INTRODUCTION

Hydrological studies and flood flow calculations for roadway drainage structures, which are part of the highway network to be built as part of the capital's highway improvement project, were conducted during the feasibility study drawing stage.

Research methodology

In carrying out this work, field research and settlement development were conducted according to the technical specifications and conditions issued by the “AUDE” LLC Company for the highway design. During the survey, the locations of large and small dry ravines and gullies crossing the road strip were mapped on a topographic map at a scale of 1:25,000. The watershed area was identified, and the soil and vegetation of its basin were surveyed, documented with photographs, and a hand drawing was created to match the shape and size of the railway construction. Samples were collected from specific areas to determine the physical and mechanical properties and structural parameters of the soil in the watershed. During the field survey, interviews were conducted with local residents about flood flow conditions, and notes were recorded. Based on the survey, flood discharge was calculated with a probability of Q1%, Q2%, and Q5%, following the methodology specified in the “Norms and Rules for Calculating Hydrological Specifications” (BNBD 2.01.14-86). The basis for the design of the working drawings was then prepared.

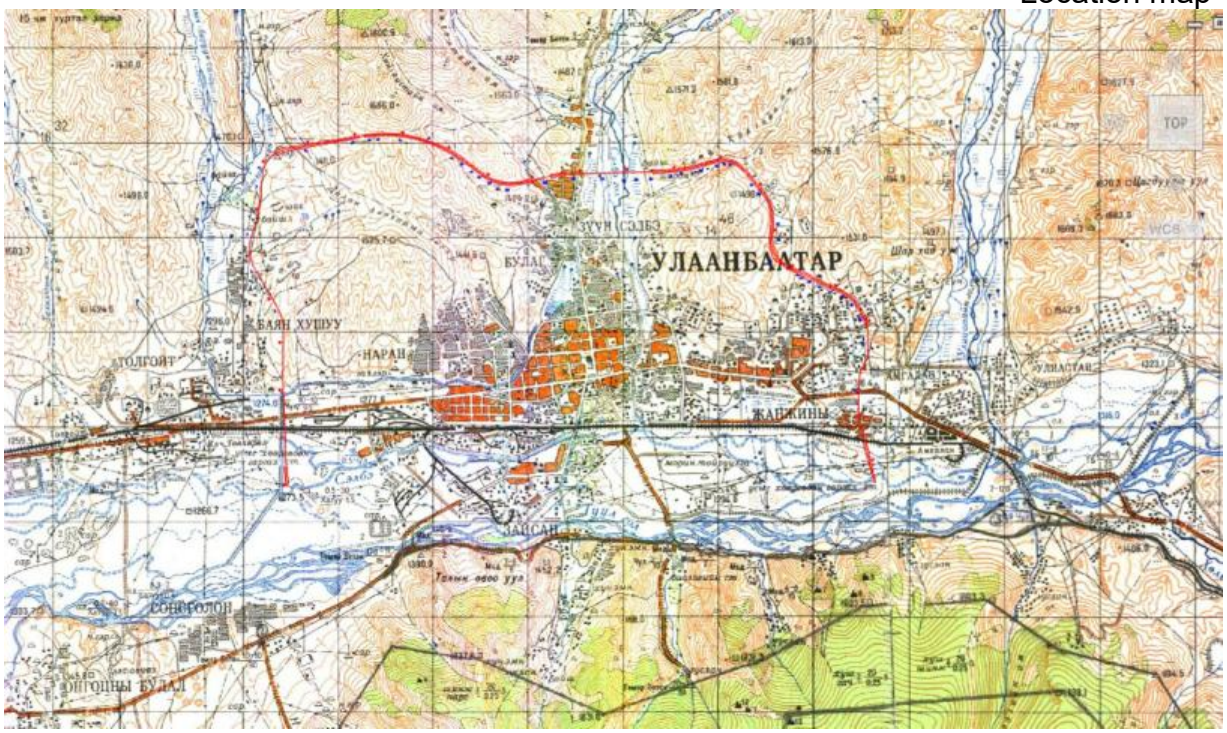
To carry out the above work, previously collected hydrological survey data for railway structures, M1:25,000 topographic maps, long-term observation data from Takhilt and Ulaanhuaran meteorological stations, and other survey materials done earlier (for agricultural purposes) in the basin were used.

GENERAL OVERVIEW OF THE STUDY AREA

Physical geographical location.

The study area where the highway is planned to be built is geographically located in the Selenga Valley region of the Khangai-Khent mountain range, at an altitude of 1380-1485 m above sea level. Hydrologically, it is located in the Tuul River catchment area of the Arctic Ocean rivers, and administratively, it is within the territory of Ulaanbaatar city.

Location map



Geomorphology

Ulaanbaatar is located in the southwestern part of the Khentii Mountains, surrounded by small and medium-sized mountains, stretching from east to west in the large valley of the Tuul River. The Bogd Mountains rise on the southern outskirts of the city, separating the forest-steppe and steppe zones. The highest peak of the Bogd Mountains, Tsetse, which is the world's watershed, the southern border of the Siberian taiga, and the southern border of the continuously spreading taiga, is 2256

m high. The top of the mountain forms a flat table-shaped platform, which is the surface of an ancient plateau. The back of the mountain is cut by many small parallel gorges and valleys, reaching a height of 600-900 m with steep, rugged sides.

The city is surrounded by Tolgoit (1832 m) and Chingeltei (1801 m) and their branches. These mountains have relatively smooth tops, their flanks are cut by steep ravines, and their height gradually decreases, reaching the Tuul Valley. The mountains located in the northeastern part of the objects have a smooth top, similar to the western mountains, and their flanks are evenly low, and their height is cut by young ravines of relatively high (400m).

To the west and east of the city are the Songinokhairkhan (1652.3m) and Bayanzurkh (1527m) mountains of tectonic denudation origin, with steep sides and sharp tops.

The mountains surrounding the city to the north are cut by the Selbe, Uliastai, and Tolgoit rivers of tectonic origin, and the river mouth valley merges into the Tuul Valley. The Tuul River valley widens to 4.5-5 km in the vicinity of the city, and the surface is flat, heavily eroded by the old riverbed, forming several erosion and depositional terraces along the river. The site is located at an altitude of 1385 m, with a relative elevation drop of 2.5 m/km, and a height difference of no more than 75 m.

Climate and weather conditions.

The area around Ulaanbaatar is located far from the ocean in a high mountainous area, in the temperate zone of the world, and is under the influence of the Siberian negative cyclone. Therefore, it has a harsh continental climate with extremely cold winters, hot summers, large fluctuations in daily and seasonal temperatures, low annual air temperatures, low precipitation, little snow cover, constant lack of moisture, constant windlessness in winter, strong winds in spring, and long duration of sunshine.

The climatic conditions of the environment where the object is located were determined using long-term data from the Ulaanbaatar city meteorological station.

Average monthly and annual temperatures. The average annual air temperature at the Ulaanbaatar station is -1.6 -3.5°C. This means that it is 7-9°C colder than the average temperature at latitudes above 50°N, which is a large amount that is not observed in our latitudes except in Central and East Asia.

Average monthly and annual temperatures

	Month	

Station name	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
UluunKhuran	-21.8	-18.7	-9.1	0.6	8.0	14.7	16.4	14.7	8.2	-0.9	-11.4	-20.1	-1.6
Baganuur	-25.5	-19.2	-10.3	1.5	9.1	15.2	17.5	14.9	8.0	-1.5	-14.1	-23.0	-2.3
Terelj	-24.1	-18.8	-11.3	-0.4	7.0	12.5	14.7	12.3	5.7	-3.1	-14.1	-22.0	-3.5

Absolute high and low temperatures. In practice, in addition to knowing the average temperature over a given period (day, month, year, etc.), it is also of interest to examine the maximum and minimum temperatures observed during that period. In Ulaanbaatar, the minimum temperature is below 0 °C in all months except June to August. The maximum temperature remains below 0 °C from December to February, while in all other months it rises above 0 °C. At this station, no frosts occur during June–August. Rare meteorological phenomena are also of interest, particularly when considered in terms of their probability of occurrence and recurrence in climatological studies.

Average absolute high and low temperatures

Station name	Month											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Absolutely great.												
UluunKhuran	-7.0	-1.0	10.0	19.9	27.4	30.3	29.8	29.2	24.2	18.0	5.1	-1.5
Absolutely less												
UluunKhuran	-33.6	-33.4	-25.6	-16.7	-7.7	0.8	4.9	1.8	-5.3	-16.2	-26.2	-33.4

Average daily air temperature. In various sectors of the national economy, it is important to calculate the average daily temperature (±0°; ±5°; ±10°; ±15°; ±20°; ±25°, etc.) by calculating the duration of warming and cooling, the number of days with temperatures above this time, and the total temperature. The sum of the positive temperatures from this value is used to assess the heat resources of a given area or to determine the heat supply of plants, and the sum of the negative temperatures is used in some engineering calculations, such as heating calculations and assessing the operating conditions of machinery.

The frequency of the average daily temperature in Ulaanbaatar can be determined by the data from 1967-1978, which shows which month has the highest

and lowest frequency of the average daily temperature. For example, in January, the probability of the average daily temperature being –20.0°- -24.9° is slightly lower in Ulaanbaatar, 34.7%. In July, the likelihood of the average daily temperature being between 15.1°-20.0° is the highest, with a probability of 57%.

In terms of the daily course of air temperature, the daily course of temperature varies from month to month and in different parts of the city. For example, in January, the absolute minimum temperature occurs at 7-8 am, the absolute maximum temperature occurs at 2-3 pm, and the difference between the daily maximum and minimum temperatures is 8.4 °C in Ulaanbaatar. In July, the maximum minimum temperature occurs at 5 am, the maximum temperature occurs at 3 pm, and the daily average is 8.6 °C in Ulaanbaatar. The daily temperature fluctuation is the largest in the spring-autumn season, for example, in April it is 10.1° at the station.

The maximum and minimum air temperature values are recorded in July and in winter in January. The maximum air temperature in July is 26.50° C in Buyant-Ukhaad, 19 °C in Khureltogoot, and the average air temperature in Buyant-Ukhaad reaches 44.10 °C and 33.60 °C in Khureltogoot.

The absolute minimum temperature is -490 in Buyant-Ukhaad, located at an altitude of 1320 m, and -36.70 in Khureltogoot, located at an altitude of 1610 m. The absolute minimum temperature in July is 31.40 °C in Buyant-Ukhaad, 31.60 °C in National University of Mongolia, 30.20 °C in Morin Tolgoi, and 26.10 °C in Khureltogoot. The coldest absolute minimum air temperature in January was observed in the above-mentioned stations in the order of –39.90° C , -31.90° C , -30.80 °C, and -30.30° C.

Soil thermal regime. The topsoil absorbs short-wave radiation from the sun during the day and heats it, passing its heat through the air to heat the lower layers of the air, and at night, it radiates its heat and cools it down, causing the lower layers of the air to cool. In other words, the thermal regime of the topsoil determines the thermal regime of the lower layers of the air.

The average annual soil surface temperature around Ulaanbaatar is –0.3…-0.2°, slightly warmer in Ulaankhurd, and coldest in Buyant-Ukhaad. The coldest

month is January, with temperatures ranging from –22.8 to -29.0°, and the warmest month is July, with temperatures ranging from 18.6 to 21.0°.

The absolute warmest soil temperature reaches 61.7-66.2°, which is higher in the city center and cooler in the outskirts, the absolute coldest temperature is –44.0°-49.4°, and the absolute maximum and minimum temperatures are 105-115°. The soil surface layer at a depth of 5, 10, 15, and 20 cm has a positive value from the end of April to the end of September. The temperature distribution in the ground is quite regular. In summer, the temperature decreases with increasing depth, and in winter, it warms up with the depth, and in spring and autumn, there is a transition. For example, in April and October, the middle depth (0.8; 1.2m) is warm, and in both directions it cools down. At the Ulaankhuran station, the 20° isotherm is distributed at a depth of 5-10 cm in July-August, the 15° isotherm at a depth of 40 cm, the 10° isotherm at a depth of 1.25 m in August-September, and the 5° isotherm at a depth of 2.5 m in October. The 0° isotherm is distributed at a depth of 2.90-3.0 m in April, the -5° isotherm at a depth of 1.7 m in March, the -10° isotherm at a depth of 1.0 m, the -15° isotherm at 0.55 m, and the -20° isotherm at 0.15 m in February.

Precipitation regime The area around Ulaanbaatar city is located in a low-humidity and high-arid zone, with an annual total precipitation of about 242 mm in Ulaanbaatar.

The majority of precipitation (80-95%) falls as heavy rain in summer and autumn, with occasional showers in late summer. In the cold season, there is little snow, and the thickness of the snow cover is not great, and it mainly melts in the ravines created by windstorms and evaporates.

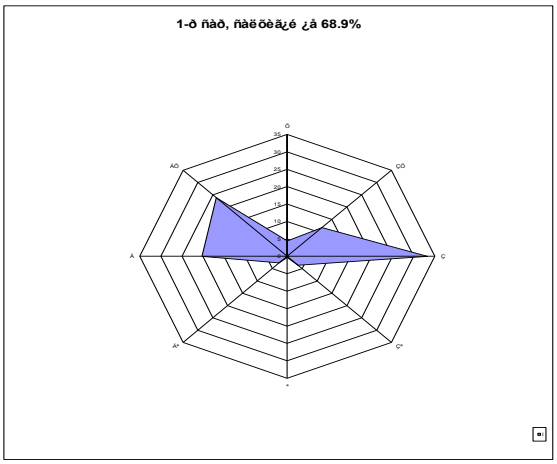
The winter season in the city is characterized by always clear skies, steady winds, and frost in the morning and evening, settling in the Tuul Valley.

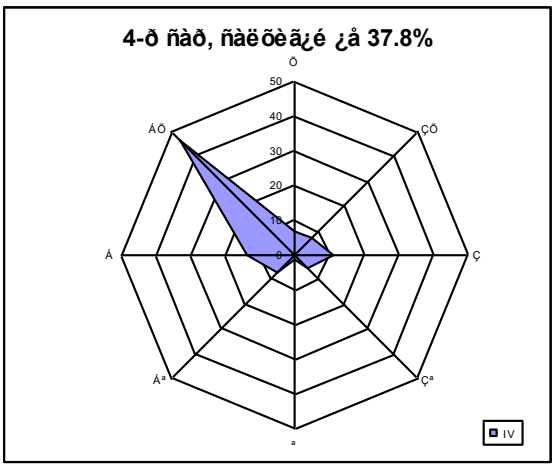
Due to the low precipitation, the amount of relative humidity is low, and the highest relative humidity is observed in December and January. From March, the relative humidity drops to 60%, and sometimes drops to 20-30%.

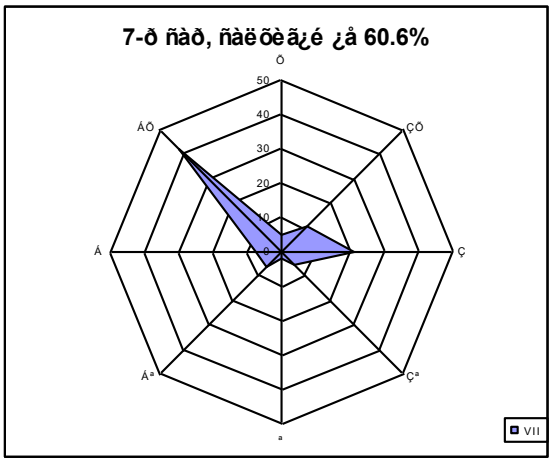
In the Ulaanbaatar area, the prevailing winds are from the west and northwest, as well as from the east and southeast, and the direction of the wind changes significantly from season to season. In addition to the general wind direction, the valley wind follows the river valley up and down. The wind regime near the surface depends on the characteristics of the local junction and the general atmospheric

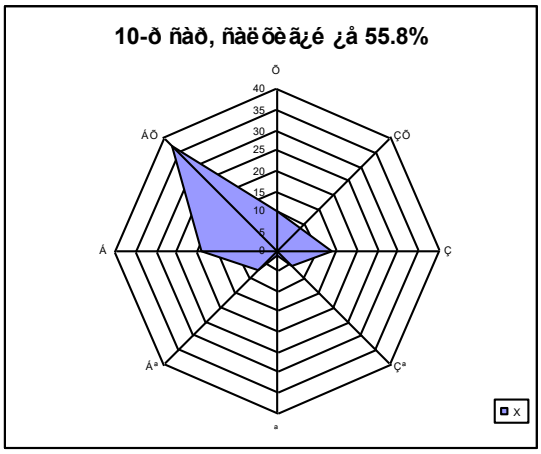
circulation. Weather elements such as heat and cold, moisture, and precipitation are carried by the wind and move from one place to another, and dangerous weather phenomena such as snow and dust storms occur due to the increase in wind force, so wind is one of the most important meteorological parameters.

<u>Wind regime</u> Wind direction varies greatly in different parts of the city and around Ulaanbaatar, and by month, season, and day. In Ulaanbaatar, the annual average northwest wind is dominant with a frequency of 41.1%, while the east wind is 17.2%, which is much more frequent than in neighboring areas. In particular, in January and February, this direction becomes the dominant direction with a frequency of 25.9-33.3%. The wind from this direction decreases significantly in spring and autumn, but increases again in summer.









Wind rose showing the wind direction and windless period of the central months of the Ulaanhuuran season, and the average speed in each direction.

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It seems that the wind from the mountains and valleys and the wind towards the city center are combined here. When evaluating the frequency of the wind from the mountains and valleys around Ulaanbaatar, it is observed that Ulaanbaatar accounts for more than half of the entire observation period. The wind period is the highest in winter and the lowest in spring, which is consistent with the average monthly wind speed.

Wind speed. The average wind speed for each month is shown in the table. According to the table, the average annual wind speed at the Ulaanhuaran station in the river valley is a uniform 1-2 m/s. This is consistent with some studies conducted abroad regarding the intensification of mild winds and weakening of strong winds in the city.

Average wind speed, m/s

Station name	Month												
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Ulaankhuran	1.2	1.7	2.3	2.9	2.9	2.5	1.9	2.2	2.1	1.8	1.5	1.3	2.0
Baganuur	0.7	1.1	2.2	3.7	3.7	2.8	2.2	1.9	2.1	2.0	1.2	0.6	2.0
Terelj	0.9	1.2	1.8	2.5	2.3	1.5	1.2	1.2	1.6	1.5	1.2	0.9	1.5

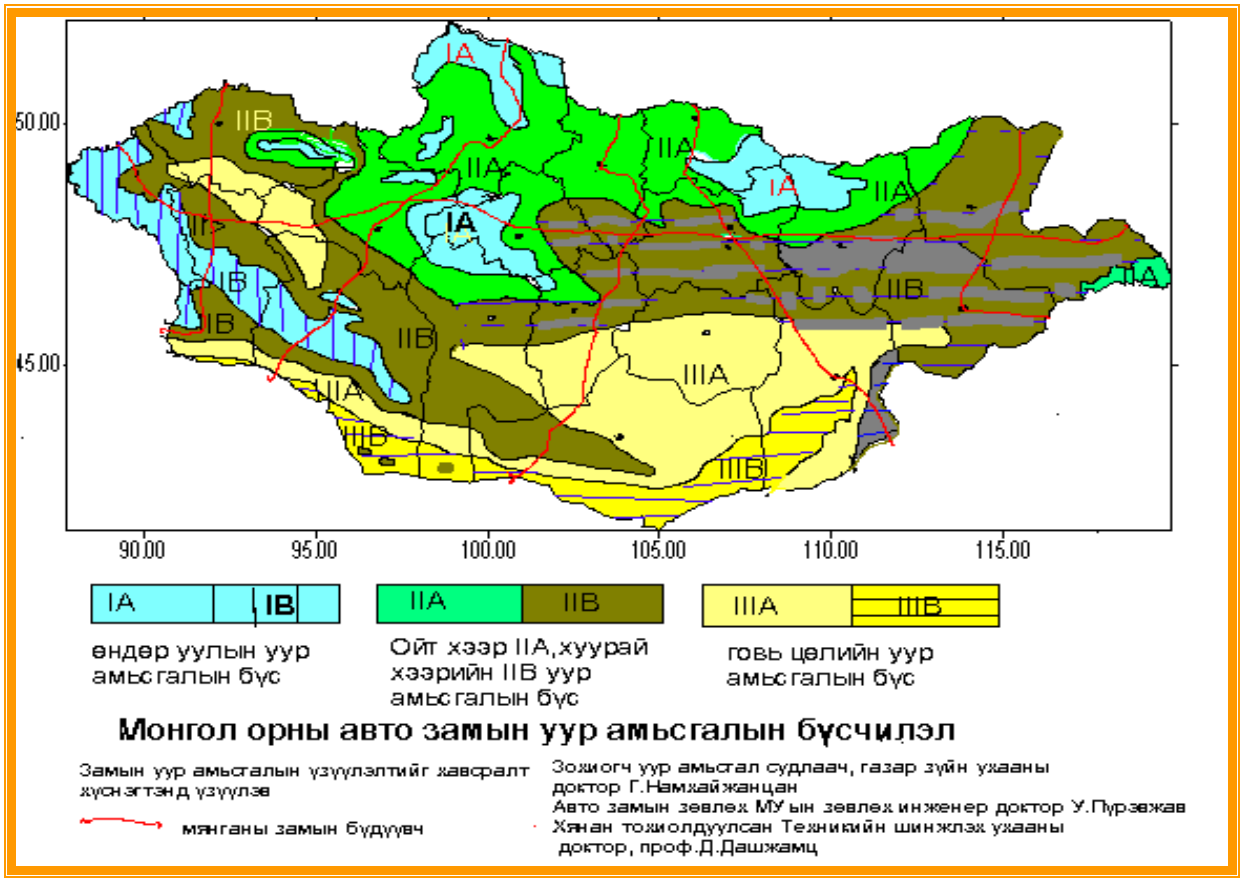
Considering the average wind speed in each direction, the prevailing wind direction is not necessarily the strongest. For example, in Ulaanbaatar, the northwest and north winds are the strongest throughout the year, while the east and southeast winds are slightly stronger than in neighboring areas

Average wind speed in each direction, m/s

Month	Х	ЗХ	З	ЗӨ	Ө	БӨ	Б	БХ
Ulaankhuran								
I	4.5	3.6	4.0	3.4	1.0	3.0	3.8	4.3
IV	4.9	3.5	4.2	4.6	3.8	4.1	4.7	4.7
VII	3.6	3.4	3.8	3.7	2.9	4.1	4.5	4.1
X	4.6	3.2	3.9	3.8	3.2	3.6	4.5	4.5
Year	4.4	3.6	4.0	3.9	2.7	3.9	4.2	4.5

In terms of wind speed frequency, in winter, the wind speed is calm /0-1m/s/, with a frequency of 61.9-70.7% in Ulaanbaatar, and in spring and summer, the frequency of wind speeds of 2-5, 6-10 m/s increases dramatically, reaching 40% in some months. In terms of the daily difference in wind speed, there are more calm periods at night, fewer calm periods during the day, and periods with 2-5, 6-10 m/s increase. In Ulaanbaatar, compared to winter, the wind speed of 0-1 m/s decreases by 27.9% during the day and night, and the wind speed of 2-5 m/s increases by 20.3%. In summer, the wind speed of 2-5 m/s occurs most often /46.4%/ at 13:00, and the wind speed does not decrease significantly even at 19:00. The spring season is harsh, with large fluctuations in air temperature from hour to hour, and there are periods of strong storms. At that time, wind speeds reached 18-24 m/s.

Climatic conditions of the highway. The area where the highway bridge is planned belongs to the IIB or mountainous-steppe sub-region of the Mongolian climatic and geotechnical conditions of the highway.



Basic definition of the region

Area number and name	sub-region index	Brief description of the region	Geoclimatic and geophysical characteristics of highways
II *steppe road climate zone*	***IIB.*** *intermontane subzone*	- The climate of the semi-mountainous steppe and steppe highway is dry-cold-cold-cold, dry-cold-cold-cold subregion.	- Permafrost is scattered over many years, and the climate of the road is seasonal, with freezing and thawing. The mountainous steppes are covered with snow, and the snow is muddy, with heavy rain and thunder, while the steppes are covered with thin, dense snow, windy, and bitterly cold.

Some of the characteristics of this region are shown below.

Duration of the season

Sub-region	Winter			Spring		Summer		Autumn
	Start	Finish	Continue days	Finish	Continue days	Finish	Continue days	Continue days
IIB	***9.XI 5.XI***	***15-24.III 19.III***	***126-143 134***	***6-12.Y 9.Y***	***45-52 48***	***8-19.IX 13. IX***	***112-156 129***	***44-54 49***

Note:
* The end of winter is the beginning of spring, the beginning of spring is the beginning of summer, the beginning of summer is the beginning of autumn, and the beginning of winter is the end of autumn.

Soil and air temperature (°C) indicators

Sub-region	Soil surface temperature, °C				Average ambient temperature		
	annual average	The hottest	The coldest	0° penetration depth, cm*	annual average	The coldest month	The warmest month
IIB	***+0…+3***	***60-65***	***-41-45***	***250-350***	***-2…+2***	***-20-25***	***15…20***

Note:
* The depth of penetration of -00C depends on the type of soil, so upper and lower limits are taken.

Soil freeze-thaw climatic period

Sub-region	Frostbite			Thawing		
	Start	Finish	Day	Start	Finish	Day
IIB	***20-30.X 25.X***	***15.II-30.IY 5.IY***	***120-195 160***	***15.III-10.IY 25.III***	***15.IY-31.Y 23.IY***	***20-50 35***

Normative depth of soil freezing and thawing
In sub-zone **IIB: 2.5m, 3.0m, 3.2m, 3.5m**

*Note: The 1st number is clay and loam, the 2nd number is sandy loam, the 3rd number is coarse and medium sand and gravel, and the 4th number is the normative depth of seasonal freezing of the subsoil in areas with permafrost, in m.

Suitable and unsuitable seasons for road construction work

Sub-region	Warm season			Cold season
	Start	Finish	Day	Day
IIB	***10.IY***	***19.X***	***192***	***173***

Note:

Note:

• - The beginning of the cold season in the road construction industry is the end of the warm season, and the end of the cold season is the beginning of the warm season.

Wind speed, air pressure, and relative humidity for the four seasons of the year on the road

Sub-region	*Wind speed, m/s*				*Pressure, mm (Hg column height)*	*Relative humidity, %p*
	Winter	Sping	Summer	Autumn		
IIB	***1.6-4.0***	***3-7***	***2-4***	***2.5-5.5***	***600-650***	***50-60***

Bioclimatic working conditions of road workers working outdoors

Sub-region	Acidity, g/cm3	Thermal properties of clothing, KLO (calculated for light work)			Climate on the human body, day		
		Winter	Spring and autumn	Summer	pleasant	Shock	Sharp
IIB	***250-260***	***4.6-5.5***	***2.8-3.0***	***1.5-1.7***	***175-190***	***110-120***	***80-90***

Factors for assessing the impact of climate change on road construction and road workers

Sub-region	Нөлөө үйлчлэлийн итгэлцүүр				
	Cold	Freezing cold	Hot	Precipitation	Humidity
IIB	***1.00***	***1.00***	***1.00***	***1.00***	***1.00***

Suitable time for preparing and paving hot mix asphalt concrete in highway climate zones

Sub-region	Asphalt and road pavement		
	Start	Finish	Day
IIB	***18.IY-16.V (02. V)***	***15. VIII-19. IX (01.IX)***	***91-154 (122)***

Suitable time for asphalt concrete paving in cold and warm climate zones

Sub-region	Asphalt and road pavement		
	Start	Finish	Day
IIB	***03. III-30.III (16. III)***	***30.X-04.XII (15.XI)***	***220-278 (250)***

Indicator	Month	I	II	III	IY	Y	YI	YII	YIII	IX	X	XI	XII	Year
Average air temperature (oC)		-21.9	-18.4	-9.1	0.5	9.4	14.8	16.8	14.3	10.2	2.2	-12.5	-17.8	**-1.2**
Absolute maximum air temperature (oC)		-0.3	0.3	16.4	23.1	30.3	31.3	34.8	32.4	24.5	21.6	13.1	-0.2	**34.8**
Absolute minimum air temperature (oC)		-40.2	-37.0	-36.3	-28.2	-12.5	-3.3	0.2	0.0	-21.9	-23.1	-34.3	-36.7	**-40.2**
Average soil surface temperature (oC)		-24.6	-19.5	-7.7	2.9	13.4	18.9	20.6	18.0	10.4	0.3	-12.1	-21.5	**-0.1**
Maximum soil surface temperature (oC)		10.0	23.5	35.2	48.0	58.6	60.7	61.4	60.0	52.0	36.9	17.0	5.5	**61.4**
Minimum soil surface temperature (oC)		-48.2	-43.0	-30.4	-22.5	-16.5	-6.0	9.5	7.4	-12.0	-21.0	-34.2	-35.9	**-48.2**
Soil temperature (oC)	**0.2**	-16.4	-14.8	-7.3	1.3	9.9	15.4	18.0	16.6	11.3	4.3	-4.5	-11.8	**1.8**
	0.4	-14.0	-13.8	-7.6	-0.4	7.5	13.3	16.2	15.7	11.3	5.3	-2.0	-9.0	**1.9**
	0.6	-11.5	-12.4	-7.8	-1.8	5.1	11.2	14.2	14.6	11.4	6.4	0.4	-6.2	**2.0**
	0.8	-9.5	-11.0	-7.6	-2.5	3.6	9.4	12.8	13.7	8.1	7.0	1.2	-4.2	**1.8**
	1.2	-7.3	-9.4	-7.4	-3.2	1.8	7.4	10.6	11.7	10.7	7.4	2.7	-2.1	**1.9**
	1.6	-3.4	-6.0	-5.8	-3.1	-0.3	5.0	7.9	10.0	10.1	8.0	4.6	0.7	**2.3**
	2.4	-0.1	-2.0	-3.2	-1.5	-1.2	0.8	3.7	6.0	7.4	6.9	5.2	2.6	**2.0**
	3.2	2.0	0.6	-0.4	-0.8	0.4	0.1	2.0	4.4	6.0	6.3	5.5	4.0	**2.4**
Total precipitation (mm)		1.4	1.8	3.3	10.3	12.6	48.2	67.1	64.6	27.2	5.2	4.0	2.8	**248.5**
Maximum daily precipitation (mm)		8.6	6.0	15.3	18.0	20.4	57.1	69.4	79.4	22.5	8.9	5.4	6.1	**79.4**
Number of rainy days (days)					2.0	5.0	14.0	20.0	16.0	9.0	2.0			**68.0**
Number of days with snow cover (days)		31.0	27.0	20.0	4.0					5.0	9.0	18.0	29.0	**142.0**
Average snow depth (cm)		3.0	3.0	2.0	1.0					0.0	1.0	1.0	3.0	**4.0**
Average wind speed (m/s)		1.5	2.1	2.9	3.8	4.3	3.5	3.1	2.8	2.8	2.5	2.0	1.5	**2.7**

HYDROLOGICAL ASSESSMENT REPORT FOR THE SELBE (MIDDLE) RIVER

General understanding of the river

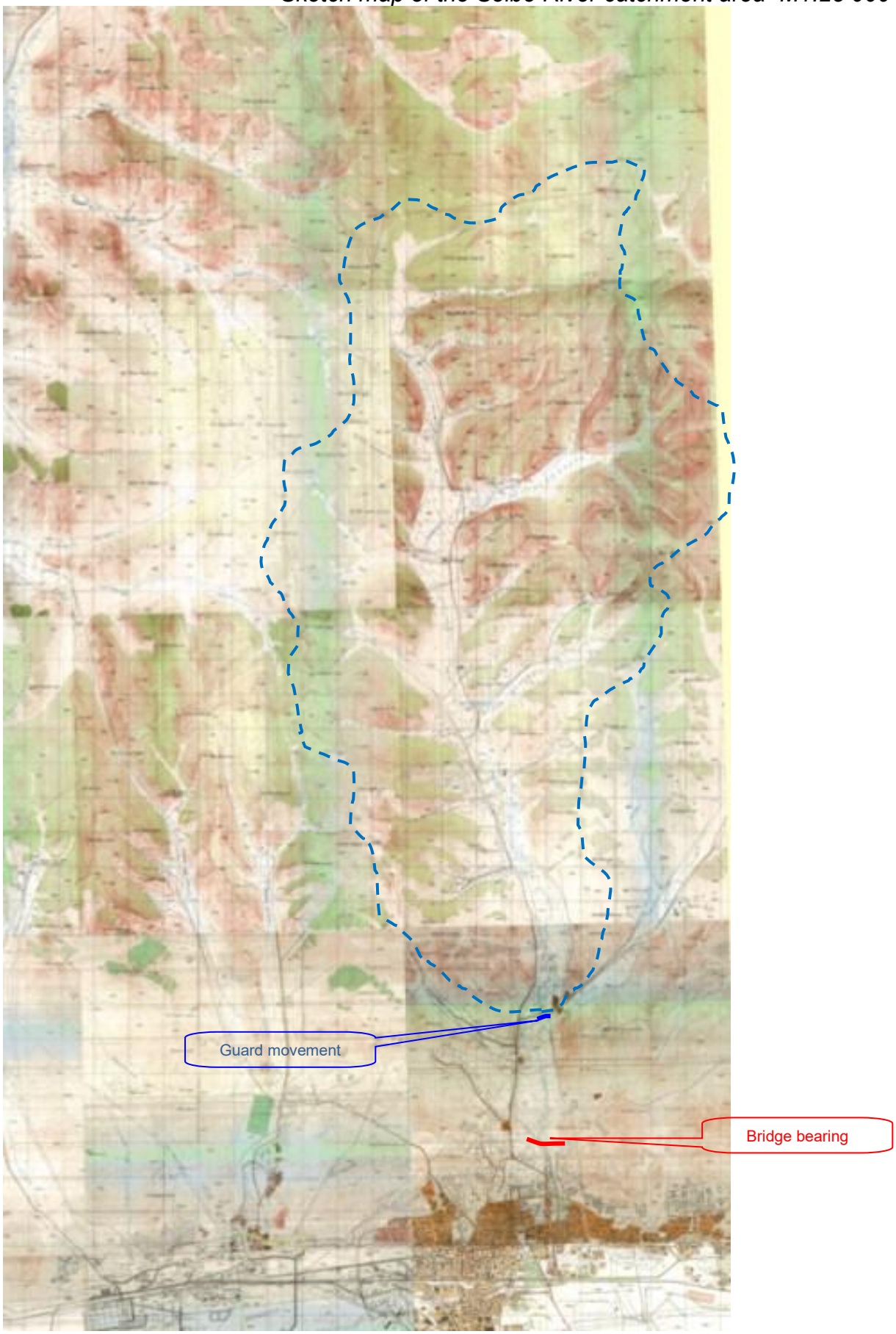
Selbe River: The Selbe River rises from a small stream in the valley of Artolgoit—one of the spur ranges of the Baga Khentii Mountains northwest of Ulaanbaatar—and flows 32.0 km before joining the Tuul River from the west, just north of the city. Its total catchment area is 498.0 km². Fed by small tributaries such as the Shargamorit and Damba streams (originating in the Baga Khentii), the river deepens and widens toward the lower reaches and its valley becomes noticeably broader. The mean longitudinal slope is 0.0030.

Spring snowmelt floods are modest in magnitude but relatively long in duration. After spring, the flow stabilizes; however, July–September rainfall substantially increases discharge. Rainfall floods form quickly and recede rapidly; on some occasions, the water level has risen by 0.5–1.0 m within a day. After September 20, the level drops sharply, entering the winter low-flow period. The river typically freezes in late October and remains ice-covered for 150+ days each year, freezing to the bed in winter.

The maximum recorded discharges include 45.0 m³/s (August 1959) and 131.0 m³/s with a 250 cm stage rise (August 1982)—the latter being nearly double the long-term average flow of the Tuul River.

Annual runoff distribution is approximately 9.5% in the low-water winter period (November–March), 25% during the spring snowmelt freshet, and 65% during the summer–autumn rainfall season. The long-term mean discharge is 1.90 m³/s (runoff modulus 0.91 l/s·km²). The mean of annual maximum discharges is 12.1 m³/s (runoff modulus 43.8 l/s·km²).

Sketch map of the Selbe River catchment area M1:25 000



Satellite image of the Selbe River catchment area

An assessment of the current runoff regime of the Selbe (Dund) River was carried out at the proposed bridge crossing in Sukhbaatar District, Ulaanbaatar. Since the study site is situated on the first river terrace along the Selbe's bank, the peak flood discharge was computed in detail, and the corresponding high-water stage under flood conditions was determined.

Flow rate and evolution

To determine the long-term mean discharge (runoff norm) at the computation cross-section, multi-year records from the Selbe–Dambadarjaa gauging station were used. The runoff modulus ($q = Q/A$) was calculated, an inter-station correlation curve was established, and the relationship was transferred to the target cross-section to derive the estimate.

Selbe River's long-term average flow indicators

Хөндлүүр	Water catchment area /km2/	Multi-year average				Flow with different supplies /m3/sec/		
		Flow /m3/sec/	Module /l/sec km2/	Evolution coefficient				
				Cv	Cs	50%	75%	95%
Shargamort Bridge	142.0	1.51	1.23	0.54	1.5 Cv	1.50	0.98	0.364
Godoin Bridge	231.0	1.81	1.28	0.54	1.5 Cv	1.89	1.39	0.439
The guard of Dambadarjaa	276.0	1.90	1.30	0.54	1.5 Cv	2.07	1.52	0.481

Distribution of annual runoff

The river's flow regime is divided into five main periods during the year.

1. By mid-November in the fall, the ice cover will cover the river and the river will switch to the winter low-flow mode. This will continue until the end of April in the spring.
2. In the spring, the snowmelt in the catchment area will flow, and the spring yellow water flood will last for about a month.
3. After the spring yellow water high-flow period, the spring-summer low-flow period begins and lasts for 20-30 days in the upper and middle reaches of the river, and for 45 days at the end.
4. In the summer, the catchment area will experience heavy rainfall and a flood or summer high-flow period until mid-September.
5. After this period, the flow will decrease due to the decrease in precipitation in the catchment area and the autumn low-flow period will continue until the winter ice cover.

Peak Discharge

Throughout the Selbe River, rainfall floods are observed to be many times larger than snowmelt floods, as rainfall is the river's principal source. The spring snowmelt flood typically begins in late April and lasts 25–30 days; it contributes about 8–10% of the annual runoff in the upper reaches and 12–15% in the lower reaches. Summer rainfall floods usually start in late June in the headwaters and middle reaches, and in early July in the lower reach, and are observed through late August; 2–3 flood waves commonly occur each season. The basin lies within a Mongolian region prone to moderate-intensity flash floods, where short, intense rainfalls generate rapid, high-velocity flooding.

Maximum recorded discharges include 45.0 m³/s (August 1959) and, with a +250 cm stage rise, 131.0 m³/s (August 1982)—nearly twice the Tuul River's long-term average flow.

To estimate the multi-year maximum rainfall-flood discharge at the design cross-section, records from the Selbe–Dambadarjaa gauging station were used. The peak runoff modulus (qmax = Qmax/A) was computed using the method of moments, an inter-station correlation curve was developed, and the relationship was transferred to the target cross-section.

Peak Discharge Values for Various Exceedance Probabilities along the Selbe River

Cross-section	Drainage area /km2/	Multi-year average				Peak Discharge by Exceedance Q /m3/sec/		
		Flow rate Q /m3/sec/	Module /l/sec km2/	Evolution coefficient				
				Cv	Cs	1%	2%	5%
Shargamort Bridge	142.0	6.82	23.8	0.96	1.5 Cv	174.5	151.8	109.9
Goodoi(n) Bridge	231.0	10.3	36,6	0.96	1.5 Cv	214.0	186,2	134.7
Dambadarjaa Gauging Station	276.0	12.1	43.8	0.96	1.5 Cv	255.0	221.8	160.6
Sansar Bridge	319.0	13.8	43.8	0.96	1.5 Cv	345.0	300,1	217,3
Arslantai Bridge	323,0	14.6	43.8	0.96	1.5 Cv	345.8	308,7	217,8

Olympic Bridge	329.0	14.8	43.8	0.96	1.5 Cv	349.0	311,55	219,8
Triangle Bridge	*373.0*	*15.2*	*43.8*	*0.96*	*1.5 Cv*	*402.0*	*349,7*	*253,3*

Low-Flow (Drought) Regime

In the river's hydrological regime, low-flow conditions are observed twice each year: (1) after the spring snowmelt flood, lasting until the onset of summer rainfall floods; and (2) from the recession of the rainy season until the following spring. In recent years, due to human activities on the Selbe River floodplain, intermittent flow cessation has been observed in spring.

Mineralization of river water

The Selbe River is classified as a river with bicarbonate water by its chemical composition. Its general mineralization does not exceed 250 mg/l. The material transport activity of the Selbe River is relatively low.

Since the Ulaanbaatar city district is located at the mouth of the Selbe River, the loose sediments of river origin distributed in the city are several tens of meters thick, and the river's water transport activity is very well distinguished and classified. The Selbe River valley is swampy in summer and frozen in winter, and there are few floods and it does not drain much.

The Selbe River water has low mineralization, belongs to the bicarbonate calcium group, and the long-term average ion concentration varies between 65.9-210.1 mg/l. The chemical composition of the Selbe River water is non-corrosive to concrete products. The mineralization and ion ratio of the Selbe River water has changed dramatically since the sewage from the ger district in the center of Ulaanbaatar was discharged into the river. For example, the concentration of Na+K ions has increased 4 times, chlorine has increased 6 times, and the cation ratio has changed to Na'+K' □Ca2+□Mg 2+, and the anion ratio has changed to HCO3 □Cl □ SO4.

River Water Level Regime

The water level of the Selbe River, like its discharge, rises sharply during spring snow- and ice-melt and then drops quickly, reaching a minimum until rainfall increases the flow. During the summer rainfall floods, the level attains several peaks; the magnitude and duration depend on storm intensity. Thereafter, the level recedes gradually to the winter low stage.

According to long-term observations at the Selbe gauging station and other studies, summer rainfall floods were recorded in 1948, 1959, 1964, 1966, 1982, and 1985, inundating sections along the riverbanks within Ulaanbaatar. The 1982 flood was particularly severe: the water level rose by 2.5 m, and flow velocity reached 4–5 m/s, inundating the floodplain along much of the reach.

For the study cross-section, water levels corresponding to various exceedance probabilities were determined by cutting the channel's cross-section and developing a stage–discharge (rating) curve Q=f(H) using the Chézy method.

$Q = v F$

Where: Q - flood discharge / m3/s /

v - flood discharge velocity / m/s /

F - water cross-sectional area / m2 /

The flood discharge velocity is calculated using the Chézy -Maning method:

$v=C (R I)1/2$

Where: C - Chézy coefficient / Depends on the slope /

I - Water level gradient

R - Hydraulic radius

The Chézy coefficient is $C=1/n*(R)1/6$

The slope coefficient is calculated by considering n=0.023.

Calculation of Peak Discharge Estimation for Ephemeral Channels (SAIR)

According to the Standards and Rules for the Calculation of Hydrological Characteristics (BNbD 2.01.14-86) and field reconnaissance, summer rainfall floods in the project area are more intense than spring snowmelt floods. Therefore, the design focused on calculating the peak discharge of rainfall floods. To derive the design peaks, a frequency (exceedance probability) analysis of daily maximum precipitation was performed, and the results were used to estimate the corresponding peak flows.

Daily Maximum Precipitation and Exceedance.

For the statistical analysis of daily maximum precipitation, records from the Ulaanbaatar meteorological station within the basin were used (series of annual 24-hour maxima). A frequency (exceedance probability) analysis was then performed. During the observation period, the largest 24-hour precipitation recorded in Ulaanbaatar was 100.3 mm in August 1982.

Daily Maximum Precipitation /Ulaanbaatar station/

Table

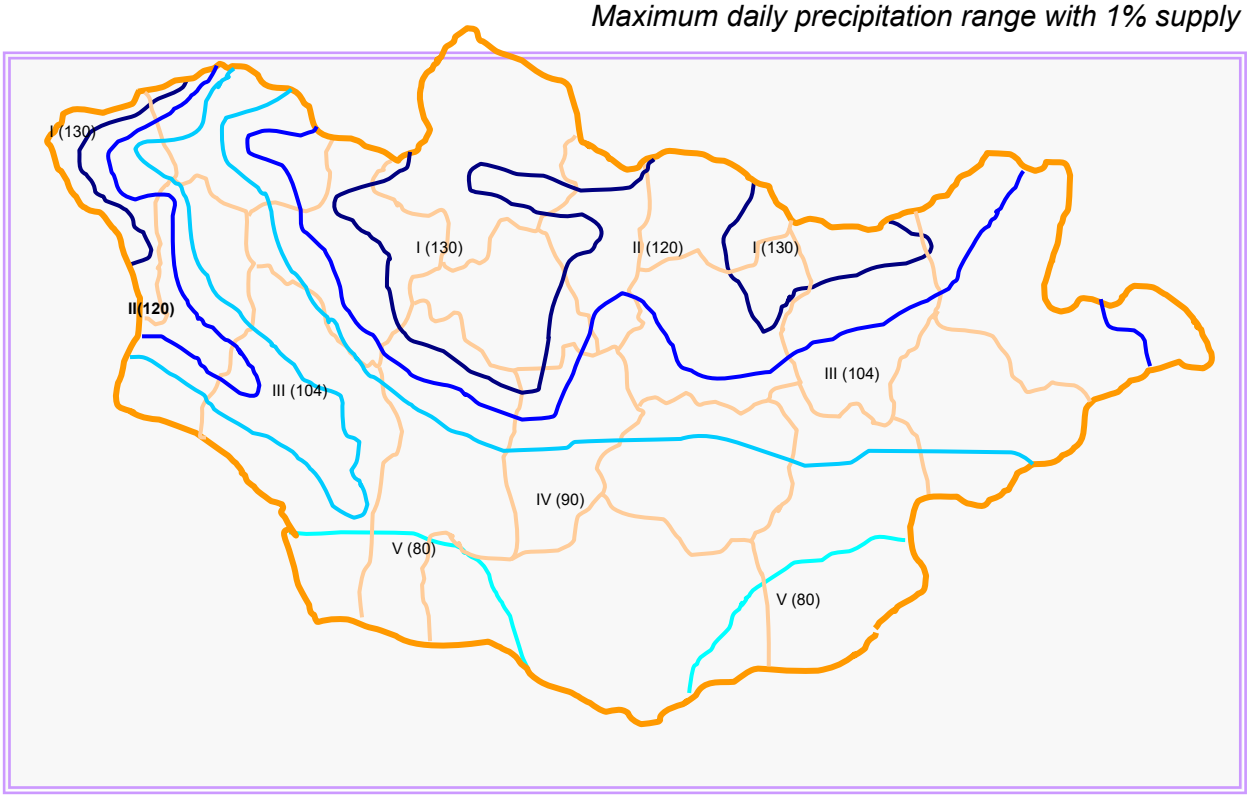
No	Year	Daily precipitation/mm/	In descending order	P /%/
1	1938	30.2	74.9	1.7
2	39	27.8	74.1	3.3
3	1940	36.8	63.4	5.0
4	41	21.1	51.7	6.7
5	42	21.3	50.0	8.3
6	43	33.2	49.8	10.0
7	44	19.8	46.8	11.7
8	45	21.6	46.5	13.3
9	46	46.5	45.4	15.0
10	47	35.9	44.2	16.7
11	48	27.6	40.5	18.3
12	49	36.2	39.9	20.0
13	1950	26.2	39.7	21.7
14	51	25.5	38.0	23.3
15	52	39.7	37.2	25.0
16	53	23.8	36.8	26.7
17	54	50.0	36.2	28.3
18	55	19.9	34.4	30.0
19	56	29.4	34.2	31.7
20	57	63.4	33.2	33.3

21	58	30.9	32.1	35.0
22	59	22.7	30.9	36.7
23	1960	39.9	30.2	38.3
24	61	24.1	29.6	40.0
25	62	26.9	29.4	41.7
26	63	37.2	29.4	43.3
27	64	32.1	28.6	45.0
28	65	20.5	28.5	46.7
29	66	74.1	28.0	48.3
30	67	74.9	27.8	50.0
31	68	29.6	27.6	51.7
32	69	28.5	27.4	53.3
33	1970	20.4	26.9	55.0
34	71	28.6	26.2	56.7
35	72	15.8	26.0	58.3
36	73	20.1	25.5	60.0
37	74	19.3	24.7	61.7
38	75	20.8	24.1	63.3
39	76	16.5	23.8	65.0
40	77	28.0	23.0	66.3
41	78	29.4	23.0	68.7
42	79	19.0	22.7	70.0
43	1980	26.0	21.7	71.3
44	81	17.9	21.6	73.7
45	82	44.2	21.6	75.0
46	83	34.4	21.3	76.3
47	84	51.7	21.1	78.7
48	85	27.4	20.8	80.0
49	86	17.7	20.5	81.7
50	87	34.2	20.4	83.7
51	88	24.7	20.1	85.0
52	89	38.0	19.9	86.7
53	1990	23.0	19.8	88.3
54	91	23.0	19.3	85.0
55	92	45.4	19.0	86.7
56	93	46.8	17.9	88.3
57	94	40.5	17.7	90.0
58	95	49.8	16.5	91.7
59	96	21.7	15.8	93.3

By performing statistical processing on the observation line using the moment method and constructing a supply curve, the maximum daily precipitation amount with 1% supply was calculated in Ulaanbaatar, which is 102.4 mm. However, as mentioned in the “Climate and Geophysical Parameters Surrounding Buildings” (UCS 1994, page

136, figure 29), which has been used in the calculation of buildings in recent years, the maximum daily precipitation amount with 1% supply in the region was determined as H1%=135 mm and used for further calculations.

Maximum daily precipitation range with 1% supply



"Climate and Geophysical Parameters for Construction"
/UTSUH 1994/ page 136, figure 29

Maximum flow calculation

The basins in question belong to the region of Mongolia that experiences flash floods (moderately) and are characterized by rapid flooding due to intense rainfall in a short period of time. Therefore, the maximum discharge of rainwater in unsurveyed basins (rivers, streams, dry streams) was calculated using the following methods.

The maximum flood discharge of rivers and streams with a catchment area of less than 200 km2 is calculated using the rainfall intensity method as specified in the ("Norms and Rules for Calculating Hydrological Specifications" /BNbD 2.01.14-86./).

$$Q1\% = q1\% * \square H1\% * \square * p\% * F$$

Here: **Q1%** - peak discharge for 1% exceedance, m³/s

q1% - peak runoff modulus, l/s·km²

φ - flood runoff coefficient

H1% - 24-hour precipitation with 1% exceedance, mm

δ - coefficient accounting for lakes, forests, wetlands (retention)

p% - transfer coefficient from the 1% exceedance level to the target exceedance

F - drainage area / km² /

The flow morphology specification (Fr) required to determine the maximum flow modulus (q1%) is determined by the following formula:

$$\Phi_r = 1000 * L / K_r * J_r * F^{1/4} * (\varphi * H)^{1/4}$$

Here: Φr - river morphological descriptor

L - length of the runway to the barrier /km/

Kr - coefficient of friction, friction coefficient

J_r - average river flow

The lateral morphology specification (Fhb) required to determine the duration of flood flow (thb) along the lateral slope of a watershed is determined by the following formula:

$$\Phi_{хб} = (1000 * L_{хб})^{1/2} / n_{хб} * J_{хб}^{1/4} * (\varphi * H)^{1/2}$$

Here: $\Phi_{хб}$ - morphological description of the lateral margin

$L_{хб}$ - Average length of the catchment area's lateral edge /km/

$J_{хб}$ - average lateral curvature

$n_{хб}$ - sidewall roughness coefficient

The flood runoff coefficient is determined by the following formula:

$$\varphi = C_2 * \varphi_0 / (F+1)^{n6} * (Jc*50)^{n5}$$

Here: C_2 - empirical coefficient

1.3 in forest areas, 1.2 in other areas)

φ_0 - F=10 км^2, Jc=50% flow coefficient during

n_5 - coefficient depending on soil structure

n_6 - coefficient depending on the climate zone

(0.07 in forest areas, 0.11 in other areas)

Formula for maximum simple flow modulus

$$Q_{1\%} = q_{1\%} * F = B_{1\%} / (F+1)^{0.4} * \delta_1 * \delta_2 * F$$

Here: $Q_{1\%}$ - High flow with 1% flood supply

$q_{1\%}$ - High flow module with 1% flood supply

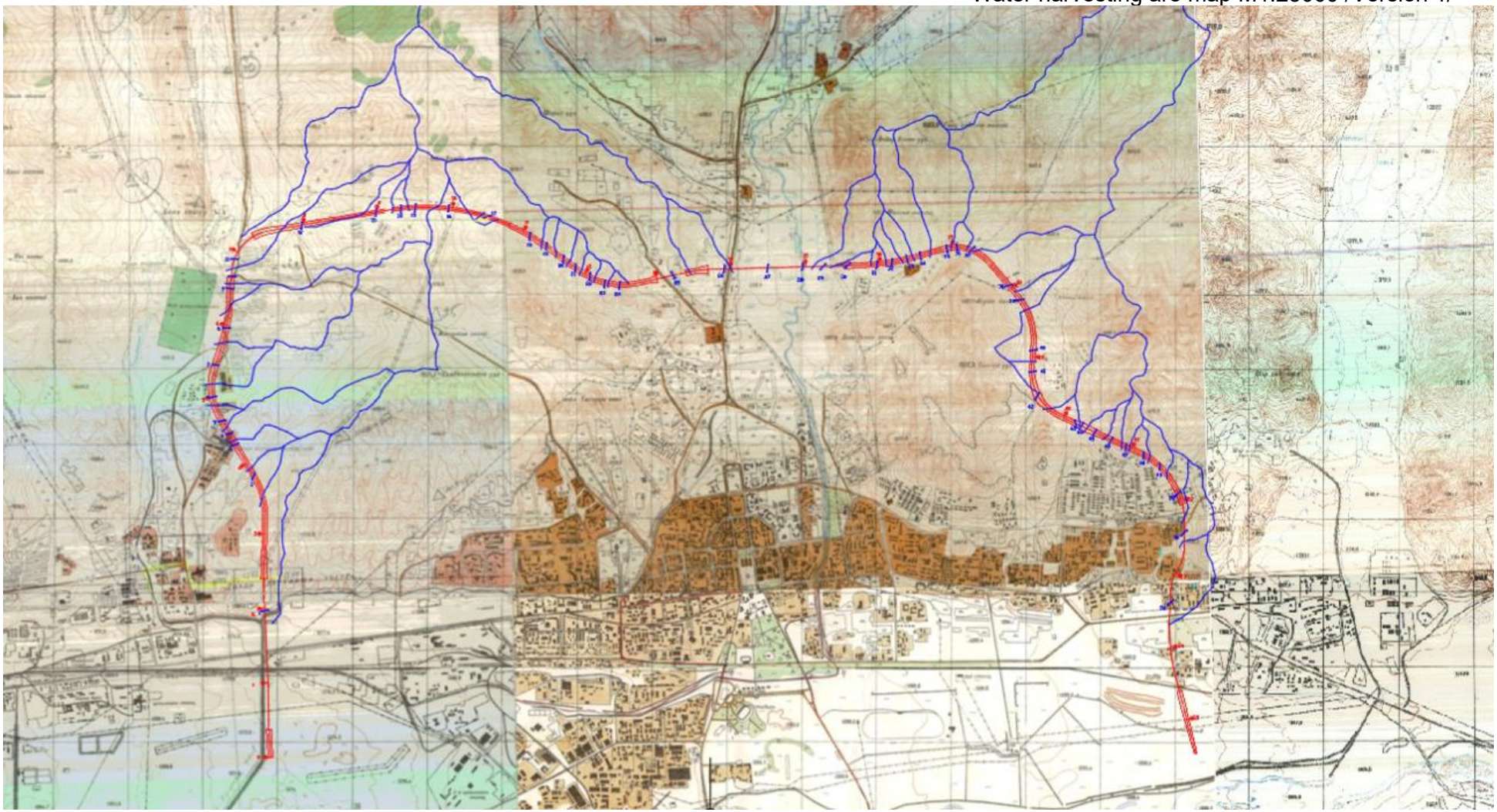
$B_{1\%}$ - Large-scale runoff module with 1% flood supply

δ_1 δ_2 - carbon, forest, and wetland coefficient

F - catchment area

The calculation parameters calculated using these methods are presented in the table.

Water harvesting are map M1:25000 /Version 1/



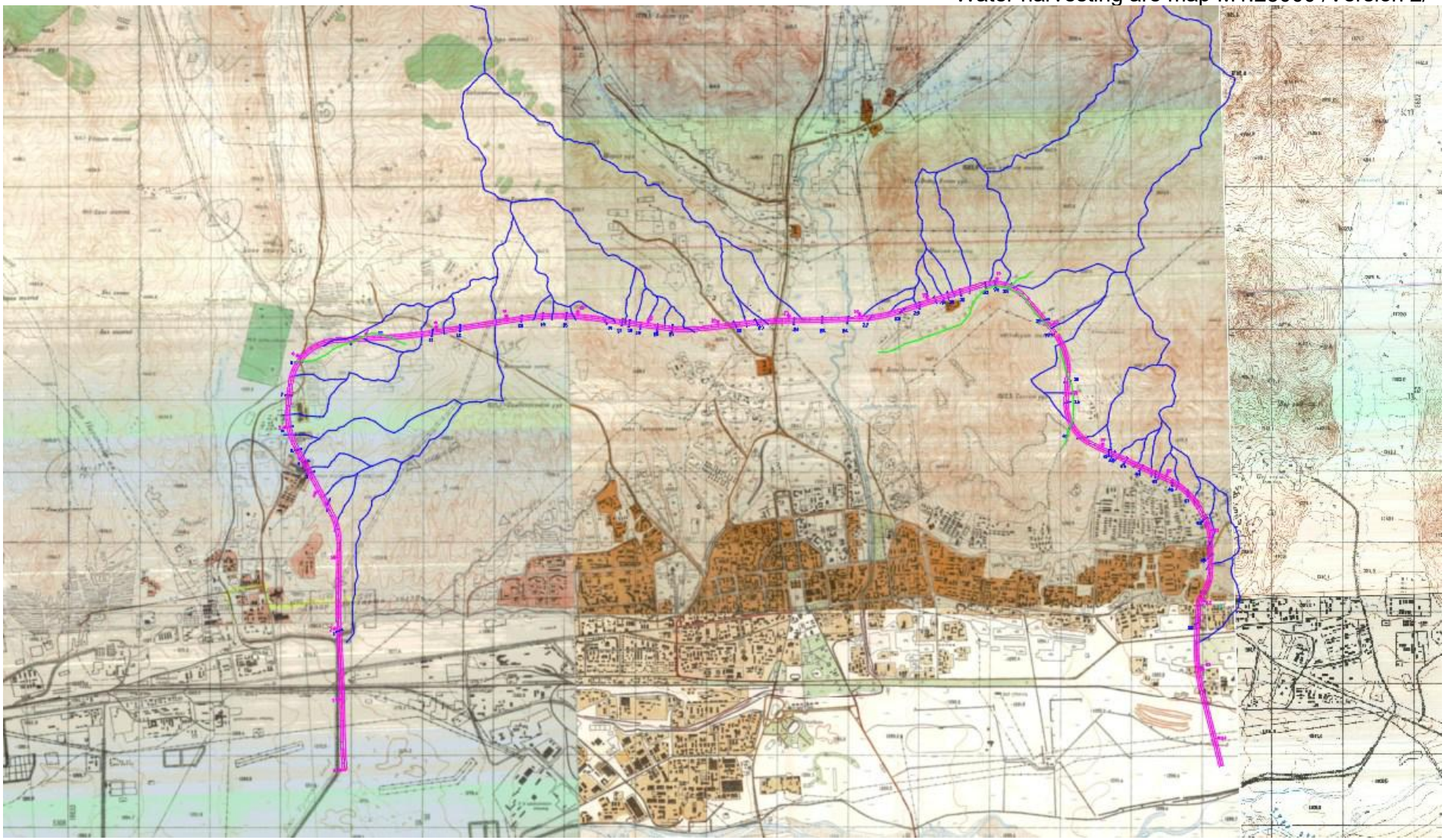
Version 1

¹	Location	F (км²)	L_r (км)	J_r (‰)	$l_{хб}$ (км)	□	□$H_{1\%}$ (мм)	$Ф_{хб}$	$t_{хб}$ (мин)	$Ф_r$	$q_{1\%}$ (л/сек.км²)	$Q_{1\%}$ (м³/сек)	$Q_{2\%}$ (м³/сек)	$Q_{5\%}$ (м³/сек)
1	1+960	**0.766**	**3.104**	54.77	0.25	0.36	48.31	6.75	60.00	30.53	0.0690	**2.553**	**2.247**	**1.838**
2	3+820	**0.138**	**0.641**	78.04	0.22	0.52	69.74	4.38	30.00	7.85	0.1600	**1.538**	**1.353**	**1.107**
3	4+290	**0.216**	**0.934**	96.37	0.23	0.62	83.71	4.15	30.00	9.12	0.1600	**2.895**	**2.548**	**2.085**
4	4+480	**0.970**	**2.741**	69.32	0.35	0.44	59.01	6.66	60.00	22.36	0.0850	**4.868**	**4.284**	**3.505**
5	4+660	**0.055**	**0.385**	51.99	0.14	0.36	48.79	4.25	30.00	7.42	0.1600	**0.430**	**0.378**	**0.309**
6	5+020	**2.758**	**3.945**	55.76	0.70	0.33	45.19	10.69	150.00	28.48	0.0480	**5.983**	**5.265**	**4.307**
7	5+450	**0.302**	**0.864**	60.98	0.35	0.41	55.04	7.41	60.00	10.03	0.1100	**1.827**	**1.607**	**1.315**
8	5+960	**1.273**	**2.107**	56.946	0.60	0.36	48.67	9.57	120.00	17.99	0.0560	**3.469**	**3.052**	**2.497**
9	6+500	**0.066**	**0.416**	72.150	0.16	0.48	65.45	3.89	30.00	6.38	0.2200	**0.955**	**0.841**	**0.688**
10	6+660	**2.619**	**3.669**	71.303	0.71	0.42	56.61	9.65	150.00	23.38	0.0480	**7.117**	**6.263**	**5.125**
11	6+900	**0.163**	**0.751**	53.245	0.22	0.37	49.32	6.26	60.00	10.93	0.1100	**0.884**	**0.778**	**0.637**
12	7+960	**0.497**	**1.786**	128.792	0.28	0.79	63.73	5.21	30.00	13.77	0.1100	**3.485**	**3.067**	**2.509**
13	8+980	**0.126**	**0.874**	183.060	0.14	1.11	90.24	3.15	10.00	7.75	0.2200	**2.502**	**2.202**	**1.802**
14	9+320	**0.057**	**0.502**	199.238	0.11	1.21	98.06	2.93	10.00	5.17	0.2200	**1.233**	**1.085**	**0.888**
15	9+500	**0.353**	**0.828**	211.391	0.43	1.24	100.66	5.11	30.00	5.27	0.1800	**6.402**	**5.634**	**4.610**
16	9+950	**0.071**	**0.409**	219.927	0.17	1.32	107.03	3.46	10.00	3.78	0.2200	**1.668**	**1.468**	**1.201**
17	10+480	**0.029**	**0.210**	237.820	0.14	1.42	115.34	3.21	10.00	2.32	0.2200	**0.734**	**0.646**	**0.528**
18	11+100	**0.821**	**1.666**	132.030	0.49	0.79	63.78	7.55	60.00	11.24	0.1100	**5.761**	**5.070**	**4.148**
19	11+360	**0.070**	**0.424**	141.611	0.17	0.89	72.02	3.78	10.00	5.01	0.2200	**1.109**	**0.976**	**0.799**
20	11+660	**0.118**	**0.569**	105.445	0.21	0.68	54.97	5.28	30.00	6.97	0.1800	**1.167**	**1.027**	**0.840**

21	11+850	***0.079***	***0.543***	147.334	0.15	0.92	74.57	4.16	30.00	6.10	0.1800	***1.057***	***0.930***	***0.761***
22	12+080	***0.061***	***0.349***	171.847	0.17	1.06	85.81	3.55	10.00	3.84	0.2200	***1.147***	***1.010***	***0.826***
23	12+300	***0.051***	***0.367***	108.988	0.14	0.70	57.01	3.90	30.00	5.43	0.2200	***0.643***	***0.566***	***0.463***
24	12+500	***0.029***	***0.213***	187.361	0.13	1.15	93.06	3.26	10.00	2.70	0.0410	***0.109***	***0.096***	***0.079***
25	13+240	***4.782***	***5.019***	85.668	0.95	0.47	63.43	9.62	150.00	25.17	0.0480	***14.559***	***12.812***	***10.483***
26	13+920	***0.433***	***1.312***	68.604	0.33	0.45	60.55	6.35	60.00	13.05	0.0520	***1.365***	***1.201***	***0.983***
27	14+500	***Spring***												
28	14+960	***304.199***	***31.741***	21.738	Selbe river							***278.435***	***192.223***	***157.273***
29	15+250	***0.489***	***1.604***	99.766	0.30	0.63	50.68	6.12	30.00	14.31	0.1100	***2.724***	***2.397***	***1.961***
30	15+560	***0.045***	***0.417***	95.840	0.11	0.63	50.82	3.95	30.00	6.85	0.0410	***0.093***	***0.082***	***0.067***
31	15+960	***0.039***	***0.265***	113.23	0.15	0.73	59.08	4.69	30.00	4.11	0.0300	***0.069***	***0.060***	***0.049***
32	16+160	***0.085***	***0.703***	184.91	0.12	1.13	91.43	2.87	10.00	6.84	0.2200	***1.712***	***1.506***	***1.232***
33	16+380	***0.124***	***0.750***	173.38	0.16	1.06	85.95	3.45	10.00	6.89	0.2200	***2.337***	***2.057***	***1.683***
34	16+550	***0.614***	***1.946***	92.49	0.32	0.58	46.92	7.05	60.00	17.14	0.0850	***2.450***	***2.156***	***1.764***
35	16+920	***1.130***	***2.133***	89.07	0.53	0.54	43.99	9.43	90.00	16.60	0.0740	***3.678***	***3.237***	***2.648***
36	17+050	***0.070***	***0.374***	53.50	0.19	0.37	49.99	5.76	60.00	6.69	0.1400	***0.487***	***0.429***	***0.351***
37	17+250	***6.606***	***5.388***	55.68	1.23	0.31	41.76	13.52	200.00	31.90	0.0440	***12.138***	***10.682***	***8.740***
38	17+950	***0.786***	***1.173***	127.86	0.67	0.77	62.10	8.20	60.00	8.14	0.1400	***6.837***	***6.016***	***4.923***
39	18+200	***0.144***	***0.897***	100.37	0.16	0.65	52.45	4.75	30.00	10.75	0.1100	***0.829***	***0.729***	***0.597***
40	18+920	***0.189***	***0.516***	135.57	0.37	0.85	68.45	5.75	30.00	4.89	0.1400	***1.815***	***1.597***	***1.307***
41	19+200	***0.061***	***0.364***	109.84	0.17	0.71	57.35	4.65	30.00	5.13	0.1400	***0.492***	***0.433***	***0.354***
42	19+540	***2.040***	***2.460***	77.24	0.83	0.46	62.02	10.77	150.00	15.88	0.0620	***7.845***	***6.903***	***5.648***
43	20+180	***0.073***	***0.393***	76.43	0.19	0.51	68.89	4.46	30.00	5.70	0.1400	***0.703***	***0.618***	***0.506***
44	20+260	***0.784***	***1.655***	84.59	0.47	0.53	71.37	6.43	60.00	12.72	0.0850	***4.755***	***4.184***	***3.423***
45	20+480	***0.077***	***0.429***	116.46	0.18	0.75	60.36	4.69	30.00	5.53	0.1400	***0.652***	***0.574***	***0.469***
46	20+700	***0.078***	***0.633***	126.32	0.12	0.80	64.93	4.11	30.00	7.77	0.1400	***0.710***	***0.625***	***0.511***
47	20+920	***0.129***	***0.774***	90.41	0.17	0.59	47.81	4.66	30.00	10.10	0.1400	***0.864***	***0.761***	***0.622***

48	21+180	***0.069***	***0.403***	149.05	0.17	0.93	75.43	3.76	10.00	4.65	0.2200	***1.144***	***1.007***	***0.824***
49	21+450	***0.150***	***0.788***	114.16	0.19	0.73	58.86	4.88	30.00	8.71	0.1400	***1.234***	***1.086***	***0.889***
50	21+880	***0.128***	***0.680***	44.14	0.19	0.31	41.80	5.28	60.00	11.63	0.0850	***0.456***	***0.401***	***0.328***
51	22+440	***0.289***	***1.110***	36.02	0.26	0.25	34.30	7.48	90.00	17.43	0.0680	***0.674***	***0.593***	***0.485***
52	23+400	***0.439***	***1.168***	18.56	0.38	0.14	18.66	13.22	200.00	14.36	0.0560	***0.459***	***0.404***	***0.331***

Water harvesting are map M1:25000 /Version 2/



Version 2														
¹	Байрлал	F (км²)	L_r (км)	J_r (‰)	$l_{хб}$ (км)	□	□$H_{1\%}$ (мм)	$Ф_{хб}$	$t_{хб}$ (мин)	$Ф_r$	$q_{1\%}$ (л/сек.км²)	$Q_{1\%}$ (м³/сек)	$Q_{2\%}$ (м³/сек)	$Q_{5\%}$ (м³/сек)
1	1+960	**0.766**	**3.104**	54.77	0.25	0.36	48.31	6.75	60.00	30.53	0.0690	**2.553**	**2.247**	**1.838**
2	3+820	**0.138**	**0.641**	78.04	0.22	0.52	69.74	4.38	30.00	7.85	0.1600	**1.538**	**1.353**	**1.107**
3	4+290	**0.216**	**0.934**	96.37	0.23	0.62	83.71	4.15	30.00	9.12	0.1600	**2.895**	**2.548**	**2.085**
4	4+480	**0.970**	**2.741**	69.32	0.35	0.44	59.01	6.66	60.00	22.36	0.0850	**4.868**	**4.284**	**3.505**
5	4+660	**0.055**	**0.385**	51.99	0.14	0.36	48.79	4.25	30.00	7.42	0.1600	**0.430**	**0.378**	**0.309**
6	5+020	**2.758**	**3.945**	55.76	0.70	0.33	45.19	10.69	150.00	28.48	0.0480	**5.983**	**5.265**	**4.307**
7	5+450	**0.302**	**0.864**	80.98	0.35	0.53	71.04	6.53	60.00	8.57	0.1100	**2.358**	**2.075**	**1.698**
8	5+960	**1.083**	**2.122**	57.70	0.51	0.37	49.72	8.70	150.00	18.68	0.0480	**2.585**	**2.275**	**1.861**
9	6+900	**0.418**	**1.184**	67.59	0.35	0.44	35.89	7.82	30.00	13.61	0.1100	**1.649**	**1.451**	**1.187**
10	7+300	**0.122**	**0.498**	40.14	0.24	0.28	38.40	7.52	60.00	9.11	0.1100	**0.513**	**0.452**	**0.370**
11	7+940	**0.141**	**0.636**	110.14	0.22	0.70	57.04	4.91	30.00	7.28	0.1600	**1.283**	**1.129**	**0.923**
12	8+340	**0.363**	**0.926**	86.38	0.39	0.55	44.95	7.33	30.00	9.62	0.1100	**1.794**	**1.579**	**1.292**
13	9+220	**0.734**	**1.468**	109.00	0.50	0.67	53.96	9.09	150.00	11.31	0.0690	**2.734**	**2.406**	**1.969**
14	9+520	**0.054**	**0.342**	87.73	0.16	0.58	46.88	5.00	60.00	5.62	0.2200	**0.560**	**0.493**	**0.403**
15	9+840	**0.041**	**0.278**	35.97	0.15	0.26	21.05	7.76	60.00	8.05	0.2200	**0.188**	**0.166**	**0.136**
16	10+380	**0.074**	**0.563**	142.18	0.13	0.89	72.25	3.67	30.00	6.55	0.2200	**1.180**	**1.039**	**0.850**
17	10+640	**1.593**	**2.490**	108.42	0.64	0.63	51.38	9.59	150.00	16.03	0.0480	**3.928**	**3.457**	**2.828**
18	10+740	**0.128**	**0.809**	123.56	0.16	0.78	63.34	3.94	30.00	8.90	0.1600	**1.295**	**1.139**	**0.932**
19	10+900	**0.092**	**0.538**	148.59	0.17	0.93	75.04	3.77	30.00	5.79	0.2200	**1.524**	**1.341**	**1.097**
20	11+140	**0.086**	**0.516**	116.26	0.17	0.74	60.21	4.15	30.00	6.47	0.2200	**1.141**	**1.004**	**0.821**
21	11+350	**0.063**	**0.336**	119.20	0.19	0.76	61.72	4.76	30.00	4.48	0.2200	**0.862**	**0.758**	**0.620**
22	12+240	**5.282**	**5.258**	83.68	1.00	0.46	36.92	12.95	200.00	29.68	0.0320	**6.241**	**5.492**	**4.493**

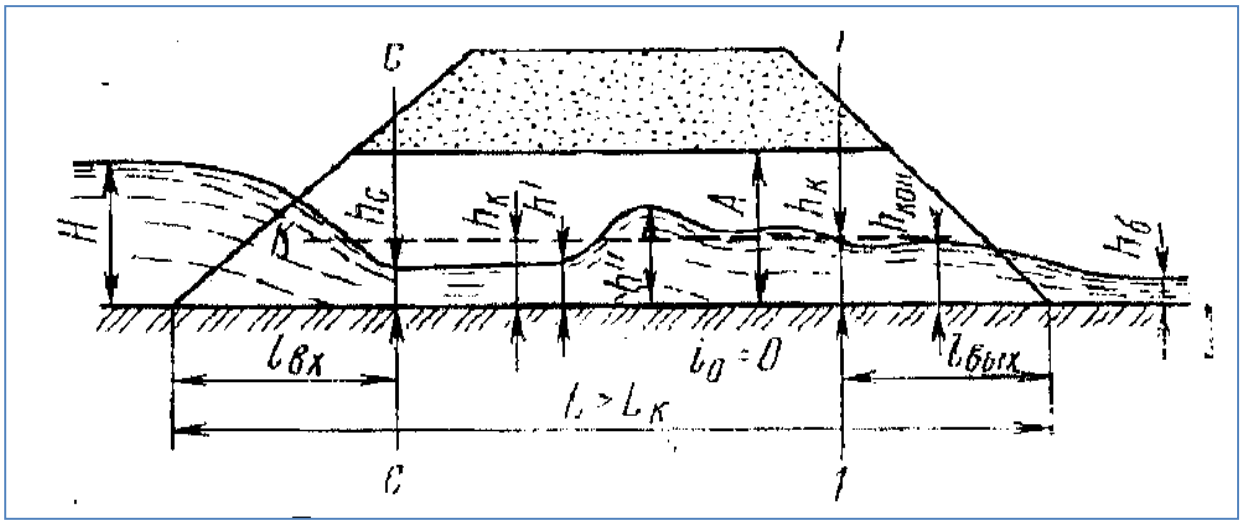
23	12+540	***0.045***	***0.530***	94.32	0.09	0.62	50.09	3.55	30.00	8.76	0.2200	***0.498***	***0.438***	***0.359***
24	13+080	***0.563***	***1.673***	53.79	0.34	0.36	48.18	7.18	60.00	17.90	0.0850	***2.304***	***2.027***	***1.659***
25	13+480	***Spring***												
26	13+820	***304.199***	***31.741***	21.738	***Selbe river***							***278.435***	***192.223***	***157.273***
27	14+160	***0.113***	***0.781***	89.66	0.15	0.59	79.21	3.36	30.00	9.30	0.0850	***0.763***	***0.671***	***0.549***
28	14+600	***0.039***	***0.265***	113.23	0.15	0.73	59.08	4.27	30.00	4.11	0.1100	***0.252***	***0.221***	***0.181***
29	14+880	***0.050***	***0.402***	149.10	0.12	0.93	75.60	3.83	30.00	5.03	0.1100	***0.416***	***0.366***	***0.299***
30	15+100	***0.085***	***0.703***	184.91	0.12	1.13	91.43	2.87	10.00	6.84	0.2200	***1.712***	***1.506***	***1.232***
31	15+290	***0.124***	***0.750***	173.38	0.16	1.06	85.95	3.45	10.00	6.89	0.2200	***2.337***	***2.057***	***1.683***
32	15+480	***0.614***	***1.946***	92.49	0.32	0.58	46.92	7.05	60.00	17.14	0.0850	***2.450***	***2.156***	***1.764***
33	15+840	***1.130***	***2.133***	89.07	0.53	0.54	43.99	9.43	90.00	16.60	0.0740	***3.678***	***3.237***	***2.648***
34	15+980	***0.070***	***0.374***	53.50	0.19	0.37	49.99	5.76	60.00	6.69	0.1400	***0.487***	***0.429***	***0.351***
35	16+180	***6.606***	***5.388***	55.68	1.23	0.31	41.76	13.52	200.00	31.90	0.0440	***12.138***	***10.682***	***8.740***
36	16+880	***0.786***	***1.173***	127.86	0.67	0.77	62.10	8.20	60.00	8.14	0.1400	***6.837***	***6.016***	***4.923***
37	17+140	***0.144***	***0.897***	100.37	0.16	0.65	52.45	4.75	30.00	10.75	0.1100	***0.829***	***0.729***	***0.597***
38	17+840	***0.189***	***0.516***	135.57	0.37	0.85	68.45	5.75	30.00	4.89	0.1400	***1.815***	***1.597***	***1.307***
39	18+120	***0.061***	***0.364***	109.84	0.17	0.71	57.35	4.65	30.00	5.13	0.1400	***0.492***	***0.433***	***0.354***
40	18+460	***2.040***	***2.460***	77.24	0.83	0.46	62.02	10.77	150.00	15.88	0.0620	***7.845***	***6.903***	***5.648***
41	19+140	***0.073***	***0.393***	76.43	0.19	0.51	68.89	4.46	30.00	5.70	0.1400	***0.703***	***0.618***	***0.506***
42	19+190	***0.784***	***1.655***	84.59	0.47	0.53	71.37	6.43	60.00	12.72	0.0850	***4.755***	***4.184***	***3.423***
43	19+390	***0.077***	***0.429***	116.46	0.18	0.75	60.36	4.69	30.00	5.53	0.1400	***0.652***	***0.574***	***0.469***
44	19+640	***0.078***	***0.633***	126.32	0.12	0.80	64.93	4.11	30.00	7.77	0.1400	***0.710***	***0.625***	***0.511***
45	19+840	***0.129***	***0.774***	90.41	0.17	0.59	47.81	4.66	30.00	10.10	0.1400	***0.864***	***0.761***	***0.622***
46	20+100	***0.069***	***0.403***	149.05	0.17	0.93	75.43	3.76	10.00	4.65	0.2200	***1.144***	***1.007***	***0.824***
47	20+380	***0.150***	***0.788***	114.16	0.19	0.73	58.86	4.88	30.00	8.71	0.1400	***1.234***	***1.086***	***0.889***
48	20+810	***0.128***	***0.680***	44.14	0.19	0.31	41.80	5.28	60.00	11.63	0.0850	***0.456***	***0.401***	***0.328***
49	21+350	***0.289***	***1.110***	36.02	0.26	0.25	34.30	7.48	90.00	17.43	0.0680	***0.674***	***0.593***	***0.485***

50	22+320	***0.439***	***1.168***	18.56	0.38	0.14	18.66	13.22	200.00	14.36	0.0560	***0.459***	***0.404***	***0.331***

Design Flood Discharge Capacity of the Structure

The water permeability of circular, square, and rectangular reinforced concrete pipes for roadway drainage is calculated by using the water depth at the compressed section of the water passing through it and the critical depth.

Calculation scheme for water discharge structures with circular and rectangular sections



Therefore, the bottom of the drainage pipe should be taken to be equal to or greater than the critical slope. The hydraulic calculation of the road drainage structure is calculated using the following formula based on the principle of a non-flowing drainage pipe. It includes:

$$Q = \varepsilon\varphi\omega_0\sqrt{\frac{2g(H_0 - h_c)}{\alpha}}$$

Here: ε – lateral compression coefficient

If we put the above formula into the following form:

Including : $Q = \varepsilon\varphi\sqrt{\frac{2g\cdot\omega_c\cdot(S_0 - K_{1V})\cdot A}{\alpha}}$; м3/с

Here: Q - Water flow through the building, m3/s
ε – lateral compression coefficient
φ - coefficient for calculating input resistance
ω - Area in the compressed section of the water flow, m2
S_0 - degree of filling of water passing through a pipe
A- pipe height, m
K_{1V}- coefficient for calculating compressed section

Depending on the design of the water inlet section of the water intake pipe, the coefficients of lateral compression and inlet section are selected, and the calculation assumes a curved design, and ε =0.9; ϕ =0.9.

A. When performing calculations with compressed sections, the following calculations are performed.

1. Degree of pipe tension: $S_0 = \frac{H_0}{A}$; $S_0 < 1.0$ in the calculation $S_0 = 0.8ч0.9$
2. Relative depth of compressed section: $K_c = \frac{h_c}{H_0}$; h_c – water depth in the compressed section
3. Water velocity in the compressed section: $V_c = \varphi\sqrt{2gH_0}$
4. Water joint depth of the compressed section h_c: $h_c" = K_{1c}"A$

$Kc \cdot Kc^{II} \cdot \sqrt{Kc^{II}}$ - This relationship can be obtained from the reference depending on φ.

For seamless pipes, the following calculation relationship is used.

$$h_a = K_{1C} \cdot A \text{ ; энд } K_{1C} = S_O \cdot K_C$$

$$A = K_{2C}\frac{\alpha V^2}{g} \text{энд } K_{2C} = \frac{1}{2\varphi^2(S_0 - K_{C1})}$$

B. In the case of calculating the critical depth, the following calculations are performed.

1. Degree of obstruction of the tube:$S_0 = \frac{H_0}{A} S_0 < 1.0$ in the calculation $S_0 = 0.8ч0.9$
2. Critical water depth: $h_K = K_{1K} \cdot A$
3. Calculating the height of the pipe $A = K_{2C}\frac{\alpha V^2}{g} A = K_{3K}\sqrt[5]{\frac{\alpha Q^2}{g\varepsilon^2}}$
4. Included in the above formulas K_{1K} , K_{2K} , K_{3K} , K_{4K} The coefficients are taken from the reference φ.

5. Critical shape of the throat: $i_K = \frac{K_{4K} \cdot gn^2}{a \sqrt[3]{A}}$

Design capacity of flood control structures (m3/sec)						
round pipe			square pipe			
pipe size	Φ1.00	Φ1.50	1.0x1.0	1.5x1.5	2.0x2.0	3.0x6.0
1 pair	1.688	3.446	1.978	4.427	7.034	31.692
2 pair	3.376	4.711	3.957	8.854	14.068	63.385
3 pair	5.064	7.066	5.935	13.281	21.102	95.077

Hydraulic calculation parameters and dimensions of water supply structures Version 1						
№	Location	F (км²)	L_r (км)	$Q_{1\%}$ (м³/сек)	Pipe type	Passage capacity (m3/sec)
1	1+960	0.766	3.104	2.553	Φ1.5x1	3.446
2	3+820	0.138	0.641	1.538	Φ1.5x1	3.446
3	4+290	0.216	0.934	2.895	Φ1.5x1	3.446
4	4+480	0.970	2.741	4.868	2.0x2.0x1	7.034
5	4+660	0.055	0.385	0.430	Φ1.0x1	1.453
6	5+020	2.758	3.945	5.983	2.0x2.0x1	7.034
7	5+450	0.302	0.864	1.827	Φ1.5x1	3.446
8	5+960	1.273	2.107	3.469	Φ1.5x1	3.446
9	6+500	0.066	0.416	0.955	Φ1.0x1	1.453
10	6+660	2.619	3.669	7.117	2.0x2.0x1	7.034
11	6+900	0.163	0.751	0.884	Φ1.0x1	1.453
12	7+960	0.497	1.786	3.485	Φ1.5x1	3.446
13	8+980	0.126	0.874	2.502	Φ1.5x1	3.446
14	9+320	0.057	0.502	1.233	Φ1.0x1	1.453
15	9+500	0.353	0.828	6.402	2.0x2.0x1	7.034
16	9+950	0.071	0.409	1.668	Φ1.5x1	3.446

17	10+480	0.029	0.210	0.734	Φ1.0x1	1.453
18	11+100	0.821	1.666	5.761	2.0x2.0x1	7.034
19	11+360	0.070	0.424	1.109	Φ1.0x1	1.453
20	11+660	0.118	0.569	1.167	Φ1.0x1	1.453
21	11+850	0.079	0.543	1.057	Φ1.0x1	1.453
22	12+080	0.061	0.349	1.147	Φ1.0x1	1.453
23	12+300	0.051	0.367	0.643	Φ1.0x1	1.453
24	12+500	0.029	0.213	0.109	Φ1.0x1	1.453
25	13+240	4.782	5.019	14.559	2.0x2.0x2	14.068
26	13+920	0.433	1.312	1.365	Φ1.0x1	1.453
27	14+500	Spring			2.0x2.0x2	
28	14+960	304.199	31.741	218.435	Bridge	
29	15+250	0.489	1.604	2.724	Φ1.5x1	3.446
30	15+560	0.045	0.417	0.093	Φ1.0x1	1.453
31	15+960	0.039	0.265	0.069	Φ1.0x1	1.453
32	16+160	0.085	0.703	1.712	Φ1.5x1	3.446
33	16+380	0.124	0.750	2.337	Φ1.5x1	3.446
34	16+550	0.614	1.946	2.450	Φ1.5x1	3.446
35	16+920	1.130	2.133	3.678	2.0x2.0x1	7.034
36	17+050	0.070	0.374	0.487	Φ1.0x1	1.453
37	17+250	6.606	5.388	12.138	2.0x2.0x2	14.068
38	17+950	0.786	1.173	6.837	2.0x2.0x1	7.034
39	18+200	0.144	0.897	0.829	Φ1.0x1	1.453
40	18+920	0.189	0.516	1.815	Φ1.5x1	3.446
41	19+200	0.061	0.364	0.492	Φ1.0x1	1.453
42	19+540	2.040	2.460	7.845	2.0x2.0x1	7.034
43	20+180	0.073	0.393	0.703	Φ1.0x1	1.453
44	20+260	0.784	1.655	4.755	2.0x2.0x1	7.034
45	20+480	0.077	0.429	0.652	Φ1.0x1	1.453
46	20+700	0.078	0.633	0.710	Φ1.0x1	1.453
47	20+920	0.129	0.774	0.864	Φ1.0x1	1.453
48	21+180	0.069	0.403	1.144	Φ1.0x1	1.453
49	21+450	0.150	0.788	1.234	Φ1.0x1	1.453
50	21+880	0.128	0.680	0.456	Φ1.0x1	1.453
51	22+440	0.289	1.110	0.674	Φ1.0x1	1.453
52	23+400	0.439	1.168	0.459	Φ1.0x1	1.453

Hydraulic calculation parameters and dimensions of water supply structures Version 2						
№	Location	F (км²)	L_r (км)	$Q_{1\%}$ (м³/сек)	Pipe type	Passage capacity (m3/sec)
1	1+960	0.766	3.104	2.553	Φ1.5x1	3.446
2	3+820	0.138	0.641	1.538	Φ1.5x1	3.446
3	4+290	0.216	0.934	2.895	Φ1.5x1	3.446
4	4+480	0.970	2.741	4.868	2.0x2.0x1	7.034
5	4+660	0.055	0.385	0.430	Φ1.0x1	1.453
6	5+020	2.758	3.945	5.983	2.0x2.0x1	7.034
7	5+450	0.302	0.864	2.358	Φ1.5x1	3.446
8	5+960	1.083	2.122	2.585	Φ1.5x1	3.446
9	6+900	0.418	1.184	1.649	Φ1.5x1	3.446
10	7+300	0.122	0.498	0.513	Φ1.0x1	1.453
11	7+940	0.141	0.636	1.283	Φ1.0x1	1.453
12	8+340	0.363	0.926	1.794	Φ1.5x1	3.446
13	9+220	0.734	1.468	2.734	Φ1.5x1	3.446
14	9+520	0.054	0.342	0.560	Φ1.0x1	1.453
15	9+840	0.041	0.278	0.188	Φ1.0x1	1.453
16	10+380	0.074	0.563	1.180	Φ1.0x1	1.453
17	10+640	1.593	2.490	3.928	2.0x2.0x1	7.034
18	10+740	0.128	0.809	1.295	Φ1.0x1	1.453
19	10+900	0.092	0.538	1.524	Φ1.5x1	3.446
20	11+140	0.086	0.516	1.141	Φ1.0x1	1.453
21	11+350	0.063	0.336	0.862	Φ1.0x1	1.453
22	12+240	5.282	5.258	6.241	2.0x2.0x1	7.034
23	12+540	0.045	0.530	0.498	Φ1.0x1	1.453
24	13+080	0.563	1.673	2.304	Φ1.5x1	3.446
25	13+480	Spring			2.0x2.0x2	
26	13+820	304.199	31.741	278.435	Bridge	
27	14+160	0.113	0.781	0.763	Φ1.0x1	1.453
28	14+600	0.039	0.265	0.252	Φ1.0x1	1.453
29	14+880	0.050	0.402	0.416	Φ1.0x1	1.453
30	15+100	0.085	0.703	1.712	Φ1.5x1	3.446
31	15+290	0.124	0.750	2.337	Φ1.5x1	3.446
32	15+480	0.614	1.946	2.450	Φ1.5x1	3.446
33	15+840	1.130	2.133	3.678	2.0x2.0x1	7.034
34	15+980	0.070	0.374	0.487	Φ1.0x1	1.453

35	16+180	***6.606***	***5.388***	***12.138***	**2.0x2.0x2**	***14.068***
36	16+880	***0.786***	***1.173***	***6.837***	**2.0x2.0x1**	***7.034***
37	17+140	***0.144***	***0.897***	***0.829***	***Φ1.0x1***	***1.453***
38	17+840	***0.189***	***0.516***	***1.815***	***Φ1.5x1***	***3.446***
39	18+120	***0.061***	***0.364***	***0.492***	***Φ1.0x1***	***1.453***
40	18+460	***2.040***	***2.460***	***7.845***	**2.0x2.0x1**	***7.034***
41	19+140	***0.073***	***0.393***	***0.703***	***Φ1.0x1***	***1.453***
42	19+190	***0.784***	***1.655***	***4.755***	**2.0x2.0x1**	***7.034***
43	19+390	***0.077***	***0.429***	***0.652***	***Φ1.0x1***	***1.453***
44	19+640	***0.078***	***0.633***	***0.710***	***Φ1.0x1***	***1.453***
45	19+840	***0.129***	***0.774***	***0.864***	***Φ1.0x1***	***1.453***
46	20+100	***0.069***	***0.403***	***1.144***	***Φ1.0x1***	***1.453***
47	20+380	***0.150***	***0.788***	***1.234***	***Φ1.0x1***	***1.453***
48	20+810	***0.128***	***0.680***	***0.456***	***Φ1.0x1***	***1.453***
49	21+350	***0.289***	***1.110***	***0.674***	***Φ1.0x1***	***1.453***
50	22+320	***0.439***	***1.168***	***0.459***	***Φ1.0x1***	***1.453***

The number of flood control structures selected for each scenario is compared.

Pipe type	Version 1	Version 2
Φ1.0x1	26	25
Φ1.5x1	13	14
2.0x2.0x1	9	8
2.0x2.0x2	3	2
Bridge	1	1

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