site (GPS coordinates)： River survey Site (GPS coordinates)：
Interviewer Name：	Contact：
Interviewee Name：	Contact：
Village Information Village Name：	Number of People：
Number of Households：	Area：
Cultivated Land Area：	Irrigation Area：

Ⅰ. River Conditions

1. When and how much does the water level of a river rise at the maximum in a year?
Answer (photo / figure):

2. When and how much does the water level of the river drop at the lowest in the year?
Answer (photo / figure):

3. Is there enough water in the river for irrigation?
Answer:

4. Is there a problem with the water quality of the river when irrigating?
Answer:

5. Does the location and shape of the channel at the planned weir site of the river change frequently?
Answer (photo / figure):

6. Does the location and shape of the sandbar at the planned weir site change often?
Answer (photo / figure):

7. What are the changes in precipitation, temperature, floods and droughts in recent years?
Answers (frequency, scale, timing, etc.):

Ⅱ. Flood Situation

8. When did the highest flood water level ever occur and how much did the river water level rise?
Answer (photo / figure):

9. Did an inundation occur at that time? How much were inundation depth, inundation area, and inundation duration?
Answer (photo / figure):

10. Where did the flood water come from?
Answer:

11. Where and how much did riverbank erosion occur?
Answer:

12. Did any damage occur? How much damage was it?
Answer:

Ⅲ. Drought Situation

13. When did the worst drought ever occur? How low was the river water level at that time?
Answer (photo / figure):

14. Did a drought damage occur? How much damage (severity and amount of damage) was it?
Answer:

Ⅳ. Existing Structures and Water Intake Situation

15. How did you take water from the river so far (with or without a weir, etc.)?
Answer:

16. What was the problem when you couldn't take water? (Frequency, cause, crop damage due to inability to take water)
Answer:

17. Is there water intake or river use on the upstream and downstream / left and right banks?
Answer:

18. Where and how much water is taken and what areas are irrigated?
Answer:

3.3.2 | Organization of Interview Results

The interview survey results include records for filling in the interview survey form, drawings recording the survey results, photos taken, and photos collected from the residents. These are organized by item and place. When arranging the survey results, it is necessary to confirm the accuracy of information firstly.
In some cases, the surveyor may not properly interview the residents. Photos are then taken during the interview survey to confirm that the residents are properly interviewed. In addition, residents may provide incorrect information due to wrong memories or misunderstandings. When organizing the survey results, it should be made sure that the answers obtained from multiple people are consistent with each other.
Furthermore, by comparing the existing materials/data collected in Section 3.2 with the results of the interview survey, the consistency of the information/data is confirmed to increase certainty. For example, it is possible to confirm the consistency of the history of maximum floods and droughts and the transition situation of river channels and sandbars from hydrological data and satellite images. In addition, the results of interview survey of irrigation water intake in the surrounding area are compared with the registered water right information collected to grasp the consistency between the actual conditions and the registered information. If these are checked and they are not consistent, interviews are conducted again, and existing information are re-examined as well. It should be strived to collect information as accurately as possible.

3.4 Observation and Measurement of River Condition

Information such as river water level, flow velocity and discharge, are required in order to plan and design a sustainable and stable PMS method irrigation project which can prevent overtopping and destruction of facilities due to flooding and which can allow sufficient water intake even in low water. In Afghanistan at present, there is often insufficient information on these river conditions. Therefore, it is particularly important to observe and grasp the river conditions on site. Rivers are constantly changing, and it is necessary to visit the site on a regular basis and grasp the situation in order to understand these changes. In particular, it is important for the person in charge of the project to visit and observe the river and flow conditions both during floods and droughts.

3.4.1 | Observation of River Channel Conditions

(1) Viewpoints and Methods for Observing River Channel Conditions

Before observation of river channel conditions, the river channel conditions are grasped in a plane view from existing topographic maps, Google Maps and Google Earth, or similar. The history of river changes from the past to present are organized based on old maps, past satellite images, and the results of interviews with local residents.
It is important to carry out the observation of river conditions from the viewpoints shown in Table 3.5. It is also essential to visit the site and work practically with use of the five human senses.

Table 3.5 Viewpoints for Observing and Measuring River Channel Conditions [2)]

Flood	Drought
-Where is the flood likely to occur? -Where are flood flows gathering and erosion likely to occur? -How will the sandbar change? -How will the river channel change?	-Where can water be taken stably? -Search for stable streamway from the transition history of streamway and the direction of flow -Search for stable sandbars and sedimentary zones based on the historical transition of riverbeds and sandbars.

The intake weir and the intake gate are particularly important structures in irrigation projects, and the planned site must be looked down from a high place to comprehensively understand the local river channel conditions. If there are no high places, a tower is set up and the whole area around the intake site is observed. When taking an aerial view of the river condition, the viewpoints shown in the table above are referred to and the conditions of the entire river channel understood, including the area around the intake site such as the streamways and the meanders of the river, the location of bedrock, the low-lying areas where floods are likely to occur, the sandbars and the sedimentation zone. The whole view is recorded on a plane to create the base map used for the facility layout planning discussed in Chapter 4.

・Observe from a high place and take an aerial view of the site. Understand the whole picture. Build a tower, if there is no high place.

•Grasp and record in a plane. Record the streamway, river meander, bedrock location, low low-lying areas, etc. while referring to the above local photograph.

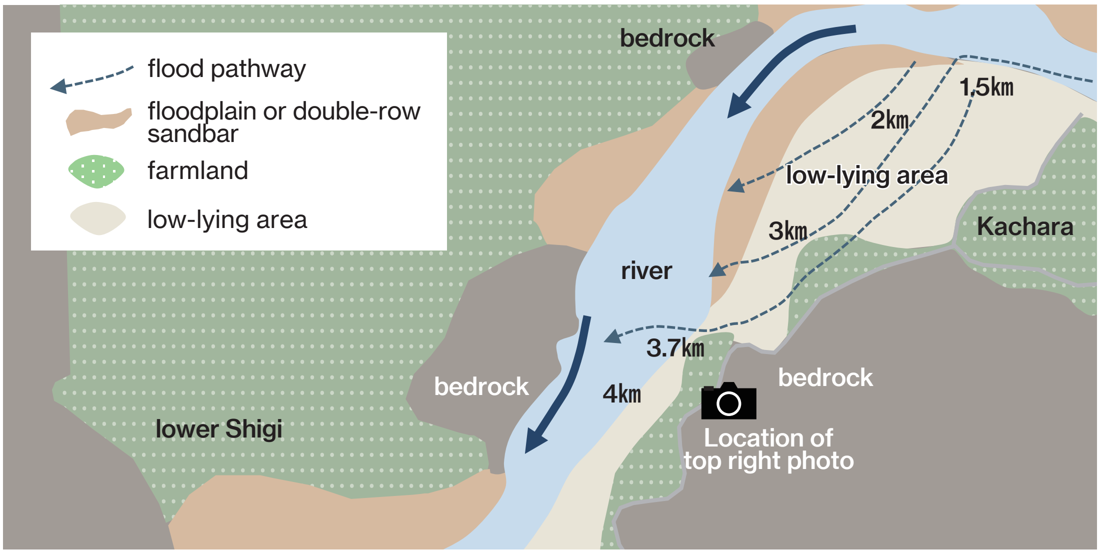


Figure 3.8 Example of Aerial View of the Whole[1),2)]

(2) Observation and Organization of Overtopping and Inundated Areas during Floods

The river topography shown in bold font below is observed, and the places where floods are likely to occur are confirmed while keeping in mind the relationship between river topography and erosion, overtopping, inundation, and damage due to floods. Those places are marked on a map and the local characteristics are noted and recorded in photos or sketches. Such information can be effectively used for planning and designing flood control works such as levees and spur dikes.

- **In places where the river is narrow**, it becomes difficult for the river to flow downstream, and the upstream part is flooded (see Photo 3.1 and Photo 3.2).

- **In places where the flow is slow such as retarding areas of the river**, the water level easily rises, and overflow easily occurs.
- **The river channel along the bedrock** is often deep and rapid, and the flow path does not change even during a heavy flood, so it is suitable for water intake. On the other hand, **on the other riverbank** of the bedrock side, if it is not bedrock, erosion is severe and flood damage tends to occur in the downstream area of bedrock [11]. The flood damage depends on the river topography and the flood level as follows: [1]
  - If **the riverbed is wide**, the extent of flood damage is wide, and if the riverbed is deep, the flood damage is large.
  - If the flood flow of the river is large, the inundation area is wide, and if the **flood water depth** is large, the flood damage is large.
  - Flood damage expands when a flood enters along the canal, and damage is likely to occur if **the soil is susceptible to erosion**.
- Water colliding fronts such as **the outer curved part** where the flood flow hits are easily eroded if there is no bedrock.
- **River channels with a lot of boulders** naturally are likely to be floodways.
- Flood flow may flow into from **the existing canal intake** and cause inundation (see Photo 3.3).
- If there are **existing flood protection facilities**, it is highly likely that the site had been damaged by floods in the past, and floods are likely to occur (see Photo 3.4).
- **Areas which have not been cultivated for a long time** are prone to damage by disasters such as floods and may have been damaged in the past.

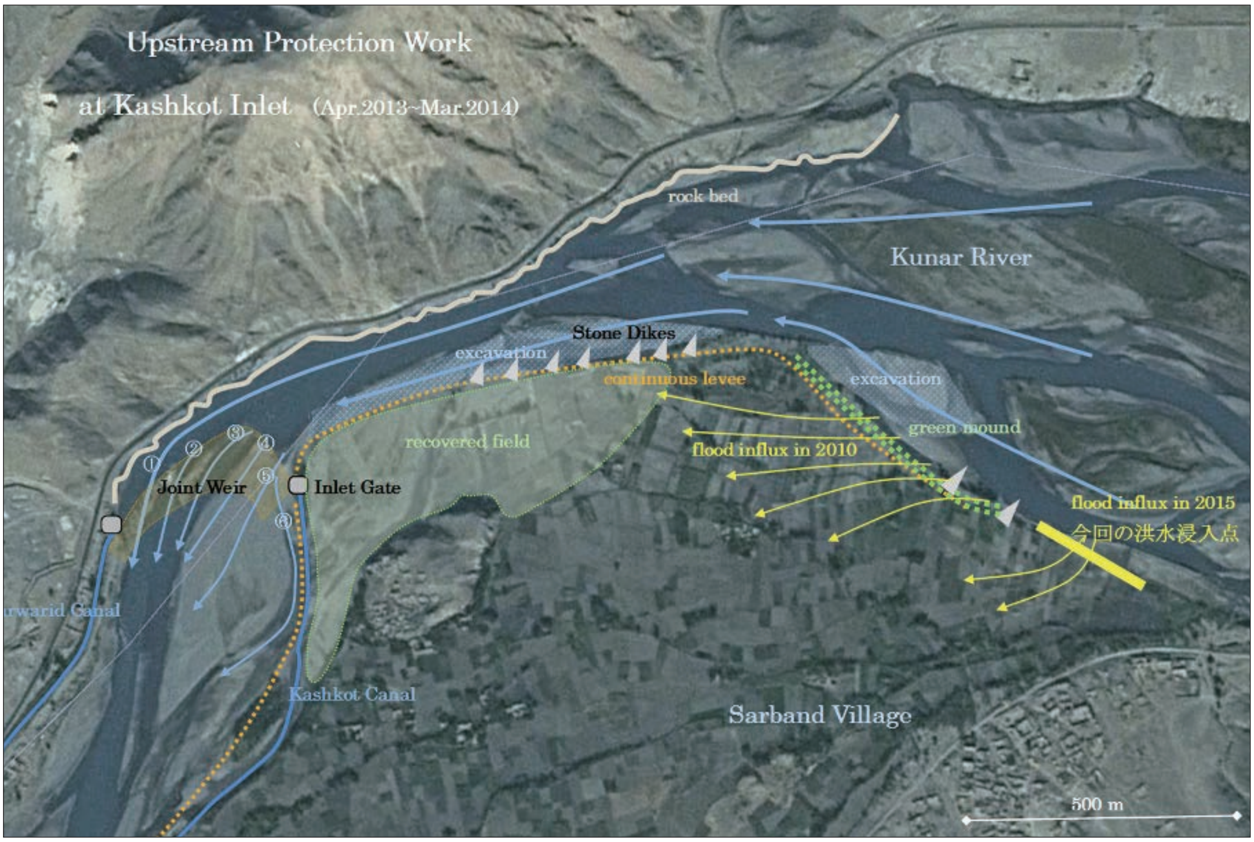


Photo 3.1 Satellite Photo of Narrow River[1]

Photo 3.2 Retarding Place of River [1)]

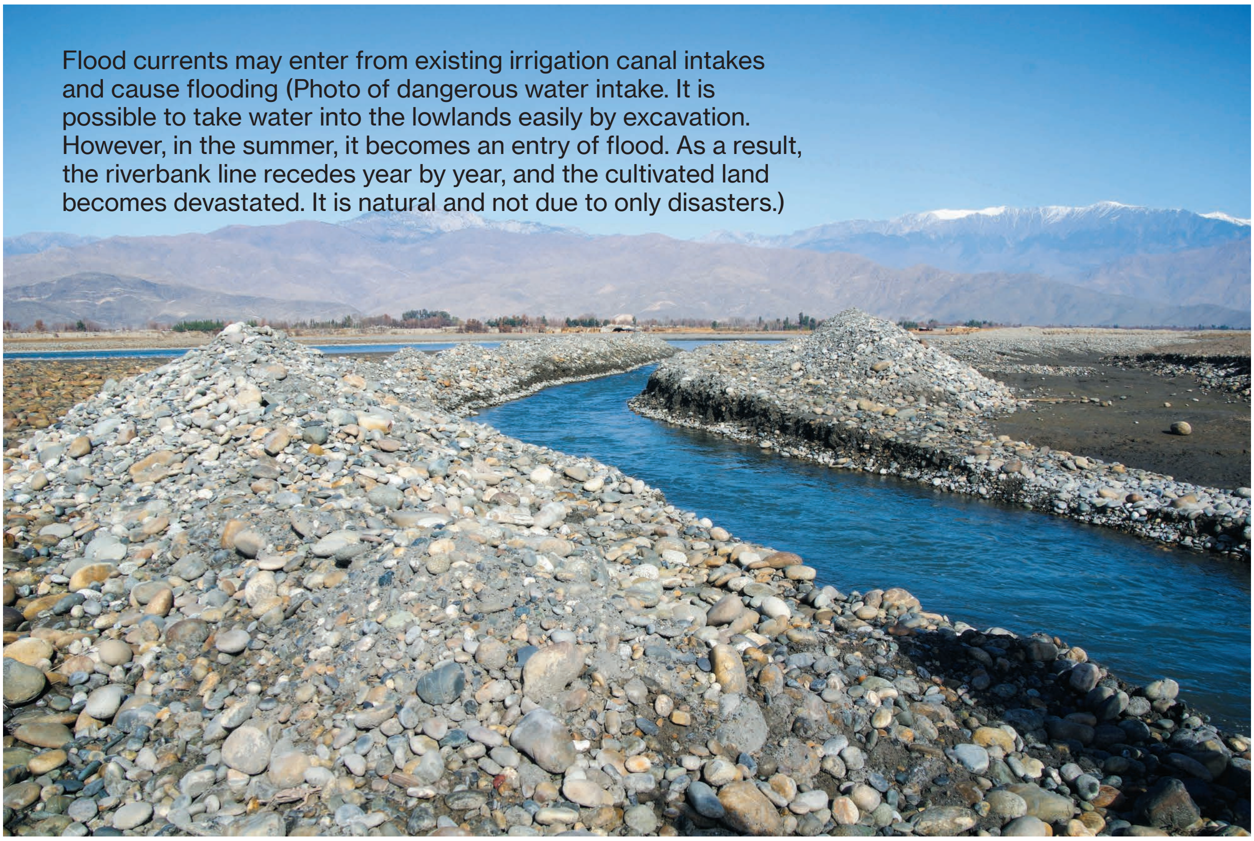


Photo 3.3 Simple Water Intake Creating Flood Water Path[1)]

Photo 3.4 Area Expected to be Flooded Under the Existing Flood Control Facilities[1)]

(3) Observation of Sandbar Fluctuation

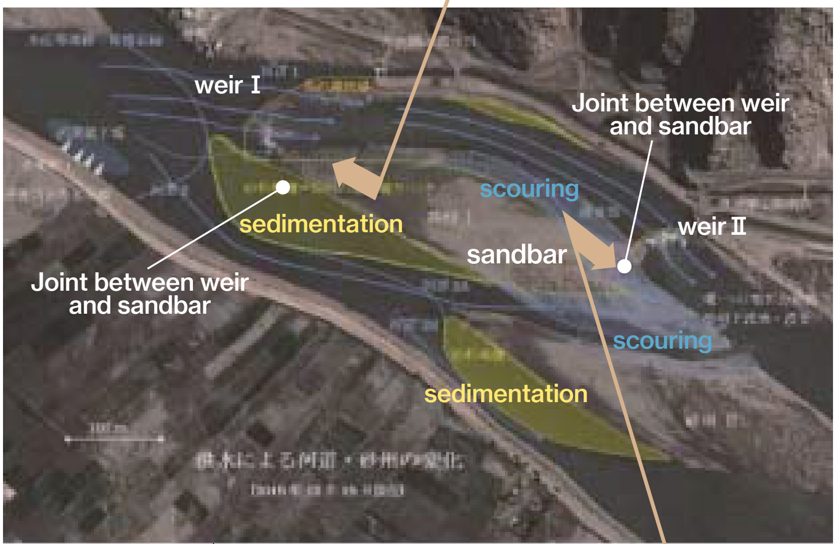
Sandbars can move and change in shape in long term, especially after a major flood. Such long-term changes in sandbars are fully understood in advance by using existing satellite images and interviews with local residents (see Sections 3.2 and 3.3). In addition, the movement and changes of sandbars are observed at the site on a long-term and regular basis, especially, the changes of sandbars after a large flood (see Column 3-1). Moreover, not only the fluctuation of sandbars from the past to the present, but also the future possible changes of sandbars, are estimated. In general rivers, sedimentation becomes remarkable at the location where the river is wide and the flow is gentle, and the sand bars tend to move in the straight parts of the river and get fixed in the curved parts. The future sandbar movements are estimated by taking into consideration such general tendency and the sandbar movements from the past to the present in the target area.

When constructing the intake weir in the PMS method irrigation project, the sandbar is often connected as an abutment. Therefore, by grasping the characteristics of sandbar fluctuations in the target river channel (such as sandbar stability and riverbed scouring conditions), it is possible to provide extremely important information to the planning and design of safe and stable intake weirs and flood control facilities.

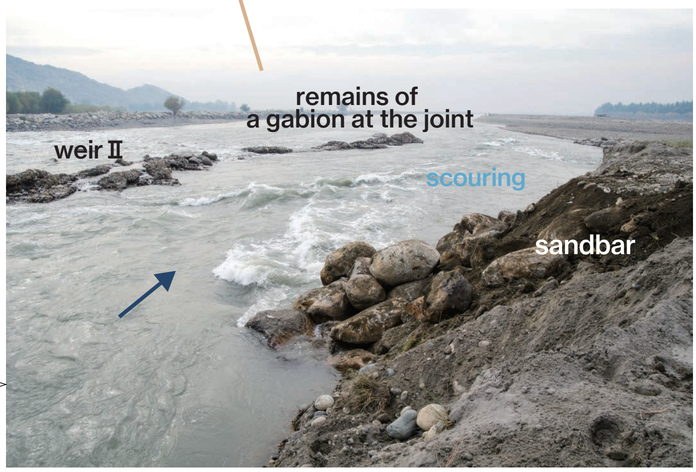
The method of analysis of sandbars and scouring using hydraulic parameters is shown in the Appendix, which is referred to, for a more detailed analysis of sandbar fluctuations.

Text Block 3-1: Observation of Sandbar Fluctuations by PMS

Gr avel deposits are occurring. The joint between the we ir and the sandbar is protected by sedimentation.



Changes in river channels and sandbars due to floods in July and August 2015 (Yellow areas are sedimentation areas, blue area s are scour areas.)

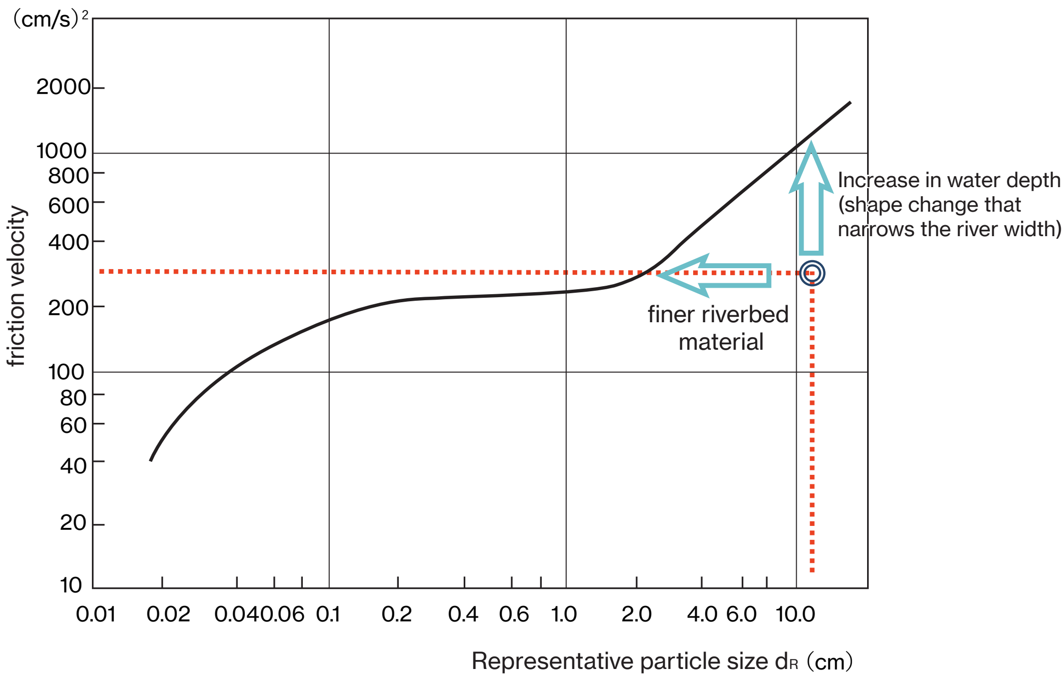


The remains of a gabion embedded at the joint of th e weir and the sandbar, and the eroded sandbar.

Figure: Changes in Sandbars [1)]

(4) Stability of River Channels and Estimation of Fluctuations

It is extremely important to know the stability and fluctuations of the river channel, i.e., the changes such as possible future rise or fall of the riverbed, for planning and designing flood control works and river facilities. Figure 3.9 shows one of the methods to evaluate such river channel stability and fluctuation. This figure shows the relationship between friction velocity and representative particle size based on the survey of rivers in Japan. The lower left of the graph is the downstream section where the flow velocity is relatively slow, and the riverbed material particle size is small. On the contrary, in the upper right area, the flow velocity is relatively high, and the upstream section is where the riverbed material has large particles size. In the target river, it is possible to evaluate the stability of the river by obtaining the frictional velocity U^* and the representative particle size dR of the riverbed material and plotting them on this graph. For example, if the plotted points deviate from the black solid line, it is estimated that in the future, changes in the river width or water depth or changes in the riverbed material occur, and channel fluctuations that approach the black solid line occur. On the other hand, if the plotted points are close to the black solid line, the river is stable. The relation between friction velocity of the riverbed material and the representative particle size in the vicinity of the Marwarid II Intake Weir in the Kunar River are shown in blue circle on the right side of the figure below. As shown, it is expected that riverbed materials will become finer or the friction velocity will increase (the water depth will increase or the river width will decrease).



Y-axis: Friction velocity ($U^* = \sqrt{gRI}$, where R: hydraulic radius, g: gravitational acceleration, I: riverbed gradient, critical particle size for sediment movement d)、R = A (flow areas) ／S (wetted perimeter)
X-axis: Representative particle size (dR, see Figure 3.19)

Figure 3.9 Stability of River Channels [2), see 12)]

The method of analysis of river channel stability and scouring conditions, using various hydraulic parameters is shown in the Appendix, which is referred to for more detailed riverbed change analysis.

(5) Understanding of River Conditions for Planning of Intake Weir Site

If there is a sandbar on the opposite bank of the intake site and the intake weir is connected to the sandbar, the river channel topography is carefully observed and understood at the upstream and downstream of the intake weir site, paying attention to the following points:

- Whether the mainstream of the river heads toward the intake site side (opposite side of the sandbar) at the time of flood.
- Whether the river water that overflows the weir is concentrated in the center of the river and its energy is reduced.
- Whether the construction of a weir erodes the sandbars on the opposite bank.

3.4.2 | Observation and Measurement of River Flow Condition

(1) Viewpoints and Methods for Observing and Measuring River Flow Conditions

The river flow conditions are observed from the viewpoints shown in Table 3.6 after analyzing the results of interviews with local residents.

Table 3.6 Viewpoints and Methods for Observing and Measuring River Flow Conditions (Water Level, Flow Velocity, Discharge, etc.) [2]

Item	Season	Viewpoint of Observation/ Measurement	Method of Observation/ Measurement	Utilization
Water Level	Flood	-The water level at the time of the maximum past flood and the water level during the flood every year -Overflow water level in past floods	-Check the water level record at the exposed rocks -Perform fixed-location measurements of water levels throughout the year to understand changes in river water levels during floods and droughts -Continue water level measurement by establishing an observation system during and after the project	-Determine the height of the dike and the height of the intake gate -Determine the height of the weir
	Drought	-The water level at the time of the maximum drought and the water level during the drought season every year		
Flow Velocity	Flood	-Flow velocity along river water paths, river banks and dikes	-Visually observe the places where the flow velocity is fast (shallows) and the places where the flow velocity is slow (pools) qualitatively. -Simply measure flow velocity at various river flows throughout the year using float -Investigate the average particle size of boulders at the river	-Estimate the energy of flood flow working on river facilities -Estimate the river flow velocity from the relationship between the average particle size and the critical flow velocity

Item	Season	Viewpoint of Observation/ Measurement	Method of Observation/ Measurement	Utilization
Discharge	Flood	-Maximum flood discharge -Flood discharge every year, flow width, water depth	-Observe water level, flow velocity, flow width, and water depth throughout the year, and simply measure.	-Multiply the flowing cross-sectional area (= flowing width x water depth) by the flow velocity, and grasp the estimated discharge at various seasons.
	Drought	-Minimum drought discharge -Discharge during the drought season every year, flow width, water depth		
Sediment Transport Volume and Water Quality	Flood	-Observe bedload, suspended load and wash load -Observe the color of river water -Observe odor, foaming, water temperature, etc.	-Measure bedload rolling on the riverbed -Measure suspended load and wash load by sampling river water -Observe the color of river water visually or by drawing water into a white bucket. -Check if there is a cause of water pollution (big cities, factories, etc.) in the upstream area or in the vicinity.	-Determine the capacity of the sand basin from the sediment transport volume -Check water quality -From the color and temperature of the river water, it may be possible to estimate whether the cause of the flood is snowmelt (light gray and cold) or rainfall (brown, etc.) from the experiences of local residents.

When a flood occurs, it is necessary to visit the site as possible and observe the river flow conditions with your own eyes. At that time, it is required to pay sufficient attention to safety. The river flow condition of the flood is recorded as shown in Photo 3.5, and its characteristics are comprehended and recorded in a record book.

River Flow Conditions during Floods (Kama Ⅱ Weir)	River Flow Conditions during Floods (Behsud Weir)
A muddy stream that swirls and flows. The front side is the end of the curved riverbank, and the weir is violently dammed by centrifugal force and the flow velocity is fast. The turbulence at the center is hydraulic jump.	The flood water level of the Kabul River is approaching the top of the intake gate.
	

Photo 3.5 Flood Situation[1)]

(2) Organization of Observation and Measurement Results

In order to grasp and understand the river situation, a wide variety of information such as flow velocity, discharge, slope, terrain inclination, location and state of rock and sandbar, curved parts of river lines, riverbed material, etc., are necessary. It is important to remember them as a "scene of a picture" and be able to follow them on the time axis. Therefore, when returning to the office from the site of observation/measurement, the survey records are organized as follows:

- Photos and memos are sorted by date and location, stored not only on a paper basis but also as electronic data. Field memos, etc. which have been memorized locally are also stored.
- Photos are taken with GPS location (Geotag) so that the location can be specified. The right bank, left bank, upstream, downstream, river direction, etc., are shown.
- Regularly, on-site memos, photos, etc., are organized to check changes in river conditions, such as monthly or quarterly.
- It should be ensured that observations of the change in river conditions after the flood are in place. If possible, the river flow conditions during the flood are observed.

(3) Basic Formula for Grasping River Flow Conditions: Manning's Formula

As a general rule, the flow velocity and discharge of a river are calculated from the following Manning's formula:

Manning's formula: $V = \frac{1}{n} R^{2/3} I^{1/2}$ ………………………………………………… (3.1) [2), see 14)]

$Q = A \times V$ ……………………………………………………………………… (3.2) [2), see 14)]

Where, Q: discharge (m^3/s)
V: flow velocity(m/s)
n: roughness coefficient (see Table 3.7)
A: cross section of flowing area (m^2)
R: hydraulic radius (m) (= A/S)
S: wetted perimeter (m)
I: riverbed slope

Table 3.7 General Values of Roughness Coefficient [2), see 13)]

	Rivers and Waterways Conditions	Manning's n Range
Natural River	Plain small channels, no weeds	0.025~0.033
	Plain small channels, weeds, shrubs	0.030~0.040
	Small channels in the plain, weeds, gravel bed	0.040~0.055
	Mountain channels, gravel, boulders	0.030~0.050
	Mountain channels, boulders, large boulders	0.040 or more
	Large channel, clay, sandy floor, less meandering	0.018~0.035
	Large channel, gravel bed	0.025~0.040

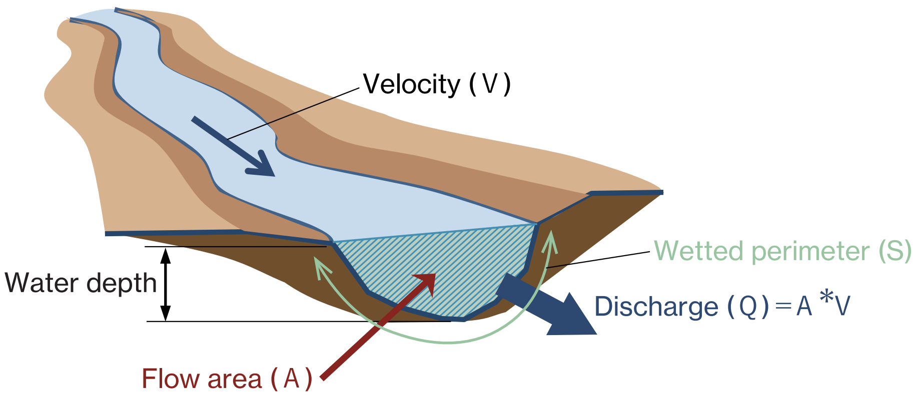


Figure 3.10 Discharge Calculation Methods [2)]

(4) Observation and Measurement of River Water Level and Utilization of Results

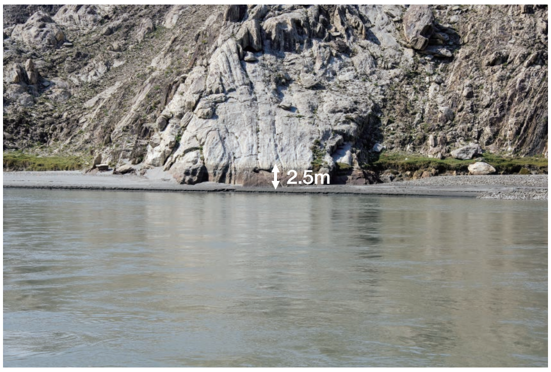
The water level at the time of the past maximum flood and the annual flood can be grasped from the existing hydrological data, the experience of local residents, and the past flood marks on the rocks (see Text Block 3-2). Annual fluctuations in river water level can be grasped from river observation and measurement records (see Text Block 3-2). Using this information, the heights of the dike and intake gate are determined with some freeboard (see Photo 3.6).

In addition, the minimum water level during the drought season can be grasped from the existing hydrological data and interview with local residents. Utilizing this, the weir height and the base elevation of the intake gate are determined, so that the required amount of water can be extracted with extra amount even during the drought season.

Photo 3.6 Relationship between Water Level During Floods and Height of Top of Intake Gate[1)]

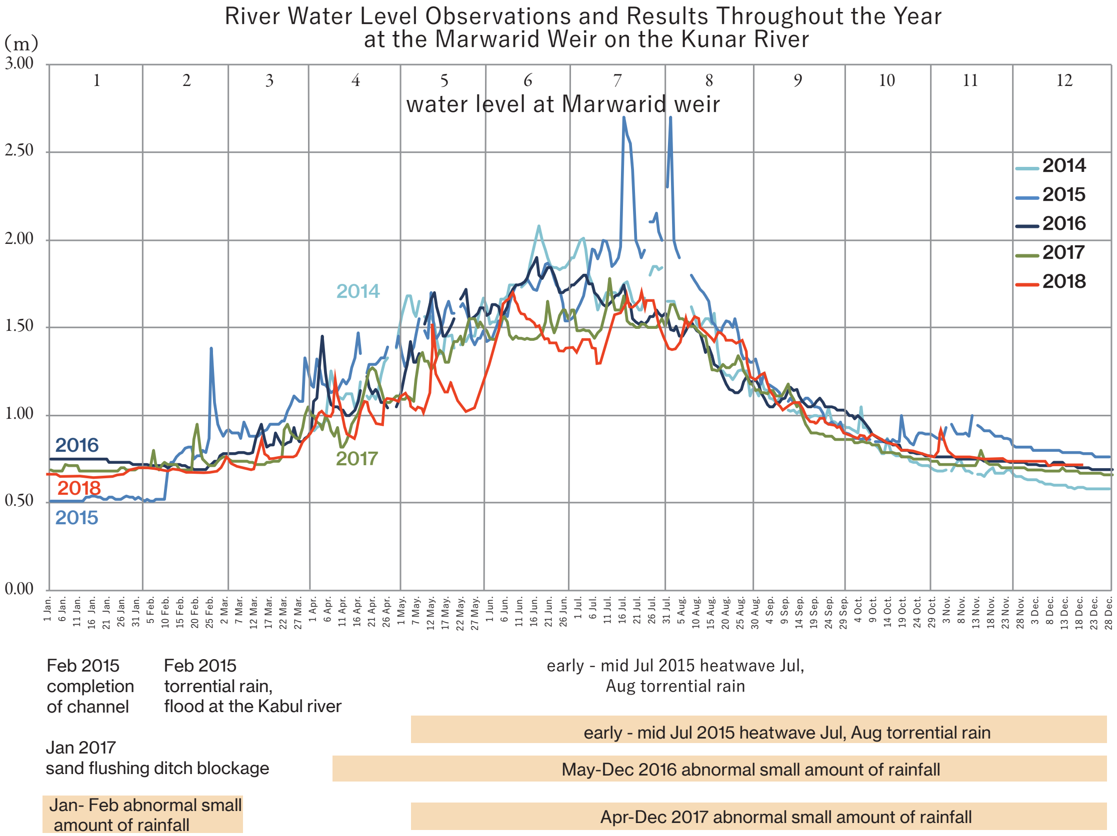
Text Block 3-2: How to check the river water level and water depth

Grasp the marks of past water levels engraved on the rock



Interview the boatman who is familiar with the local situation

River Water Level Observations and Results Throughout the Year at the Marwarid Weir on the Kunar River



level in summ er tends to be low after 2014, and especially in 2018 (red line), the water level in summer is low and the water level fluctuation is large.

Figure: How to Check River Water Level Fluctuations and Water Depth[1)]

(5) Observation and Measurement of River Flow Velocity and Utilization of Results

The methods for estimating the river flow velocity are: 1) the method by Manning's formula; 2) the method of measuring directly on site; and 3) the method of roughly estimating from the riverbed materials. Direct observation and measurement of river flow velocity is indispensable for the calculation of discharge and energy estimation of flood flow. In addition, when the water flow is low, the flow velocity of the river should be checked at shallow areas and also at pool areas, due to the difference in the formation of sandbars by qualitatively visually observing places where the flow velocity is high (shallow water) and places where the flow velocity is slow (pool). The results are used for planning and designing weirs, intake gates and flood control facilities.

1) Method by Manning's Formula

The rough estimation of river flow velocity from the Manning's formula is done by assuming that the flowing water section is rectangular, performing the following simple survey on site, and calculating from the obtained river width and water depth and the approximate river slope. When it is required to calculate the river velocity more accurately, river survey is needed as described in Section 3.5.

- Length, such as river width: A thick thread on both banks of the river is tightened so that it is as straight as possible at right angles against the river. The thread is measured on a metric scale. A laser rangefinder can measure the distance more easily if it is available (see the photo in Figure 3.11).
- River water depth, river channel scouring depth, etc.: Staffs (levelling rods) and rods can be placed on the river to measure water depth and scouring depth (see the photo in Figure 3.11.
- Vertical slope and height difference of such as dike height: Water is put in the hose to level it, and simple levelling is performed to measure the height difference. This method can also be used to measure the profile slope of irrigation canals. The profile slope of the river should be also grasped from topographic maps.

Simple Surveying Method for Distances such as River Width using Thread[1)]

・Pass the thread to the opposite bank, take a straight line distance, and measure the thread on a metric scale.

Simple Method of Measuring Depth such as Water Depth and Scour Depth[1)]

・Bathymetry using staff and rods

Leveling [2)]

・Leveling using a hose

Figure 3.11 Examples of Measuring Distance, Depth and leveling by Simple Surveying

2) Method of Direct Measurement on Site

There are the methods, using a current meter and methods using a float for directly detecting the flow velocity in the field. The float method estimates the flow velocity from the distance and time that the float flows as shown in Figure 3.12. It is also possible to estimate the flow velocity by taking a video of the float in the case of sand flushing ditch on a weir under high flow velocity (see Figure 3.13).

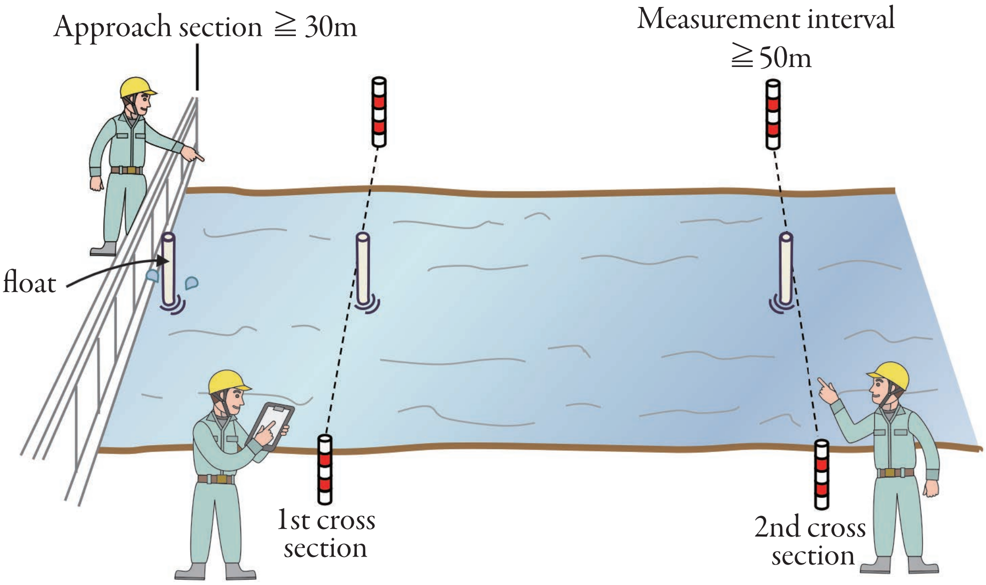
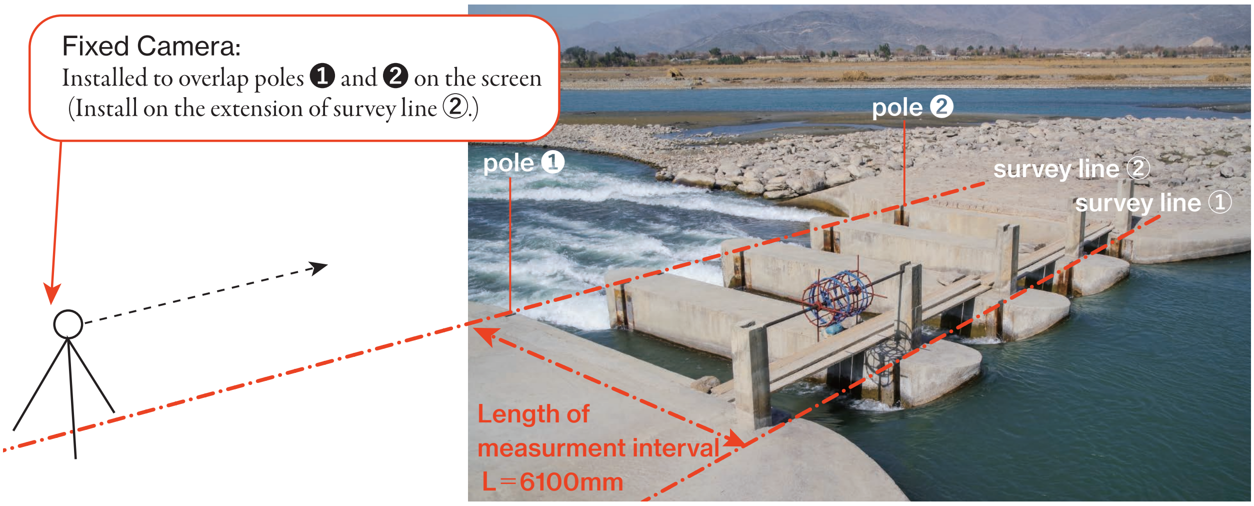


Figure 3.12 Flow Velocity Measurement by Float 2)



Flow velocity measurement method by video recording
in sand flushing ditch of intake weir (draft):

I: Survey line setting
Install tapes as survey lines ① and ② in the order of upstream and downstream at the two double-flush board installation sites of the upstream and the downstream of the sand flushing ditch. Survey line ① is the place where the float for measuring the flow velocity is thrown in, and survey line ② is the place to check the passing time with a fixed position camera.

II: Pole installation on the left and right banks of survey line ②
Stand the pole vertically at the place where the double-flush board of survey line ② is installed. At this time, make sure that no one stands between the camera and the pole so that no one gets in the way when shooting a movie.

III: Camera installed on the extension of survey line ②
Fix the camera on a tripod and install it on the extension of survey line ②. At this time, fix the poles ❶ and so that they overlap in the center of the camera. In addition, make sure that throwing of the float can be shown on survey line ① at the right end of the camera so that the float landing on the water it can be seen clearly while shooting the movie.

IV: Throwing float and recording video
Based on the precautions in I ~III above, throw the float from survey line ① while shooting a video. Change the throwing point in order from the front and throw the float multiple times. Be sure to throw the float directly from above of survey line ①.
Be careful so that the float appears on the video screen after throwing. In some cases, raise the camera fixing position so that it can look down from above.

V: Measure time using video editing software
Using commercially available and free video editing software, measure the time it takes for the float to pass from survey line ① to survey line ② using functions such as slow motion. Video editing software displays a timeline below the video in units of one-hundredth of a second, so that the video can show the landing time of the float and the time to pass survey line ②. With this feature, more accurate time than manual measurement on-site is possible.

Figure 3.13 Flow Velocity Measurement by Video Recording [1),2)]

3) Method of Roughly Estimating from Riverbed Material

The river flow velocity at the time of flood can be roughly estimated indirectly from the riverbed material size. Figure 3.14 shows the relationship between the flow velocity and the critical particle size for sediment movement. The flow velocity of the largest flood flow can be roughly estimated from the riverbed material size.

The relationship between the flow velocity and the critical particle size for sediment movement is calculated from the Manning's formula, friction velocity formula, and the Iwagaki's formula shown below.

Manning's Formula: $V = \frac{1}{n} R^{2/3} I^{1/2}$ ······························ (3.3)[2),see14)]

Friction Velocity Formula: $U_* = \sqrt{gRI}$ ······························ (3.4)[2),see14)]

Iwagaki's Formula: Empirical formula related to the relationship between friction velocity and the critical particle size for sediment movement. [2), see 14)]

$d \geqq 0.303$ cm ; $U^2_{*c} = 80.9 d_c$

$0.118 \leqq d \leqq 0.303$ cm ; $= 134.6 d_c^{31/32}$

$0.0565 \leqq d \leqq 0.118$ cm ; $= 55.0 d_c$

$0.0065 \leqq d \leqq 0.0565$ cm ; $= 8.41 d_c^{11/32}$

$d \leqq 0.0565$ cm ; $= 226 d_c$

Where, V: flow velocity (m/s), R: hydraulic radius (m), g: gravitational acceleration (m/s^2), I: riverbed gradient, n: roughness coefficient, U_* : Friction velocity, U_{*c}: friction velocity at the critical particle size for sediment movement, dc: the critical particle size for sediment movement (m)

At a riverbed where boulders are spread, the average particle size (or typical particle size) is measured by measuring the three sizes of the average boulders at the riverbed, which are the length, width, and height. shown in Figure 3.15. By the riverbed material survey, it is necessary to confirm that the flood flow has certainly flowed at the riverbed, and that it is not a place where debris flow flows, artificial excavation takes place, or stones are being dumped. A more detailed method of riverbed material survey is shown in Subsection 3.5.1.

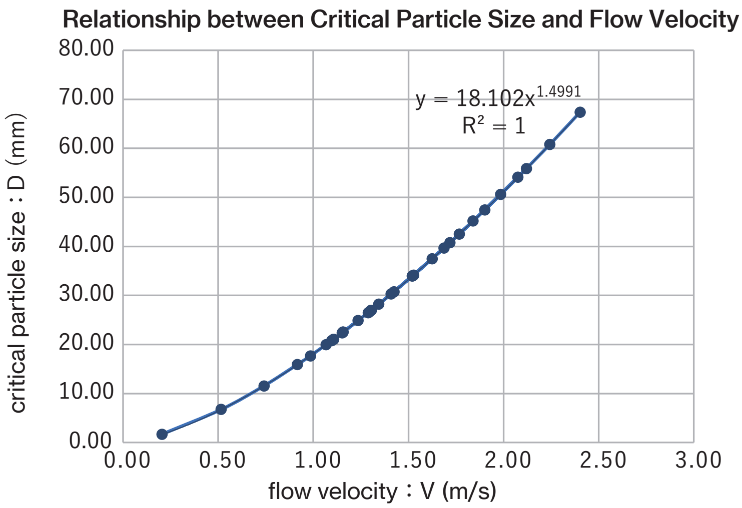
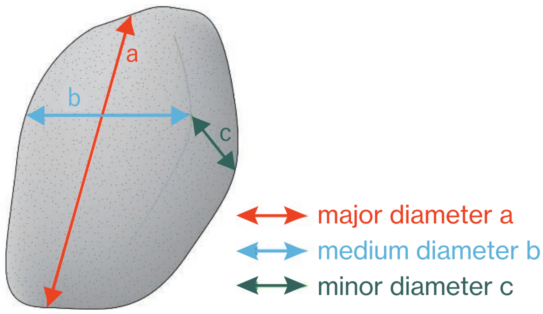


Figure 3.14 Relationship between Critical Particle Size and Flow Velocity[2)]



$r = (a \times b \times c)^{1/3}$ r: average particle size (m)

Figure 3.15 Calculation Method of Average Particle Size of Boulders [1),2)]

Text Block 3-3: Estimation of Flow Velocity based on Observation of Riverbed Materials

(**Words of Dr. Tetsu Nakamura**) It is well known that the flow velocity of a river can be estimated fairly accurately by the size of the boulders in the river. When constructing revetments and weirs, we always measure the size of the stone, estimate the flow velocity, and adopt a method that matches the velocity. Heavy stones remain and light stones are washed away. In the Kunar River, the riverbed generally has a thick layer of boulders just below the thin sand layer on the surface, and those with a large particle size in proportion to the flow velocity (bed load) are exposed. According to a textbook, the rapid flow of 3 to 5 m/s had passed. In this case, the size of the stone is 25 cm to 75 cm.

Photo: Observation of Riverbed Material [1)]

(6) Calculation and Utilization of River Discharge

The discharge (Q) is calculated from the formula ($Q = V \times A$) from the observed/measured water level/water depth and flow velocity (V), and the flow cross section (A) obtained by simple measurement or survey. From the measurement results of various water levels, flow velocity and flow cross section throughout a year from low water level to flood water level, the relationship between discharge and water level is plotted as shown in Figure 3.16, and the relational expression (rating curve) between discharge and water level is created. Using the rating curve, the river discharge is calculated from the measured river water level, and the annual discharge fluctuation should be grasped.
By comparing the discharge data obtained with the existing discharge data of neighboring hydrological stations, the reliability of the existing hydrological data is verified and the relationship to the discharge data

of neighboring hydrological stations (see Figure 3.17) is investigated, and a correlation equation is created. Based on this, the discharge at the target site can also be estimated from the discharge data of nearby observation stations. If there is no existing data, the discharge data from such rough measurement is used for planning and designing irrigation facilities, but one should be aware that the roughly estimated discharge may contain large uncertainty, requiring comparison with the other discharge estimation methods, to be used carefully with comprehensive judgment.
The most reliable year-round river discharge data is obtained through the existing hydrological data, interviews with residents, and own observations/ measurements. Using this, the river flow condition (flow regime), probable drought discharge, probable flood discharge, etc., are all calculated again to grasp a more accurate river flow condition. Utilizing these highly reliable flow data, it should be examined whether the required amount of intake water can be extracted, as well as the planning and design of irrigation facilities, including the impact of structures and water intake on the upstream and downstream/left and right banks.

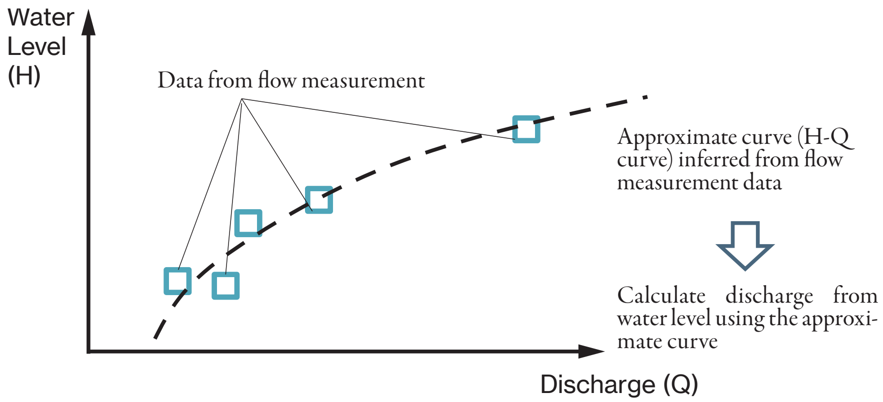


Figure 3.16 Water Level (H) - Discharge(Q) Relationship 2)

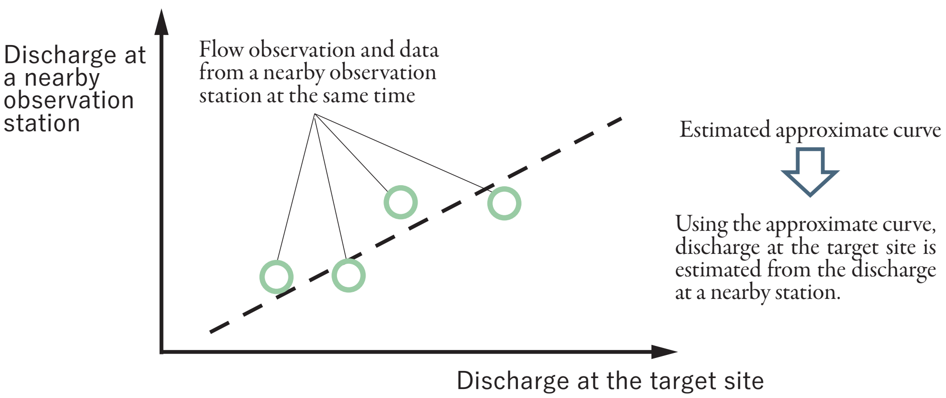


Figure 3.17 Relationship with Discharge Data from Nearby Hydrological Observation Station2)

(7) Observation/Measurement of Sediment Transport Volume/Water Quality and Utilization of Results

Sediment discharge includes wash load, suspended load, and bedload. The bedload is discharged to downstream as possible from sand flushing ditches of the weir, and the inflow of the bedload to the irrigation canal is prevented by the base elevation of the intake gate and flush boards. On the other hand, it is difficult to prevent the inflow of suspended load and the wash load into the irrigation canal. In this paragraph, the surveillance and measurement of the wash load and suspended load are described in more detail, while the bedload is observed and measured as needed.

For the measurement of wash load and suspended load, the running water in the river is collected with a bucket, or similar container, and the volume is measured. Then, after drying, the particle size distribution of the remaining sediment is examined, and the weight of the sediment is measured. Finally, sediment concentration (mg/ ℓ) is calculated with respect to the weight of sediment against the volume of water. In the Miran Weir of the Kunar River, the sediment concentration of the river water during the highest turbidity season is about 2,000 mg/ ℓ . The particle size characteristics and sediment concentration of the wash load and suspended load of irrigation water flowing into the irrigation canal are used to set the minimum flow velocity in the irrigation canal and the capacity of the sand basin.

The color of the river water is also observed, because the river water becomes murky when there is a lot of wash load and suspended load. In the Kunar River area, it is judged from the color of the river water that if the river water is brown, it is runoff created from rainfall (although strictly speaking, the soil quality differs depending on the valley where the inflow comes from), and if it is grayish white and cold, it is runoff originated from snowmelt. Since there is a possibility of various assessments in various areas, the characteristics of river flow condition is grasped from the color of river water, utilizing the wisdom of local residents.

The quality of river water is visually examined, and also measured using a simple water quality measurement instrument. If there is a foul odor or foaming, it is highly possible that the water quality is poor, and a more thorough water quality survey is required. In particular, if there is a large town or industrial area nearby, there is a possibility of wastewater flowing into the river. Thereafter, the situation of the wastewater discharge site is checked. In addition, if the water temperature is higher than that of the surrounding area, or if the water temperature is high even though it is snowmelt water, there is a high possibility that wastewater got mixed in.

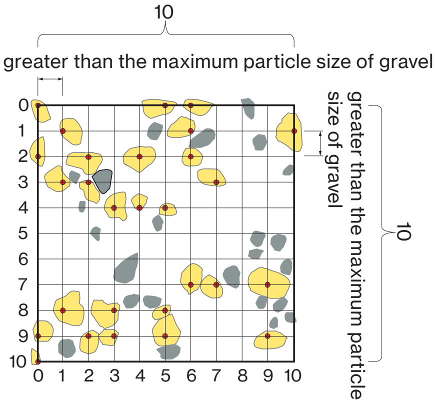
3.5 River Survey Methods

The methods of the detailed riverbed material survey, the cross-sectional survey, the profile survey and the topographic survey of rivers which are required for planning, designing and construction of the PMS method irrigation facilities are described below. Contemporary survey methods are also introduced.

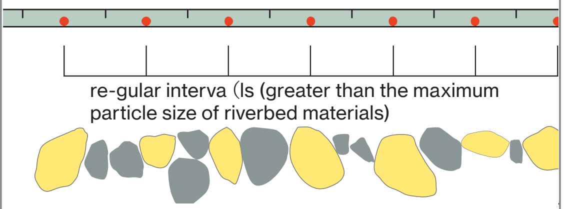
3.5.1 | Riverbed Material Survey

The riverbed material survey methods can be divided into three types, according to the particle size of riverbed materials. The *area grid method* is applied for gravel beds with a maximum particle size larger than 300 mm. The *line grid method* is applied for sandy gravel beds with a maximum particle size between 100 and 300 mm. The *volumetric method* is applied for sand beds with a maximum particle size between 75 μm and 100 mm (see Figure 3.18). If the particle size is smaller, the *sedimentation method* is applied. As a result of the riverbed material survey, a particle size accumulation curve, as shown in Figure 3.19, is created, and the particle size with an accumulation rate of 60% is used as the representative particle size. These riverbed material characteristics are used for grasping the classification and characteristics of river channel as shown in Table 3.2 in page 97, and for estimating the roughness coefficient for the Manning's formula, which is essential for calculating river flow and flow velocity. This is an important information, necessary to grasp the river conditions. In addition, representative particle sizes are required for detailed hydraulic analysis such as the estimation of river channel stability [Subsection 3.4.1(4)] and scouring conditions (see Appendix).

Area Grid Method



Line Grid Method



Volumetric Method

Sieve Analysis

- The area grid method collects and analyzes 100 stones at the intersection of the frames. It is accurate when it is necessary to grasp the plane distribution or when the particle size is large, and it is possible to grasp the local change in surface particle size. The size of the surface grid is about 1 m to 2 m on each side, and the grid spacing is about the size of the maximum particle size.
- The line grid method collects and analyzes 100 stones on a straight line at regular intervals (intervals of the maximum particle size). It requires the fewest tools and is also advanced in terms of random sampling of riverbed gravel.
- The volumetric method is applied to sandy riverbeds with small particle size, and the riverbed material pit with dimensions of 0.5 m in length × 0.5 m in width × 0.3 m in depth is collected from a depth of 30 cm below the surface. After collecting the riverbed materials, a sieving test is conducted.

Figure 3.18 Riverbed Material Survey 2)

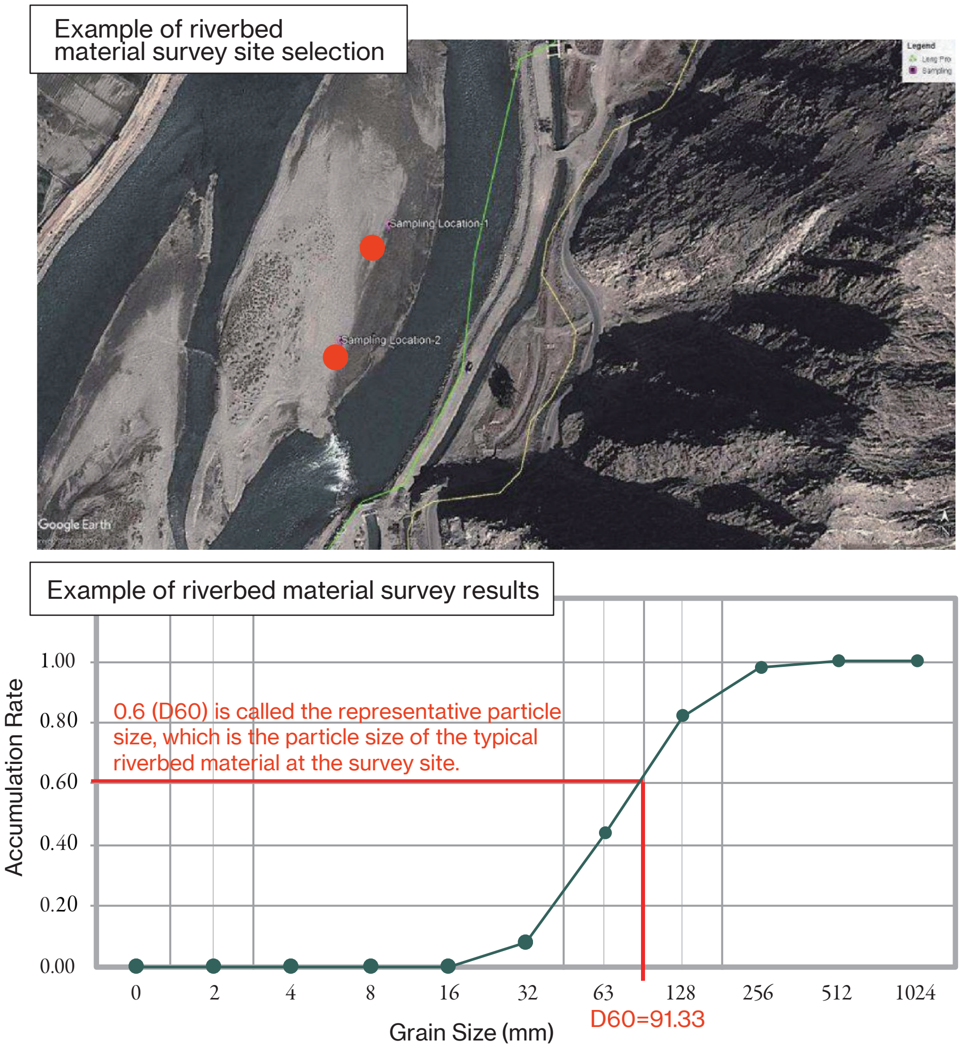
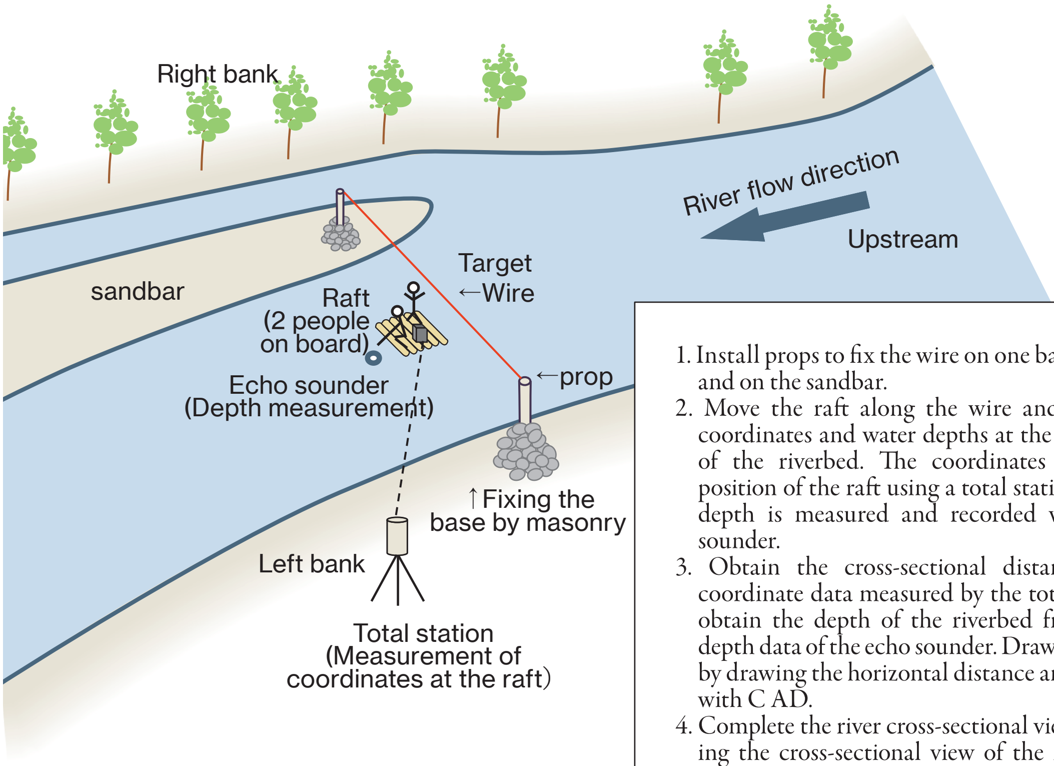


Figure 3.19 Riverbed Material Survey Results [2)]

3.5.2 | River Survey

Detailed river surveys are required for understanding river topography, which would facilitate layout planning/ designing irrigation facilities. In river surveying, river cross section, profile, and topographic surveys are conducted using equipment such as the total station (see Photo 3.7). For deep places in rivers, the water depth is measured using the echo sounder, etc. (see Figure 3.20). For the results of surveys, cross-sectional views, profile views, and plan views are created using software such as CAD, (see Figure 3.21 to Figure 3.23). River surveys are carried out preferably during periods of low water levels, when it is easier to survey the riverbed. While surveying, one should be on alert, aware of possible sudden rise of water level.

Photo 3.7 River Survey by Total Station [2)]



1. Install props to fix the wire on one bank of the river and on the sandbar.
2. Move the raft along the wire and measure the coordinates and water depths at the change point of the riverbed. The coordinates measure the position of the raft using a total station. The water depth is measured and recorded with an echo sounder.
3. Obtain the cross-sectional distance from the coordinate data measured by the total station, and obtain the depth of the riverbed from the water depth data of the echo sounder. Draw a cross section by drawing the horizontal distance and water depth with C AD.
4. Complete the river cross-sectional view by connecting the cross-sectional view of the running water section and the cross-sectional view of the river channel without running water.

Figure 3.20 Surveying Deep Rivers [1),2)]

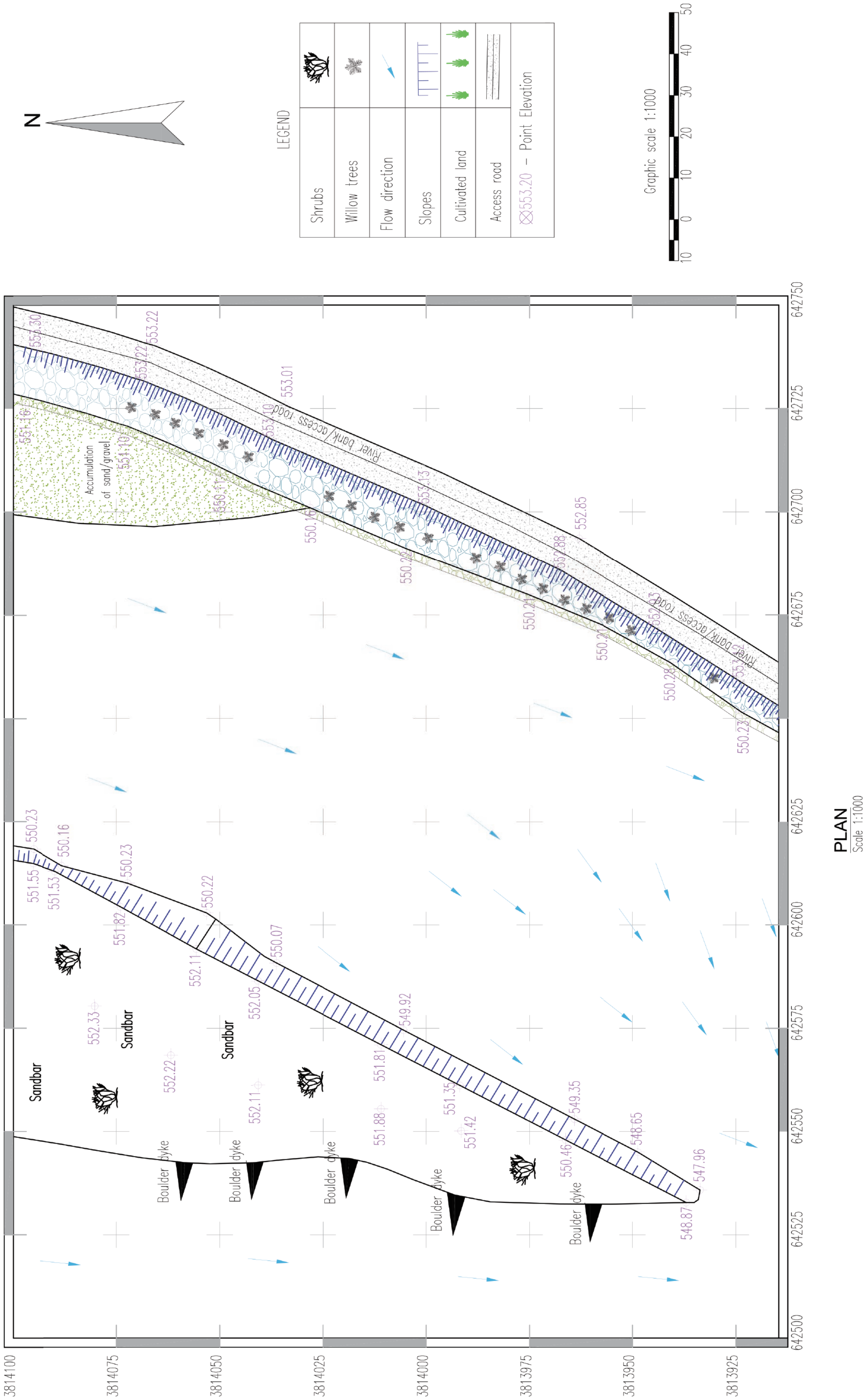


Figure 3.21 Example of Plane Drawing 15)

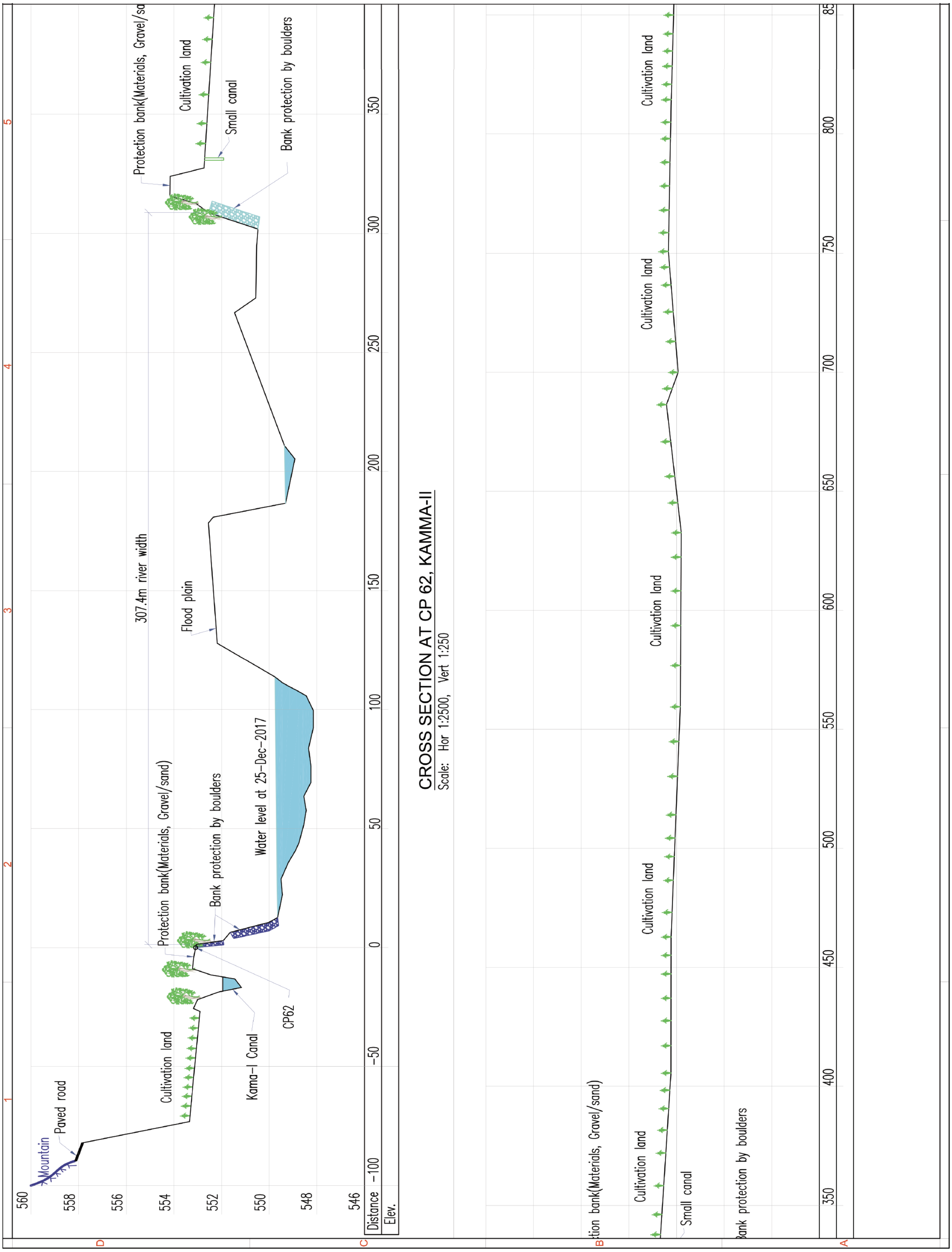


Figure 3.22 Example of Cross-Section Drawing 15)

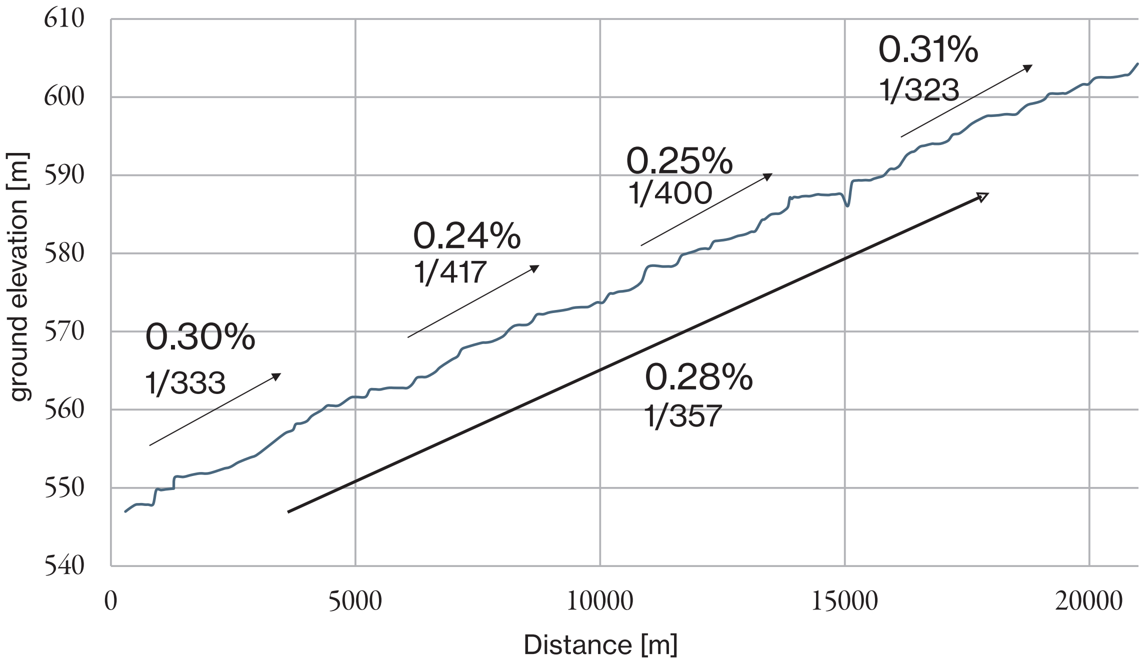


Figure 3.23 Example of Profile Drawing [15)]

3.5.3 | Contemporary River Survey

Some contemporary river survey methods, the use cases of the auto-tracking type of total station, three-dimensional laser survey instrument, drone and acoustic Doppler current profiler (ADCP) are briefly described below. Compared with the existing total station, these methods can perform more efficient and more precise surveys and are expected to be used in Afghanistan in near future.

- The auto-tracking type of total station is a machine which can automatically perform surveying by operating the target with a built-in control unit and can save labor.
- The three-dimensional laser survey instrument can perform precise 3D surveying by recording the local situation as 3D point cloud data with a 3D laser scanner.
- Drone is a surveying instrument which has been attracting attentio in recent years. It is possible to create 3D data by taking aerial photographs with a drone and analyzing and integrating these multiple aerial images.
- ADCP can perform underwater surveys and since it can measure the flow velocity along with the underwater river channel topography, it is possible to calculate the discharge. ADCP was introduced to NWARA and has been used practically.

Auto Tracking Type of Total Station[2)]

Three Dimensional Laser Survey Instrument [2)]

Drone [2)]

ADCP[16)]

Photo 3.8 Contemporary Hydrological Measurement

3.6 Setting Basic Information for Irrigation Facility Plan and Design (Water Levels, Discharges, Sediment Particles Size and Sediment Transport Volume)

The design methods for irrigation facilities and flood control facilities are explained in Chapters 4 and 5. In order to design irrigation facilities, it is necessary to set the following design conditions of rivers:

- Design conditions for intake weirs/intake gates: 1) Design drought discharge/Design drought water level; 2) Design flood discharge/Design flood water level;
- Design conditions for steep gradient main irrigation canals/sand basins, main irrigation canals/ reservoirs, etc.: 1) Information on sediment transport volume and sediment particle size;
- Design conditions for dikes/stone spur dikes: 1) Design flood discharge/design flood water level.

3.6.1 | Setting of Design Drought Discharge and Design Drought Water Level

These settings aim to ensure that the required amount of intake water can be extracted even during drought. For the purpose of planning of irrigation facilities, the expected drought scale is decided first.

In the PMS method irrigation project as shown in the graph of river water level fluctuations in Column 3-2, the annual water level and discharge fluctuations in the river at the weir are observed and the minimum drought water level during the drought season (winter) is estimated. This water level is verified by interview survey. In Afghanistan, there are many rivers for which water sources are snowmelt, and the baseflow occurs during the drought season (winter), which is the time of the minimum drought water level. It is considered that there is no significant difference in the water level from year to year. Therefore, it is considered that there is no large error

in the drought water level even if the design drought water level is judged by observing the water level during the drought period of a limited number of years. However, it should be kept in mind that the water levels may change from year to year due to riverbed fluctuations caused by sediment transported by floods. Since the general density of hydrological observations is low in Afghanistan, hydrological data at appropriate locations may be insufficient, and it is desirable to set the design drought water level according to the drought water level at the site. If the minimum drought water level during a major drought in the past is known, the design drought water level is set appropriately from the probability evaluation described below.
The design drought discharge is the discharge corresponding to the design drought water level. For the discharge conversion methods, see Subsection 3.4.2. However, it should be kept in mind that errors may occur if the cross section of the river channel is not the same as when the design drought water level occurred. In addition, the probability scale of the set design drought discharge is grasped. Generally, in the planning of irrigation projects, the 5-year return period (10-year return period in Japan) is adopted as the design return period, which has been studied for the existing PMS irrigation facilities, to take water at the 5-year return perio. It should be noted that there is high uncertainty involved, because the probability evaluation data, used for probability evaluation of drought water levels at the intake site, are from the hydrological station site, where the data may be limited, and it may differ from the past trends, due to climate changeand human influence. It should be also noted that there is a difference between the discharge at the station site from the discharge at the weir site. Therefore, it is necessary to improve the accuracy by converting the discharge at the hydrological observation station into the design drought discharge at weir site. This requires consideration of the inflow of tributaries upstream and downstream and water extraction volumes. If the probability scale becomes extremely small, it means that a smaller discharge than the design drought discharge frequently occurs. Therefore, it should be checked whether or not the discharge conversion from the design drought water level is appropriate and whether the design drought water level is appropriate for the above sites, and should be reset accordingly when necessary. Similarly, when the probability scale becomes extremely large, the validity should be confirmed and reset.

3.6.2 | Setting of Design Flood Discharge and Design Flood Water Level

The design flood discharge/design flood water level is the flood discharge/flood water level targeted when planning the safety of river structures such as dikes and spur dikes. In the PMS method irrigation project, the design flood water level is determined by observing or by interviewing residents on the mark of the highest flood water level at the time of flood during the past period.
The design flood discharge is the discharge corresponding to the design flood water level. The probability scale of the design flood discharge is grasped. As with the setting of the design drought discharge, it is reset as necessary by considering the design points to keep in mind. The design flood water level is calculated by the method shown in the profile design of the dike in Chapter 5, 5.2.3 (2), in order to consider its impact to the weir.
There are two methods for setting the design flood water level and design discharge: one is to refer to the observed water level and the mark of water level, and the other is to calculate it. In the existing PMS irrigation project, the design flood water level is based on the observed water level in the past, also considering the effects of climate change in Afghanistan. There is some uncertainty with the calculation method, due to the data quality and quantity, and the insufficient human resources capable to calculate. However, when the design discharge is decided, it is still necessary to calculate it, as precise as possible and make a comprehensive judgment (cross check) by referring to various methods through interviews. The method by calculation is to determine the target return period, set the discharge of the target return period as the design discharge from the probability evaluation at the hydrological observation station, and calculate the water level by the uniform/non-uniform flow calculation under the condition with the weir from the discharge (calculation from the observation station site to the weir site) as the design water level.

3.6.3 | Setup of Design Sediment Transport Volume and Design Sediment Particles Size

The PMS method irrigation facility shown in Table 3.8 is designed with the sediment transport volume and the sediment particles size during design drought or flood as design conditions.

Table 3.8 Irrigation Facility applied Sediment Transport Volume and Sediment Particles Size and Design Method[2)]

No.	Design Specifications for PMS Irrigation Facilities	Design Methods
1	Design of sand flushing ditch (width and slope) at the intake weir	• When the design flood discharge flows down the river channel, the sediment particle size that flow from the upstream of the intake weir and deposit on the back of the weir is calculated from the relationship between the flow velocity and the critical particle size for movement. • Set the width and bottom slope of the sand flushing ditch using the Manning's formula so that the velocity can be secured to discharge sediment with a particle size that is expected to deposit at the back of the weir.
2	Cross section and slope of steep gradiemt main irrigation canal	• Set the cross section (width / depth) of the steep gradiemt main irrigation canal so that the flow velocity can be secured and the suspended load contained in the water taken from the river does not deposit even when the amount of irrigation water flows down during the drought season. • Check whether the sand with the particle size obtained by the particle size survey is washed away without any problem at the flow velocity of the steep gradiemt main irrigation canal and no sediment deposition occurs.
3	Shape of sandbasin	• Set the shape of the sand basin where the sand conveyed from the steep gradiemt main irrigation canal to the sand basin can deposit. Set a shape that can secure an appropriate surface loading rate and moving velocity that allow sand of the target particle size to deposit. • Estimate the sediment volume from the concentration of suspended load contained in the intake water. Set an appropriate sand basin capacity and the number of sand basin installation sites considering the maintenance frequency such as dredging of the sand basin.

3.6.4 | Estimation of Hydraulic Parameters of Rivers by Non-Uniform Flow Calculation

There are the uniform flow calculation and the non-uniform flow calculation as the methods of calculating the water level and the flow velocity when a certain constant discharge flows through a river. The uniform flow calculation is used when a constant discharge flows through rivers and waterways where the cross-sectional shape and slope are not expected to change longitudinally, and the water level and flow velocity of artificial waterways are calculated using the Manning's formula. On the other hand, the non-uniformflow calculation is used when a constant discharge flows in a river or waterway where cross-sectional shape and slope change gently. It is used for calculating the water level and flow velocity of many rivers. Finally, if the temporal change in the discharge cannot be neglected, the longitudinal and temporal changes in the water levels and flow velocities of the river are calculated using the unsteady flow calculation method.
To calculate the non-uniform flow of a river, a cross-sectional view of the river measured at regular intervals is required such as the fixed interval of 200 m, 500 m, etc. In Japan, the river surveying interval is appropriately determined according to the scale of the river with 200 m as the standard. When calculating non-uniform flow, the average water level shape cannot be obtained with a small interval of cross-section in a case of a wide river, with large width. Therefore, there is also a concept that the interval should be about the width of the river or more. The interval is decided appropriately according to the scale of the river. If the non-uniform flow calculation is performed on the assumption that a constant discharge flows in multiple cross sections of the

river from upstream to downstream, the river water level and flow velocity is calculated in each cross-section, and the longitudinal shape of the water level is grasped (See Figure 3.24). This is useful information when determining the height of dikes. In addition, hydraulic analysis such as river channel stability (see Figure 3.9) and scouring (see the Appendix) are performed using the calculation results of hydraulic parameters such as flow width, water depth, and flow velocity under the assumed discharge. A lot of softwares which can calculate non-uniformly is available free of charge, and HEC-RAS of the US Army Corps of Engineers Hydrologic Engineering Center is one of the most commonly used.

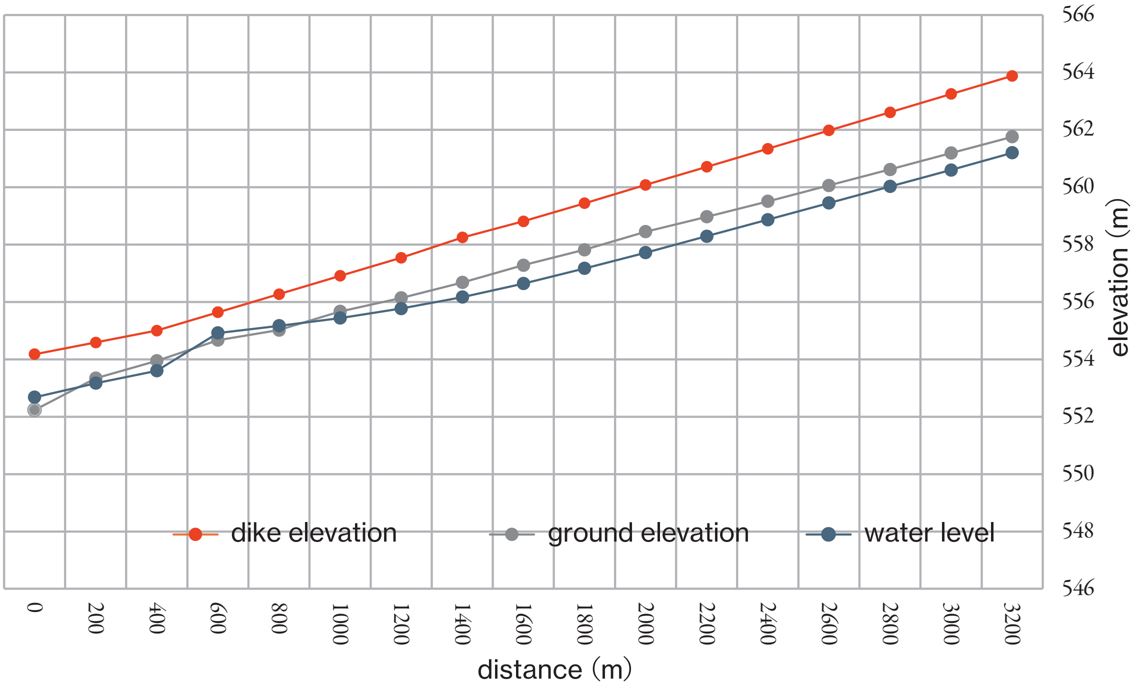


Figure 3.24 River Water Level Profile by Non-Uniform Flow Calculation [2)]