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Corps of Engineers

Dept. of Army

Washington District

SPECIAL STUDY S-52-3

RUR (ROER) RIVER

ARTIFICIAL FLOODING

POTENTIALITIES

PREPARED BY
MILITARY HYDROLOGY R&D BRANCH
ENGINEERING DIVISION
WASHINGTON DISTRICT, CORPS OF ENGINEERS
WASHINGTON, D. C.
NOVEMBER 1952

SPECIAL STUDY S-52-3

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SPECIAL STUDY S-52-3

ARTIFICIAL FLOODING POTENTIALITIES RUR (ROER) RIVER

SECTION I INTRODUCTION

1-01 ASSIGNMENT.

This special study was assigned to the Military Hydrology Research and Development Branch, Engineering Division, Washington District by letter from Office, Chief of Engineers, ENGFE, to the Division Engineer, North Atlantic Division: subject "Military Hydrology R&D Project No. 8-72-12-001: Special Assignment" dated 9 September 1952.

1-02 PURPOSE AND SCOPE.

a. This report presents information regarding the hydraulic effects and nature of artificial flooding potentialities in the Rur (Roer)* River basin. It consists largely of a compilation and consolidation of information presented in various intelligence documents and technical publications, with certain supplementary analyses and discussions. The material forming the basis of this report was limited to that available in the Washington, D. C. area. Additional data from other sources and field reconnaissance are needed to adequately cover the subject for general military requirements.

b. The report is designed to furnish basic data and results of analyses needed to answer questions concerning:

(1) Normal and extreme discharges, stages, and velocities at key stations on the Rur River in the reach influenced by the Urft Dam, Schwammenauel (Rur) Dam and other dams in the group commonly known as the "Schmidt Dams" or "Eifeltallsperren" (Eifel Reservoirs).

(2) Stream characteristics including gradients, depths and widths of channel and flood-plain in that reach.

(3) Data concerning locations and zero elevations of gaging stations.

(4) Data concerning locations and dimensions of dams and bridges.

(5) The extent of flooding possible by erection of temporary dams.

*German spelling is "Rur," Dutch spelling is "Roer."

(6) The magnitude and duration of flood waves and flow variations created by breaching or regulated discharge from the dams and reservoirs and the effect on military bridging and crossing operations on the Rur River.

1-03 ARRANGEMENT.

This report is sub-divided as follows:

Section I	Introduction
Section II	Drainage Basin Characteristics and Developments
Section III	Hydrologic Characteristics
Section IV	Artificial Flood Potentialities
Section V	Effect on Military Operations
Bibliography	
Tables	
Plates	
Exhibit A	Description of Watercourse and Control Structures, The Rur (Roer) and Urft Rivers
Exhibit B	Abstracts from German Technical Literature
Exhibit C	Excerpts from VII Corps Report: "The Roer River Crossings and Advance to the Rhine."

1-04 DEFINITIONS AND REFERENCE DATUM.

a. <u>Equivalent English-Metric Terms.</u>

Both the English and Metric systems are used in this report. Conversion factors are presented for convenient reference in Table 1.

b. <u>Hydrologic Terms and Abbreviations.</u>

(1) The following abbreviations are used in this report:

cm	centimeters
mm	millimeters
m	meters
km	kilometers

1-04

l	liters
km^2	square kilometers
m^3	cubic meters
m^3/sec	cubic meters per second
fps	feet per second
m/sec	meters per second

(2) Abbreviations, in conformance with standard German Hydrologic practice, are defined in Table 2.

c. Elevation Datum.

All elevations referred to in this report are in meters above "Normal Null" (N. N.), the zero of the German Land Survey Datum.

d. Kilometerage Datum.

River kilometers in this report are based on Zero Kilometer at a point 1.1 km east of Monti Rigi, Belgium in the headwaters of the Rur River and are measured in a downstream direction.

e. Maps.

The area of the Rur River basin is covered by the following standard American-British maps of GSGS (Geographic Section General Staff) series:

Scale	GSGS Map Series	Sheet Numbers
1:250,000	4042	A, B, E
"	4356	K-51, K-52
1:100,000	4416	Q-1, R-1, S-1
"	4336	4, 9
"	2541	2, 5
1:25,000	4414	4802, 4902, 4903, 5003, 5004, 5104, 5204, 5304, 5404

f. Reference Grid.

Grid references cited in this report are to the "Nord de Guerre" Grid System.

1-05 REFERENCES.

All references cited in this report are listed in the Bibliography following Section V of the text.

SECTION II
DRAINAGE BASIN CHARACTERISTICS AND DEVELOPMENTS

2-01 GENERAL.

a. The Rur (Roer) River rises in the Eifel Highlands in Belgium and flows generally northward along the German side of the Belgium-German and Dutch-German borders, emptying into the Maas (Meuse)* River near Roermond, Holland. It serves as a major source of domestic and industrial water supply for the Prussian Rhine Province and provides electric power for the area of Germany south and southwest of Cologne (Köln). The major tributaries of the Rur River are the Urft, Kall, Inde, and Wurm Rivers. Locations of the river and its tributaries are shown on the maps presented as Plates 1, 2, and 3 of the report. A detailed description is contained in Reference 1, a translation of which is included in this report as Exhibit A.

b. This report is confined to consideration of the main stem of the Rur River below the Urft and Schwammenauel (Rur) Dams.

2-02 TOPOGRAPHY.

The headwaters of the Rur River are in the Eifel Highlands which comprise three distinct regions; the "High Eifel," a region dissected by deeply incised streams; the "Volcanic Eifel," characterized by lava-blocked valleys and volcanic crater lakes; the "Hohn Venn," composed of undulating hills with slate ridges and peat-filled depressions. The Rur River continues to flow in mountainous country as far as Kreuzau (km 90). From there to Juelich (also spelled as Jülich) at km 112, the terrain is hilly, but at Juelichit changes to the flat agricultural plains of the Maas (Meuse) Valley. * The Urft River originates in a deep-cut valley in the mountains near Schmitheim and joins the Olef River in the "Volcanic Eifel" region near Gemuend (Gemünd), meandering through a deep valley to the confluence with the Rur River. The Kall River has its source in the highlands of the "Hohe Venn" region and flows northward through mountainous country to its junction with the Rur River near Zerkall (km 79). Reference is made to the document listed in the Bibliography as Reference 2 for detailed topographic information.

2-03 GEOLOGY.

The Rur and Kall Rivers originate in the Eifel region, which is marked by alluvial moor formations. The Rur, Kall, and Olef Rivers, and part of the Urft River, cut their way through Lower Devonian layers consisting of graywackes and schists. As the rivers emerge from the "Hohe Venn" region, they successively cross layers of graywacke, slate, sandstone and calcite, and on the line between Eschweiler and Weissweiler reach the "Bight of Juelich" with its heavy loess cover. The Urft River originates in the calcareous "Ravine of Blankenheim," and crosses

* Dutch spelling is Maas, Belgian spelling is Meuse

the Lower Devonian region to enter the calcareous "Ravine of Soestenich" and then the mottled sandstone of the Triassic "Bight of Kommern," with its sandstones and conglomerates. Above Gemuend, it again enters a Lower Devonian region. At least half of the area of the Urft River basin is composed of calcites, dolomites, and slates of the Middle Devonian Age. Detailed geologic information is contained in Reference 3.

2-04 DRAINAGE AREAS.

The total drainage area of the Rur River is 2299 km^2. The extent of the drainage basin is illustrated on the Drainage Basin Map, Plate 3. Drainage areas at key gaging stations are included in Table 5. A tabulation of areas drained by the Rur River and its major tributaries follows:

River	Location	Drainage Area (km^2)
Rur	Above mouth of Urft River	246.5
"	At Rur Dam (less Urft R.)	300.0
"	Above mouth of Kall River	709.3
"	At Obermaubach Dam	794.6
"	Above mouth of Inde River	970.9
"	Above mouth of Wurm River	1609.5
"	At Confluence with Maas R.	2299.0
Urft	At Urft Dam	375.4
Kall	At Kall Dam	29.0
"	At Rur River Confluence	77.8
Inde	At Dreilaegerbach Dam	10.9
"	At Rur River Confluence	352.4
Wurm	At Rur River Confluence	456.1

2-05 GRADIENTS AND PROFILES.

The Rur River has a very steep gradient, dropping 663 m in a distance of 160 km between its source (elevation 686 m/NN), and the German-Dutch border (elevation 22 m/NN), for an average gradient of 41 per 10,000. The mountainous upper regions of the river have gradients of as high as 300 per 10,000, while the lower reaches below Stah (km 152) have gradients averaging 10 per 10,000. Reference is made to the Rur River stream-bed profile on Plate 4 and to the following tabulation:

Reach of Rur R.	River Km	Average Gradient per 10,000
Urft R. - Heimbach	61- 63	38
Heimbach - Zerkall	63- 79	22
Zerkall - Dueren	79- 98	28
Dueren - Juelich	98-115	23
Juelich - Dutch Border	115-160	12
Dutch Border - Maas R.	160-180	9

2-06 CHANNEL DEPTHS.

The Rur River channel, exclusive of the reservoirs and retention ponds, varies in depth between 0.4 and 1.0 m at Mean Water, in the reaches located upstream from the German-Dutch border. In spite of the relatively shallow depths, fording becomes difficult at stages above MW because of the high velocities resulting from the prevailing steep gradient of the river. During flood conditions, the river may reach an average depth of above 2.5 m. Reference is made to the tabulation of depths included in Exhibit A and to the depth profile presented on Plate 10. Representative normal depths at selected points along the Rur River are given in the following table:

Location	River Km	Depth at MW (m)
Zerkall	79	0.6
Dueren	98	0.5
Juelich	113	0.5
Orsbeck	149	1.0

2-07 CHANNEL AND FLOOD-PLAIN WIDTHS.

Detailed information on channel and flood-plain widths are contained in Exhibit A and on Plate 5. A tabulation of representative widths along the Rur River follows:

Reach of Rur River	River Km	Channel Width (m)	Flood-Plain Width (m)
Heimbach - Zerkall	63- 81	16	———
Zerkall - Kreuzau	81- 89	18	100-200
Kreuzau - Lendersdorf	89- 93	18-20	20-300
Lendersdorf - Dueren	93- 98	26-30	No overflow
Dueren - Juelich	98-113	25	400-500
Juelich - Linnich	113-126	20	300-600
Linnich - Orsbeck	126-149	18-20	300-600
Orsbeck - Dutch Border	149-160	23	500-1000

2-08 NAVIGATION.

The Rur River and its tributaries are not navigable except for a short reach near the mouth in the Roermond harbor area.

2-09 REGULATION.

Seasonal variation of flow in the Rur River is controlled to a great extent by the operation of the reservoir system in the Rur River valley. High water flows are impounded in four major storage reservoirs and two equalizing pools. The two larger dams, the Urft and Schwammenauel (Rur) Dams, have storage capacities of 45.5 and 100 million m^3 respectively, and are used for power generation and water supply as well as flood protection. The Kall and Dreilaegerbach Dams on tributaries of the Rur River are primarily small water-supply projects for the Aachen district.

The storage reservoirs are normally kept at 80% capacity from April to June, at 50% capacity from August to December, and average 67% capacity during the remaining transition periods of the year. Re-regulation of discharges from the large dams and control of water levels for downstream industries is made possible by operation of the Heimbach and Obermaubach Dams. A more detailed description of the structure and operation of these dams is contained in paragraph 2-10. In order to control stream velocity and to provide industrial water to the developed reaches of the Rur River, low check dams have been installed approximately one km apart along the river. These check dams, augmented by 4 m wide channels on either side of the main stream-bed, permit withdrawal of water for industrial use from the Rur River during periods of low flow.

2-10 DAMS AND RESERVOIRS.

a. General. In the Rur River system there are seven important dams, namely: the Urft, Paulushof, Schwammenauel (Rur), Heimbach, Obermaubach, Kall, and Dreilaegerbach Dams. Collectively, they are commonly known as the "Eifeltalsperren" (Eifel Reservoirs), Rur Dams, or Schmidt Dams. Table 3 provides a summation of their individual general characteristics. The geographic locations are shown on Plates 2 and 3, and sketches and photographs illustrating details of the dams are presented on Plates 6 to 9, inclusive. Detailed description is contained in Exhibits A and B which consist of translations of pertinent excerpts from German military documents and technical literature.

b. Urft Dam. In the period 1900-05, this large masonry dam was built on the Urft River, approximately 4.5 km upstream from the confluence of the Urft and Rur Rivers. It is a multiple purpose reservoir, impounding 45.5 million m^3 of water for power, water supply, and flood control. The dam structure is 226 m long, 58 m high and 50.5 m wide at its base. 30 m^3/sec can be discharged at full pool through the 3 bottom outlets into the Schwammenauel (Rur) Reservoir, and 34 m^3/sec through the 2.8 km long tunnel and penstock leading to the Heimbach Power Plant. Reference is made to Plate 6, Table 3 and Exhibits A and B for further details.

c. Schwammenauel (Rur) Dam. This is the largest dam in the Rur River valley and was built in 1935-37 to complete the regional water economy program. It is located on the Rur River at km 59.8, about 15 km below the Urft Dam. The existing reservoir capacity of 100 million m^3 supplements the Urft Dam's multiple purpose functions of power, water supply, and flood control. The Rur Dam is 300 m long, 62 m high, and 300 m wide at the base; and is of an unusual type, consisting of several layers of earth with a flexible core of steel and concrete. Provision was made in the design for future enlargement of the structure to provide double the existing storage capacity. The 2 bottom outlets can discharge about 80 m^3/sec at the existing full pool, while the spillway capacity is approximately 750 m^3/sec. Table 3, Plate 7 and Exhibits A and B contain additional information.

2-10

d. Paulushof Dam. The small (10.5 m high) earth dam at Paulushof was built in conjunction with the construction of the Schwammenauel (Rur) Dam to regulate the water level in the upper reaches of the Schwammenauel Reservoir. It has little hydraulic significance, but primarily serves to prevent the natural beauty of the area from being impaired by unsightly exposure of mud-flats during periods of low pool levels in the Schwammenauel Reservoir. See Table 3, Plate 8 and Exhibits A and B for further details.

e. Heimbach and Obermaubach Dams. These so-called equalizing basins on the Rur River at km 63.4 and 83.9 (See Plate 2) were built in 1934 to complement the Urft and Schwammenauel Dams in regulation of the Rur River. Their functions are to equalize the discharges from the storage reservoirs and to control the water supply to the industrial regions of the Rur Valley. These two dams are respectively 9 and 7.3 m high, and have storage capacities of 1.25 and 1.65 million m^3, respectively. The Heimbach Dam has a gated weir 5.5 m high and 18 m long, which provides automatic regulation of upstream stage. The dual gates of the Obermaubach Dam are each 5.5 m high and 18 m long and are similar in design and operation to the Heimbach installation. Additional detailed information appears in Table 3, on Plate 8, and in Exhibits A and B.

f. Dreilaegerbach Dam.* In 1909-11, this 43 m high by 240 m long masonry dam was built on the Dreilaegerbach, a tributary of the Vicht River, a branch of the Inde River which flows into the Rur River at km 112 near Juelich. Its sole function is to provide a portion of the water supply for the Aachen district and it impounds up to 4.3 million m3 of water. The natural drainage area was increased by construction of the Kall Dam, Kall Tunnel, and several collecting channels, as explained in detail in Exhibits A and B. Pertinent data are summarized in Table 3, and sketches of the dam are included on Plate 9.

g. Kall Dam. The Kall Dam was built to supplement the Dreilaegerbach Dam as part of the 1934-39 regional water economy program. The dam is located on the Kall River about 15 km above the Rur River confluence at km 79 near Zerkall. It is a 180 m long, 39.5 m high earth dam with a concrete core. The existing reservoir storage capacity is 2.1 million m^3. After the proposed future 9.3 m increase in dam height is effected, the storage capacity would be increased to 4 million m^3. (See Plate 9 and Exhibits A and B). The Kall reservoir is connected by means of 6.2 km tunnel to the Dreilaegerbach reservoir. Pertinent dam data are summarized in Table 3.

2-11 LEVEES.

The levee system of the Rur River is concentrated in the developed areas below Obermaubach (km 84). The following table extracted from Exhibit A is an indication of the extent of the flood protection levees:

* Also spelled as "Dreilägerbach"

Reach	River km.	Remarks
Obermaubach-Kreuzau	84- 89	Revetted RR embankment on right bank.
Kreuzau-Lendersdorf	89- 93	No protection.
Lendersdorf-Dueren	93- 98	High water does not overflow banks.
Near Dueren	98-102	Dueren to Hoven is regulated.
Dueren-Juelich	102-113	No protection except for local factories, etc.
Juelich-Linnich	113-116	Flood protection on right bank at Juelich.
	116-126	No protection.
Linnich-Orsbeck	127-129	Dikes both sides.
	130-149	Dikes both sides.
Orsbeck-Stah	150-152	Flood protection Dikes both sides.

2-12 CANALS.

There are no navigation canals in the Rur River basin. The only significant canals in this area are those mentioned in paragraph 2-09b and which supply river water to the local industries. Although detailed current information on the status or location of those industrial canals is not available, it is assumed that the reach of the Rur River between Keruzau and Orsbeck has industrial canals along both banks of the river.

These canals have a standard width of approximately 4 m and, for the most part, parallel the river channel. Reference is made to Exhibit A for information circa 1940.

2-13 BRIDGES.

Reliable information with respect to post-war bridge reconstruction was not available in this office at this time; however, a tabulation of available bridge data extracted from Reference 17 is presented in Table 4. Locations and clearances (wherever data are available) is indicated on Plate 4.

SECTION III

HYDROLOGIC CHARACTERISTICS

3-01 GENERAL.

a. Information regarding river stage, discharge, flow duration and velocity are presented in generalized graphical form insofar as practicable to facilitate application of the data to specific military problems. The cited references should be utilized for supplementary data.

b. Most available long-term stage and discharge records in the Rur (Roer) River basin cover periods prior to completion of the present reservoir system in 1937 and consequently are not indicative of the regulatory effect of the reservoirs. Data presented in this report for the available 1937-1946 period probably reflect the general stage and discharge trends to be expected with the present reservoir system in operation.

3-02 CLIMATOLOGY.

Climatological data for the region covered by this report may be found in References 3, and 18 to 21, inclusive. The significant facts concerning precipitation in this basin are; (1) the relatively higher volume falling in the drainage area of the upper Rur, Kall and Inde Rivers when compared with the Urft River basin; (2) the periodical cycle of wet and dry years; and (3) the general decline of the mean annual runoff over the past 15 years. Reference should be made to the publication listed as Reference 3 for detailed discussion of the geographical distribution of annual runoff in the Rur River basin. A tabulation of annual mean rainfall and runoff over the drainage areas at key locations for the period 1934-43, extracted from Reference 3 follows:

River	Location	Drainage Area (km^2)	Rainfall (mm/km^2)	Runoff (mm/km^2)
Rur	Rur Dam	300.0	1014	619
"	Zerkall	787.1	910	420
"	Juelich	1344.2	813	340
"	Stah	2075.8	766	280
Urft	Urft Dam	375.0	853	434
Kall	Kall Dam	29.0	1044	588
Inde	Dreilaegerbach	10.9	1011	561
"	Eschweiler	215.8	839	603
Wurm	Geilenkirchen	227.6	729	292

3-03 STREAM GAGING STATIONS.

Stream gaging stations have been established on the main stem of the Rur River at Zerkall, Juelich, and Stah; on the Inde River at Eschweiler; and on the Wurm River at Geilenkirchen. Stage and discharge records for these stations appear in References 18 to 20, inclusive. Locations are indicated on the River Basin Map, Plate 2 and on the Rur River Stream Profile, Plate 4. Pertinent data concerning the [illegible] River gages are contained in Plate 5.

3-04 RIVER STAGES.

a. Records. Statistical data regarding the mean and extreme stages experienced at key gaging stations on the Rur River during the 1937-40 water-years are summarized in Table 5. Reference is made to the German Hydrologic Yearbooks, References 18 to 20, inclusive, for additional information.

b. Seasonal Variation. The mean monthly gage heights for the key Rur River gages during the 1937-40 water-years are tabulated in Table 5, and the monthly variations of stage are graphically illustrated on Plate 12. Stage durations extracted from Reference 18 are shown as Plate 11. The effect of regulation of the Rur River reservoirs for water supply of the Dueren-Juelich industries is reflected in the slight variation of stages during the summer months. While the short period of record cannot give an accurate indication of the maximum stages to be expected, this period does include a time of abundant precipitation and it is believed that the data presented provide a reasonably accurate index of the normal stages to be expected.

3-05 RIVER DISCHARGES.

a. Records. As mentioned in paragraph 3-01, the completion of the reservoir system in 1937 makes the records of discharges in this area during the period prior to that time generally unrepresentative of the present day flow. The paucity of post-war data further complicates the establishment of norms upon which to base comparisons. However, the lack of specific current discharge information is not considered a serious handicap, and consequently the derived short-term records were utilized wherever possible. Generous use was made of data given in Exhibit A and References 3, and 18 to 21, inclusive. Long-term records of mean natural discharges for areas above the damsites are shown in order to provide basis for estimates of the filling time of the reservoirs. These natural runoffs or inflows would be unaffected by construction of the dams.

b. Runoff Volume. From information contained in Reference 3, the natural runoff for the drainage areas above the major damsites is presented below. It may be seen that between 70 and 80 percent of the average yearly water supply is obtained during the first six months of the water-year; while, on the other hand, the natural flow does not satisfy the normal industrial usage during the remaining six months.

Mean Volume of Natural Runoff (million m^3)

N	D	J	F	M	A	M	J	J	A	S	O	Year
Urft Dam, 375 km^2 (1897-1942)												
20.1	26.3	30.8	23.6	24.0	19.8	10.5	5.6	5.2	5.2	6.8	10.5	188.5
Schwammenauel (Rur) Dam, 300 km^2 (1912-1928)												
20.3	30.3	39.2	22.5	20.4	17.9	12.9	6.6	6.3	6.3	9.6	12.6	204.8
Obermaubach (Estimated), 795 km^2												
43.1	55.1	65.1	49.6	51.1	41.6	21.9	12.6	11.1	10.6	14.1	22.1	398
Kall Dam, 29 km^2 (1926-1942)												
2.1	2.3	2.6	2.0	1.8	1.9	0.8	[illegible]	0.6	0.6	0.5	1.2	17.3
Dreilaegerbach Dam, 11 km^2 (1913-1942)												
0.8	0.9	1.2	0.8	0.7	0.8	0.4	0.3	0.3	0.3	0.3	0.5	7.4

c. **Mean Discharges.** As discussed in Exhibit B, runoff in the Rur River area is subject to large seasonal variation, being very high in winter and low in summer. During the summer months the natural runoff only averages 6 to 7 liters/sec/km^2. Operation of the reservoir system of the Rur River regulates the flow so as to insure about 9 m^3/sec to meet the water requirements of the industrial regions below Heimbach. For purposes of comparison, mean monthly and annual discharge rates (corresponding approximately to natural runoff or inflow rates) for the areas above the damsites as derived from basic data in Reference 3 are tabulated below, together with regulated discharge rates for key locations downstream of the reservoirs as extracted from Reference 18. It may be noted in the following tabulation that the minimum mean monthly rates at Zerkall and Juelich are less than the 9 m^3/sec industrial requirements. This seeming discrepancy is probably due to the difference between average flow and peak usage of industrial water during working hours or to diversion of water through the industrial canals mentioned in paragraph 2-12.

Mean Monthly and Annual Discharge (m^3/sec)

N	D	J	F	M	A	M	J	J	A	S	O	Year
Reservoir Inflow Rates												
Urft Damsite 375 km^2 (1897-1942)												
7.9	[illegible]	12.2	8.5	9.6	7.6	4.2	2.2	2.1	2.1	2.5	4.2	6.1

Schwammenauel (Rur) Damsite 300 km² (1912-1922)

7.8	12.1	14.3	8.1	8.1	7.0	5.1	2.6	2.5	2.5	3.7	5.0	6.6

Obermaubach Damsite 795 km² (1897-1942) estimated

15.6	20.5	24.2	20.6	19.1	16.2	8.3	4.6	4.1	4.1	5.4	8.3	12.7

Kall Damsite 29 km² (1926-1942)

0.8	0.9	1.0	0.9	0.7	0.8	0.3	0.2	0.2	0.2	0.2	0.5	0.6

Dreilaegerbach Damsite 11 km² (1913-1942)

0.3	0.4	0.5	0.3	0.3	0.3	0.2	0.1	0.1	0.1	0.1	0.2	0.2

Regulated Stream Discharge Rates

Zerkall 787 km² (1937-1940)

11.3	17.0	18.0	23.0	18.5	20.0	10.0	7.0	7.0	7.0	7.0	7.5	12.8

Juelich 1344 km² (1937-1940)

12.0	18.0	20.0	31.0	20.0	23.0	9.5	5.0	4.0	6.0	7.5	7.5	13.6

Stah 2066 km² (1937-1940)

17.5	23.5	26.5	35.0	28.5	28.0	16.5	11.5	10.5	10.5	11.5	11.0	19.2

d. Maximum Discharges. The maximum discharges of record, derived from data in Exhibit A and References 3 and 20, are tabulated below. It should be noted that these values represent estimated, rather than observed rates of discharge, and that certain discrepancies are apparent (probably due to different periods of records being utilized by the various sources).

Maximum Discharges-Rur River

Station	Drainage Area (km²)	Date	HHq (1/sec/km²)	HHQ (m³/sec)
Urft Dam	375	Unknown	550	206
Rur Dam	300	"	1437	430
Heimbach	675	"	620	418
Zerkall	787	12 Jan 1920	355	280
Juelich	1344	12 Jan 1920	208	280
Stah	2066	31 Dec 1925	242	500

3-04 RIVER VELOCITIES

a. General. The velocity of stream flow varies according to the conformation of the river bed, depths, obstructions, restrictions, local variation of slope, etc. Channel improvements and cut-offs, training walls and levees, operation of dams and other modifications of natural conditions appreciably affect the stream velocity. Influent rivers in flood tend to elevate the main river waters at the point of confluence according to the magnitude of the flood, thus tending to reduce the slope above and to increase it below the point of confluence. Accordingly, correlations between river stages and surface velocities at gaging stations cannot be interpreted as applicable to all points along the adjacent river sections, but only serve as general indications.

b. Surface Velocities. Insufficient basic information concerning the stream hydraulic functions (cross-sectional area, wetted perimeter, water surface slope, roughness factor, etc.), was available to permit accurate determination of stream velocities. Estimates were based on velocities observed during discharge measurements at gaging stations as recorded in Reference 19. The observed velocities were assumed to be mean cross-sectional velocities, which were increased by 18 percent to indicate the mean surface velocity. As indicated in the velocity studies in Reference 22, the mean cross-sectional velocities should be increased by 25 to 75 percent to obtain the maximum surface velocities likely to be encountered during crossing operations. Mean cross-sectional velocity durations are illustrated on Plates 11 and 12. Mean surface velocity ratings at the gaging stations are presented in Plate 13. Mean surface velocities at selected stations, as shown on Plate 10, are tabulated below:

Mean Surface Velocities (m/sec)

Station	River Km	MW	HHW (Exhibit A)
Zerkall	79	0.9	3.0
Juelich	115	0.7	2.7
Stah	152	0.7	1.7

c. Flood Wave Travel Time. Examination of flood crest times as recorded in the official German Hydrologic Yearbooks (References 18, 19, 20) provided the following estimate of travel time and rate of travel of natural flood waves on the Rur River:

Reach	River Km	Average travel (time-hrs.)	Average travel rate of peak (km/hr.)
Zerkall-Juelich	79-115	8.0	4.5
Juelich-Stah	115-152	14.5	2.5

SECTION IV

ARTIFICIAL FLOODING POTENTIALITIES

4-01 GENERAL.

a. The term "artificial flood" as used in this report applies to any major increase in the extent of flooding, over that normally prevailing with existing developments, that is brought about by manipulation of control structures, breaching of dams or levees, or temporary damming operations designed to create flooding conditions. Applications of artificial flooding considered in this report fall into the following four general categories:

(1) Still-water barriers, created by flooding land to form water obstacles, using such means as breaching levees, diverting flow from canals, raising crests of existing dams or constructing temporary dams.

(2) Drainage obstacles or mud-flats, in which the wetness of the soil is increased to form muddy or marshy conditions that would impede military traffic, brought about by disrupting the normal drainage, destroying pumping and drainage facilities used to drain marshy or low land, or by inducing shallow inundation of flood-plains or reclaimed land. Mud-flats may also be formed by draining areas normally inundated by reservoirs or ponds.

(3) Stream flow variations, in which changes in discharges, depths, velocities and widths of streams are brought about to hinder stream-crossing operations or navigation such as might be accomplished by opening and closing outlet works of water control structures.

(4) Major flood waves, created by sudden breaching of a dam to release large quantities of impounded water.

b. Opportunities exist for effective use of each of the four general categories of artificial flooding. The potentialities are reviewed and quantitative evaluation of the effects are presented in this section.

c. Previous studies by German and Allied military staffs indicate the nature and extent of possible artificial flooding. The document listed in the Bibliography as Reference 1, a translation of which is included in this report as Exhibit A, was prepared for the German General Staff and contains considerable information on the effects of artificial floods. The information contained in that document formed the basis for "Estimates of the Situation" and planning by both German and Allied staffs during the Rur (Roer) River crossings of World War II, as illustrated in the document listed as Reference 23.

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d. The possibility of a flood wave induced by the destruction of Schwammenauel and Urft Dams by the Germans to hinder the Allied crossing of the Rur River, and the actual German demolition of the outlets of those dams had a great effect upon tactical operations by both the German and Allied forces. A detailed account of that operation is contained in Reference 24, a VII Corps report included as Exhibit C of this report. Reference is also made to References 23 and 25 for additional information.

4-02 STILL-WATER BARRIERS AND DRAINAGE OBSTACLES.

a. General. The studies herein reviewed in this paragraph pertain to artificial flooding produced by creation of still-water barriers and drainage obstacles along the Rur River below the Schwammenauel (Rur) Dam. The studies were largely based on a map study, using the 1:25,000 GSGS 4414 map series. Exact determination of elevations, contours, and boundaries from those maps was difficult; however, the results of this study are believed to offer good indications of the relative possibilities of such flooding. First-hand information should be obtained by local reconnaissance regarding ground elevations and the locations, elevations and dimensions of levees, roadfills and culverts in the vicinity of specific barriers in order to accurately establish the area subject to artificial flooding.

b. Hydrologic Considerations. The effect of artificial flooding is largely contingent upon the natural hydrologic conditions prevailing at the time of the operation. The volume of water stored and available within the basin, the rate of stream flow and the river stage are important factors. Reference is made to Section III of this report for detailed description, and to the following summation of pertinent hydrologic considerations.

(1) Attention is directed to the wide range between high and low flows and to the seasonal variation in discharge shown in Table 5 and Plates 10 to 12, inclusive and discussed in paragraph 3-05. The annual average mean discharges are tabulated below:

Reach	Average Mean Discharge (m^3/sec)
Heimbach-Dueren	12
Dueren-Juelich	13
Juelich-Orsbeck	16
Orsbeck-Maas R.	20

(2) A plentiful supplementary water supply is afforded by the 150 million m^3 storage capacity of the existing reservoirs located within the drainage area. During extended dry periods, the volume of stored water available for artificial flooding would be considerably reduced.

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c. Means of Creating Still-Water Barriers and Drainage Obstacles.

(1) The water obstacle afforded by the existing streams of the Rur River basin could be increased by utilization of one or more of the following means:

(a) Creation of still-water barriers by raising crests of existing dams or by construction of temporary dams, combined with closing of culverts and other openings in levees and road fills.

(b) Inundation of lowlands along the streams by breaching dikes and levees and opening of flood gates in levees.

(c) Inundation of lowlands by closing normal drainage outlets.

(2) In order to obtain a comparative quantitative evaluation of the potential artificial flooding at various locations, analysis was arbitrarily confined to still-water barriers resulting from temporary damming to 3 m above mean water (MW). In this study, it was assumed that the water surface of the pools above the temporary dams would be level, and that mean water conditions would prevail at the time of the operation. During high water conditions, greater flooding could be expected due to the increased slope of water surface upstream from the temporary dams.

d. Effect of Still-Water Barriers.

(1) General. The effects of artificial flooding created by temporary damming operations on the Rur River are summarized in Table 6 and the extent of inundation outlined on Plate 14. Serial numbers of sites correspond to bridge serial numbers of Table 4. The flooding produced by the temporary damming would cover isolated areas about 0.1 to 0.6 km wide. Formation of continuous overbank flooding would not be practicable except during periods of high flows. Insufficient data regarding the existing small check dams along the river were available to permit analysis of the possibility of increasing their height, but it appears probable that the resulting overbank flooding would be slight. Review of the effects of still-water barriers in specific reaches of the Rur River follows.

(2) Heimbach (Km 63) to Dueren (Km 98). Temporary damming at the 2 bridges in Untermaubach (km 85.3 and 85.6) and at the Udingen bridge (Serial 25) could produce a still-water barrier practically continuous for about 3 km, and averaging 100 to 200 m wide as shown in Table 6. As illustrated on Plate 14, the only other suitable site in this reach is at Kreuzau (Serial 26); at which location, damming would have to be carried to the height of the road embankment in order to be effective.

(3) Dueren to Juelich (Km 115). In the upper part of this reach, two suitable still-water barrier sites exist; the Neisenau railroad bridge (Serial 31) and the Autobahn bridge (km 101.4). Inundation of areas 1 km long and 100 to 200 m wide to an average depth of about 0.5 m could be produced by temporary dams at these locations. At the extreme lower end of this reach, a continuous barrier about 2.5 km long, 150 to 500 m wide, and averaging about 0.7 m deep could be produced by temporary damming operations at the 3 Juelich bridges (Serials 35, 36, and 37). As indicated in Table 6 and on Plate 14, no other suitable sites for significant flooding exist in this reach.

(4) Juelich to Orsbeck (Km 149). Significant flooding could be effected at Baal (Serial 43) and Orsbeck (Serial 47) by temporary dams at these bridges. Inundation of areas about 2 km long and 600 m wide to an average depth of 0.5 m at each of these locations could be produced. See Table 6 and Plate 14. Otherwise there are no suitable sites for significant still-water barriers in this reach.

(5) Orsbeck to Maas River. No significant flooding could be produced in this reach by means of temporary damming operations during other than periods of extremely high flows in the river.

e. Water Requirements for Still-water Barriers.

(1) Approximately 2.5 million m^3 of water would be required to effect the artificial flooding described in the preceding paragraph and shown in Table 6 and on Plate 14. The still-water barriers in the vicinity of Juelich, Baal, and Orsbeck would account for about 2 million m^3 of that required volume and could be filled in about 36 hours, at the normal mean rates of flow given in paragraph 4-02b. The remainder of the volume could be furnished in approximately 12 hours at these rates, thus corresponding to a total estimated time of filling of 48 hours.

(2) The volume stored in the reservoirs, about 150 million m^3, could be made available for supplying water for the still-water barriers. The combined outflow from the Schwammenauel, Urft, Kall and Dreilaegerbach Dams is approximately 140 m^3/sec under full pool conditions. Studies described in paragraph 4-04 indicate that it would take about 12-15 hours for the initial increase in flow to travel downstream to the vicinity of Orsbeck, plus about 60 hours for the flow there to reach the maximum sustained rate.

4-03 MAJOR FLOOD WAVES.

a. General. The studies in this paragraph pertain to the artificial flooding that might be produced along the Rur River

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by breaching of the Schwammenauel (Rur), Urft, Kall and Dreilaegerbach dams. Breaching of the Heimbach and Obermaubach Dams was not considered, because the effect would be but slightly greater than that produced by the sudden opening or demolition of their large weir gates discussed in paragraph 4-04. Reference is made to paragraph 2-10 and to Exhibits A and B for descriptive data and to Plates 6 to 9, inclusive, for sketches and photographs of the dam structures.

b. Hydrologic Considerations.

(1) The Rur River stages are regulated by operation of the reservoirs to increase flow during dry periods and to reduce flood flows during wet periods. In study of the effect of major flood waves on the Rur River, it was assumed that the base flow in the stream at the start of the wave approximated a mean water flow of 10 m^3/sec, comprised of 5 m^3/sec constant inflow into the Urft Reservoir and 5 m^3/sec flow in the Rur River above the Urft River confluence.

(2) Peaks and durations of artificial flood waves are greatly influenced by the initial reservoir pool level and storage capacity of the reservoir. In this study it was assumed that, for most of the artificial floods studied, the reservoirs were at the maximum level in order to define the maximum probable limits of the flood waves. However, a number of floods resulting from breaching of the dams when the reservoirs were filled to one-half of their maximum capacity were studied in order to illustrate the effect of partial filling of the reservoirs upon artificial flood waves. As noted in Exhibit A, the reservoirs are generally only one-half full from August to December, 4/5 full from April to June and in the other months filled to 2/3 capacity. Only after a heavy rain or in time of melting snow do the pool levels exceed the full or spillway elevation. Following is a tabulation from Plates 15 and 16 of the reservoir levels corresponding to full and one-half full capacity:

Dam	Full Pool		1/2-Full Pool	
	Capacity $10^6 m^3$	Elevation mAN	Capacity $10^6 m^3$	Elevation mAN
Urft	45.5	322.5	27.75	311.5
Palushof	1.75	263.0	0.87	260.3
Schwammenauel	100.0	265.5	50.0	252.5
Heimbach	1.25	214.0	0.62	211.2
Obermaubach	1.65	165.0	0.82	163.0
Kall	2.1	421.5	1.05	414.5
Dreilaegerbach	4.28	392.6	2.14	386.0

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The reservoir storage curves shown on Plates 15 and 16 were developed by the method presented in Reference 26. The resulting equations for the storage curves can be expressed as:

$$S = CH^n$$

Where S equals storage volume in m^3, H equals reservoir depth in m, and where C is a coefficient and n an exponent. The values of C and n as computed for the various reservoirs follow:

Reservoir	C	n
Urft	5,350	2.27
Paulushof	8,320	2.26
Schwammenauel (Rur)	11,100	2.35
Heimbach	21,900	1.84
Obermaubach	19,200	2.23
Kall	49.7	3.02
Dreilaegerbach	90.2	3.08

(3) During passage of a major flood wave downstream, an appreciable amount of volume is retained behind embankments and in depressions on the flood-plain, and lost through evaporation, seepage, etc. For example, 39.5 percent of the volume of water discharged from the Eder Dam breach of May 1943 was lost in the passage of the flood wave to Intschede, 426.6 km below the dam (See References 27 and 28). Consequently it was assumed in this study that for each 10 km of travel, about 1 percent of the volume within the flood wave would be lost or retained on the flood-plain.

c. Means of Creating Major Flood Waves.

(1) Major artificial flood waves can be created on the Rur River by breaching of the Urft and Schwammenauel Dams, on the Kall River by breaching of the Kall Dam, and on the Vicht and Inde Rivers by breaching of the Dreilaegerbach Dam.

(2) The bombing of the Mohne, Sorpe, and Eder Dams by the R.A.F. in May 1943 (described in Reference 19) provided the basis for estimating the size and shape of breach. For purpose of this study, it was assumed that demolition would cause an opening similar to that produced by the Eder Dam bombing.

(3) The assumed breach approximates a parabolic shape, corresponding closely to the equation:

4-23c

x^2 equals 51 y

Where x equals horizontal distance from vertical axis of the opening

y equals vertical distance above lowest point of breach opening

It was considered that the assumed breach approximates the largest feasible opening likely to be produced in the Urft, Schwammenauel, Kall and Dreilaegerbach Dams. Breaching of earth dams with steel or concrete cores like the Schwammenauel and Kall Dams would require special preparations and procedures as described in Reference 27.

(4) In order to permit comparative evaluation of the artificial flood waves it was assumed that the lowest point of the breach was 23 m below the normal full pool water surface (similar to the Eder Dam breach) for large breaches designated in this study as "Breach I" and 10 m below full pool level for smaller breaches designated as "Breach II." At the water surface, the length of opening of Breach I would be about 68 m and of Breach II would be 45 m.

d. Effects of Dam Breaching Operations.

(1) General. The estimated effects of artificial flood waves on the Rur River produced by breaching of the storage dams are summarized in Tables 7, 8, and 11, and typical discharge hydrographs at key locations are presented on Plates 17 and 18. The artificial floods studied are described in subsequent paragraphs. The various major flood waves are designated as follows:

Artificial Flood No.	Dam Breached	Type of Breach	Pool Conditions
1	Urft	I	Full
2	"	II	"
3	Rur	I	"
4	"	I	1/2 Full
5	"	II	Full
6	Urft & Rur	I	"
7	"	I	1/2 Full
8	Urft	I	(Urft-Full) (Rur-Empty)
9	Kall	II	Full
10	Dreilaegerbach	II	"

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(2) Artificial Flood No. 1 results from large sized breaching (Breach I) of the Urft Dam when the reservoir of both Urft and Schwammenauel (Rur) Dams are full, the resulting wave passing over the fixed spillway and opened spillway weir gate of the Rur Dam. (See Sketches of Dams, Plates 6 and 7). The spillway capacity of the Rur Dam is sufficient to permit the passage of this wave without overflowing the crest of the dam. The peak discharge of 8500 m^3/sec from the Urft Dam breach would be reduced to 1250 m^3/sec during its passage through the Schwammenauel (Rur) reservoir, and would decrease to 740 m^3/sec at Stah and to 600 m^3/sec at the confluence of the Rur and Maas Rivers. Discharge hydrographs at key locations are shown on Plate 17 and the effects are tabulated in Table 7. Plate 10 shows the depth, discharge and velocity resulting from Flood No. 1 compared to natural values.

(3) Artificial Flood No. 2 results from smaller sized breaching (Breach II) of the Urft Dam during full pool conditions. The peak breach discharge of 1000 m^3/sec would be reduced to 360 m^3/sec during its passage through the full Rur reservoir pool and over the spillway and opened weir of the Rur Dam. Peak discharge would be only 252 m^3/sec at Stah and 224 m^3/sec at the Maas River junction, as shown in Table 7.

(4) Artificial Flood No. 3 discharge hydrographs shown on Plate 17 result from large sized breaching (Breach I) of Schwammenauel (Rur) Dam when the reservoir is full. The peak discharge of 8500 m^3/sec at the dam would reduce to 2660 m^3/sec at Stah or 2000 m^3/sec at the Maas River, as shown on Plate 17 and in Table 7. The width of flooding during the peak of the flood is shown on Plate 5.

(5) Artificial Flood No. 4 would result from the large Breach I in Rur Dam when the reservoir was filled to 1/2 of full capacity. In this case, as shown in Table 7, the peak discharge at the dam would be only 1100 m^3/sec which would decrease to 375 m^3/sec at the Maas River, illustrating the influence of initial reservoir stage upon breach discharge, when compared to Flood No. 3.

(6) Artificial Flood No. 5 is the result of the smaller sized Breach II in Rur Dam under full pool conditions. Table 7 shows that the peak discharge at the dam of 1000 m^3/sec would reduce to 385 m^3/sec at the Maas River, approximating the results of Flood No. 4.

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(7) Artificial Flood No. 6 is produced by simultaneous breaching of both Urft and Rur Dams with openings corresponding to Breach I under full pool conditions in both reservoirs. The resulting 8500 m^3/sec peak discharge at the breached dams would produce the maximum peak of the various flood waves studied. As shown in Table 7, peak discharge would be 2850 m^3/sec at Stah and 2180 m^3/sec at the confluence of the Rur and Maas Rivers. This is the largest of the artificial floods studied.

(8) Artificial Flood No. 7 differs from Flood No. 6 in that the reservoir storage was assumed to be at 1/2 of full capacity, resulting in great diminution of discharge. A peak discharge of 1350 m^3/sec would issue from the breached Urft Dam and 1130 m^3/sec from Rur Dam. The flow at Stah would be 635 m^3/sec and at the Maas River 535 m^3/sec. (See Table 7).

(9) Artificial Flood No. 8 would result from breaching (Breach I) of Urft Dam at a time when that reservoir was full and at some time subsequent to drawing down of Rur Reservoir due to a previous Breach I opening in the Rur Dam. This flood might be considered as a sequel to Flood No. 3 and illustrates the cyclic effect attainable by progressive breaching of those two dams. (Another cyclic combination could be Flood 1 followed by Flood 3). The Flood No. 8 initial peak discharge of 8500 m^3/sec at the Urft Dam would be diminished to only 540 m^3/sec after passing through the partially filled Rur Reservoir, resulting in flows of 352 m^3/sec and 306 m^3/sec at Stah and the Maas River confluence, respectively, as shown in Table 7.

(10) Artificial Flood No. 9 discharge hydrographs are presented on Plate 18 and the effects are summarized in Table 8, showing the results obtainable by the smaller sized breaching (Breach II) of the Kall Dam, located on a tributary of the Rur River. (See Plate 9 for sketch of that dam). The 1000 m^3/sec peak discharge at the dam would be reduced to 300 m^3/sec in passage to the confluence of the Kall and Rur Rivers near Zerkall, 15 km below the Kall Dam. Due to the small capacity of the reservoir, the duration of the flood wave would be less than 6 hours as may be seen on Plate 18 and in Table 8.

(11) Artificial Flood No. 10 is, similarly, the result of the smaller Breach II at Dreilaegerbach Dam, located 37 km from the Rur River up the Vicht and Inde River. See Plate 2 for location and Plate 9 for sketch of the dam. The discharge hydrographs plotted on Plate 18 and the summary of effects tabulated in Table 8 show that the resulting flow at the Rur River near Juelich would reach a peak of only 222 m^3/sec and that the duration of the wave would be short.

e. Comparison of Effects of Dam Breaching Operations. The comparative peak values and durations of the various flood waves produced by dam breaching operations are summarized in Tables 7 and 8 and the resulting widths of flooding during passage of the peak of the waves are tabulated in Table 11. The relation of representative artificial flood waves to natural conditions is graphically illustrated on Plates 9 and 10. Extracts of pertinent effects from Tables 7, 8 and 11 at selected key locations are presented below to facilitate comparison between the various artificial floods:

	Peak Values					Duration	
Flood No.	Disch. m³/sec	Stage m-[illegible]	Mean Surf. Vel. m/sec	Arrival Time Hour	Width Flooded Km	Above 100 m³/sec Days	Above 30 m³/sec Days
(1) At Zerkall, Km 79							
1	1085	177.7	3.5	4	0.1	1.5	3.5
2	330	175.4	3.0	6	"	1.5	3.5
3	5260	182.4	4.3	2	"	1.0	1.5
4	745	176.9	3.3	3	"	1.0	1.5
5	700	176.8	3.3	3	"	1.5	3.0
6	5510	182.6	4.3	2	"	2.0	3.0
7	920	177.3	3.4	4	"	1.5	3.0
8	480	176.1	3.2	5	"	1.0	2.5
9	300	175.2	3.0	2	"	(2 hrs.)	(3 hrs.)
10	—	—	-	-	-	-	-
(2) At Juelich, Km 116							
1	960	81.6	2.9	8	0.9	1.5	3.5
2	288	79.8	2.6	12	0.1	1.5	3.5
3	3610	82.8	3.1	5	1.8	1.0	1.5
4	580	81.0	2.8	8	0.5	1.0	1.5
5	560	81.0	2.8	9	0.5	1.5	3.0
6	4000	82.8	3.1	5	1.8	2.0	3.0
7	755	81.3	2.9	9	0.9	1.5	3.0
8	400	80.4	2.7	11	0.3	1.0	2.5
9	170	79.1	2.3	4	0.1	(5 hrs.)	(6 hrs.)
10	222	79.5	2.4	11	0.1	(3 hrs.)	(5 hrs.)
(3) At Stah, Km 152							
1	740	33.5	1.3	15	1.7	1.5	3.5
2	252	33.3	1.2	18	1.4	1.5	3.5
3	2660	35.1	1.3	10	2.4	1.0	1.5
4	465	33.4	1.2	14	1.7	1.0	1.5
5	465	33.4	1.2	15	1.7	1.5	3.5
6	2850	35.1	1.3	10	2.4	2.5	3.0
7	635	33.5	1.3	15	1.4	1.5	3.0
8	352	33.3	1.2	17	1.4	1.5	2.5
9	—	—	-	-	-	-	-
10	146	33.1	1.2	15	0.6	(7 hrs.)	(10 hrs.)

4-04 STREAM FLOW VARIATIONS.

a. General.

(1) The studies in this paragraph pertain to the artificial flooding effects that might be produced by release of water from the outlets of the Urft, Schwammenauel (Rur), Heimbach, Obermaubach, Kall and Dreilaegerbach reservoirs.

(2) Included are quantitative estimates of the potential effects of detrimental flow variation produced by operation of the existing outlets and by modification of the outlet structures to increase the discharge capacity.

(3) Reference is made to paragraph 2-10 and Exhibits A and B for descriptions of the structures, to Plate 2 for locations, to Plates 6 to 9 for sketches of the dams, and to documents listed as References 4 to 16, inclusive, in the Bibliography of this report for detailed descriptions and drawings of the dams and their outlet structures.

(4) Flow variations may be repeated to produce cyclic effects, dependent upon the replenishment of the depleted storage in the reservoirs.

b. Hydrologic Considerations. Reference is made to paragraph 4-03b for discussion of the influence of natural stream discharge and initial reservoir pool level on artificial flooding.

c. Means of Creating Detrimental Flow Variations.

(1) General. Detrimental flow variations may be produced downstream from the Rur River dams by one of the following two methods:

(a) Type A, operation of the existing controlled outlets for sustained or cyclic discharge.

(b) Type B, modification of the outlets to increase discharge capacity, accomplished by temporary by-passing, alteration, demolition or dismantling of restrictions, machinery or other outlet appurtenances.

(2) Urft Dam Outlet Discharges.

(a) Type A.. The three existing outlets beneath the dam have a combined capacity of about 30 m^3/sec when the reservoir is full, discharging into Schwammenauel (Rur) Dam reservoir pool. The tunnel and penstock from the Urft reservoir to the Heimbach Power Plant can carry 34 m^3/sec under full pool conditions. Reference is made to Exhibits A and B for detailed descriptions and to Plate 6 for a photograph and sketches of the Urft Dam outlets.

(b) Type B. Removal of the valves and a short length of conduit pipe downstream of the concrete plug in the bottom outlet tunnels would effect an increase in the discharge capacity of these three outlets to about 44 m^3/sec. See Figures II and III of Plate 6. Removal or bypassing of the turbines in the Heimbach Power Plant and breaking of the penstock would increase the capacity of the power outlet to about 36 m^3/sec under full pool conditions. However, under lesser pool elevations, such action could result in drastic decrease of the capacity by elimination of siphonic action, thus reducing the effective head. The demolition of this penstock by the Germans before their retreat from the locality resulted in a low rate of discharge from this source, according to eyewitness accounts.

(3) Paulushof Dam Outlet Discharges. As explained in Exhibits A and B, the Paulushof Dam serves only to prevent the upper reaches of the Schwammenauel reservoir from being subject to great fluctuations in extent of inundation, and serves more for an esthetic than a hydraulic purpose. The large spillway gates shown in Figure II of Plate 8, have a capacity far in excess of the Schwammenauel normal outlets. Consequently, no analysis was made of the possible effect of discharge from this dam as the critical control point would be at the outlets of the main Schwammenauel Dam.

(4) Schwammenauel (Rur) Dam Outlet Discharges.

(a) Type A. The outlet tunnel of the Schwammenauel (Rur) Dam, shown on Plate 7, has a discharge capacity at full pool of about 80 m^3/sec, as described in Exhibits A and B.

(b) Type B. Destruction of the control valves and pipes at the exit of the outlet tunnel (Figures III and V, Plate 7) would increase the discharge capacity at full pool to about 135 m^3/sec. Sudden opening or demolition of the 9 m wide weir gate in the spillway would increase the peak combined discharge capacity at full pool to approximately 305 m^3/sec. Since the crest of this gated weir is only 4 m below the full pool elevation, the duration of discharge through the weir opening would not exceed about 24 hours. Reference is made to Plate 7 and to the detailed description contained in Exhibits A and B. The outlet exit valves and entrance gate were blasted by the Germans upon their retreat as described in Exhibits B and C. The reservoir was only partly full at the time and the estimated discharge computed by the Allies at that time was approximately 91 m^3/sec.

(5) Heimbach and Obermaubach Dams-Outlet Discharges. The outlets of Heimbach and Obermaubach Dams are similar, both consisting of large flap gates hinged at the bottom, as shown on Plate 8 and described in Exhibits A and B. In addition both have a small bottom gated outlet. Upon sudden opening at full pool, approximately 407 m^3/sec can be discharged from Heimbach Dam and 500 m^3/sec from Obermaubach Dam.

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(6) Kall Dam Outlet Discharges.

(a) Type A. The two existing bottom outlets have a combined discharge capacity of 15 m^3/sec at full pool. The spillway is of the fixed overflow type. Reference is made to the sketches on Plate 9 and to Exhibits A and B for further detail.

(b) Type B. The discharge capacity could be increased to about 37 m^3/sec at full pool by means of destruction of the valves in the outlet tunnel and removal of a short section of the 2 outlet pipes immediately downstream of the concrete core of the dam. (See Figure V, Plate 9). It is possible that further increase in discharge might be effected by breaching or demolition of the round spillway tower, shown in Figure I of Plate 9; however, insufficient data were available regarding its detailed construction to permit inclusion in this report of the possible effects of such action.

(7) Dreilaegerbach Dam Outlet Discharges.

(a) Type A. The bottom outlet has a design discharge capacity of 12 m^3/sec under full head; although in normal operation, the full capacity is not utilized due to vibration in the faulty valve as discussed in Exhibit B. A plan and cross-section of the Dreilaegerbach Dam showing the outlets is included on Plate 9 and description is contained in Exhibits A and B.

(b) Type B. A slight increase in discharge capacity of the bottom outlets to 16 m^3/sec at full pool could be effected by removal of the valves and short sections of the outlet pipe near the concrete plug in the outlet tunnel. (See Figure III, Plate 9).

d. Effects of Detrimental Flow Variations.

(1) General. The effects of the detrimental flow variations produced by release of discharge from the outlets of the various Rur River dams are summarized in Tables 8 to 11, inclusive. Plates 19, 20, and 21 show representative discharge hydrographs at key locations. The artificial floods studied are individually described in subsequent sub-paragraphs. For purposes of identification, the artificial floods resulting from flow variations are designated herein as follows:

4-04d(1)

Artificial Flood No.	Dam	Type of Outlet Discharge	Initial pool conditions
Urft & Rur Dams			
11	Rur	A: Normal outlets	Full
12	"	" "	1/2 Full
13	"	B: Enlarged "	Full
14	"	" "	1/2 Full
15	Urft & Rur	*A-1: Normal "	Full
16	"	*A-2: " "	"
17	"	*A-1: " "	1/2 Full
18	"	*A-2: " "	1/2 "
19	"	*B: Enlarged "	Full
20	"	" "	1/2 Full
21	"	" "	Urft-Full
Heimbach & Obermaubach Dams			
22	Heimbach	A: Sudden opening	Full
23	(Heimbach & Obermaubach)	A: Synchronized opening	"
24	"	A: Delayed opening	Heim.-Full Ober.-Empty
25	Obermaubach	A: Sudden opening	Full
Kall & Dreilaegerbach Dams			
26	Kall	A: Normal outlets	Full
27	"	B: Enlarged "	"
28	Dreilaegerbach	A: Normal "	"
29	"	B: Enlarged "	"

*Type A-1 & B: Urft Dam bottom outlets and power tunnel plus Rur Dam outlets
Type A-2: Urft Dam power tunnel only plus Rur Dam outlets

(2) Flow Variations Created by Urft and Rur Dams.

(a) Artificial Flood No. 11 corresponds to the flow variation created by sustained (Type A) discharge from the existing normal bottom outlets of Rur Dam under initial full pool conditions as described in paragraph 4-04c(4). The peak discharge at the dam of 80 m^3/sec would be only slightly diminished at downstream locations, decreasing to 76 m^3/sec at the mouth of the Rur River, as summarized in Table 9.

(b) Artificial Flood No. 12 differs from Flood No. 11 in that initial discharge was assumed to occur when the Rur reservoir is at 1/2 full capacity. The initial peak outlet discharge of 70 m^3/sec at the dam would be reduced to 64 m^3/sec at the Maas River confluence as shown in Table 9.

(c) Artificial Flood No. 13 would result from sustained (Type B) discharge from the enlarged outlets and from the opened spillway weir-gate of Rur Dam under initial full pool as described in paragraph 4-04c(4). The initial peak discharge of 305 m^3/sec would rapidly diminish to 130 m^3/sec in about 24 hours as the pool stage dropped to the crest of the weir, and then decrease at a slower rate to empty the reservoir in about 12-13 days. The peak discharge at the Maas River confluence would be 195 m^3/sec. See tabulated effects in Table 9.

(d) Artificial Flood No. 14 results from discharge from the enlarged bottom outlets of Rur Dam when the initial reservoir stage corresponds to 1/2 full storage capacity. Table 9 summarizes the effects. The peak discharge would be 117 m^3/sec at the dam and 107 m^3/sec at the Maas River and the duration of the wave would be about 5 days less than that of Flood No. 13, illustrating the effect of initial pool level upon the discharge from the dam.

(e) Artificial Flood No. 15 represents the resulting flow variation created by simultaneous discharge from the existing normal bottom outlets and power tunnel of both Urft and Rur Dams. The combined peak flow at Heimbach would be 114 m^3/sec and at the Maas River 109 m^3/sec. As may be noted in Columns 13 and 14 of Table 9, the duration of the wave above 100 m^3/sec would be about 9 days and above 30 m^3/sec would be about 24 days as compared to the respective values of zero days and 21 days shown for Flood No. 11 discharges from the Rur Dam.

(f) Artificial Flood No. 16 is similar to Flood No. 15 except that it was assumed that the bottom outlets of Urft Dam would be kept closed until the pool had receded to the elevation of the intake of the Urft Dam-Heimbach Power Tunnel. As may be noted in Table 9, no difference in peak discharge would result; hoeever, Flood No. 16 would be sustained above 100 m^3/sec (approximately bank-full flow) about 1 day longer than Flood No. 15, but would be of about 3 days less duration above 30 m^3/sec.

(g) Artificial Flood No. 17 is the result of discharge from all the normal outlets and power tunnel of both Urft and Rur Dams like Flood No. 15, but with the reservoirs initially at 1/2 full capacity. The peak flow at Heimbach would be 102 m^3/sec compared to 114 m^3/sec for Flood No. 15, but the duration of flow would be only 1 to 2 days above 100 m^3/sec and 15 days above 30 m^3/sec. (See Table 9). Representative hydrographs for this artificial flood are presented on Plate 19 and a graph of widths of flooding is shown on Plate 5. This flood approximates the conditions described in paragraph III-1a of Exhibit A.

(h) Artificial Flood No. 18 is the result of conditions similar to Flood No. 17, except that it was here assumed that the bottom outlets of Urft Dam would be kept closed as in Flood No. 16. The result of such operation would be that the duration of flow would be reduced several days from that produced by Flood No. 17 as may be seen in Table 9.

(i) Artificial Flood No. 19 involves Type B discharges from all the outlets of Urft and Rur Dams enlarged as described in paragraph 4-04c(2) and (4). The enlarged outlets would increase the discharge at Heimbach to 341 m^3/sec, but the duration of the wave above 100 m^3/sec would be only one day longer than the 9 days computed for Flood No. 15. Flood No. 19 would recede to 30 m^3/sec in 16 days, about 8 days sooner than in the case of Flood No. 15, as shown in Table 9. Plate 10 shows the depth, discharge, and velocity of this flood compared to natural flows.

(j) Artificial Flood No. 20 shows the effect of initial pool stage. The pool was assumed to be at 1/2 full capacity whileotherwise conditions were identical to those of Flood No. 19. The initial discharge of Flood No. 20 is 148 m^3/sec at Heimbach as compared to 341 m^3/sec for Flood No. 19, while the duration of flow is about 5 days less as may be noted in Table 9. Discharge hydrographs of Flood No. 20 at Heimbach and the Maas River appear on Plate 19.

(k) Artificial Flood No. 21 illustrates the possible flow variation that could be effected by means of the Urft Dam outlets in the event that the Rur Reservoir had been previously emptied. A peak discharge of approximately 68 m^3/sec would be attained at Heimbach from the combined flow of the normal bottom outlets and power tunnel of Urft Dam. The discharge would be sustained above 30 m^3/sec for about 10 days, considerably less than the 21 days from similar opening of Rur Dam alone (See Flood No. 11) and the 24 days of Flood No. 15, involving combined discharges from both the Urft and Rur Dams, as shown in Table 9.

(3) Flow Variations Created by Heimbach and Obermaubach Dams.

(a) Artificial Flood No. 22 represents the flow variation in the Rur River resulting from sudden opening of the weir gate at Heimbach Dam under normal full pool conditions. See Paragraph 4-04e(5) for description of the weir discharge capacity. The peak discharge would be 407 m^3/sec at the dam, but the duration of the wave would be only about 2 hours as shown in Table 10. Assuming that the similar dam at Obermaubach was previously opened or destroyed, the peak discharge at the Maas River would be 76 m^3/sec and the duration of the wave about 5 hours at the latter location. Plate 20 shows representative discharge hydrographs for this flood.

4-04d(3)

(b) Artificial Flood No. 23 shows the effect of synchronized operation of Heimbach and Obermaubach Dams. Assuming that the gate at Obermaubach was held in closed position until arrival of the peak of the wave resulting from opening of the Heimbach weir gate, the peak discharge from Obermaubach Dam would be about 630 m^3/sec as shown in Table 10 and on Plate 20. The resulting peak discharge at the Maas River would be 170 m^3/sec as contrasted with 76 and 99 m^3/sec corresponding respectively to separate operation of the Heimbach and Obermaubach Dams. (See Floods 22 and 25).

(c) Artificial Flood No. 24 shows the effect produced by permitting the wave from Heimbach Dam (Flood No. 22) to be temporarily retained in the initially empty Obermaubach pool and then suddenly released. The peak at Obermaubach would be thus increased from 176 to 304 m^3/sec but the resulting peak discharge at the Maas River would be lowered from 76 to 54 m^3/sec as compared to the uninterrupted wave of Flood No. 22. The duration of the flow would not be appreciably changed, as shown in Table 10.

(d) Artificial Flood No. 25 is the result of sudden opening of the Obermaubach weir gates and outlet under normal full pool conditions. A peak discharge of 500 m^3/sec would emit from the opening but the flow would recede in about 2 hours to the base flow, as shown in Table 10. The peak discharge at the Maas River would be about 99 m^3/sec.

(4) Flow variations Created by Kall and Dreilaegerbach Dams.

(a) Artificial Flood No. 26 is the result of sudden full opening of the existing normal outlets of Kall Dam under conditions of full pool. The resulting hydrograph would have a peak of 15 m^3/sec and a total duration of about 46 hours, as shown in Table 8 and on Plate 21. The resulting peak flow in the Rur River at Zerkall would be 24 m^3/sec, an increase of 14 m^3/sec, over the assumed 10 m^3/sec initial base flow in the Rur River, thus representing practically no reduction in the peak flow.

(b) Artificial Flood No. 27 is the result of discharge from the outlets of Kall Dam enlarged as indicated in paragraph 4-04c(6). The initial peak discharge would be increased from 15 to 44 m^3/sec but the reservoir would be emptied in about 18 hours as compared to the 46 hour duration from the unmodified outlets of Flood No. 26. Effects are summarized in Table 8.

(c) Artificial Flood No. 28 represents the effect of full opening of the existing outlets of Dreilaegerbach Dam at full reservoir stage. The resulting discharge hydrographs are shown on Plate 21. The peak discharge from the dam of 12 m^3/sec would be practically undiminished at the confluence of the Inde and Rur Rivers, as indicated on Table 8.

(d) Artificial Flood No. 29 is the result of discharge from the outlets of Dreilaegerbach Dam, enlarged as described in paragraph 4-04c(7). Initial peak discharge at the dam would be increased only to 16 m^3/sec, thus reducing the total duration of the discharge to 92 hours, as compared with the 124 hour duration of Flood No. 28. Effects are summarized in Table 8.

e. Comparison of Effects of Flow Variations.

The comparative peak values and durations of the flow variations produced by discharges from the outlets of the various Rur River dams are summarized in Tables 8, 9, and 10, and the resulting widths of flooding during passage of the peaks are tabulated in Table 11. Extracts of pertinent effects at Juelich from Tables 8 to 11, inclusive, are presented, as follows, to facilitate comparison:

4-04e

Comparison of Flow Variations at Juelich (Km 116)

Flood No.	Peak Values: Disch. m^3/sec	Stage m NN	Mean Surface Vel. m/sec	Arrival Time Hour	Width Flooded Km	Duration: Above 100 m^3/sec Days	Above 30 m^3/sec Days
(1) Urft & Rur Dam Flow Variations							
11	78	78.2	1.8	58	0*	0	21
12	67	78.2	1.8	42	0*	0	12
13	225	79.5	2.4	12	0.1	8	12
14	111	78.7	2.1	34	"	3	7
15	111	78.7	2.1	50	"	9	24
16	111	78.7	2.1	50	"	9	21
17	100	78.6	2.1	50	"	1	15
18	100	78.6	2.1	50	"	0	12
19	251	79.6	2.5	12	"	10	16
20	140	78.9	2.2	42	"	6	11
21	65	78.2	1.8	75	0*	0	10
(2) Heimbach & Obermaubach Flow Variations						Hours	Hours
22	128	78.8	2.2	8	0.1	1	4
23	322	80.0	2.6	8	"	3	5
24	114	78.7	2.1	13	"	1	3
25	197	79.3	2.4	5	"	1	3
(3) Kall & Dreilaegerbach Flow Variations						Days	Days
26	23 (Est)	-	-	-	0*	-	-
27	34 "	-	-	-	0*	-	-
28	21	77.6	1.2	18	"	6 (total)	
29	25	77.7	1.3	13	"	5 "	

*No apparent flooding; flow probably confined within stream bank

4-05 ARTIFICIAL FLOODING POTENTIALITIES OF CANALS.

The absence in this area of navigation canals or any other large canal system precludes utilization of canals for artificial flooding. The industrial water-supply canals mentioned in paragraph 2-12, would serve to increase the extent of flooded areas resulting from still-water barriers, major flood waves, and flow variations discussed in this section. Insufficient data are available at this time to permit analysis of the extent of such increased flooding.

4-06 SUMMARY.

The artificial flooding potentialities of the Rur River described in preceding paragraphs 4-01 to 4-05 are herein summarized:

a. Temporary damming operations at suitable bridge openings would create flooding conditions extending 1 to 3 km upstream from those locations with average widths of overbank flooding ranging from 100 to 500 m and depths of 0.4 to 0.8 m. A continuous barrier could not be formed by this means except during periods of high flows. Associated breaching of local levees would also be necessary. Reference is made to paragraph 4-02 for detailed discussion and to Table 6 and Plate 14 for tabular and graphical summation of effects.

b. Breaching of the Urft and Schwammenauel (Rur) Dams would create major artificial flood waves in the Rur River with amplitudes ranging from approximately 4 to 11 m at Zerkall (km 79) and from 2 to 4 m at Stah (km 152). Effects on the Maas River were not analyzed in detail, but based on information in Reference 29, it is estimated that the waves would not exceed 3 m above normal navigation pool stage, assuming that the navigation dams were lowered prior to arrival of the wave. The start of the artificial flood waves would arrive at Zerkall in about 1 to 2 hours and at Stah in 7 to 11 hours. The average rate of rise of stage would vary considerably, ranging from about 1 to 10 m/hr at Zerkall and 0.3 to 4 m/hr at Stah. Mean surface velocities at the crest of the wave would vary from about 3 to 4.5 m/sec at Zerkall but would be only about 1.3 m/sec at Stah. Overbank flooding could be expected to persist for not over 2 days in most locations, and stream velocities in excess of about 1 to 2 m/sec would prevail for 2 to 4 days. Reference is made to paragraph 4-03 for detailed discussion of effects under various conditions and to Table 7 for summation of effects.

c. Breaching of the Kall or Dreilaegerbach Dams would create relatively small and short flood waves. On the Rur River, amplitudes would be less than 2 m and the duration of the wave would be less than 12 hours as shown in Table 8 and described in paragraph 4-03.

d. Detrimental flow variations could be produced in the Rur River ranging in amplitude from approximately 1 to 3.5 m at Zerkall (km 79) and 1.5 to 2 m at Stah (km 152) by manipulation of the controlled outlets of Urft and Schwammenauel (Rur) Dams. It would take about 2 hours for the start of the wave to arrive at Zerkall and from 12 to 15 hours to arrive at Stah. The rate of rise would vary considerably depending on conditions at the dams, and would range from 0.04 to 1.2 m/hr at Zerkall and 0.02 to 0.23 m/hr at Stah. Mean surface velocities during the passage of the crest of the waves would reach as high as about 3 m/sec at Zerkall and 1.2 m/sec at Stah. Overbank flooding could be effected for periods of 3 to 10 days in most locations by combined discharge from the outlets of both the Urft and Schwammenauel Dams. Mean surface velocities in excess of about 1 to 2 m/sec would persist for periods up to nearly 4 weeks. Cyclic variation of flow with amplitudes as high as 2 m could be maintained for an extended period by repeated opening and closing of the outlets. Detailed information is contained in Table 9 and in paragraph 4-04.

e. Sudden opening or demolition of the weir gates at Heimbach and Obermaubach Dams would produce detrimental flow variations in the Rur River downstream of those structures of 1.8 m amplitude at Zerkall and ranging from 1.5 to 2 m at Stah. As shown in Table 10, synchronized operation of these two structures could appreciably intensify the effects downstream of Obermaubach Dam. The start of the rise would require about 2 hours to travel from Heimbach Dam to Obermaubach Dam and about 10 hours from the latter point to Stah. The average rate of rise of the waves would be nearly 2 m/hr in the reaches between the two structures and range from about 0.5 to nearly 2 m/hr downstream of the Obermaubach Dam. The duration of overbank flooding would be short, only about 1 hour; and the duration of above normal velocities would not exceed 3 to 6 hours. Possibilities of cyclic variation are excellent, due to large volume of water stored in the Urft and Schwammenauel reservoirs. From these sources, the Heimbach pool can be refilled in about 4 hours, and the Obermaubach pool in less than 8 hours. A summary of effects is presented in Table 10 and detailed discussion of possible flow variations is included in paragraph 4-04.

f. Flow variations in the Rur River caused by operation of the Kall and Dreilaegerbach Dam outlets would be slight. Discharge from the existing outlets of Kall Dam would result in a rise of stage in the Rur River at Zerkall of only about 0.3 m, and enlargement of the outlets would only result in about 0.8 m rise at that location. The Dreilaegerbach outlet discharge would not raise the stage at Juelich over 0.2 m, even if enlarged. Stages would recede to normal in 1 to 6 days. Flow from these dams could be utilized to provide water for still-water barriers or to slightly increase the peak or duration of flow variations from the other dams. More detailed information may be found in Table 8 and in paragraph 4-04.

g. The numerous small check dams located approximately one km apart along the Rur River would have little effect upon the artificial flooding effected by dam breaching or outlet discharge, as was observed during the February 1945 Rur River crossings described in Exhibit C. Insufficient data were available to evaluate the possibilities of increasing the height of these dams to create still-water barriers.

h. The amount of flooding to be expected as a result of breaching or regulated discharge depends largely upon the base flow, (i.e. the flow of water existing in the stream prior to the artificial flood or flowing into the reservoirs). Normally most of the flow in the Rur River is comprised of discharge from the Urft and Schwammenauel Dams, and in that event, high base flow would not appreciably increase the amplitude of artificial flood waves, but would increase somewhat the rate of travel of the start and peak of the waves, and would increase the duration of the recession of the wave. For example, if no inflow were entering the reservoirs, the duration of overbank flooding for the flow variations designated as Floods 11 to 21 (with an average 10 m^3/sec base flow assumed in this report) would be reduced approximately one day and the duration of flows in excess of 30 m^3/sec would be reduced approximately 10 to 20 percent.

SECTION V

EFFECT ON MILITARY OPERATIONS

5-01 GENERAL.

The purpose of this section is to assist military planning personnel in estimating the relative value and effect of artificial floods upon associated military factors such as bridging, ferrying, and trafficability. The effects of artificial floods upon military operations may vary greatly, depending on hydrologic and weather conditions, the tactical and logistical situation, and the type of equipment involved. Reference is made to Section IV for discussion of the hydraulic features associated with artificial flooding.

5-02 CHARACTERISTICS OF MILITARY BRIDGING.

a. The loading capacities of standard U. S. Army floating bridging, for conditions classified as "Safe, Caution, and Risk Crossings," for various current velocities are tabulated in Table 12. Included are the current velocities which are presumed to destroy the bridge in place with no load, the values ranging from 9 to 16 feet per second (i.e. about 2.7 to 4.9 m/sec). Table 12 is primarily based on data contained in References 30 and 31.

b. It should be noted that the velocities shown in Table 12 represent general averages. The ability of floating bridges to withstand current velocities depends upon numerous variable factors, such as special provisions for securing the bridge, the rate of change in river stage, direction and variability of current debris carried by the stream and other considerations. Standard bridging has been successfully utilized under conditions more severe than indicated in Table 12, and has failed under apparently less critical velocity.

5-03 1945 RUR RIVER CROSSING.

a. A detailed account of the difficulties encountered by the American forces during the crossing of the Rur River in February 1945 (presented as Exhibit C of this report) includes description of the effect that the German possession of Urft and Schwammenauel Dams and the destruction of the outlets of those dams by the retreating Germans, had upon the Allied crossing of the Rur River. Information is also contained in References 23 and 25, listed in the bibliography, as well as in several other documents unlisted for security reasons.

5-03

b. The American forces reached the west side of the Rur River in December 1944. Estimates of the situation emphasized that large-scale crossings of the Rur River below the sites of the Urft and Schwammenauel (Rur) Dams should not be undertaken until those dams were in friendly hands, due to the possibility that the Germans might release artificial flood waves by destruction of the dams or their outlets. Attempts to remove this threat by destruction of the dams by aerial bombing were unsuccessful. Intensive efforts were made to capture those damsites by ground attack prior to attempting crossing of the river.

c. The Ardennes breakthrough by the Germans caused withdrawal of Allied forces from the Rur River line until 5 February 1945. The Urft and Rur damsites were captured on 10 February, but the enemy had blown the outlet gates, which created flooding to a depth of 3 feet over the banks near Dueren. The resulting current velocities were estimated as being 10 to 12 miles per hour, and crossing operations were delayed until the current moderated.

d. The Rur River was successfully crossed by American forces on 23 February, although the current velocities, were still over 8 miles per hour. Considerable difficulties were encountered due to the swift current as well as to enemy resistance. (See Exhibit C). Construction of floating bridges was hindered by the swift current and by the rapid fall in river stage during and after the night of 23-24 February. Reference is made to Exhibit C and to References 23 and 25 for more detailed description of the effect of artificial flooding on the Rur River crossing.

5-04 EFFECT OF STILL-WATER BARRIERS AND DRAINAGE OBSTACLES.

a. Reference is made to paragraphs 4-02 and 4-06 for discussion of the hydraulic features associated with formation and augmentation of water obstacles by means of temporary damming operations or by disruption of normal drainage.

b. Bridging and ferrying operations within the backwater reaches upstream from the temporary dams would be hindered by reason of the resulting greater width and depth of crossing, indicated in Table 6 and on Plate 14. Approach trafficability would be decreased by the shallow overbank flooding, and the increased stream depths would hinder fording of the affected reaches of the river. Since the resulting increased water obstacle would not be continuous along the streams (as illustrated on Plate 14), still-water barriers must be combined with other natural obstacles and with tactical operations in order to channelize military action.

c. Continuous military support of the temporary dam installations would be necessary to prevent their destruction by enemy air or ground action. Destruction of a temporary dam would release a flood wave of short duration that would temporarily hinder crossing operations below the structure and which might cause progressive failure of other downstream structures.

d. Breaching of levees would be necessary in some cases while, in others, blocking of culverts and drainage outlets would be required in addition to temporary damming operations in order to create effective still-water barriers and drainage obstacles.

5-05 EFFECT OF MAJOR FLOOD WAVES.

a. Reference is made to paragraphs 4-03 and 4-06 for discussion of the hydraulic features associated with creation of major flood waves by means of breaching of the storage dams located on the Rur River and its tributaries.

b. Breaching of the Urft, Schwammenauel (Rur), Kall or Dreilaegebach Dams would create artificial flood waves that would destroy or endanger bridges and dams along the streams for an undetermined distance below the breached dam. Insufficient data are available regarding the structural features of existing bridges and dams to permit estimate of the degree of destruction.

c. Breaching of either or both the Urft and Schwammenauel (Rur) Dam would produce temporary flood conditions and high stream velocities which could interfere with stream crossing operations and endanger equipage and floating bridges along the Rur River for several days. See Tables 7 and 11 for summary of resulting flood conditions.

d. Destruction of the Rur River dams would seriously disrupt industrial water supply and electrical power supply of Dueren, Juelich and other important industrial and urban areas.

e. Destruction of the Kall or Dreilaegerbach Dams would seriously disrupt the municipal water supply of the Aachen area.

f. Destruction of the Heimbach or Obermaubach equalizing basins would hinder regulation of industrial water supply for the Dueren-Juelich area.

g. Deliberate demolition of the Rur dams would prevent their use by the enemy in producing detrimental major flood waves or flow variations during a later critical period.

5-06 EFFECT OF FLOW VARIATIONS.

a. Reference is made to paragraphs 4-04 and 4-06 for discussion of the possible detrimental flow variations that could be created on the Rur River by means of regulated discharge from the Rur Dams. The resulting flow conditions are summarized in Tables 8 to 11, inclusive.

5-06

b. Combined or cyclic release of water from the outlets of the Urft and Schwammenauel (Rur) Dam, especially if the outlets are modified to increase the discharge capacity, would produce appreciable flow variations along the Rur River that would endanger floating bridging for considerable distances downstream. The large storage capacities of the reservoirs permit extended durations or multiple repetitions of flow variations. See paragraph 5-03 and Exhibit C for description of observed effects and difficulties encountered during the actual 1945 crossing of the Rur River.

c. Sudden opening of the weir gates of Heimbach and/or Obermaubach Dams would produce appreciable flow variations along the Rur River of short durations that could be repeated for cyclic effect by utilization of water impounded in Urft or Schwammenauel reservoirs.

d. Flow variations induced by release of water from the outlets of Kall or Dreilaegerbach Dams would not have a significant effect on floating bridges and crossing operations on the Rur River.

e. Deliberate demolition of the Rur dams or their outlet controls would produce flow variations lasting up to several weeks and prevent use by the enemy in producing major flood waves or detrimental flow variations during a later critical period.

5-07 EFFECTS RELATED TO OTHER BASINS.

Artificial flooding along the Rur River could be coordinated with similar operations on other river basins (especially on the nearby Rhine or Maas Rivers) to create simultaneous or progressive water obstacles affecting military action. Reference is made to reports on studies of artificial flooding possibilities on the Rhine, Danube, Weser, Ems, Aller and Leine Rivers listed as References 28, 30 and 32 to 35, inclusive, in the Bibliography of this report. Some information regarding artificial flooding possibilities on the Maas (Meuse) River is contained in Reference 29.

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* Translation of pertinent excerpts presented in Exhibits A or B.

Reference No.	Document
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* Translation of pertinent excerpts presented in Exhibits A or B.

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*Translation of pertinent excerpts presented in Exhibits A or B.

Reference No.	Document
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TABLES

TABLE I
EQUIVALENT ENGLISH-METRIC TERMS

To reduce A to B, multiply A by F. To reduce B to A, multiply B by G.

Unit A	Factor F	Factor G	Unit B
	LENGTH		
Miles	1.60935	.62137	Kilometers
Meters	3.2808	.30480	Feet
Meters	39.370	.025400	Inches
	AREA		
Square Miles	2.590	.3861	Square kilometers
Square Miles	259.000	.0038610	Hectares
Hectares	2.47104	.40469	Acres
Acres	4046.9	.00024710	Square Meters
	VOLUME		
Cubic Meters	35.3145	.028317	Cubic Feet
Cubic Feet	28.317	.035314	Liters
Acre-feet	43560.	.000022957	Cubic Feet
Acre-foot	1233.5	.00081071	Cubic Meters
	DISCHARGE		
Cubic feet per second	1.9835	.50417	Acre-feet per 24 hours
Cubic meters per second	35.3145	.028317	Cubic-feet per second
	VELOCITY		
Miles per hour	1.60935	.62137	Kilometers per hour
Miles per hour	1.4667	.68182	Feet per second
~~Meters per second~~	~~2.239~~	~~.4470~~	~~Miles per hour~~
Meters per second	3.2808	.30480	Feet per second
Meters per second	2.2369	.44704	Miles per hour
Feet per second	1.097	.9113	Kilometers per hour
	WEIGHT		
Tons (metric)	1.102	.9072	Tons (short)
Tons (long)	1.016	.9842	Tons (metric)
Tons (metric)	2205.	.0004536	Pounds (avoirdupois)
Tons (metric)	1000.	.001	Kilograms

TABLE 2
HYDROLOGIC TERMS AND ABBREVIATIONS
(In conformance with German practice)

Non-Tidal Stage	High-Tide Stage	Low-Tide Stage	Rate of Discharge (m^3/sec)	Discharge per Unit area (1/sec-km^2)	Definition
HHW	HHThw	HHTnw	HHQ	HHq	Highest value ever known or observed
HW	HThw	HTnw	HQ	Hq	Highest value observed during a stated period of time
MHW	MHThw	MHTnw	MHQ	MHq	The mean high value during a stated period, derived by averaging the highest values of each unit time element (i.e. MHW 1926/35 is average of the 10 yearly peak stages)
MW	MThw	MTnw	MQ	Mq	The mean (arithmetical average) of all observations during a stated time period
MNW	MNThw	MNTnw	MNQ	MNq	The mean low value during a stated period, derived by averaging the lowest values of each unit time element (MNW 1926/35 is the average of the 10 yearly lowest stages)
NW	NThw	NTnw	NQ	Nq	Lowest value observed during a stated period of time
NNW	NNThw	NNTnw	NNQ	NNq	Lowest value ever known or observed

TABLE 3

SUMMARY OF DAM DATA

Dam	Urft	Paulushof	Schwammenauel	Heimbach	Obermaubach	Kall	Dreilaegerbach
River	Urft	Rur	Rur	Rur	Rur	Kall	Inde
Grid Coordinates	068234	045242	083272	110262	090360	990283	922301
Drainage Area (km^2)	375	—	300***	—	794.6	29	11
Year Built	1904	1934-35	1935-37	1933-35	1933-35	1934-36	1909-11
Material	Masonry	Earth	Earth	Masonry	Earth	Earth	Masonry
Storage Cap. ($10^6 m^3$)	45.5	1.75	100.0	1.25	1.65	2.1	4.3
Height (m)	58	10.5	62	9.0	7.3	39.5	[illegible]
Length (m)	226	132	350	170	166	180	240
Width (base) (m)	50.5		[illegible]			164	[illegible]
Purpose*	(1),(2),(3)	—	(1),(2),(3)	(4)	(4)	(1)	(1)
Mean Annual Power (10^6 kwh)	15	—	16	—	—	—	—
Operating Company**	(a)	(a)	(a)	(a)	(c)	(b)	(b)
Annual outflow ($10^6 m^3$)	172.0	—	173.0	—	398.0	18.6	24.6

*Purpose: (1) water supply; (2) power generation; (3) flood control; (4) equalizing basin
**Operating Company: (a) Rurtalsperren-Gesellsch
(b) Wasserwerk d. Landkreis-Aachen
(c) Wasser-Gen. Obermaubach
***Exclusive of Urft Dam, located upstream of Schwammenauel Dam, on the Urft River, A branch of the Rur River

Source: Reference 3, 36

TABLE 4: Description of Bridges

ROER (RUR) RIVER

Serial No.	Location	Kilometer Point	Description	Bridge Length (feet)	Bridge Width (feet)	Spans	Capacity	River Width (feet)	River Depth (feet)	Remarks
1	GSGS 4416 Sheet Sl KALTENHERBERG K 9[illegible]C[illegible]	7.5 Km (4.66 miles)	Single span double track railroad bridge with stone arches.		27.8	1 @ 39.37 ft clearance width.		20.[illegible]	1.6	ST. VITH-AACHEN line.
2	KALTENHERBERG K 917146	12 Km (7.45 miles)	2 span road bridge of stone superstructure.	55.7	16.4	2 @ 13.1 ft clearance width.	15 ton vehicle load. Class II	16.4	.9	KALTENHERBERG-KINZWEILER-[illegible] road.
3	KALTENHERBERG K 917147	12.1 Km (7.53 miles)	Single span double track railroad bridge of stone superstructure.		29.5	1 @ 108.2 ft clearance width.		22.6	[illegible]	AACHEN-ST. VITH line.
4	KALTENHERBERG K 916150	12.75 Km (7.91 miles)	3 span double track railroad bridge of stone superstructure.		29.5	2 @ 42.6 ft 1 @ 13.1 ft clearance width.		42.[illegible]	1.2	AACHEN-ST. VITH line.
5	KALTENHERBERG K 913153	13.3 Km (8.25 miles)	Single span double track railroad bridge of stone superstructure.		[illegible]	1 @ 42.6 ft clearance width.		[illegible]	[illegible]	AACHEN-ST. VITH line.
6	REICHENSTEIN K 913154	15.4 Km (9.56 miles)	Single span road bridge with stone superstructure.	35.2	19.6 ft plus 2 sidewalks 1.6 ft ea.	1 @ 22.9 ft clearance width.	16 ton vehicle load. Class II	49.2	.7	[illegible] road.
7	MONSCHAU K 943183	21.2 Km (13.2 miles)	2 span road bridge of stone superstructure.	49.2	19.6 ft plus 2 sidewalks 1.6 ft ea.	1 @ 22.9 ft 1 @ 26.6 ft clearance width.	16 ton vehicle load. Class II	49.2	[illegible]	[illegible]-[illegible] road.
8	North of ROHREN K 981182	2[illegible].5 Km (15.4 miles)	2 span road bridge of steel superstructure.	85.3	14.7	2 @ 27.8 ft clearance width.	16 ton vehicle load. Class II	[illegible]	[illegible]	[illegible]-[illegible] road.

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TABLE 4: Description of Bridges

[illegible] (RUR) RIVER

No.	Location	Kilometer Point	Description	Bridge Length (Feet)	Bridge Width (Feet)	Spans	Capacity	River Width (Feet)	River Depth (Feet)	Remarks
9	[illegible] F 038[illegible]	[illegible] Km ([illegible] miles)	1 span road bridge with stone arches.	395.2	18	3 @ 24.4 ft clearance width.	24 ton vehicle load Class I	65.6	[illegible].9	[illegible] road.
[illegible]	Southeast of [illegible] F 0592[illegible]	[illegible] Km (27.47 miles)	9 span road bridge of wood superstructure.	432.9	9.8	9 @ 37.7 ft clearance width.	3 ton vehicle load Class IV	311.6	19.6	
[illegible]	Near [illegible] F 063922	45.[illegible] Km (28.1 miles)	5 span road bridge of reinforced concrete superstructure.	141	9.8 ft plus 2 sidewalks 2.4 ft ea.	4 @ 26.2 ft 1 @ 15.4 ft clearance width.	16 ton vehicle load Class II	433	34.4	
[illegible]	[illegible] 1.[illegible] Km [illegible] of [illegible] F 079275			984	50.5					
11	South of [illegible] [illegible] bank. F 109262		Footbridges.	328	4.9					
[illegible]	[illegible] F 137271	[illegible] Km (46.[illegible] miles)	3 span road bridge with stone arches.	176.3	15.7	2 @ 39.3 ft 1 @ 35.9 ft clearance width.	24 ton vehicle load Class I	59	1.6	[illegible] road.
	Near [illegible] K 421288		Ford.							Only to be used when the water is completely retained by RUR dam.

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TABLE 4: Description of Bridges

ROER (RUR) RIVER

Serial No.	Location	Kilometer Point	Description	Bridge Length (feet)	Bridge Width (feet)	Spans	Capacity	River Width (feet)	River Depth (feet)	Remarks
16	[illegible] F 112[illegible]	7[illegible].9 Km (4[illegible].02 miles)	3 span road bridge with stone arches.	[illegible]	[illegible]	[illegible] 32.8 ft clearance width.	[illegible] vehicle load, Class II	[illegible]	1.[illegible]	[illegible]
[illegible]	1 Km South of [illegible] F [illegible]		[illegible] span single track railroad bridge with stone arches	[illegible]5	1[illegible]	[illegible] clearance width.		[illegible]	1.7	[illegible]
18	[illegible] F 11[illegible]	73.6 Km (45.7 miles)	3 span road bridge of reinforced concrete superstructure.	1[illegible]	8.2	1 @ 49.2 ft 1 @ 45.9 ft 1 @ 32.8 ft clearance width.	1[illegible] vehicle load Class II	65.6	1.[illegible]	[illegible] road.
19	[illegible] F 103321		Ford.					In use only when water is completely retained by Rur dam.		
20	BRUCK F 106331	76.8 Km (47.6 miles)	3 span road bridge with stone arches.	164	15.7 ft plus 2 sidewalks 3.2 ft ea.	1 @ 38 ft 1 @ 36.5 ft clearance width.	24 ton vehicle load. Class I	65.6	1.6	[illegible] road.
21	BRUCK F [illegible]5333		3 span single track railroad bridge with steel plate girder superstructure.	196.8	16.4 ft plus 2 sidewalks .9 ft ea.	3 @ 54.4 ft center to center.	Class G	[illegible].4	1.6	[illegible] line.
22	[illegible] F 100338		Ford.					Only to be used when water is completely retained by Rur dam.		
23	OBERMAUBACH F 090360	83.9 Km (52.1 miles)	2 span road bridge of reinforced concrete superstructure.	134.5	8.2 ft plus 2 sidewalks 2.9 ft ea.	2 @ 59 ft clearance width.	16 ton vehicle load. Class II	82	13	

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Table 4: Description of Bridges

ROER (RUR) RIVER

Serial No.	Location	Kilometer Point	Description	Bridge Length (feet)	Bridge Width (feet)	Spans	Capacity	River Width (feet)	River Depth (feet)	[illegible]
[illegible]	UNTERMAUBACH [illegible] F 009173	85.62 Km (53.2 miles)	4 span road bridge with stone arches.	216	15.7 ft plus 2 sidewalks 1.6 & 2.6 ft.	4 @ 43.2 ft clearance width.	16 ton vehicle load. Class II	158.4 (?)	13	
[illegible]	[illegible] F 112772	87.3 Km (54.08 miles)	3 span road bridge with stone arches.	206	7.2 ft plus 2 sidewalks 2.1 & .8 ft.	1 @ 55.6 ft 1 @ 52.8 ft 1 @ 50 ft clearance width.	7 ton vehicle load. Class III	[illegible]	2.6	
[illegible]	[illegible] F 115[illegible]	89.3 Km (55.4 miles)	5 span road bridge with stone arches.	242.7	18.7 ft plus 2 sidewalks 3.1 ft ea.	5 @ 37.5 ft clearance width.	24 ton vehicle load. Class I	82	1.3	[illegible]
[illegible]	Sheet #1 F 117[illegible]	92.8 Km (57.[illegible] miles)	4 span road bridge with stone arches.	244.4	17 ft plus 2 sidewalks 3.7 ft ea.	4 @ 43.3 ft clearance width.	24 ton vehicle load. Class I	[illegible]	1.1	[illegible]
[illegible]	[illegible] F 121444	95.8 Km (59.4 miles)	5 span road bridge with stone arches.	229.6	21.6 ft plus 2 sidewalks 7.8 ft ea.	5 @ 36 ft clearance width.	24 ton vehicle load. Class I	131	.5	[illegible]
[illegible]	[illegible] F 107452	96.5 Km (59.9 miles)	2 span double track railroad bridge with steel truss superstructure.	295.2	32	2 @ 124.[illegible] ft clearance width.	24 ton axle load. Class I	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] F 106456	96.7 Km (60 miles)	2 span double track railroad bridge with steel truss superstructure.	295.7	[illegible] ft plus 2 sidewalks 1.9 ft ea.	2 @ 127.9 ft clearance width.	24 ton [illegible] load [illegible]	[illegible]	[illegible]	[illegible]
31	[illegible] F 10[illegible]	98.2 Km (61.1 miles)	5 span single track railroad bridge.	303.4	15	5 @ 49.2 ft clearance width.	[illegible] ton [illegible] load Class [illegible]	[illegible]	[illegible]	

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TABLE 4: Description of Bridges

ROER (RUR) RIVER

Serial No.	Location	Kilometer Mark	Description	Bridge Length (feet)	Bridge Width (feet)	Spans	Capacity	River Width (feet)	River Depth (feet)	Remarks
[illegible]	F [illegible]	[illegible] ([illegible] miles)	4 span road bridge of reinforced concrete superstructure.	[illegible]	[illegible] ft plus 2 sidewalks [illegible] & [illegible] ft.	4 @ 56.[illegible] ft clearance width.	2[illegible] ton vehicle load. Class I	[illegible]	[illegible]	[illegible]-[illegible] road.
[illegible]	East of [illegible] F [illegible]	107.[illegible] Km ([illegible].4 miles)	12 span road bridge of wood superstructure and wooden piling.	180	8.[illegible]	12 @ 11.[illegible] ft clearance width.	Class IV	91.8	1.6	KRAUTHAUSEN SELGERSDORF road.
[illegible]	2 Km South of JULICH F [illegible]	111.[illegible] Km ([illegible] miles)	3 span single track railroad bridge of steel truss superstructure 2 reinforced concrete piers.	328	14.7	3 @ 94.8 ft clearance width.	Class E	49.2	2.9	STOLBERG-JULICH line/ prepared for demolition.
[illegible]	1½ Km South of JULICH F [illegible]	113.2 Km (7[illegible].2 miles)	6 span single track railroad bridge of steel truss superstructure.	288.7	15.[illegible] ft plus 2 sidewalks 3.[illegible] ft ea.	5 @ 29.5 ft 1 @ 114.8 ft clearance width.	Class K	114.8	4.9	JULICH-[illegible] line. Prepared for demolition.
[illegible]	KIRCHBERG F [illegible]	113.2 Km (7[illegible].2 miles)	5 span single track railroad bridge of steel superstructure.	288.7		5 @ 3[illegible].8 ft clearance width.	Class G	65.6	5.9	[illegible]-JULICH line. Prepared for demolition.
[illegible]	JULICH F [illegible]	11[illegible].[illegible] Km (71.[illegible] miles)	[illegible] span road bridge with stone arches.	295.2	21.[illegible] ft plus 2 sidewalks 5.2 & 4.9 ft.	3 @ 78.7 ft clearance width.	24 ton vehicle load Class I	[illegible].4	1.6	JULICH-AACHEN road.
[illegible]	Near FLOSSDORF K [illegible]	12[illegible].1 Km (7[illegible].[illegible] miles)	9 span road bridge of wood superstructure and wooden piling.	156.8	7.2	9 openings	Class IV	65.6	5.9	
[illegible]	[illegible]DORF K [illegible]	124.6 Km (77.3 miles)	2 span road bridge of reinforced concrete superstructure.	206.6	15.5	1 @ 78.7 ft 1 @ 65.6 ft clearance	16 ton vehicle load Class II	65.6	1.6	TETZ-[illegible] road.

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TABLE 4: Description of Bridges

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SECURITY INFORMATION

ROER (RUR) RIVER

[illegible]	Location	[illegible] Point	Description	Bridge Length (Feet)	Bridge Width (Feet)	Spans	Capacity	River Width (Feet)	River Depth (Feet)	Remarks
[illegible]	[illegible]	[illegible]	[illegible] road bridge of [illegible] superstructure.	[illegible]	[illegible] ft plus 2 sidewalks [illegible] ft ea.	2 @ 24.6 ft 1 @ 83.3 ft clearance width.	24 ton vehicle load. Class I	65.6	1.9	[illegible]-[illegible]ACHEN road.
[illegible]	[illegible]	[illegible]	[illegible] span road bridge with stone [illegible] arches.	[illegible]5.2	19.6	9 openings.	Class IV	65.6		[illegible]INRICH - [illegible] road.
[illegible]	[illegible]	[illegible]	Single span road bridge of reinforced concrete superstructure.	131.2	9.8 ft plus 2 sidewalks 1.9 ft ea.	1 @ 101.7 ft clearance width.	7 ton vehicle load. Class III	65.6	2.3	[illegible]-[illegible]BRACHELEN road.
[illegible]	[illegible]	[illegible]	[illegible] span railroad bridge of masonry [illegible] superstructure.	344.4	25.5	6 @ 46.2 ft clearance width.	20 ton axle load. Class G	76.7	8.2	[illegible]
[illegible]	[illegible]	[illegible]	Private Bridge.							
[illegible]	[illegible]	[illegible]	Single span road bridge of reinforced concrete superstructure.	98.[illegible]	20.3 ft plus 2 sidewalks 3.2 ft ea.	[illegible] @ 70.5 ft clearance width.	24 ton vehicle load. Class I	59	2.6	[illegible]-HILFARTH road.
[illegible]	[illegible]	[illegible]	7 span road bridge.	141.3	10.1	7 openings.	7 ton vehicle load. Class III	65.6	2.8	[illegible] road.
[illegible]	[illegible]	[illegible]	[illegible] span road bridge of reinforced concrete superstructure.	3[illegible]7	[illegible]	5 @ 43.3 ft 1 @ 73.7 ft clearance width.	24 ton vehicle load. Class I	65.6	[illegible].6	[illegible] road.
[illegible]	[illegible]	[illegible]	3 span road bridge of reinforced concrete superstructure.	246	14.7 ft plus 2 sidewalks 2.3 ft ea.	2 @ 5.2 ft 1 @ 72.1 ft. clearance width.	24 ton vehicle load. Class I	75.4	2.4	[illegible]-[illegible]OPHOVEN road.

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Table 4
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RESTRICTED

TABLE 4: Desciption of Bridges

ROER (RUR) RIVER

Serial No.	Location	Kilometer Point	Description	Bridge Length (Feet)	Bridge Width (Feet)	[illegible]	Capacity	[illegible]	[illegible]
59	North of STEINKIRCHEN [illegible]		Road bridge.						

RESTRICTED [illegible]

Table 4
7 of 7 pages

TABLE 5

SUMMARY OF GAGE DATA - RUR (ROER) RIVER

Gaging Station	River Km	Gage Zero	Drainage Area	Period	NNW NNQ NNq	MNW MNQ MNq	MW MQ* Mq	MHW MHQ MHq	HHW HHQ HHq	N	D	J	F	M	A	M	J	J	A	S	O
	km	m ¢ NN	km^2		cm m^3/s $l/s/km^2$	cm m^3/s $l/s/km^2$	cm m^3/s $l/s/km^2$	cm m^3/s $l/s/km^2$	cm m^3/s $l/s/km^2$												
										Mean Monthly Gage Heights (cm.)											
ZERKALL	78.2	171.13	787.1	1937 to 1940	7	12	44	188	(1) 400	43	56	58	69	59	62	39	29	29	29	29	31
										Mean Monthly Discharge (m^3/s)											
					1.0	1.5	12.8	95	280	11.3	17.0	1[illegible].0	23.0	18.5	20.0	10.0	7.0	7.0	7.0	7.0	7.5
					1.3	1.9	16.2	120	355												
										Mean Monthly Gage Heights (cm.)											
JUELICH	115.2	76.96	1344	1937 to 1940	0	14	47	183	(2) 278	46	58	61	79	62	66	40	28	26	31	35	34
										Mean Monthly Discharge (m^3/s)											
						1.5	13.6	130	280	12.0	18.0	20.0	31.0	20.0	23.0	9.5	5.0	4.0	6.0	7.5	7.5
						1.1	10.1	97	209												
										Mean Monthly Gage Heights (cm.)											
STAH	150.5	30.07	2066	1937 to 1940	28	45	110	298	(3) 328	104	138	151	185	161	159	101	71	64	65	69	67
										Mean Monthly Discharge (m^3/s)											
					5.0	8.0	19.2	150	500	17.5	23.5	26.5	35.0	28.5	28.0	16.5	11.5	10.5	10.5	11.5	11.0
					2.4	3.9	9.3	72	241												

NOTES:

*Average mean monthly discharge
(1) 12 January 1920
(2) 12 January 1920
(3) 31 December 1925
Stage data from "References 18-20;" "Q" and "q" values obtained by application of discharge rating curves, Plate 13.

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TABLE 6
RUR (ROER) RIVER
INUNDATION EFFECT OF STILLWATER BARRIERS

Serial No.	GSGS Map Series 4414 4416	*Nord de Guerre* Grid	River Km	Location and Description*	Dimensions of Inundated Areas: Barrier Height (? m NN): Pond Level m NN	Pond Length km	Pond Width** m	Pond Depth** m	Pond Area km²	Pond Vol. $10^6 m^3$	Max. Effective Barrier: Pond Level m NN	Pond Length km	Pond Width** m	Pond Depth** m	Pond Area km²	Pond Vol. $10^6 m^3$
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
---	5204 S1	F100374	65.3	Untermaubach 5 span stone arch Total opening 91.7 m Stream width 30 m	151 Flooding back to Obermaubach Dam. Confined mainly to left bank.	1.4	[illegible]	0.6	0.33	0.13						
24	5204 S1	F099373	65.6	Untermaubach Hwy. Bridge 4 span stone arch Total opening 75 m Stream width 36 m	155 No significant flooding.						157 Requires blocking to crest of arch. Elev. 155.6 m NN. 157 m NN is roadway elevation.	0.3	100	0.8	0.03	0.024
25	5204 S1	F112372	67.1	Udingen Hwy. Bridge 3 span stone arch Total opening 63 m Stream width 14.7 m	153.2	1.5	140	0.5	0.21	0.1						
26	5204 S1	F115389	89.3	Kreuzau Hwy. Bridge 5 span stone arch Total opening 74 m Stream width 25 m	145	-	-	-	-	-	147 Pool elev. determined by minimum elev. of embankment.	1.0	240	0.4	.24	0.09
27-30			89.3-98.4	Sites not suitable												
31	5104 R1	F100468	98.4	Weisenau RR Bridge 5 spans Total opening 92.5 m Stream width 50 m	118.2 Flooding probably confined to gravel bed on left bank.	1.0	200	0.5	0.2	0.1						
32	5104 R1	F094486	100.4	Birkesdorf Hwy. Bridge	No significant flooding											
---	5104 R1	F091496	101.4	Autobahn Bridge 3 span Total opening 174 m Stream width 35 m	110.6 Mostly confined to channel except immediately above site.	1.0	100	0.5	0.1	0.05						
33-34			107.9-111.0	Sites not suitable												
35-36	5004 R1	F030572	113.2	South of Juelich RR Bridge 6 span steel truss Total opening 113 m Stream width 35 m	83.8 Flooding mainly on right bank.	0.8	150	0.7	0.12	0.064						

*See Bridge Table for details
**Average width and depth of inundation

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TABLE 6
RUR (ROER) RIVER
INUNDATION EFFECT OF STILLWATER BARRIERS

Serial No.	GSGS Map Series 4414 4416	"Bord de Guerre" Grid	River Km	Location and Description*	Dimensions of Inundated Areas — Barrier Height (3m) Pond Level m MSL	Pond Length km	Pond Width** m	Pond Depth** m	Pond Area km²	Pond Vol. 10⁶m³	Max. Effective Barrier Pond Level m MSL	Pond Length km	Pond Width** m	Pond Depth** m	Pond Area km²	Pond Vol. 10⁶m³
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
37	5004 R1	F027588	114.8	Juelich Hwy. Bridge 3 span stone arch Total opening 103 m Stream width 20 m	82 Flooding mainly on left bank.	1.6	500	0.8	0.8	0.64						
38-42			114.8-132.6	Sites Not Suitable												
43	4903 R1	K961703	132.6	Baal RR Br. 6 span masonry Total opening 105 m Stream Width 24 m	55 Flooding mainly on right bank.	1.7	600	0.5	1.0	0.5						
47	4902 R1	K887775	146	Orsbeck Hwy. Br 6 span Total opening 117 m. Stream width 20 m	27.8	2.3	600	0.4	1.36	0.83						
--	4802 R1	K843830	160.5	Vlodrop Hwy. Br.	No significant flooding.											
--	4802 R1	K790847	168.5	Melick Hwy. Br.	No significant flooding.											

*See Bridge Table for details
**Average width and depth of inundation

TABLE 7

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SUMMARY OF EFFECTS OF MAJOR FLOOD WAVES
URFT & SCHWAMMENAUEL (RUR) DAM BREACHES

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Location	Rur River km	Artificial Flood No.	Type of Outflow		Initial Conditions		Values at Peak of Wave			Time of Arrival		Duration of Wave	
			Urft Dam	Rur Dam	Pool Storage Level	Base Flow	Discharge	Stage	Mean Surface Velocity	Start of Wave	Peak of Wave	Above 100m³/sec	Above 30m³/sec
						m³/sec	m³/sec	m NN	m³/sec	Hour	Hour	Days	Days
Urft Dam	45	1	Breach I	Spillway	Full	5	8500	—	—	0	0	0.5	1.0
Rur Dam	60				Full	10	1250	—	—	0	2	1.5	3.5
Zerkall	79				—	"	1085	177.7	3.5	1	4	"	"
Juelich	116				—	"	960	81.6	2.9	4	8	"	"
Stah	152				—	"	740	33.5	1.3	9	15	"	"
Maas R.	181				—	"	600	16.0	—	16	22	"	4.0
Urft Dam	45	2	Breach II	Spillway	Full	5	1000	—	—	0	0	0.5	1.0
Rur Dam	60				Full	10	360	—	—	0	3	1.5	3.5
Zerkall	79				—	"	330	175.4	3.0	2	6	"	"
Juelich	116				—	"	288	79.8	2.6	5	12	"	"
Stah	152				—	"	252	33.3	1.2	11	18	"	"
Maas R.	181				—	"	224	14.1	—	17	26	"	"
Urft Dam	45	3	—	Breach I	—	—	—	—	—	—	—	—	—
Rur Dam	60				Full	10	6500	—	—	0	0	1.0	1.5
Zerkall	79				—	"	5260	182.4	4.3	1	2	"	"
Juelich	116				—	"	3610	82.8	3.1	3	5	"	"
Stah	152				—	"	2660	35.1	1.3	7	10	"	"
Maas R.	181				—	"	2000	19.4	—	13	18	"	"
Urft Dam	45	4	—	Breach I	—	—	—	—	—	—	—	—	—
Rur Dam	60				½ Full	10	1100	—	—	0	0	1.0	1.5
Zerkall	79				—	"	745	176.9	3.3	1	3	"	"
Juelich	116				—	"	560	81.0	2.8	4	8	"	"
Stah	152				—	"	465	33.4	1.2	9	14	"	"
Maas R.	181				—	"	375	15.0	—	17	22	"	"
Urft Dam	45	5	—	Breach II	—	—	—	—	—	—	—	—	—
Rur Dam	60				Full	10	1000	—	—	0	0	1.0	3.0
Zerkall	79				—	"	700	176.8	3.3	1	3	1.5	"
Juelich	116				—	"	560	81.0	2.8	4	9	"	"
Stah	152				—	"	465	33.4	1.2	10	15	"	3.5
Maas R.	181				—	"	365	15.1	—	17	23	"	"

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TABLE 7

SUMMARY OF EFFECTS OF MAJOR FLOOD WAVES
URFT & SCHWAMMENAUEL (RUR) DAM BREACHES

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Location	Nur River km	Artificial Flood No.	Type of Outflow		Initial Conditions		Values at Peak of Wave			Time of Arrival		Duration of Wave	
			Urft Dam	Nur Dam	Pool Storage Level	Base Flow	Discharge	Stage	Mean Surface Velocity	Start of Wave	Peak of Wave	Above 100m³/sec	Above 30m³/sec
						m³/sec	m³/sec	m NN	m³/sec	Hour	Hour	Days	Days
Urft Dam	45	6	Breach I	Breach I	Full	5	8500	--	--	0	0	—	—
Nur Dam	60		(Simultaneous)		Full	10	6500	--	--	0	0	2.0	3.0
Zerkall	79				—	"	5510	182.6	4.3	1	2	"	"
Juelich	116				--	"	4000	82.8	3.1	3	5	"	"
Stah	152				—	"	2850	35.1	1.3	7	10	2.5	"
Maas R.	181				--	"	2180	19.5	—	13	18	2.5	3.5
Urft Dam	45	7	Breach I	Breach I	½ Full	5	1350	—	—	0	0	—	—
Nur Dam	60		(Simultaneous)		½ Full	10	1130	—	—	0	0.5	1.5	2.5
Zerkall	79				--	"	920	177.3	3.4	1	4	"	3.0
Juelich	116				—	"	755	81.3	2.9	4	9	"	"
Stah	152				—	"	635	33.5	1.3	9	15	"	"
Maas R.	181				—	"	535	15.5	—	16	23	"	"
Urft D.	45	8	Breach I	(Previously breached by Breach I to give Flood 3)	Full	5	8500	—	—	0	0	—	—
Nur Dam	60				Part Full	10	540	--	—	0	3	1.0	2.0
Zerkall	79				—	"	480	176.1	3.2	2	5	"	2.5
Juelich	116				—	"	400	80.4	2.7	5	11	"	"
Stah	152				—	"	352	33.3	1.2	10	17	1.5	"
Maas R.	181				—	"	306	14.6	—	17	25	"	"

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TABLE 8

SUMMARY OF EFFECTS OF MAJOR FLOOD WAVES & FLOW VARIATIONS
KALL & DREILAEGERBACH DAM

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Location	Km below Dam	Artificial Flood No.	Type of Outflow	Initial Conditions: Pool Storage Level	Initial Conditions: Base Flow m³/sec	Values at Peak of Wave: Discharge m³/sec	Values at Peak of Wave: Stage m/NN	Values at Peak of Wave: Mean Surface Velocity m/sec	Time of Arrival: Start of Wave Hours	Time of Arrival: 75% of Peak Hours	Time of Arrival: Peak of Wave Hours	Duration of Wave: Above 100m³/sec Hours	Duration of Wave: Above 30m³/sec Hours	Duration of Wave: Total Hours
Major Flood Waves by Dam Breaches														
Kall Dam														
Kall Dam	0	9	Breach II	Full	0	1000	--	--	0	0	0	1	2	--
Rur R. (Zerkall)	15			--	10	300	175.2	3.0	1	--	2	2	3	--
Juelich	52			--	"	170	79.1	2.3	2	--	4	5	6	--
Dreilaegerbach Dam														
Dreilaegerbach Dam	0	10	Breach II	Full	0	1000	--	--	0	0	0	2	4	--
Rur R. (Juelich)	37			--	10	222	79.5	2.4	9	--	11	3	5	--
Stan	73			--	"	146	33.1	1.2	11	--	15	7	10	--
Flow Variations by Outlet Discharges														
Kall Dam														
Kall Dam	0		Type A	Full	0	15	--	--	0	0	0	--	--	46
Rur R. (Zerkall)	15	26	(Normal Outlets)	--	10	24	171.8	1.7	2	6	12	--	--	55
Kall Dam	0		Type B	Full	0	37	--	--	0	0	0	--	--	18
Rur R. (Zerkall)	15	27	(Enlarged Outlets)	--	10	44	172.3	2.1	2	6	12	--	--	26
Dreilaegerbach Dam														
Dreilaegerbach Dam	0		Type A	Full	0	12	--	--	0	0	0	--	--	124
Rur R. (Juelich)	37	28	(Normal Outlets)	--	10	21	77.6	1.2	9	18	42	--	--	150
Dreilaegerbach Dam	0		Type B	Full	0	16			0	0	0	--	--	92
Rur R. (Juelich)	37	29	(Enlarged Outlets)	--	10	25	77.7	1.3	9	13	36	--	--	118

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TABLE 9

SUMMARY OF EFFECTS OF FLOOD VARIATIONS
URFT & [illegible] DAMS

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Location	Rur River Km	Artificial Flood No.	Type of Outflow: Urft Dam	Type of Outflow: Rur Dam	Initial Conditions: Pool Storage Level	Initial Conditions: Base Flow m^3/sec	Values of Peak of Wave: Discharge m^3/sec	Values of Peak of Wave: Stage m(NN)	Values of Peak of Wave: Mean Surface Velocity m/sec	Time of Arrival: Start of Wave Hour	Time of Arrival: Peak of Wave Hour	Duration of Wave: Above 100 m^3/sec Days	Duration of Wave: Above 30 m^3/sec Days
Urft Dam	45	11	--	Type A	--	--	--	--	--	--	--	--	--
Rur Dam	60			(Normal	Full	10	[illegible]	--	--	0	0	0	21
Zerkall	79			Bottom	--	"	[illegible]	172.8	2.?	2	25	"	"
Juelich	116			Outlets)	--	"	78	78.2	1.8	7	58	"	"
Stah	152				--	"	77	32.9	1.2	14	82	"	"
Maas R.	181				--	"	76	12.6	--	22	94	"	"
Urft Dam	45	12	--	Type A	--	--	--	--	--	--	--	--	--
Rur Dam	60			(Normal	½ Full	10	70	--	--	0	0	0	12
Zerkall	79			Bottom	--	"	68	172.6	2.2	2	18	"	"
Juelich	116			Outlets)	--	"	67	78.2	1.8	7	42	"	"
Stah	152				--	"	66	32.7	1.2	15	62	"	"
Maas R.	181				--	"	64	12.4	--	23	74	"	"
Urft Dam	45	13	--	Type B	--	--	--	--	--	--	--	--	--
Rur Dam	60			(Enlarged	Full	10	305	--	--	0	0	8	12
Zerkall	79			Bottom	--	"	251	174.8	2.9	2	6	"	"
Juelich	116			Outlets	--	"	225	79.5	2.4	6	12	"	"
Stah	152			& Opened	--	"	210	33.2	1.2	12	21	"	"
Maas R.	181			Weir Gate)	--	"	195	13.5	--	16	29	"	"
Urft Dam	45	14	--	Type B	--	--	--	--	--	--	--	--	--
Rur Dam	60			(Enlarged	½ Full	10	117	--	--	0	0	4	7
Zerkall	79			Bottom	--	"	114	173.3	2.5	2	14	3	"
Juelich	116			Outlets)	--	"	111	78.7	2.1	7	34	"	"
Stah	152				--	"	109	33.0	1.2	13	52	"	"
Maas R.	181				--	"	107	13.0	--	21	64	"	8
Urft Dam	45	15	Type A-1	Type A-	Full	5	35/34*	--	--	0	0	--	--
Rur Dam	60		(Normal	(Normal	Full	5	80	--	--	0	0	--	--
Heimbach	61		Bottom	Bottom	--	10	114	--	--	0	0	9	24
Zerkall	79		Outlets	Outlets)	--	"	112	173.3	2.5	2	21	"	"
Juelich	116		& Power		--	"	111	78.7	2.1	7	50	"	"
Stah	152		Tunnel)		--	"	110	33.0	1.2	13	72	"	"
Maas R.	181						109	13.0		21	84	8	"

* 1st Figure is discharge from Urft Dam bottom outlets into Rur Reservoir; 2nd Figure is discharge from Urft Dam through the power tunnel to Heimbach Power Plant

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TABLE 9

SUMMARY OF EFFECTS OF FLOW VARIATIONS
URFT & SCHWAMMENAUEL (RUR) DAMS

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Location	Rur River Km	Artificial Flood No.	Type of Outflow: Urft Dam	Type of Outflow: Rur Dam	Initial Conditions: Pool Storage Level	Initial Conditions: Base Flow m³/sec	Values of Peak of Wave: Discharge m³/sec	Values of Peak of Wave: Stage m/NN	Values of Peak of Wave: Mean Surface Velocity m/sec	Time of Arrival: Start of Wave Hour	Time of Arrival: Peak of Wave Hour	Duration of Wave: Above 100 m³/sec Days	Duration of Wave: Above 30 m³/sec Days
Urft Dam	45	16	Type A-2	Type A	Full	5	0/34*	--	--	0	0	--	--
Rur Dam	60		(Normal	(Normal	Full	5	80	--	--	0	0	--	--
Heimbach	61		Power	Bottom	--	10	114	--	--	0	0	10	20
Zerkall	79		Tunnel)	Outlets)	--	•	112	173.3	2.5	2	21	9	21
Juelich	116				--	•	111	78.7	2.1	7	50	•	•
Stah	152				--	•	110	33.0	1.2	13	72	•	•
Maas R.	181				--	•	109	13.0		21	84	•	•
Urft Dam	45	17	Type A-1	Type A	Full	5	27/32*	--	--	0	0	--	--
Rur Dam	60		(Normal	(Normal	Full	5	70	--	--	0	0	--	--
Heimbach	61		Bottom	Bottom	--	10	102	--	--	0	0	2	15
Zerkall	79		Outlets	Outlets)	--	•	101	173.1	2.4	2	21	1	•
Juelich	116		& Power		--	•	100	78.6	2.1	7	50	•	•
Stah	152		Tunnel)		--	•	99	32.9	1.2	14	72	•	•
Maas R.	181				--	•	98	12.8	--	22	84	•	16
Urft Dam	45	18	Type A-2	Type A	Full	5	0/32*	--	--	0	0	--	--
Rur Dam	60		(Normal	(Normal	Full	5	70	--	--	0	0	--	--
Heimbach	61		Power	Bottom	--	10	102	--	--	0	0	1	12
Zerkall	79		Tunnel)	Outlets)	--	•	101	173.1	2.4	2	21	1	•
Juelich	116				--	•	100	78.6	2.1	7	50	0	•
Stah	152				--	•	99	32.9	1.2	14	72	0	•
Maas R.	181				--	•	98	12.8	--	22	84	0	•
Urft Dam	45	19	Type B	Type B	Full	5	44/36*	--	--	0	0	--	--
Rur Dam	60		(Enlarged	(Enlarged	Full	5	305	--	--	0	0	--	--
Heimbach	61		Bottom	Bottom	--	10	341	--	--	0	0	10	16
Zerkall	79		Outlets	Outlets	--	•	280	175.0	3.0	2	6	•	•
Juelich	116		& Power	& Opened	--	•	251	79.6	2.5	5	17	•	•
Stah	152		Tunnel)	Weir Gate)	--	•	234	33.3	1.2	11	20	•	•
Maas R.	181				--	•	218	14.0	--	18	28	•	•

* 1st Figure is discharge from Urft Dam bottom outlets into Rur Reservoir; 2nd Figure is discharge from Urft Dam through the power tunnel to Heimbach Power Plant

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TABLE 9

SUMMARY OF EFFECTS OF FLOW VARIATIONS
URFT & SCHWAMMENAUEL (RUR) DAMS

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Location	Rur River Km	Artificial Flood No.	Type of Outflow		Initial Conditions		Values of Peak of Wave			Time of Arrival		Duration of Wave	
			Urft Dam	Rur Dam	Pool Storage Level	Base Flow	Discharge	Stage	Mean Surface Velocity	Start of Wave	Peak of Wave	Above 100 m³/sec	Above 30 m³/sec
						m³/sec	m³/sec	m-NN	m³/sec	Hour	Hour	Days	Days
Urft Dam	45	20	Type B	Type B	¾ Full	5	39/31*	—	—	0	0	—	—
Rur Dam	60		(Enlarged	(Enlarged	½ Full	5	117	—	—	0	0	—	—
Heimbach	61		Bottom	Bottom	—	10	148	—	—	0	0	6	11
Zerkall	79		Outlets	Outlets	--	"	144	173.7	2.6	2	18	"	"
Juelich	116		& Power	& Opened	—	"	140	78.9	2.2	6	42	"	"
Stah	152		Tunnel)	Weir Gate)	--	"	138	33.1	1.2	12	62	"	"
Maas R.	181				—	"	136	13.3	--	21	74	"	"
Urft Dam	45	21	Type A-1	Type A	Full	5	30/34*	—	--	0	0	—	--
Rur Dam	60		(Normal	(Normal	Empty	5	34	—	—	0	24	—	—
Heimbach	61		Bottom	Bottom	—	10	68	—	—	0	24	0	10
Zerkall	79		Outlets	Outlets)	—	"	67	172.6	2.2	2	53	"	"
Juelich	116		& Power		—	"	65	78.2	1.8	8	75	"	"
Stah	152		Tunnel)		--	"	65	32.7	1.2	15	87	"	"
Maas R.	181				---	"	64	12.4	—	23	97	"	"

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* 1st Figure is discharge from Urft Dam bottom outlets into Rur Reservoir; 2nd Figure is discharge from Urft Dam through the power tunnel to Heimbach Power Plant

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TABLE 10

SUMMARY OF EFFECTS OF FLOW VARIATIONS
HEIMBACH & OBERMAUBACH DAMS

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Location	Rur River Km	Artificial Flood No.	Type of Outflow		Initial Conditions		Values at Peak of Wave			Time of Arrival		Duration of Wave	
			Heimbach	Obermaubach	Pool Storage Level	Base Flow	Discharge	Stage	Mean Surface Velocity	Start of Wave	Peak of Wave	Above 100 m^3/sec	Above 30 m^3/sec
						m^3/sec	m^3/sec	m	m/sec	Hour	Hour	Hour	Hour
Heimbach Dam	63	22	Gate	Gate	Full	10	407	—	—	0	0	1	2
Zerkall	79		suddenly	previously	—	"	195	174.3	2.8	1	2	1	3
Obermaubach Dam	84		opened	opened or	Empty	"	176	—	—	2	3	1	3
Juelich	116			destroyed	—	"	128	78.8	2.2	6	8	1	4
Stah	152				—	"	94	32.9	1.2	12	16	0	4
Maas R.	181				—	"	76	12.0	—	21	24	0	5
Heimbach Dam	63	23	Gate	Gate suddenly	Full	10	407	—	—	0	0	1	2
Zerkall	79		suddenly	opened at	—	"	195	174.3	2.8	1	2	1	3
Obermaubach Dam	84		opened	arrival of	Full	"	176/630	—	—	2	3	1/2	3/4
Juelich	116			crest of wave	—	"	322	80.0	2.6	6	8	3	5
Stah	152				—	"	224	33.3	1.3	12	14	4	6
Maas R.	181				—	"	170	13.7	—	19	22	6	9
Heimbach Dam	63	24	Gate	Gate suddenly	Full	10	407	—	—	0	0	1	2
Zerkall	79		suddenly	opened at	—	"	195	174.3	2.8	1	2	1	3
Obermaubach Dam	84		opened	hour 8	Empty	"	176/304	—	—	2/8	3/8	1/1	3/2
Juelich	116				—	"	114	78.7	2.1	12	13	1	3
Stah	152				—	"	69	32.7	1.2	19	21	0	5
Maas R.	181				—	"	54	12.2	—	27	30	0	6
Obermaubach Dam	84	25	—	Gate suddenly	Full	10	500	—	—	0	0	1	2
Juelich	116			opened	—	"	197	79.3	2.4	3	5	1	3
Stah	152				—	"	118	33.0	1.3	9	10	1	3
Maas R.	181				—	"	99	12.9	—	17	18	0	5

CONFIDENTIAL
SECURITY INFORMATION

TABLE 11

ESTIMATED WIDTHS OF FLOODING DUE TO ARTIFICIAL FLOODS (KM)

Location	River Km	Artificial Flood No. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Zerkall Gage	78.8	0.1	0.1	0.1	0.1	Approximately same as Flood #4	0.1	0.1	0.1	0.1	—	0*	Approximately same as Flood #11	0.1	0.1	Approximately same as Flood #14	Approximately same as Flood #14	Approximately same as Flood #14	Approximately same as Flood #1[illegible]	Approximately same as Flood #13	0.1	0*	0.1	0.1	0.1	—	0*	0*	—	—
	94.3	1.5	1.0	2.7	1.7		2.9	1.2	0.9	0.7	—	0.1		0.7	0.5						0.6	0*	0.6	0.8	0.6	0.5	0*	0*	—	—
	103.9	3.0	2.8	3.4	3.0		3.4	3.4	[illegible]	[illegible]	—	1.8		2.5	2.7						2.7	1.7	2.7	2.8	2.7	2.7	0*	0*	—	—
	108.3	5.7	3.6	7.7	5.8		7.7	7.7	3.8	3.6	--	2.2		3.6	2.2						[illegible]	[illegible]	3.6	3.8	3.6	3.6	0*	0*	—	—
Juelich Gage	115.2	0.9	0.1	1.8	0.5		1.8	0.9	0.3	0.1	0.1	0*		0.1	0.1						0.1	0*	0.1	0.1	0.1	0.1	0*	0*	0*	0*
	121.1	1.7	0.1	1.7	1.4		1.7	1.4	0.8	0.1	0.6	0.1		0.5	0.1						0.1	0*	0.1	0.5	0.1	0.1	0*	0*	0*	0*
	132.6	2.7	0.1	2.8	2.6		2.8	0.1	0.1	0.1	0.1	0*		0.1	0.1						0.1	0*	0.1	0.1	0.1	0.1	0*	0*	0*	0*
	141.[illegible]	0.5	0.3	2.1	0.4		2.1	0.4	0.3	0.1	0.3	0*		0.3	0.1						0.1	0*	0.1	0.3	0.1	0.3	0*	0*	0*	0*
Orsbeck	149.0	1.7	1.4	2.4	1.7		2.4	1.4	1.4	0.1	0.6	0.1		1.4	0.4						0.3	0*	0.4	1.4	0.3	0.4	0*	0*	0*	0*
	165.0	0.8	0.4	1.5	[illegible]		1.7	1.0	0.6	0*	0*	0*		0.4	0*						0*	0*	0*	0.4	0*	0*	0*	0*	0*	0*
	170.0	0*	0*	1.1	0*		1.7	0*	0*	0*	0*	0*		0*	0*						0*	0*	0*	0*	0*	0*	0*	0*	0*	0*
	175.0	0*	0*	0.4	0*		0.7	0*	0*	0*	0*	0*		0*	0*						0*	0*	0*	0*	0*	0*	0*	0*	0*	0*

*No apparent flooding; flow probably confined within stream banks.

Table 11

RESTRICTED
SECURITY INFORMATION

[illegible]
LOAD CHARACTERISTICS OF U. S. ARMY FLOATING BRIDGES
LOAD CLASS (TONS) OF FLOATING BRIDGES, BY VELOCITY, BY TYPE, BY RELATIVE CROSSING SAFETY

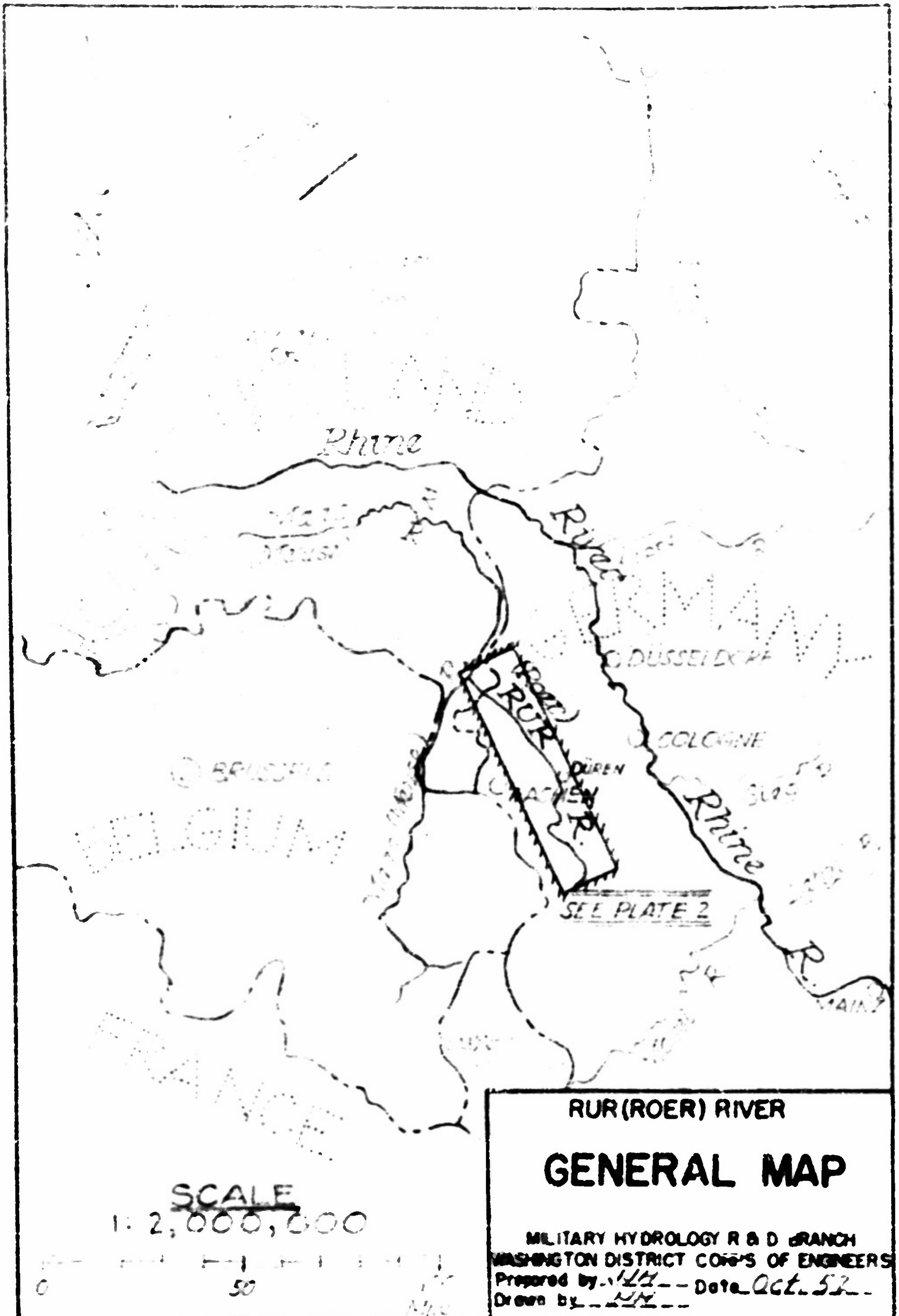
Type	Current Status (1952)	Relative Crossing Safety: Safe — Maximum Surface Velocity fps / m/sec						Caution — Maximum Surface Velocity fps / m/sec					Risk — Maximum Surface Velocity fps / m/sec					Velocity to destroy with no Load (fps)
		0 / 0	3 / 0.92	5 / 1.5	7 / 2.1	9 / 2.7	11 / 3.4	3 / 0.92	5 / 1.5	7 / 2.1	9 / 2.7	11 / 3.4	3 / 0.92	5 / 1.5	7 / 2.1	9 / 2.7	11 / 3.4	
M2 Assault Boat Bridge (Normal Construction)	Standard	8	8	5	5	-	-	8	6	5	-	-	9	7	6	-	-	10
M2 Assault Boat Bridge (Reinforced Construction)	Standard	13	13	9	7	-	-	13	11	8	-	-	14	12	9	-	-	9
Widened Steel Treadway Br.	Standard	50	50	50	40	30	15	50	50	45	35	20	55	55	50	45	30	14
50-T (Divisional Airborne)	Standard	50	45	35	30	10	-	50	40	35	15	-	55	50	45	25	-	12
M4 (Normal Construction) (15' Bay)	Standard	55	55	55	55	45	30	60	60	60	50	40	65	65	65	55	45	16
Steel Class 60 Floating Br.	Standard	60	60	60	55	50	15	65	65	60	55	30	75	75	70	65	45	-
M4 (Reinforced Construction) (7½' Bay)**	Standard	95*	95*	95*	95*	70	40	100*	100*	100*	85	55	105*	105*	105*	100	70	16
M4-T6	Developmental	55	50	50	50	35	15	(No further data)										-
Aluminum Class 60 Floating Br.	Developmental	70	70	70	65	55	45	(No further data)										

*Tank data (limited by width of roadway and width of tank)
**(100% reinforced, with full Pontoons)
SOURCES:
(1) Ref 30
(2) Ref 31
(3) Misc data Engr. R&D Lab. Engr. Center, Ft. Belvoir

RESTRICTED
SECURITY INFORMATION

Table 12

PLATES

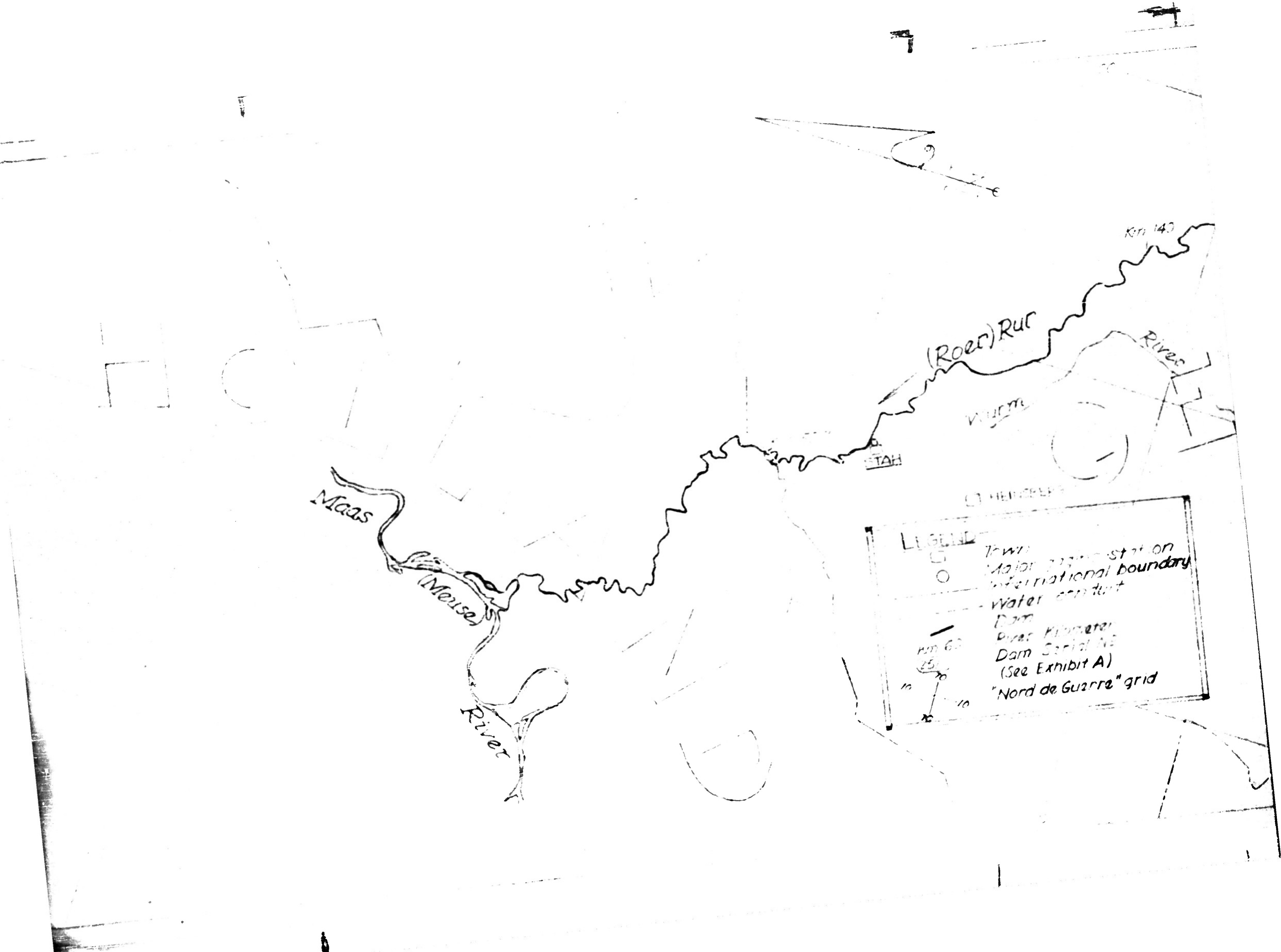


RUR (ROER) RIVER

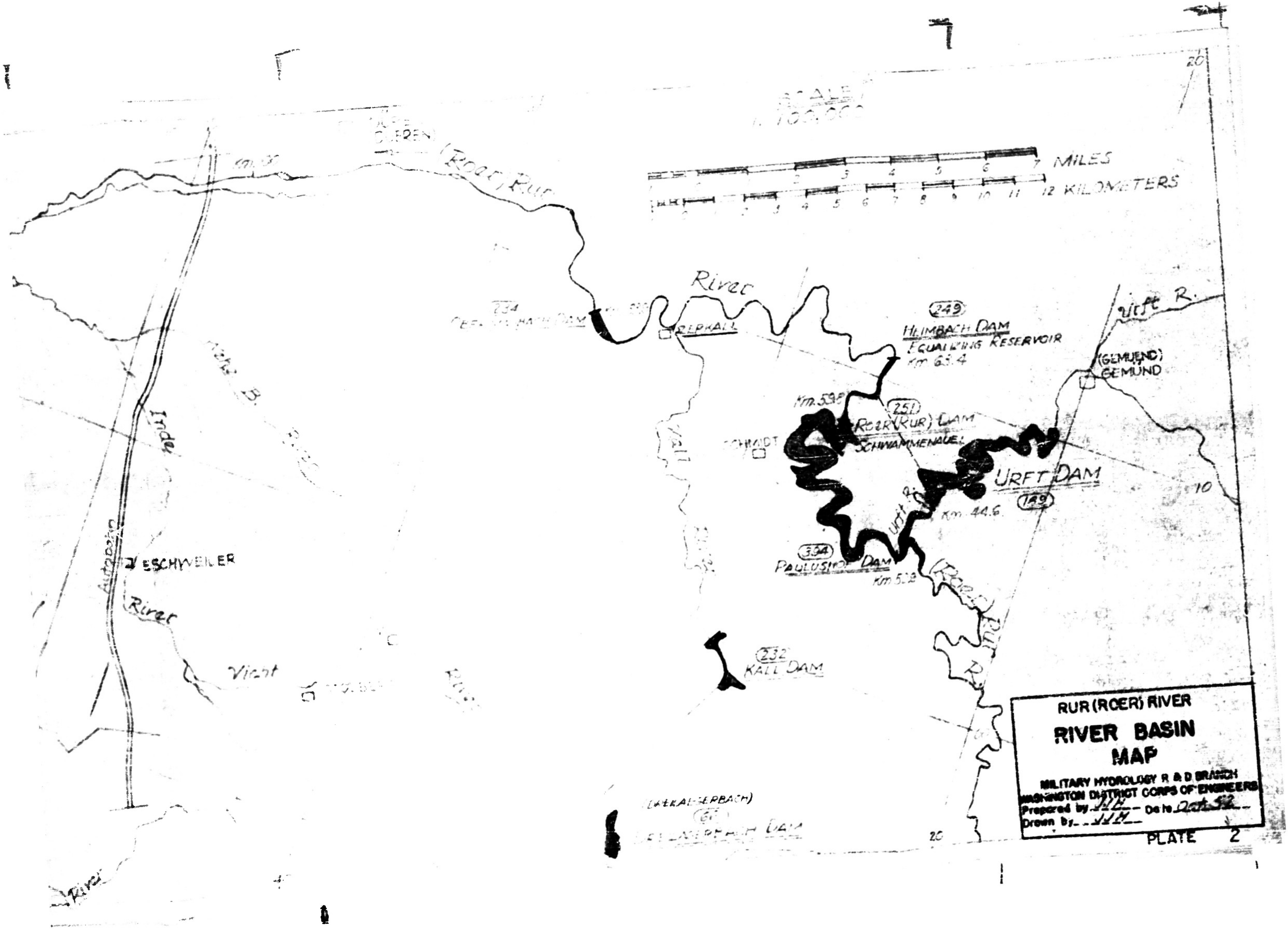
GENERAL MAP

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by ___ Date Oct. 52
Drawn by ___

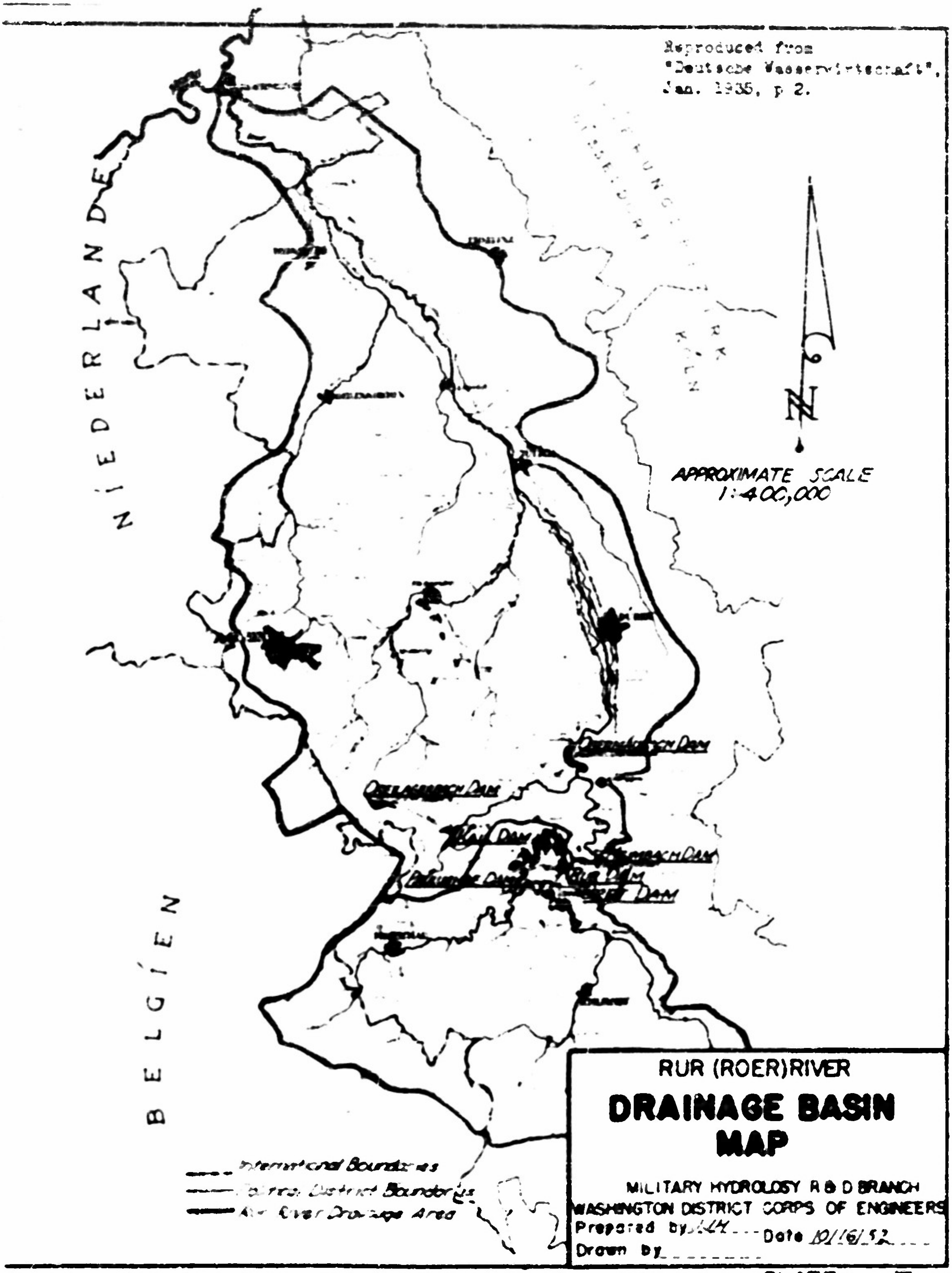
PLATE 1


Km 140
(Roer) Rur
River
Wurm
STAH
Maas
(Meuse)
River
LEGEND
Town
International boundary
Water
Dam
River Kilometer
Dam
(See Exhibit A)
"Nord de Guerre" grid

DÜREN
(DUEREN)
River
Rur
River
Inde
River
Vicht
River
Town
International boundary
Dam
(See Exhibit A)
"Nord de Guerre" grid



SCALE
1:100,000
MILES
KILOMETERS
(Roer) Rur
River
(249)
HEIMBACH DAM
EQUALIZING RESERVOIR
Km 63.4
(GEMUEND)
GEMUND
Urft R.
Km. 59.5
(251)
ROER (RUR) DAM
SCHWAMMENAUEL
SCHMIDT
URFT DAM
(149)
Km. 44.6
Urft R.
(334)
PAULUSHOF DAM
Km 53.2
(Roer) Rur R.
Inde
ESCHWEILER
River
Autobahn
Vicht
(232)
KALL DAM
RUR (ROER) RIVER
RIVER BASIN MAP
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by
Date Oct 52
Drawn by
PLATE 2



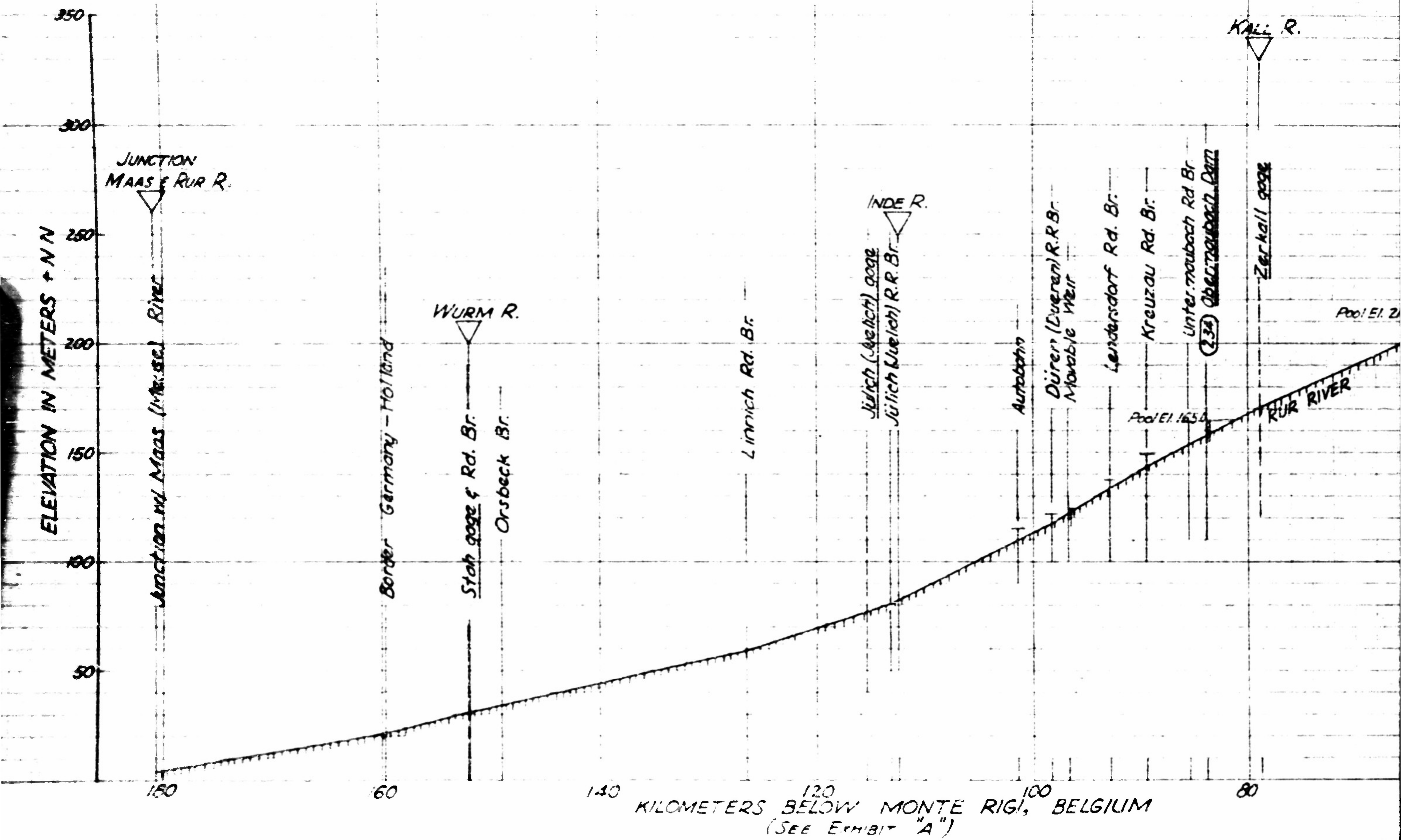
RUR (ROER) RIVER

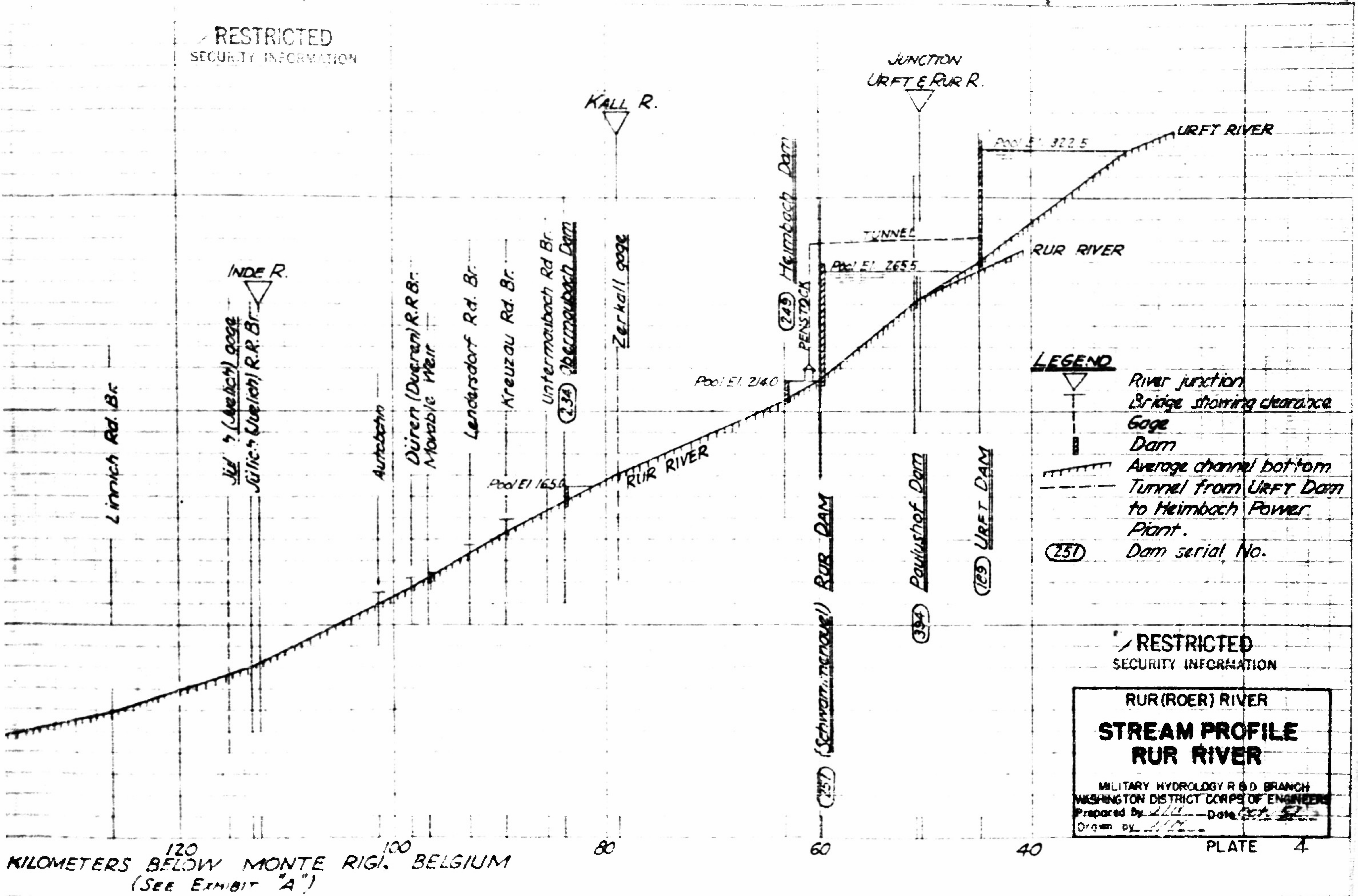
DRAINAGE BASIN MAP

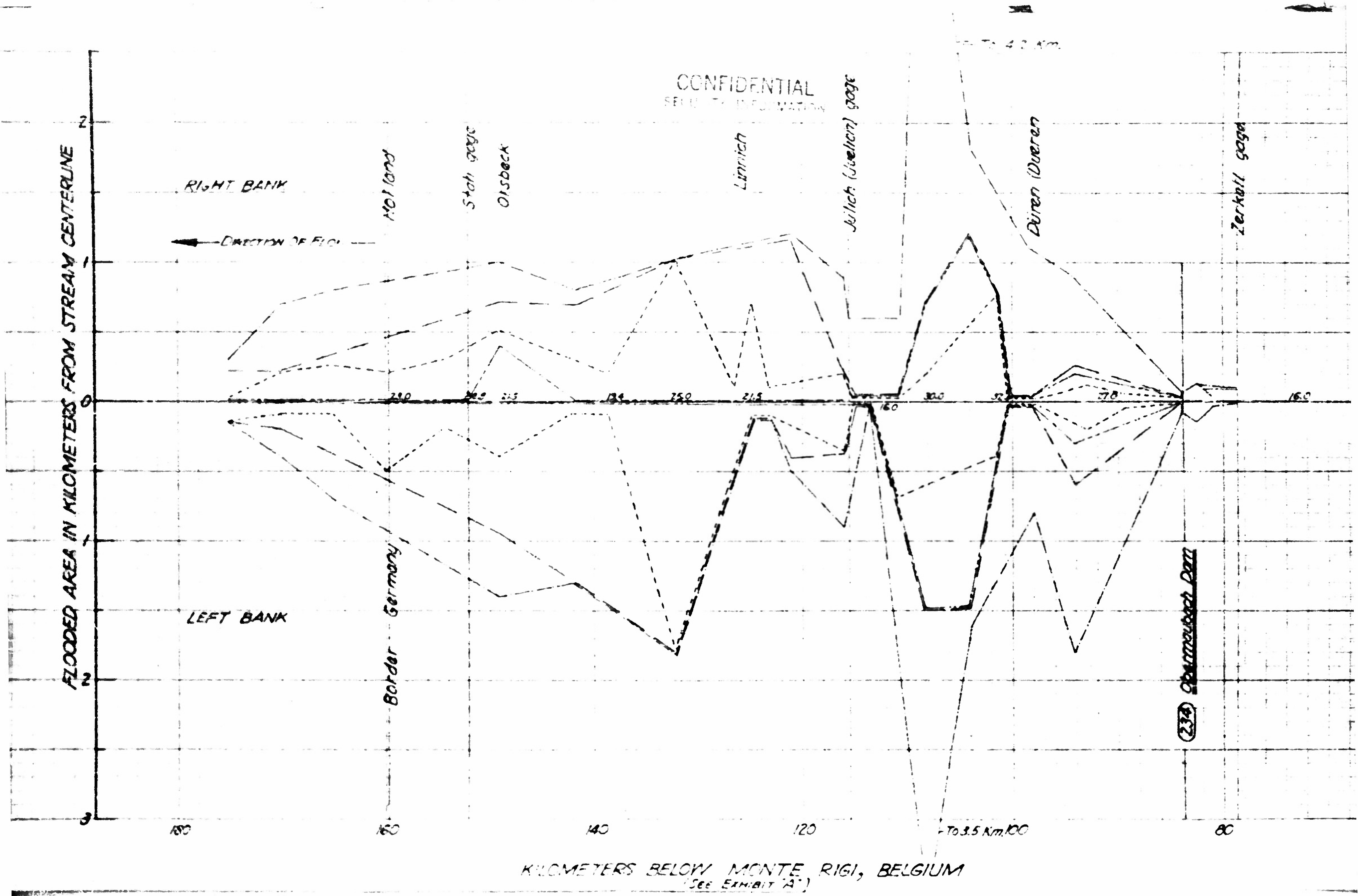
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by ___ Date 10/16/52
Drawn by ________

PLATE 3

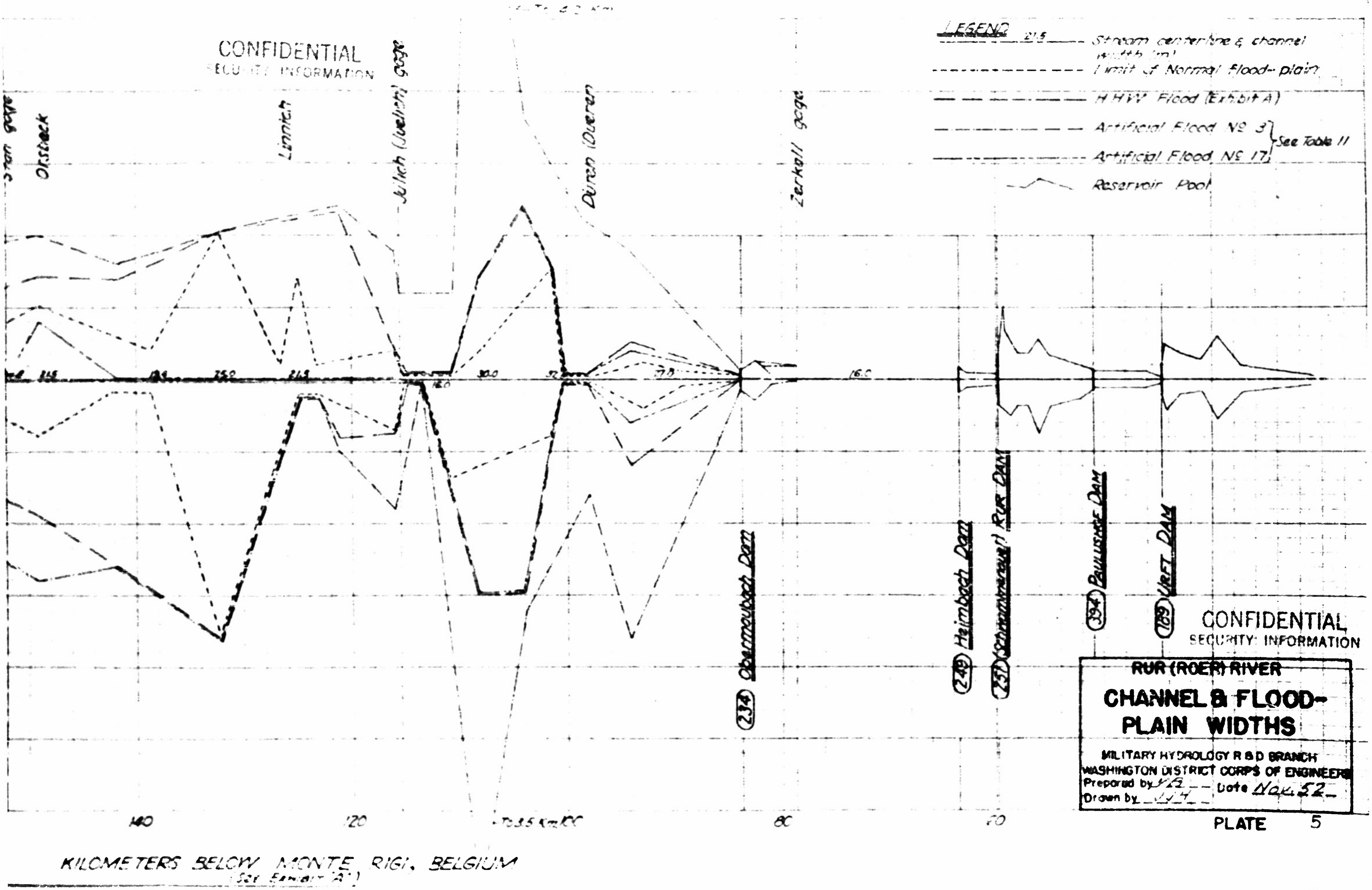
RESTRICTED
SECURITY INFORMATION




RESTRICTED
SECURITY INFORMATION
JUNCTION URFT & RUR R.
KALL R.
URFT RIVER
Pool El. 322.5
Heimbach Dam
TUNNEL
RUR RIVER
Pool El. 265.5
249
PENSTOCK
INDE R.
Jülich (Juelich) gage
Jülich (Juelich) R.R. Br.
Düren (Dueren) R.R. Br.
Lendersdorf Rd. Br.
Kreuzau Rd. Br.
Untermaubach Rd. Br.
Obermaubach Dam
234
Zerkall gage
Pool El. 214.0
Linnich Rd. Br.
Autobahn
Movable Weir
Pool El. 165.0
RUR RIVER
RUR DAM
(Schwammenauel)
251
Paulushof Dam
394
URFT DAM
129
LEGEND
River junction
Bridge showing clearance
Gage
Dam
Average channel bottom
Tunnel from URFT Dam to Heimbach Power Plant.
251
Dam serial No.
RESTRICTED
SECURITY INFORMATION
RUR (ROER) RIVER
STREAM PROFILE
RUR RIVER
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared By
Date Oct. 52
Drawn by
PLATE 4
120
100
80
60
40
KILOMETERS BELOW MONTE RIGI, BELGIUM
(SEE EXHIBIT "A")



CONFIDENTIAL
To 4.2 Km.
RIGHT BANK
DIRECTION OF FLOW
LEFT BANK
Holland
Stah gage
Olsbeck
Linnich
Jülich (Juelich) gage
Düren (Dueren)
Zerkall gage
Border Germany
Obermaubach Dam
234
FLOODED AREA IN KILOMETERS FROM STREAM CENTERLINE
2
1
0
1
2
3
180
160
140
120
To 3.5 Km.100
80
KILOMETERS BELOW MONTE RIGI, BELGIUM
(See Exhibit "A")



CONFIDENTIAL
SECURITY INFORMATION
LEGEND
21.5 Stream centerline & channel width (m)
Limit of Normal flood-plain
H.H.W. Flood (Exhibit A)
Artificial Flood Nº 3
Artificial Flood Nº 17
See Table II
Reservoir Pool
Ofstieck
Linnich
Jülich (Juelich) gage
Düren (Dueren)
Zerkall gage
21.5
13.5
25.0
21.5
12.0
30.0
16.0
Obermaubach Dam
Heimbach Dam
Rur Dam
Paulushof Dam
Urft Dam
234
249
251
394
189
140
120
100
80
70
KILOMETERS BELOW MONTE RIGI, BELGIUM
CONFIDENTIAL
SECURITY INFORMATION
RUR (ROER) RIVER
CHANNEL & FLOOD-PLAIN WIDTHS
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by
Date Nov. 52
Drawn by
PLATE 5

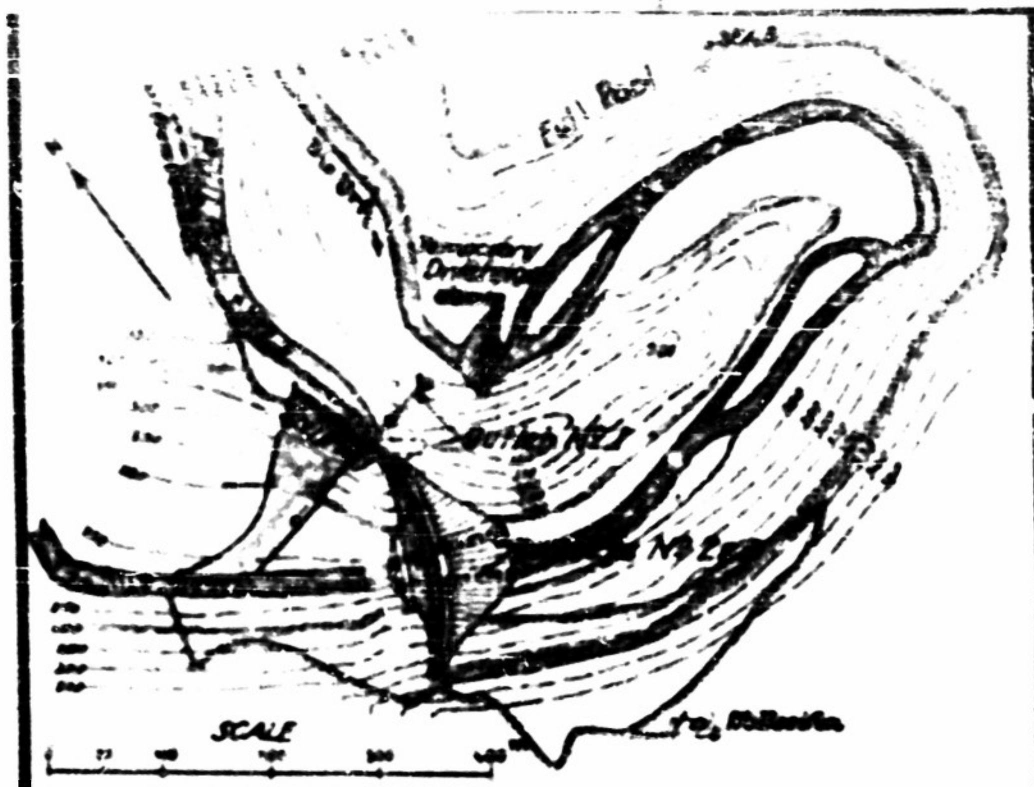


Fig. I - PLAN OF DAM

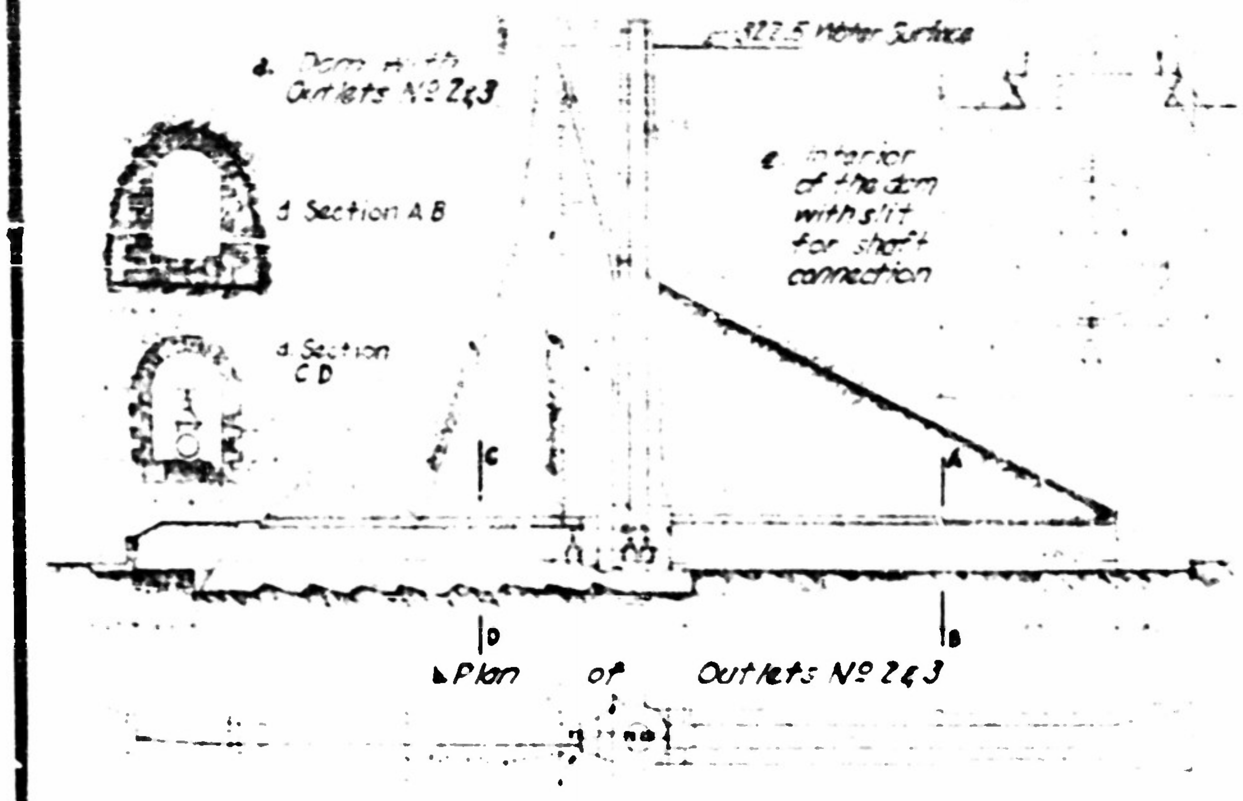


Fig. II - CROSS SECTION OF DAM AT OUTLETS NO. 2 or 3

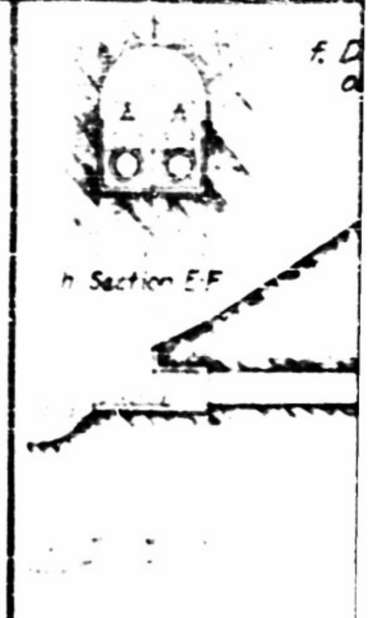


Fig. I

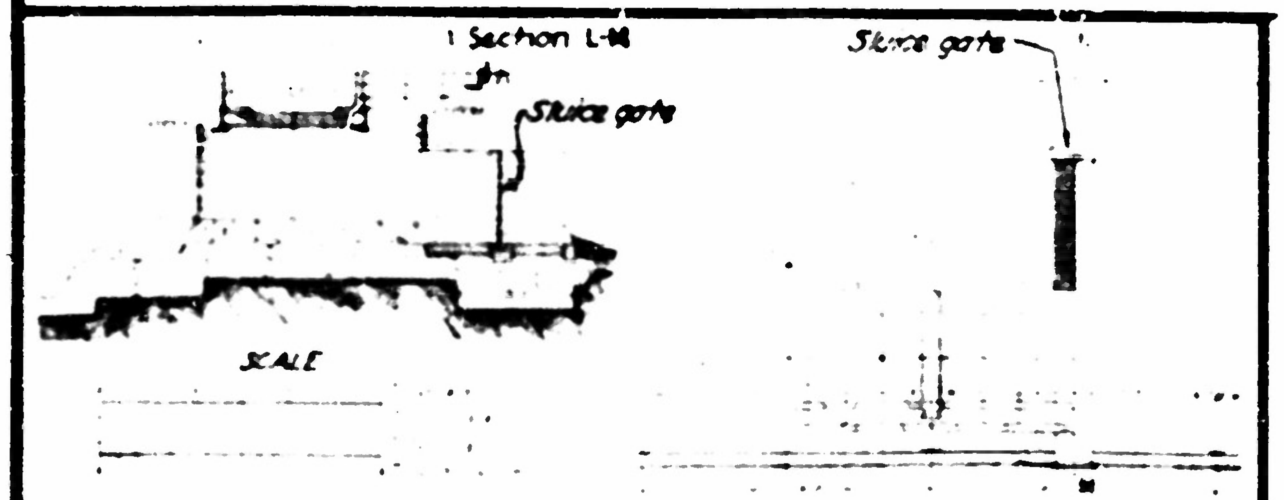


Fig. IV - SPILLWAY DETAILS

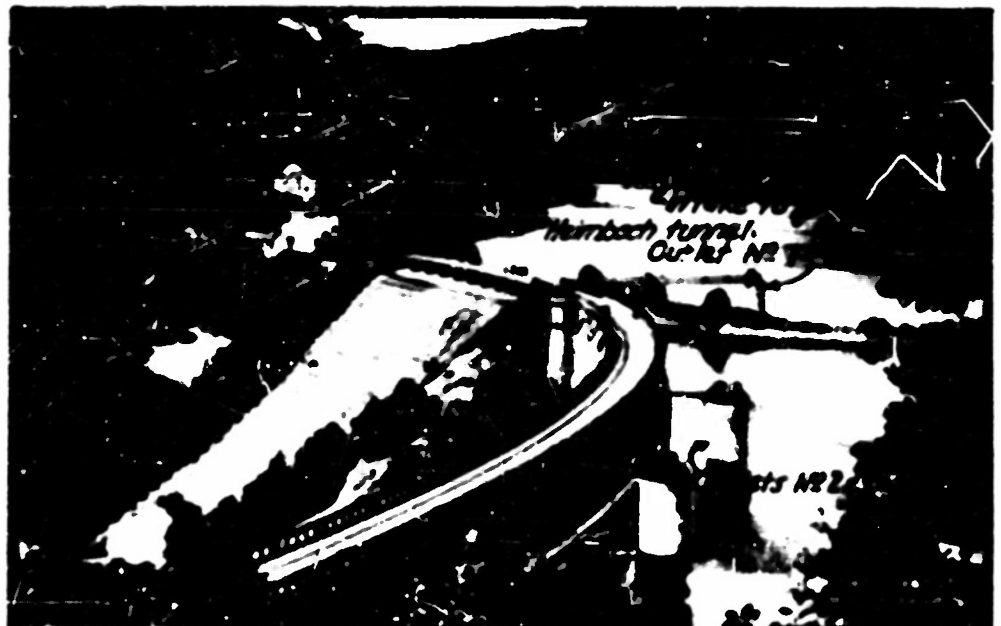


Fig. V - PHOTOGRAPH OF DAM

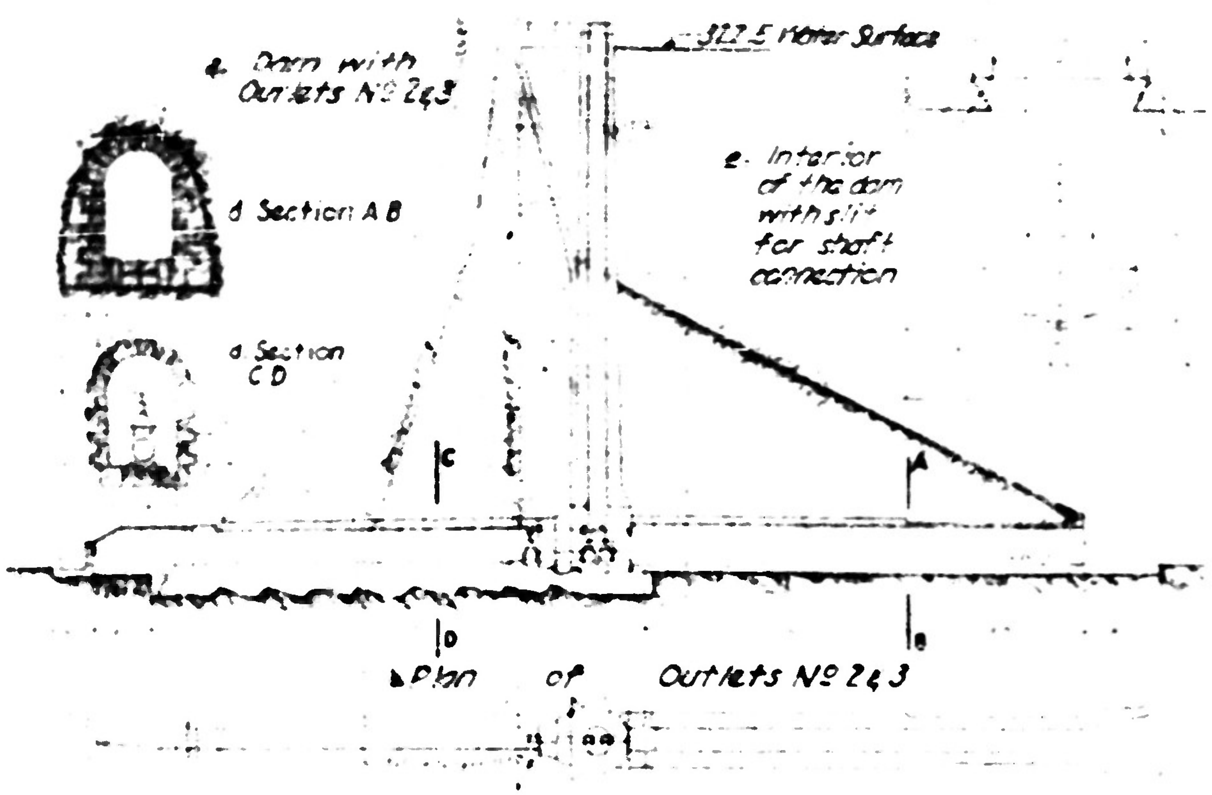


Fig. II - CROSS SECTION OF DAM AT OUTLETS NO. 2 or 3

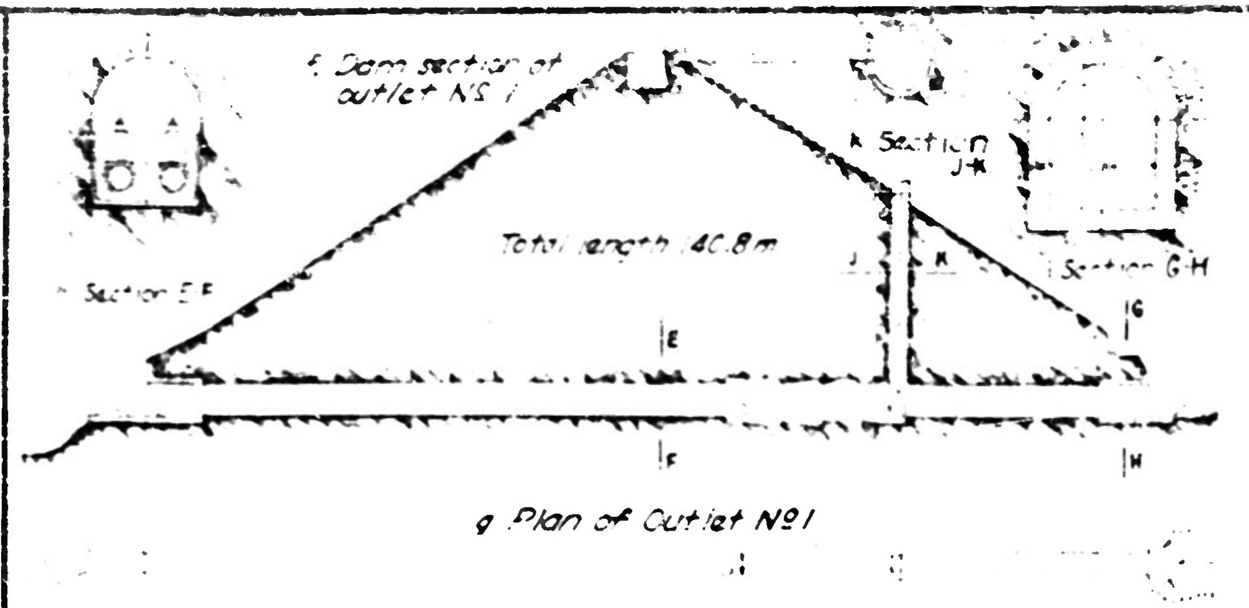
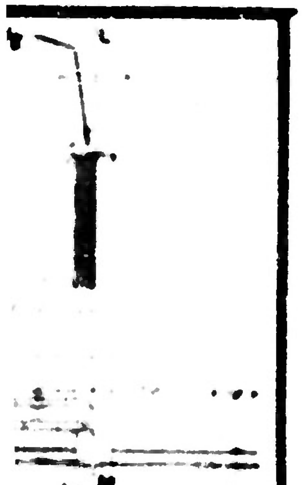


Fig. III - CROSS SECTION OF DAM AT OUTLET NO. 1



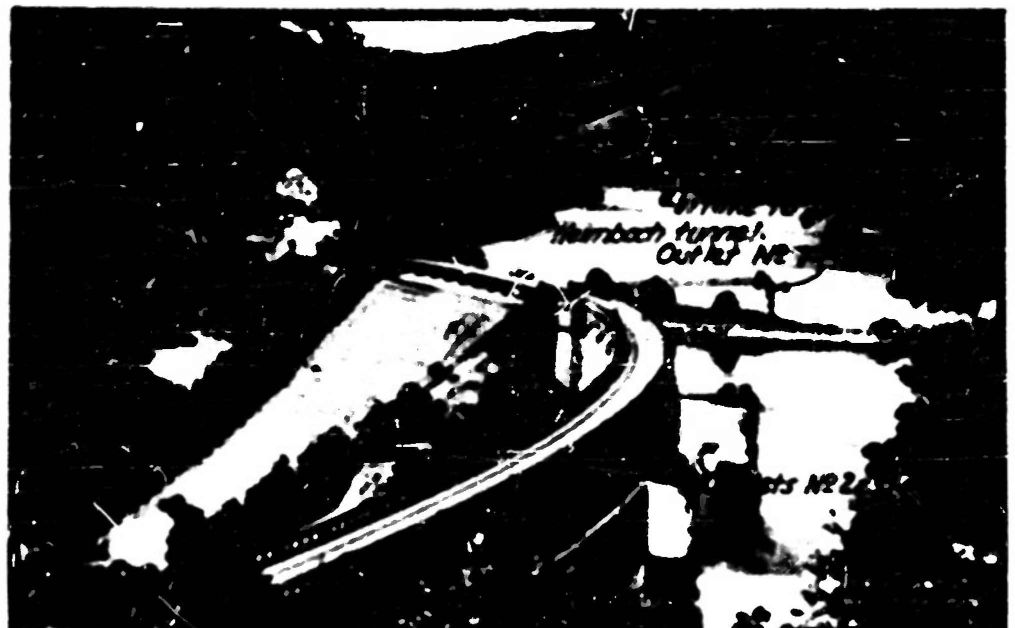


Fig. V - PHOTOGRAPH OF DAM

SOURCE:

Fig. I	"Deutsche Bauzeitung", 14 March 1903, p 134.
Fig. II-IV	"Deutsche Bauzeitung", 21 March 1903, p 148.
Fig. V	Prewar German postcard - Karl Arens, Hotel Seehof, Gemuend.

RUR (ROER) RIVER

SKETCHES OF DAM
URFT DAM

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS

Prepared by JJM Date 10/22/52
Drawn by

PLATE 6.

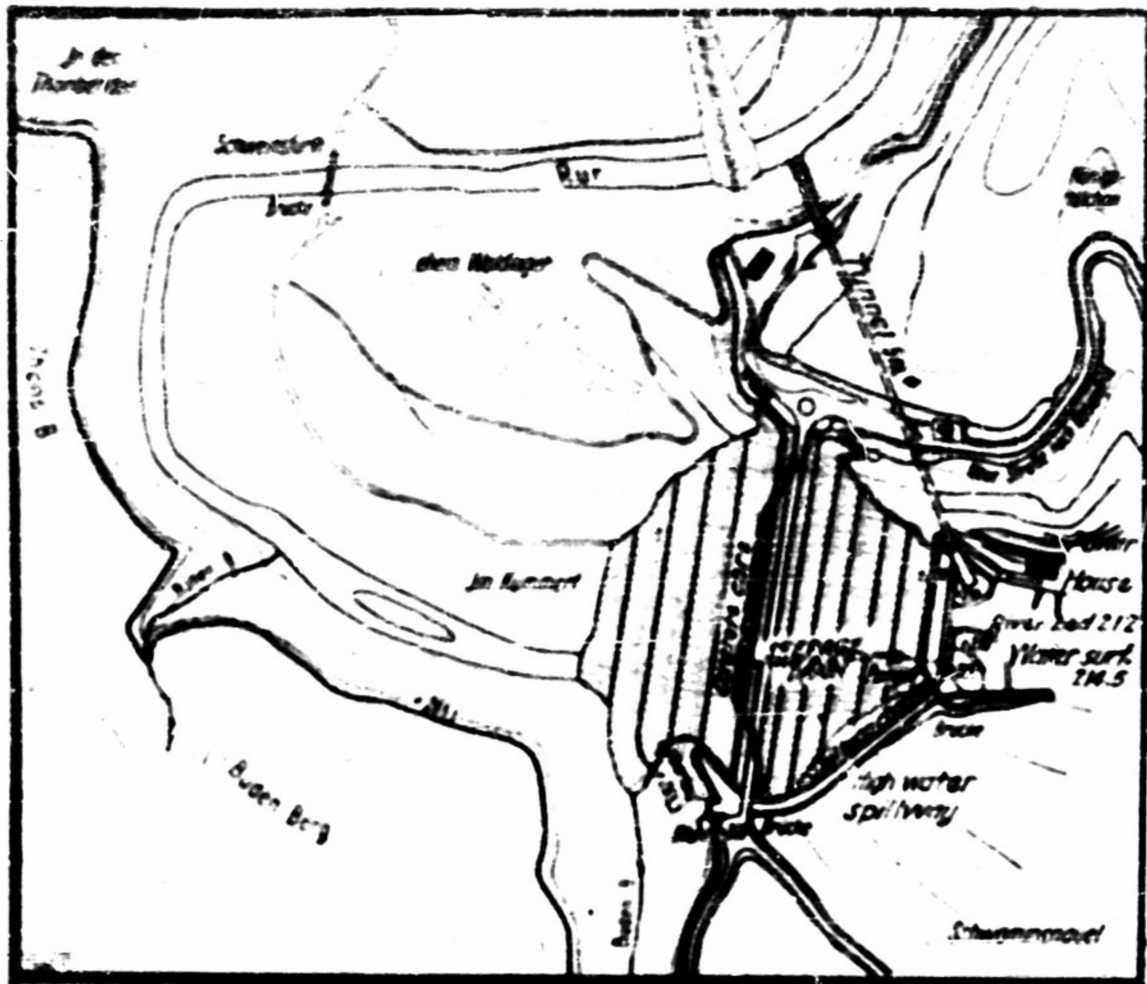


Fig. I - PLAN OF DAM

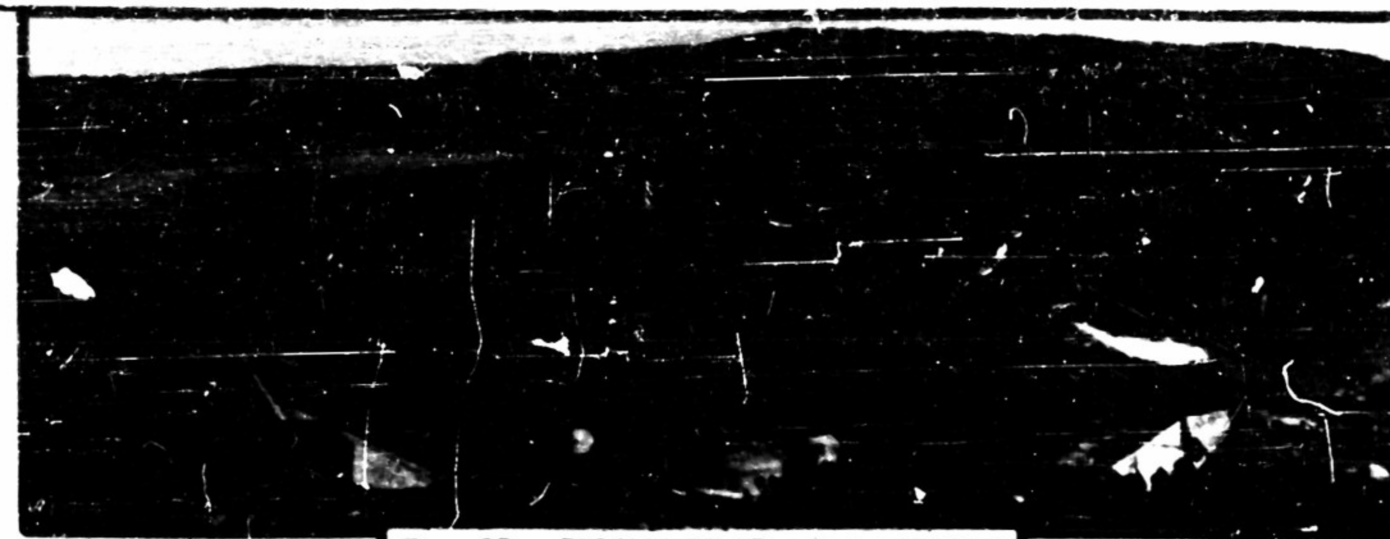


Fig. II - PHOTOGRAPH OF DAM & SPILLWAY

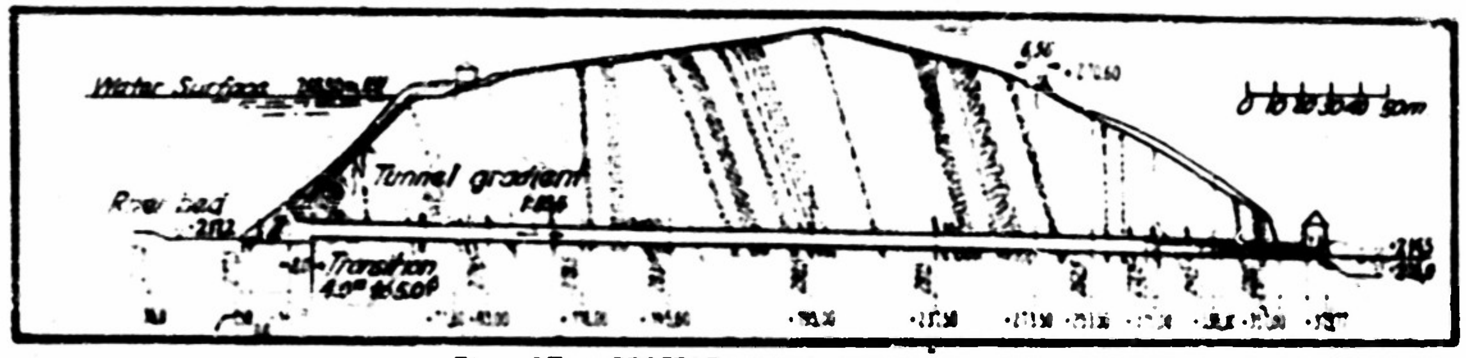


Fig. IV - PROFILE ALONG OUTLET TUNNEL

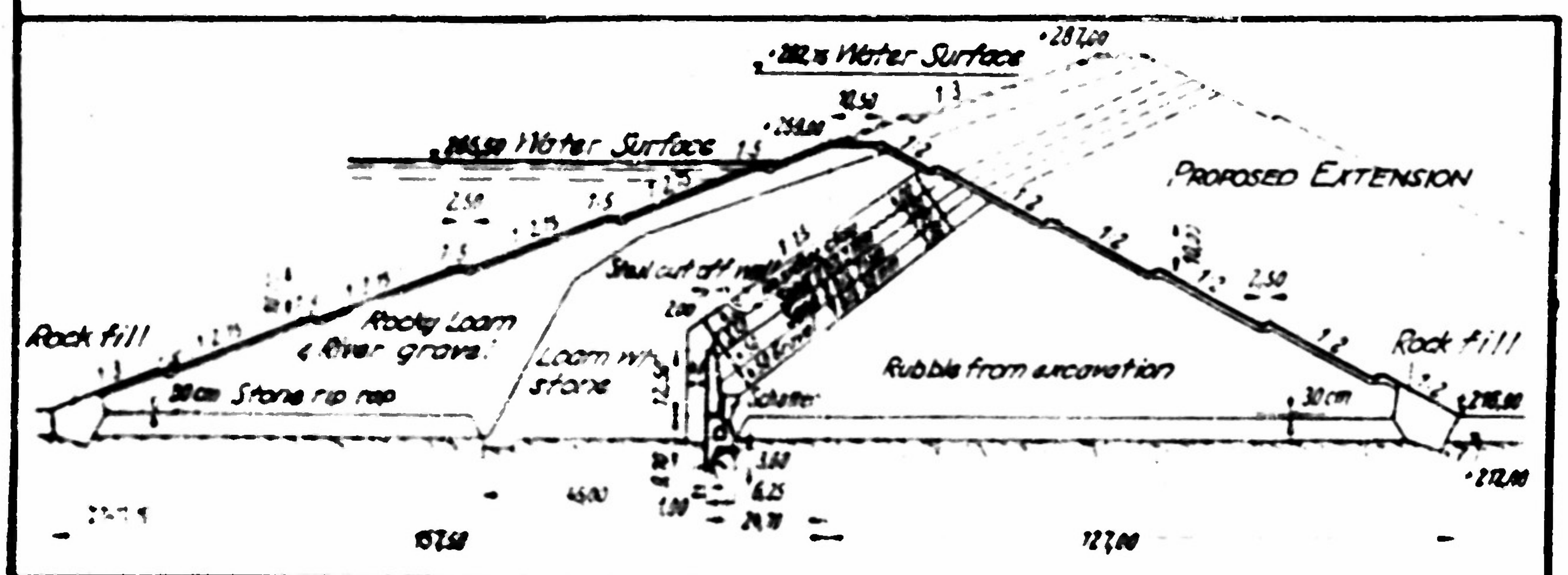


Fig. VI - CROSS SECTION OF DAM

SOURCE :

Fig. I	"VDI Zeitschrift", 25 June 1938,	p 77
Fig. II	"Der Bauingenieur", Sept. 1938,	p 50
Fig. III	"Deutsche Wasserwirtschaft", 1938,	p 13
Fig. IV	"Der Bauingenieur", Sept. 1938,	p 50
Fig. V	"Deutsche Wasserwirtschaft", 1938,	p 13
Fig. VI	"VDI Zeitschrift", 2? Aug. 1936,	p 10

Fig. II - PHOTOGRAPH OF DAM & SPILLWAY

Fig. III - PHOTOGRAPH OF OUTLET EXIT PIPES DURING CONSTRUCTION

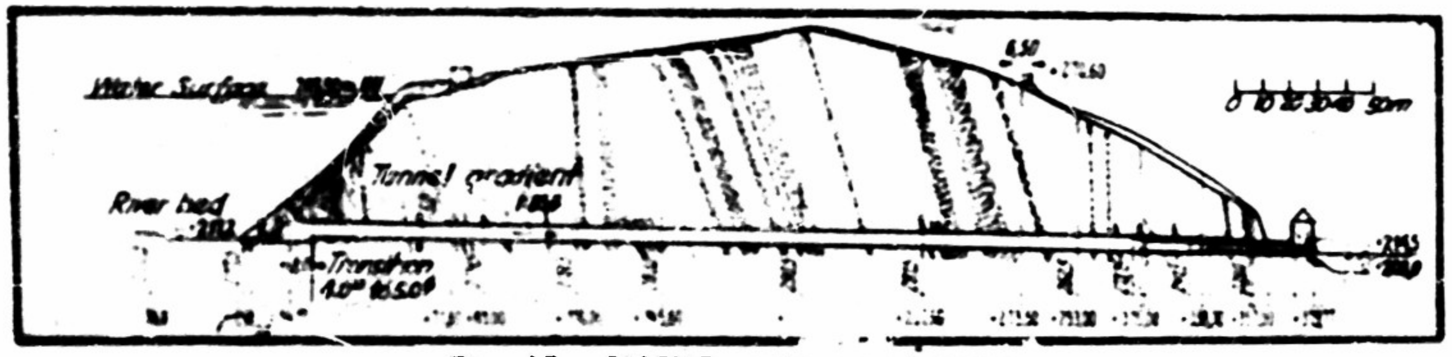


Fig. IV - PROFILE ALONG [illegible]

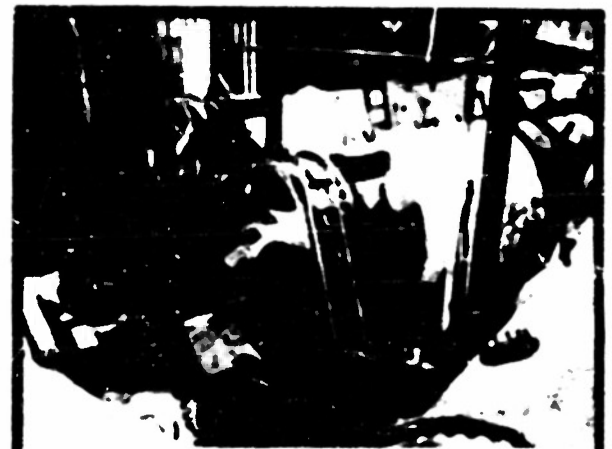
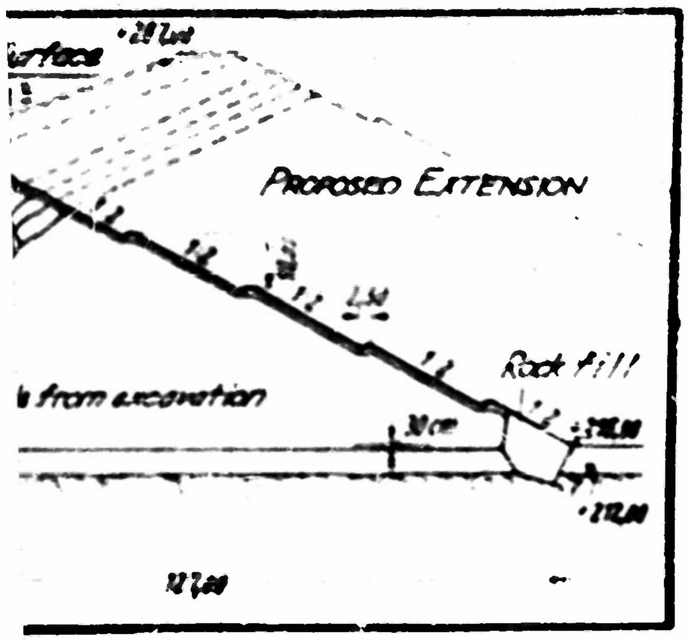


Fig. V - PHOTOGRAPH OF CONTROL VALVES ON OUTLET EXIT PIPES



DAM

SOURCE :

Fig. I "VDI Zeitschrift", 25 June 1938, p 770
Fig. II "Der Bauingenieur", Sept. 1938, p 568
Fig. III "Deutsche Wasserwirtschaft", 1938, p 133
Fig. IV "Der Bauingenieur", Sept. 1938, p 568
Fig. V "Deutsche Wasserwirtschaft", 1938, p 133
Fig. VI "VDI Zeitschrift", 21 Aug. 1936, p 1065

RUR (ROER) RIVER

SKETCHES OF DAM (SCHWAMMENAUEL) RUR

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by ___ Date 10/21/52
Drawn by ___

PLATE 7

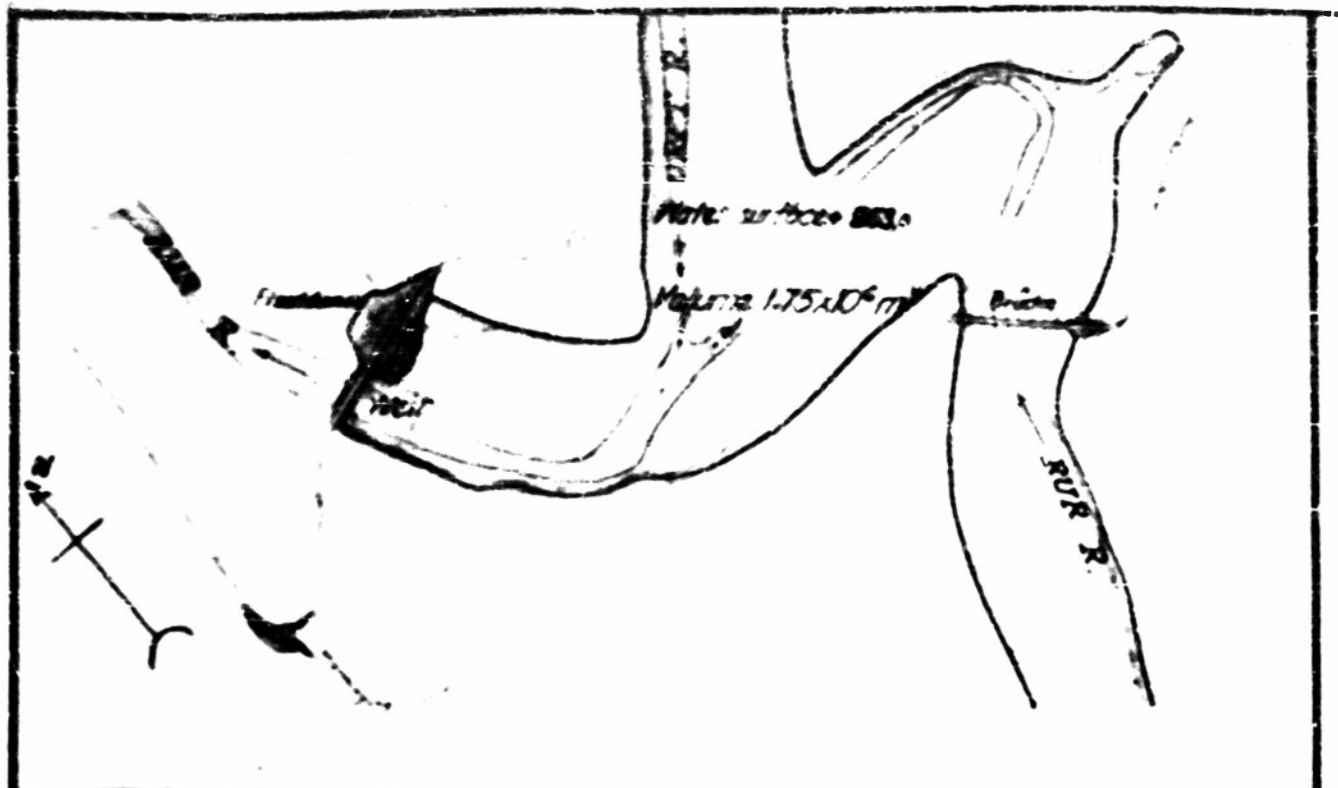


Fig. I - PAULUSHOF DAM - PLAN

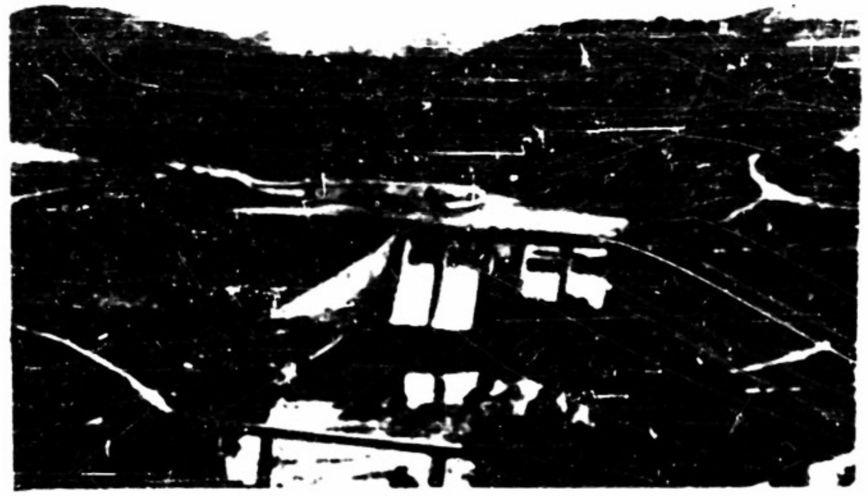


Fig. II - PAULUSHOF DAM - PHOTOGRAPH OF DAM

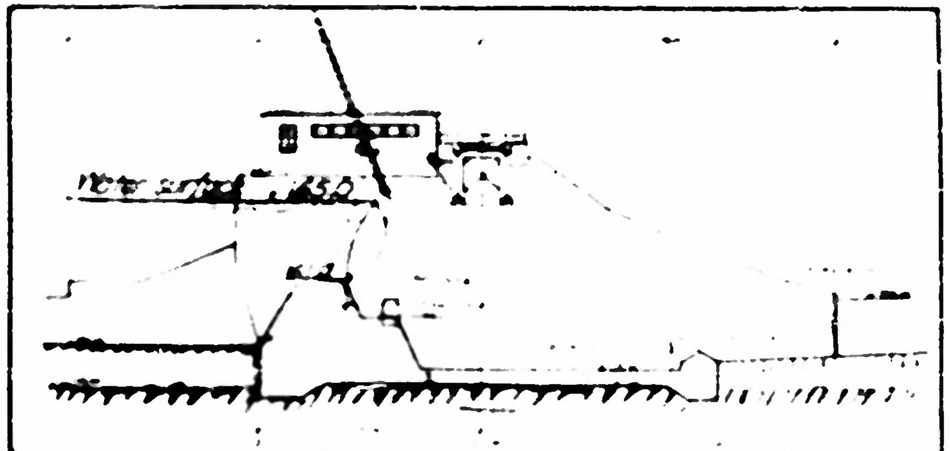


Fig. IV - OBERMAUBACH DAM - CROSS SECTION AT GATED WEIR

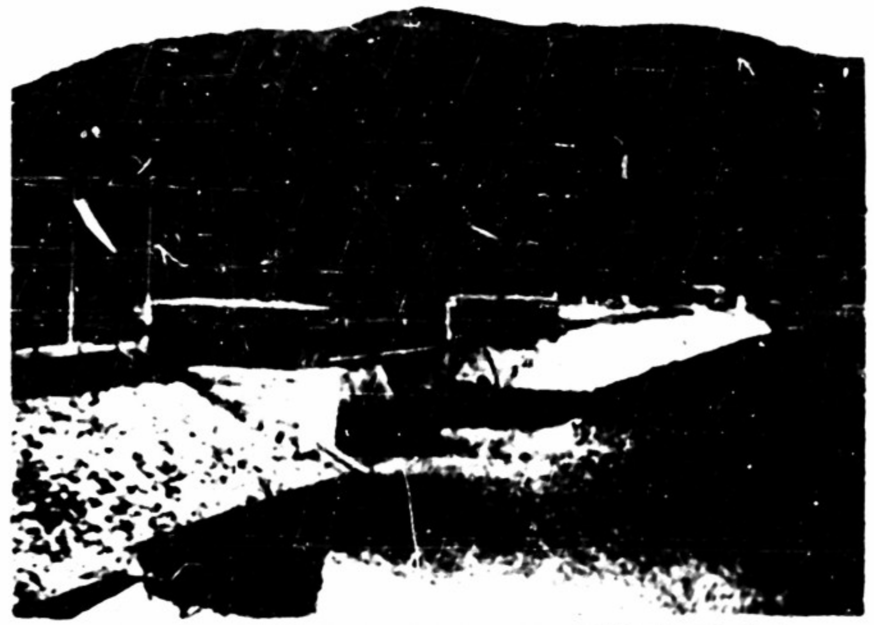


Fig. V - OBERMAUBACH DAM - PHOTOGRAPH OF DAM

Fig. VI -

SOURCE:
Fig. I "Deutsche Wasserwirtschaft", Feb.
Fig. II German publication (Title unknown
Fig III Files of Army Map Service ESID (
Branch) (Photograph date 7/6/48).
Fig. IV-VI "Deutsche Wasserwirtschaft", Ja

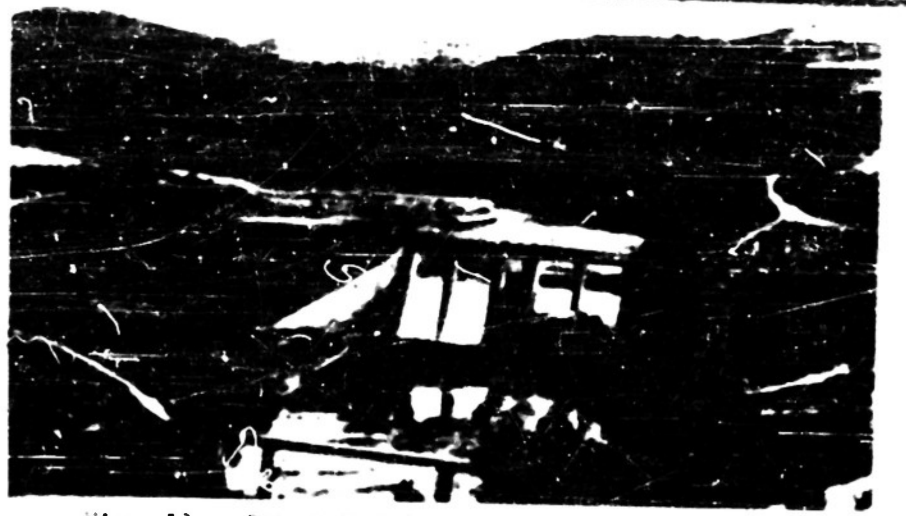
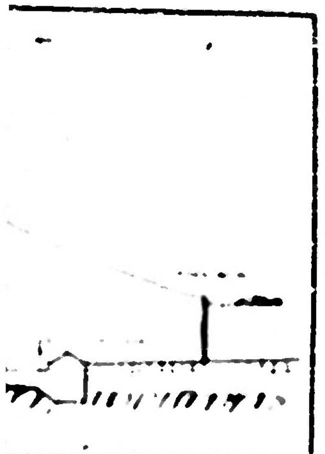


Fig. II - PAULUSHOF DAM - PHOTOGRAPH OF DAM

Fig. III - HEIMBACH DAM - PHOTOGRAPH OF DAM



...ION AT GATED WEIR

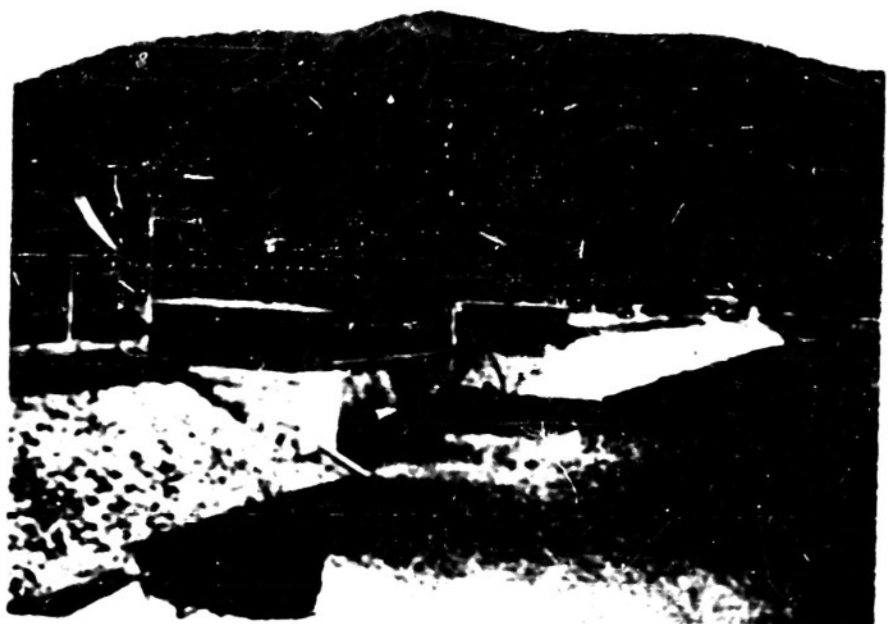


Fig. V - OBERMAUBACH DAM - PHOTOGRAPH OF DAM

Fig. VI - OBERMAUBACH DAM - PHOTOGRAPH OF WEIR GATES

SOURCE:
- Fig. I "Deutsche Wasserwirtschaft", Feb. 1935, p [illegible]
- Fig. II German publication (Title unknown).
- Fig. III Files of Army Map Service ESID (Western Europe Branch) (F [illegible] date [illegible] 4[illegible]).
- Fig. IV-VI "Deutsche Wasserwirtschaft", Jan. 1935, p 5

RUR (ROER) RIVER
SKETCHES OF DAMS
PAULUSHOF, HEIMBACH & OBERMAUBACH

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS

Prepared by [illegible] Date 10/17/52
Drawn by

PLATE 8

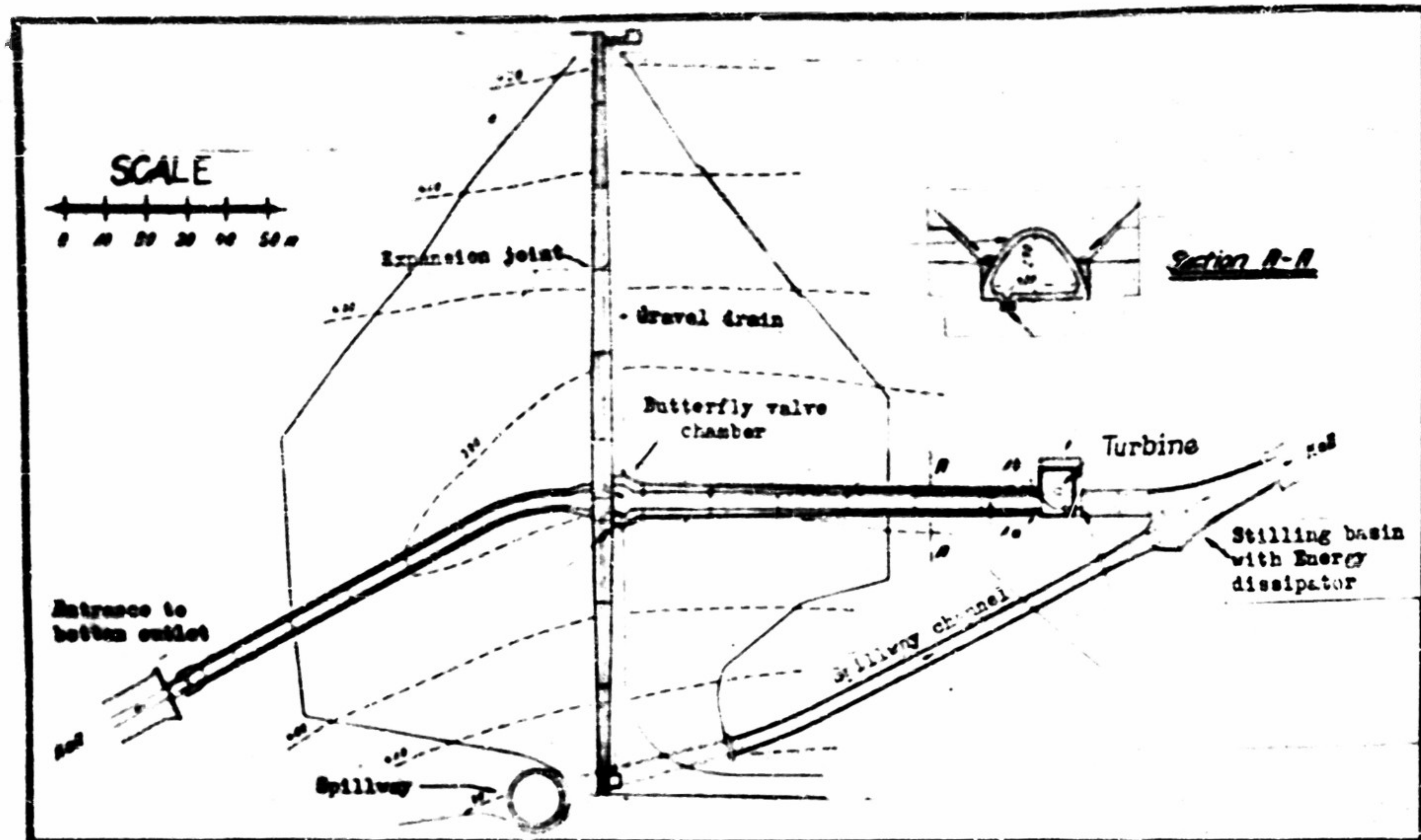


Fig. I: KALL DAM - PLAN

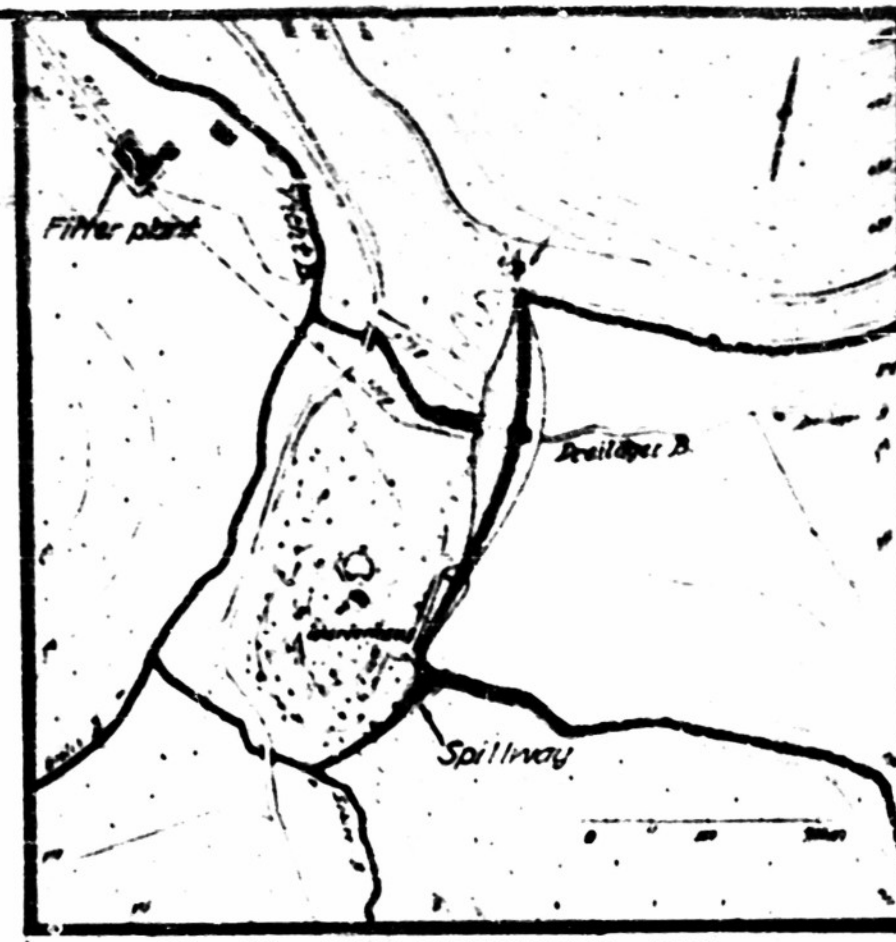


Fig. II: DREILAEGERBACH DAM - PLAN

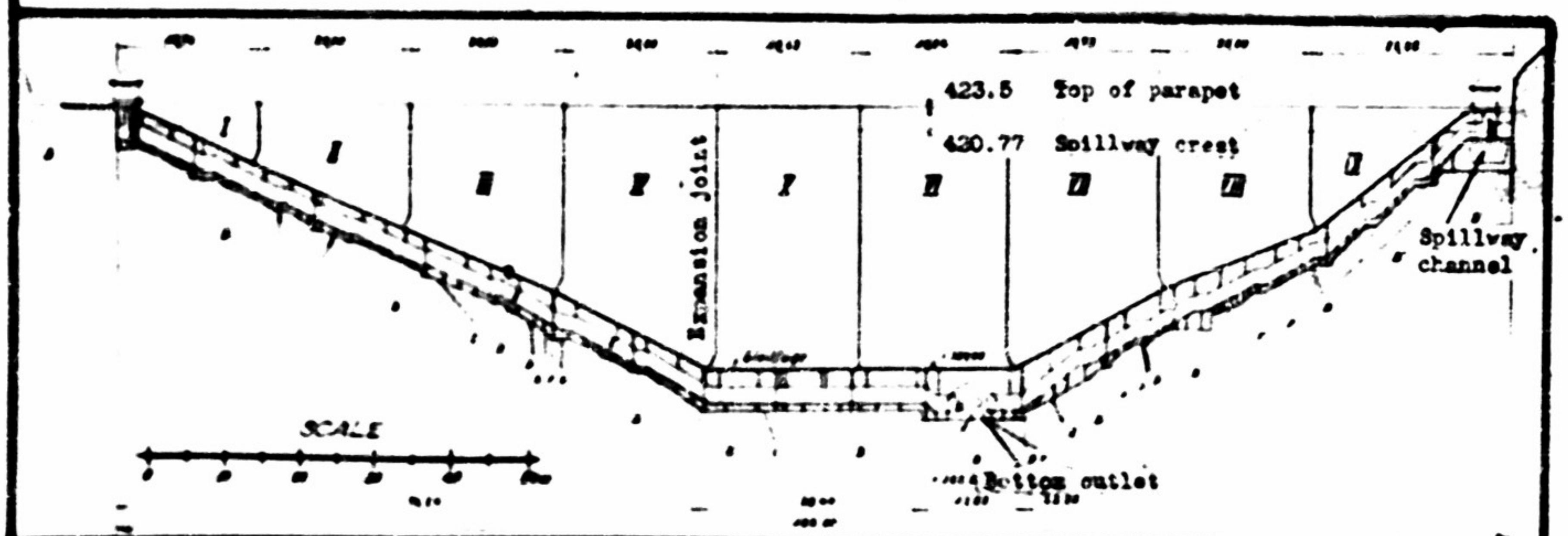


Fig. IV: KALL DAM - ELEVATION

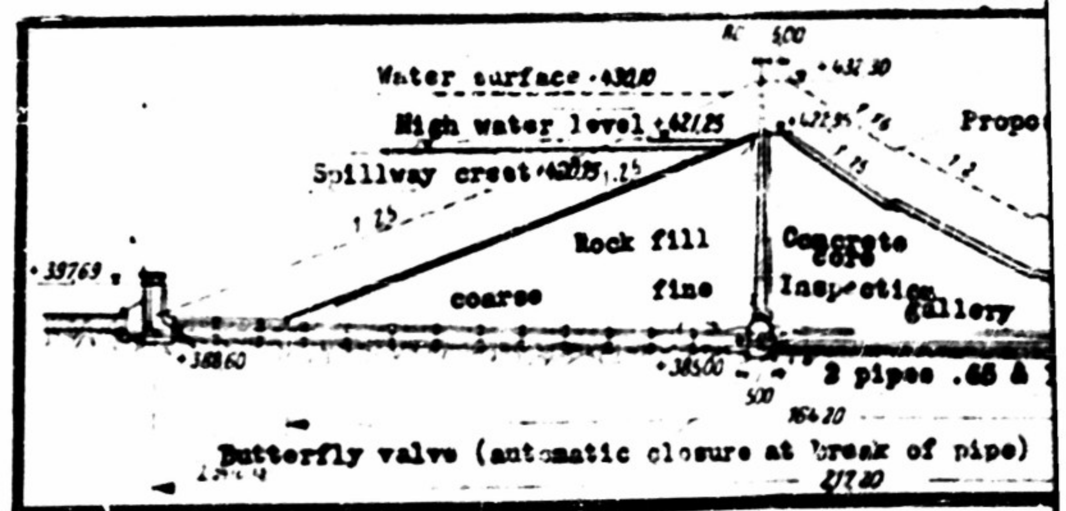
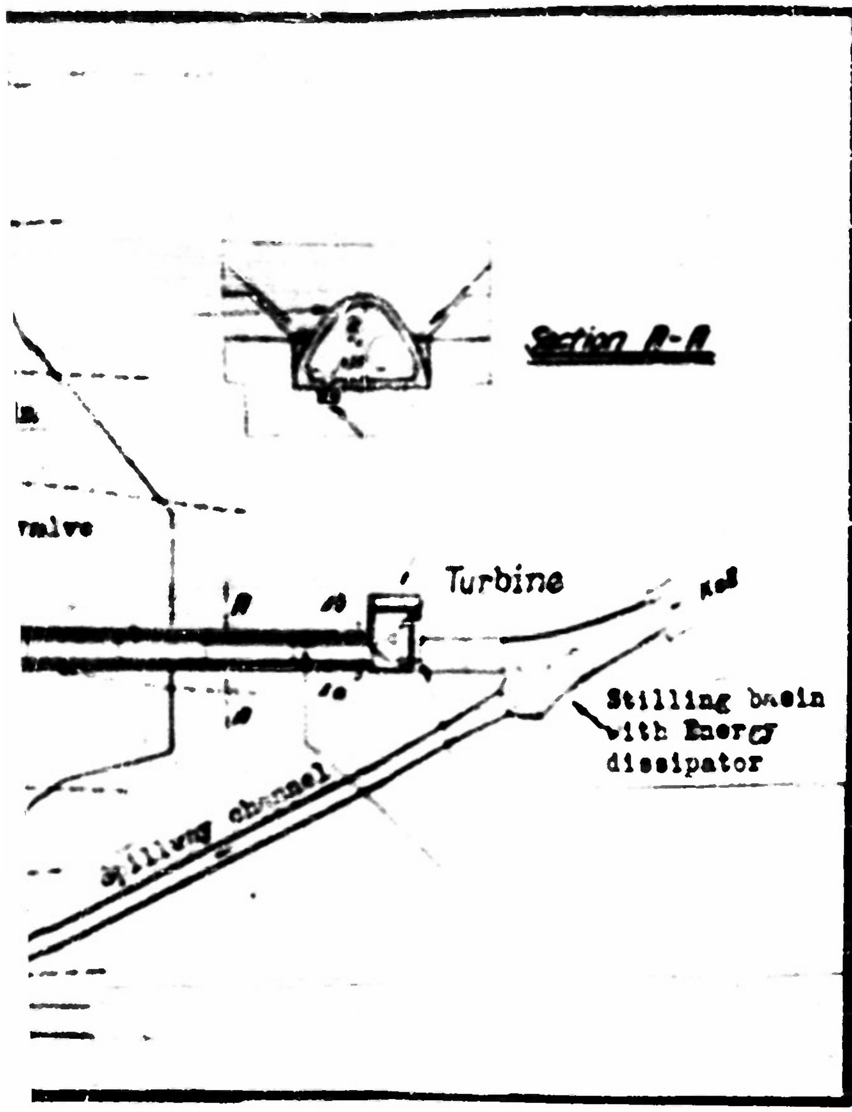


Fig. V: KALL DAM - CROSS SECTION

SOURCE:

Fig I	"Deutsche Wass
Fig II	"Deutsche Wass
Fig III	"Deutsche Wass
Fig IV	"Deutsche Wass
Fig V	"VDI Zeitschri



- PLAN

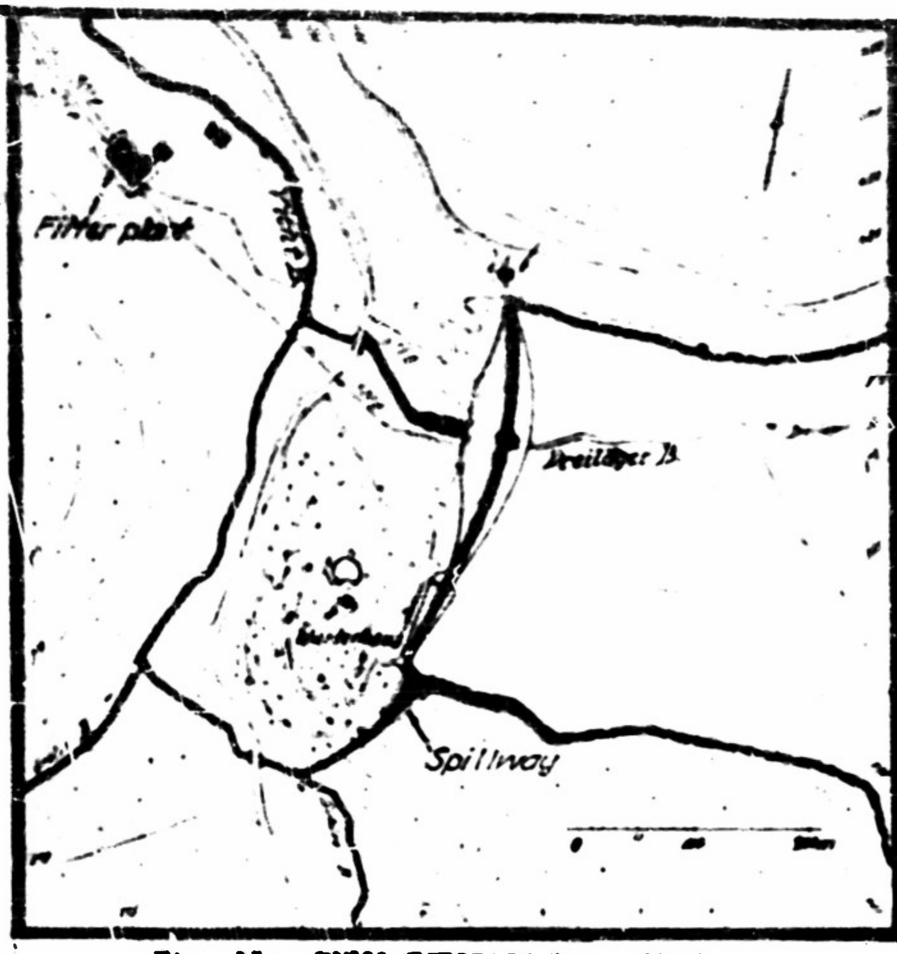


Fig. II: DREILAEGERBACH DAM - PLAN

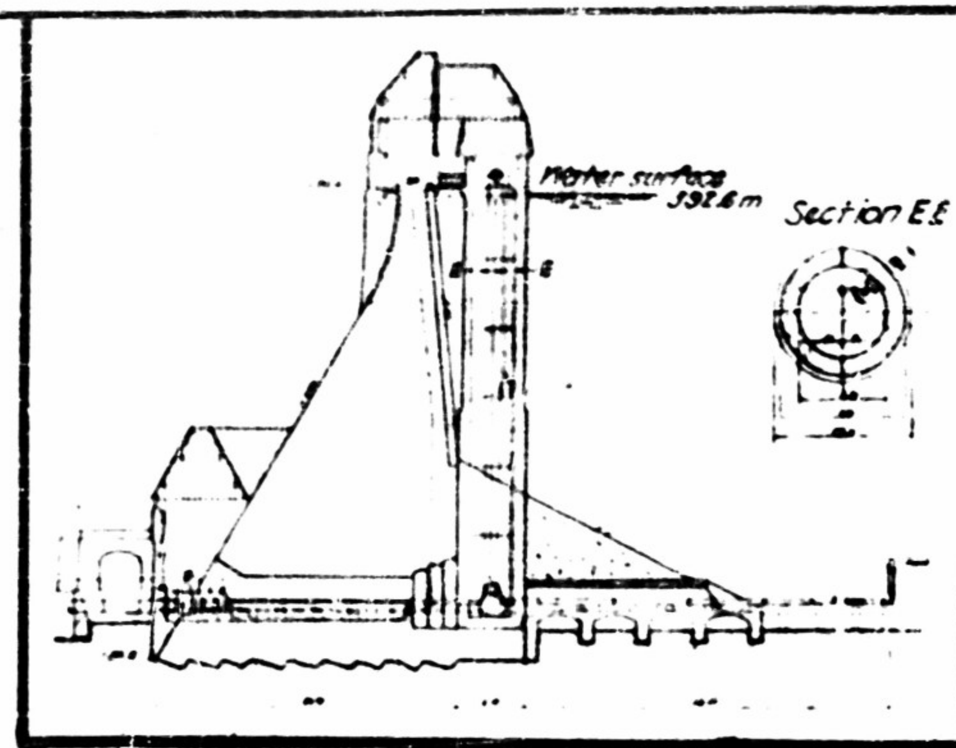
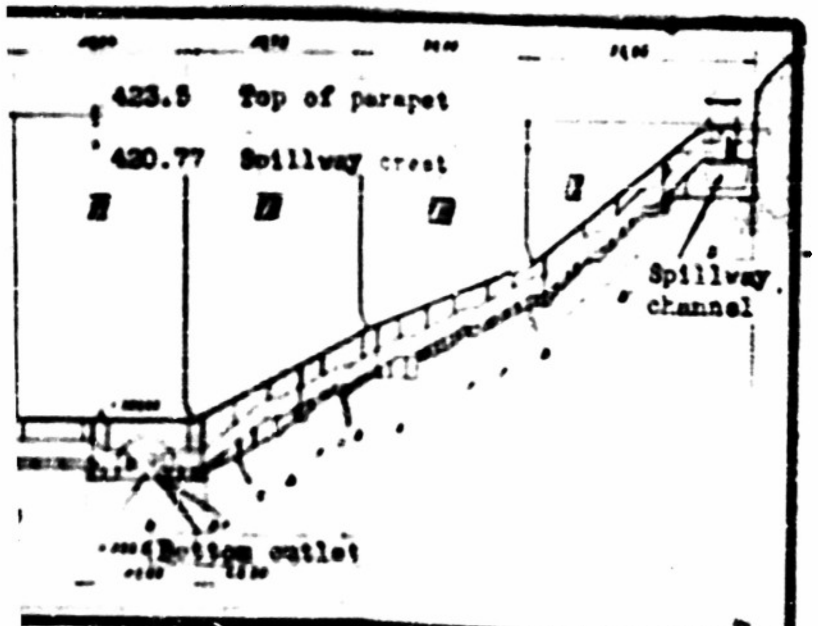


Fig. III: DREILAEGERBACH DAM - CROSS SECTION



- ELEVATION

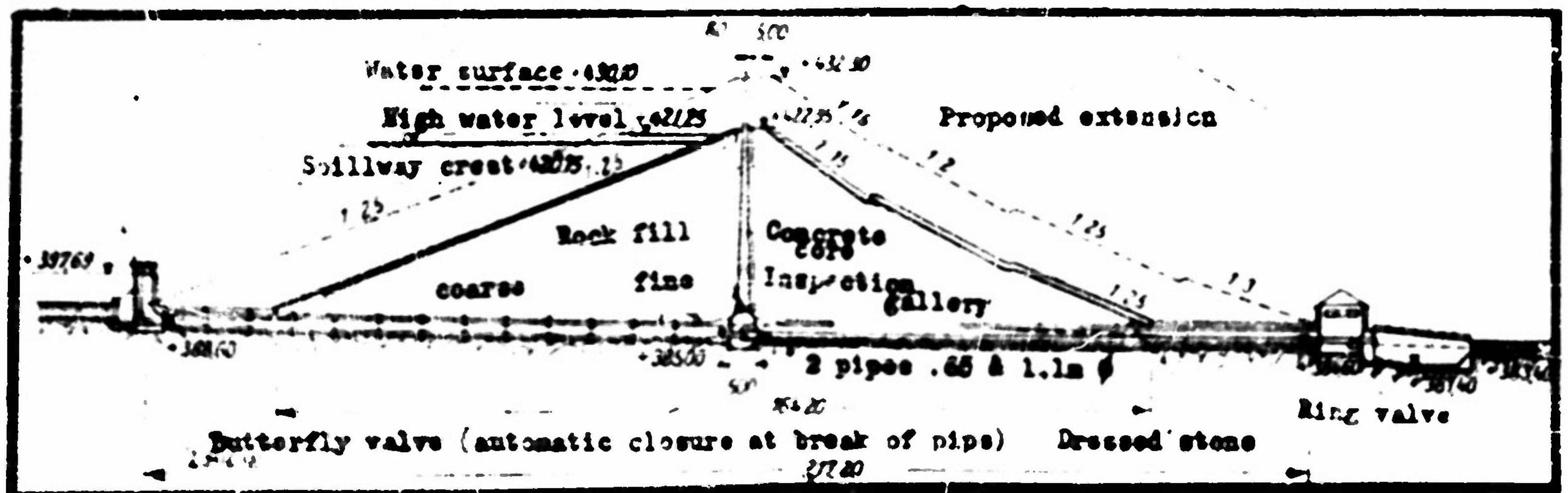


Fig. V: KALL DAM - CROSS SECTION

SOURCE :

Fig I "Deutsche Wasserwirtschaft", 1938, p156
Fig II "Deutsche Wasserwirtschaft", 1938, p150
Fig III "Deutsche Wasserwirtschaft", 1938, p150
Fig IV "Deutsche Wasserwirtschaft", 1938, p154
Fig V "VDI Zeitschrift", 22 Aug. 1936, p1065

RUR (ROER) RIVER

SKETCHES OF DAMS KALL & DREILÄGERBACH

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
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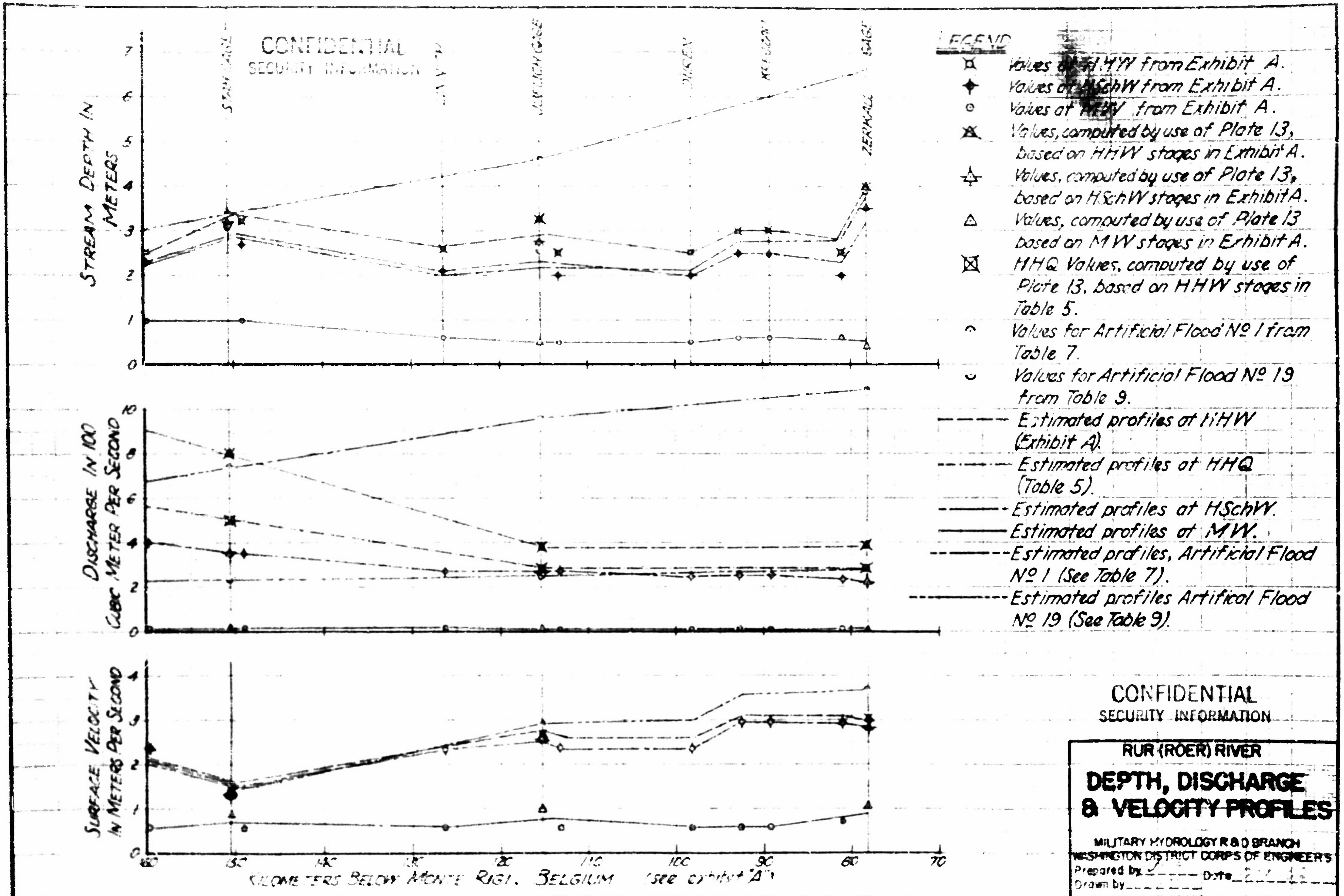
Drawn by ____

PLATE 9


CONFIDENTIAL
SECURITY INFORMATION
STREAM DEPTH IN METERS
DISCHARGE IN 100 CUBIC METER PER SECOND
SURFACE VELOCITY IN METERS PER SECOND
ZERKALL
KILOMETERS BELOW MONTE RIGI, BELGIUM (see exhibit "A")
LEGEND
from Exhibit A.
from Exhibit A.
from Exhibit A.
Values, computed by use of Plate 13, based on HHW stages in Exhibit A.
Values, computed by use of Plate 13, based on HSchW stages in Exhibit A.
Values, computed by use of Plate 13 based on MW stages in Exhibit A.
HHQ Values, computed by use of Plate 13, based on HHW stages in Table 5.
Values for Artificial Flood Nº 1 from Table 7.
Values for Artificial Flood Nº 19 from Table 9.
Estimated profiles at HHW (Exhibit A).
Estimated profiles at HHQ (Table 5).
Estimated profiles at HSchW.
Estimated profiles at MW.
Estimated profiles, Artificial Flood Nº 1 (See Table 7).
Estimated profiles Artifical Flood Nº 19 (See Table 9).
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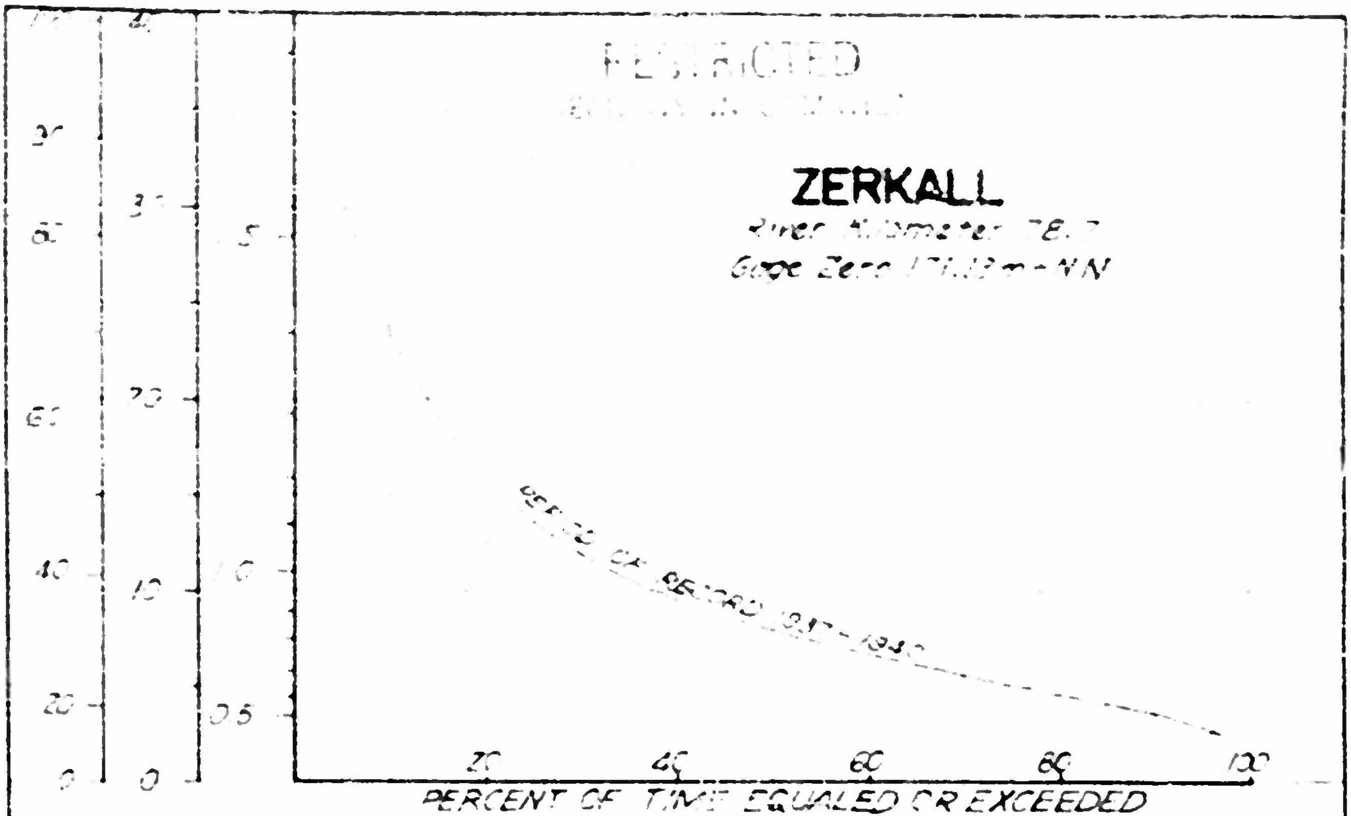
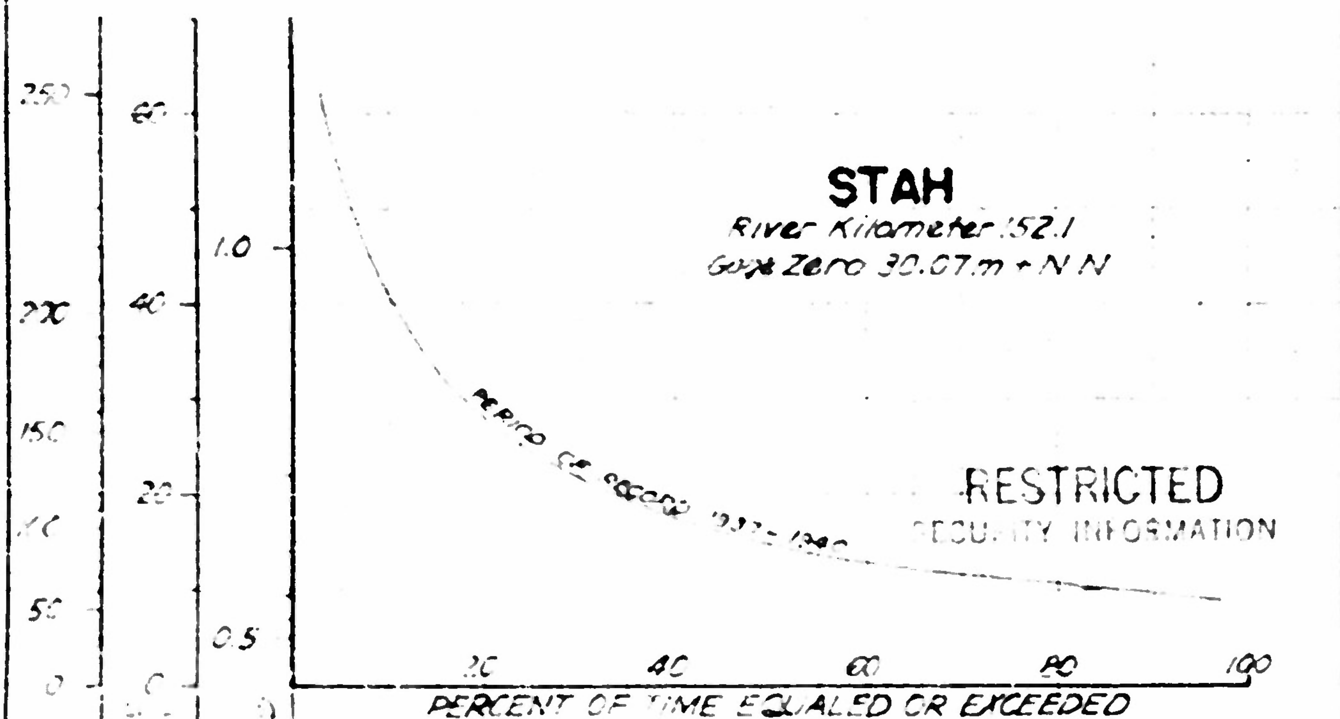
SECURITY INFORMATION
RUR (ROER) RIVER
DEPTH, DISCHARGE & VELOCITY PROFILES
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by
Date
Drawn by

PLATE 10





NOTES:

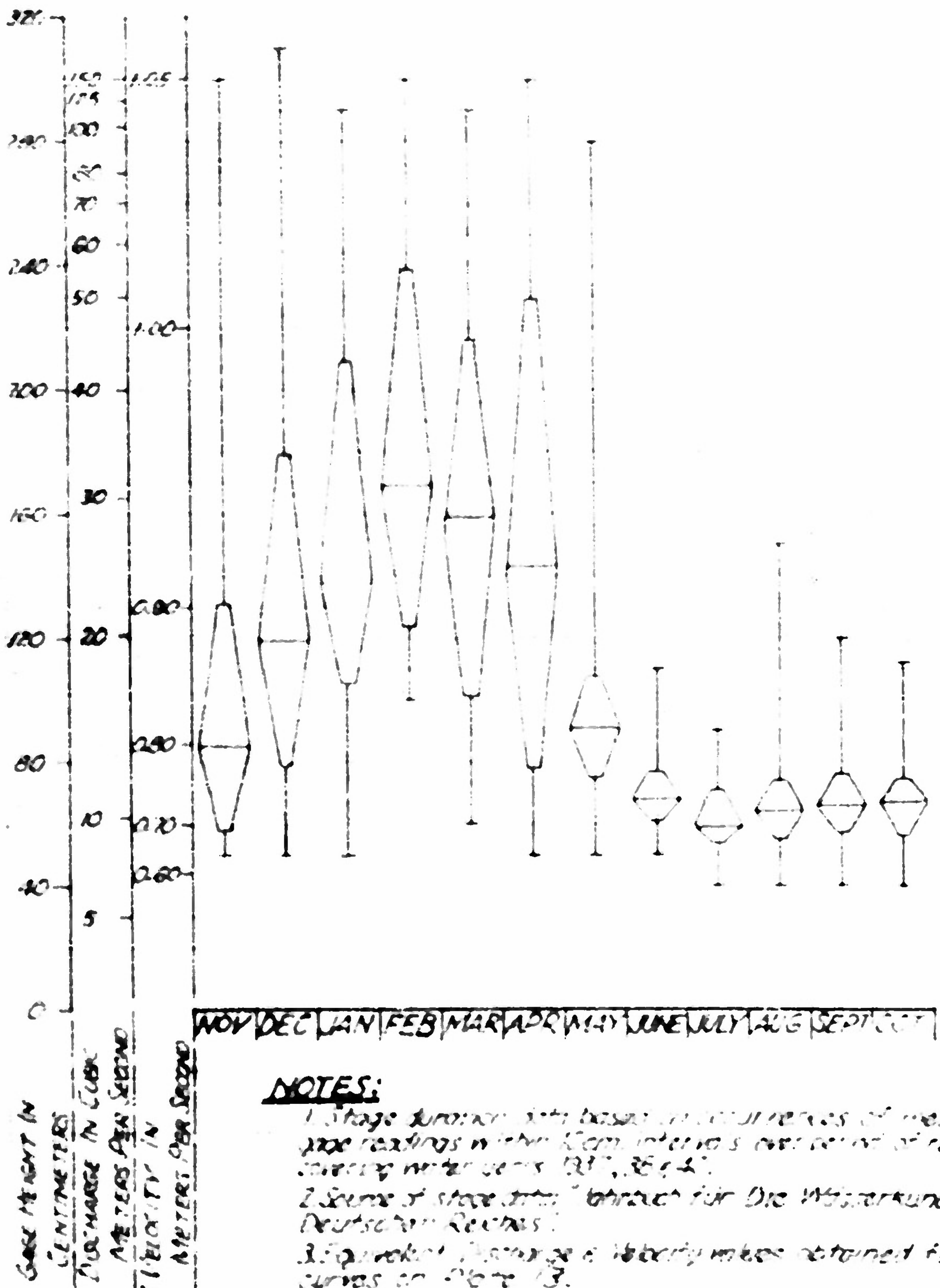
1. Source: Jahrbuch für die Wasserkunde des Deutschen, Teil IV 1942, p. 152.
2. Equivalent stage values ... obtained from curves on Plate 13
3. See Note 4, Plate 17

RUR(ROER)RIVER
STAGE, DISCHARGE & VELOCITY DURATION CURVES

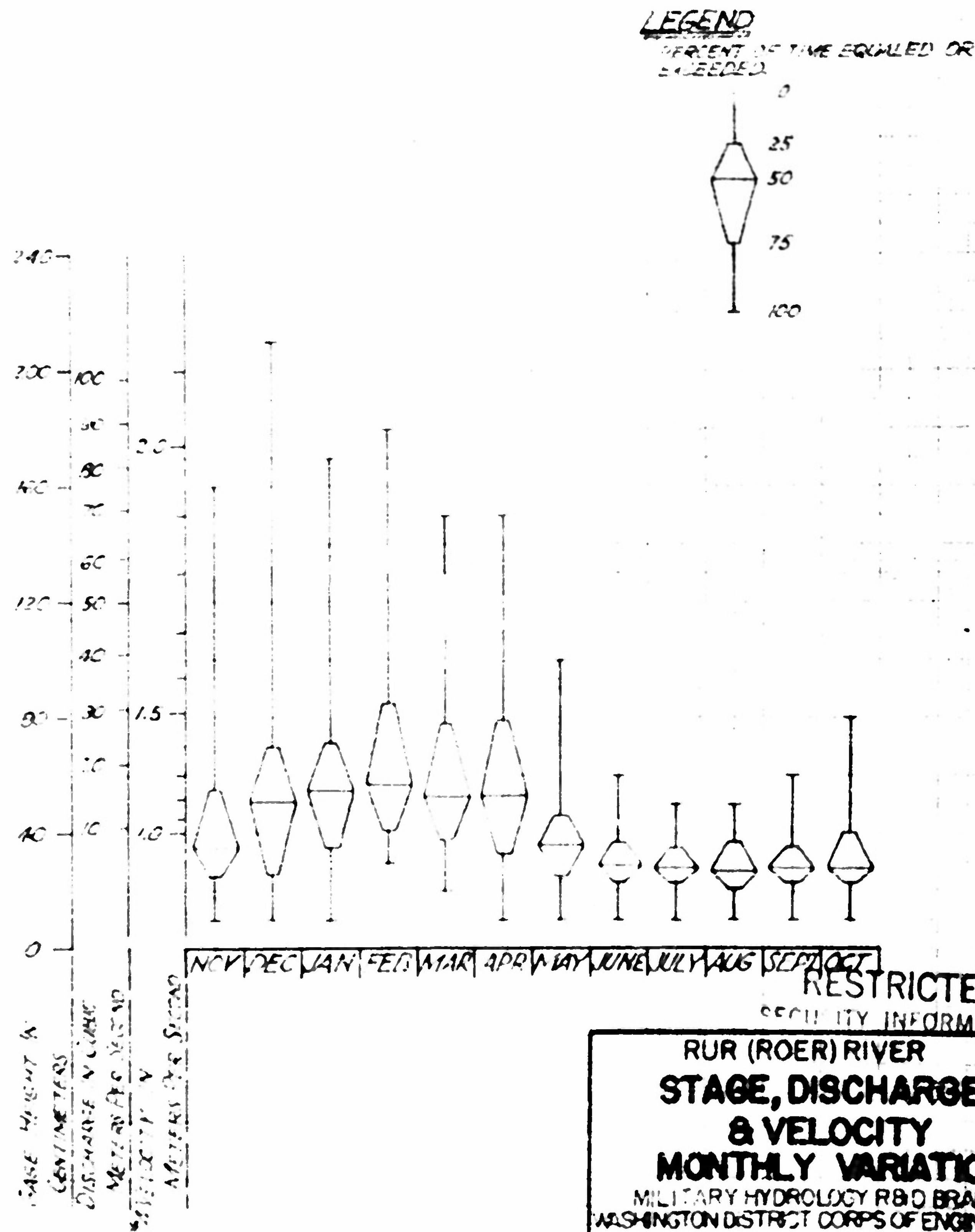
MILITARY HYDROLOGY R&D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by ______ Date ______
Drawn by ______

RESTRICTED

STAH



ZERKALL



NOTES:

1. Stage duration [illegible] based [illegible] of mean daily gage readings [illegible] intervals [illegible] of record [illegible] water years [illegible].
2. Source of stage data: "Jahrbuch für Die Wasserkunde des Deutschen Reiches".
3. Equivalent discharge & velocity values obtained from curves on Plate 13.
4. Velocities shown are Mean Velocities of the section. Multiply these values by 1.18 to obtain Mean Surface Velocity.

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RUR (ROER) RIVER

STAGE, DISCHARGE & VELOCITY MONTHLY VARIATION

MILITARY HYDROLOGY R&D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS

Prepared by [illegible] Date [illegible]
Drawn by [illegible]

PLATE 12

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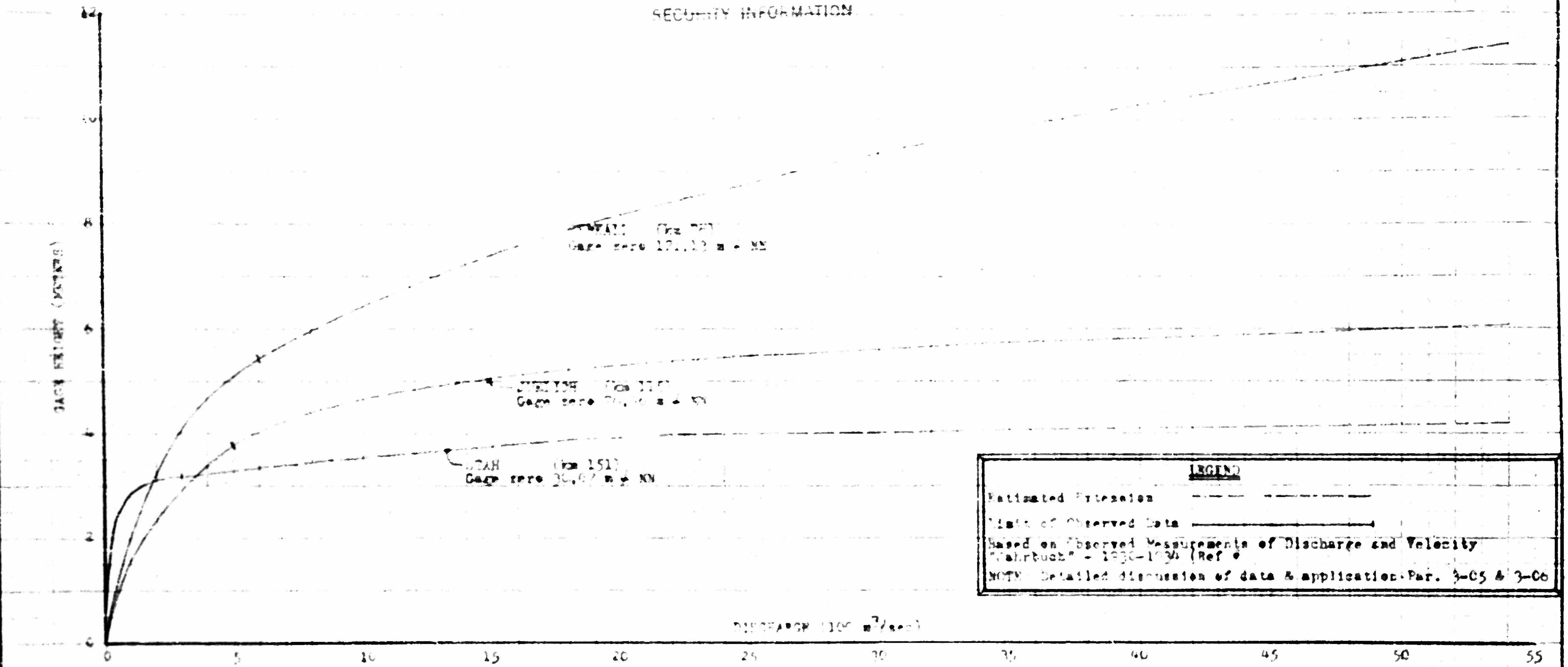
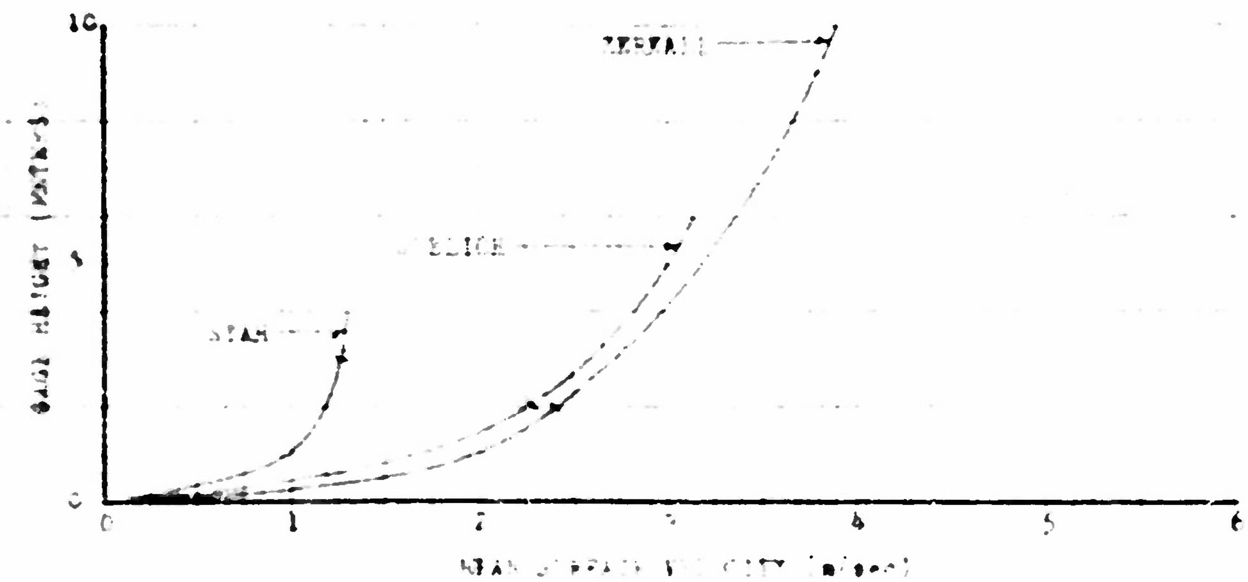
SECURITY INFORMATION





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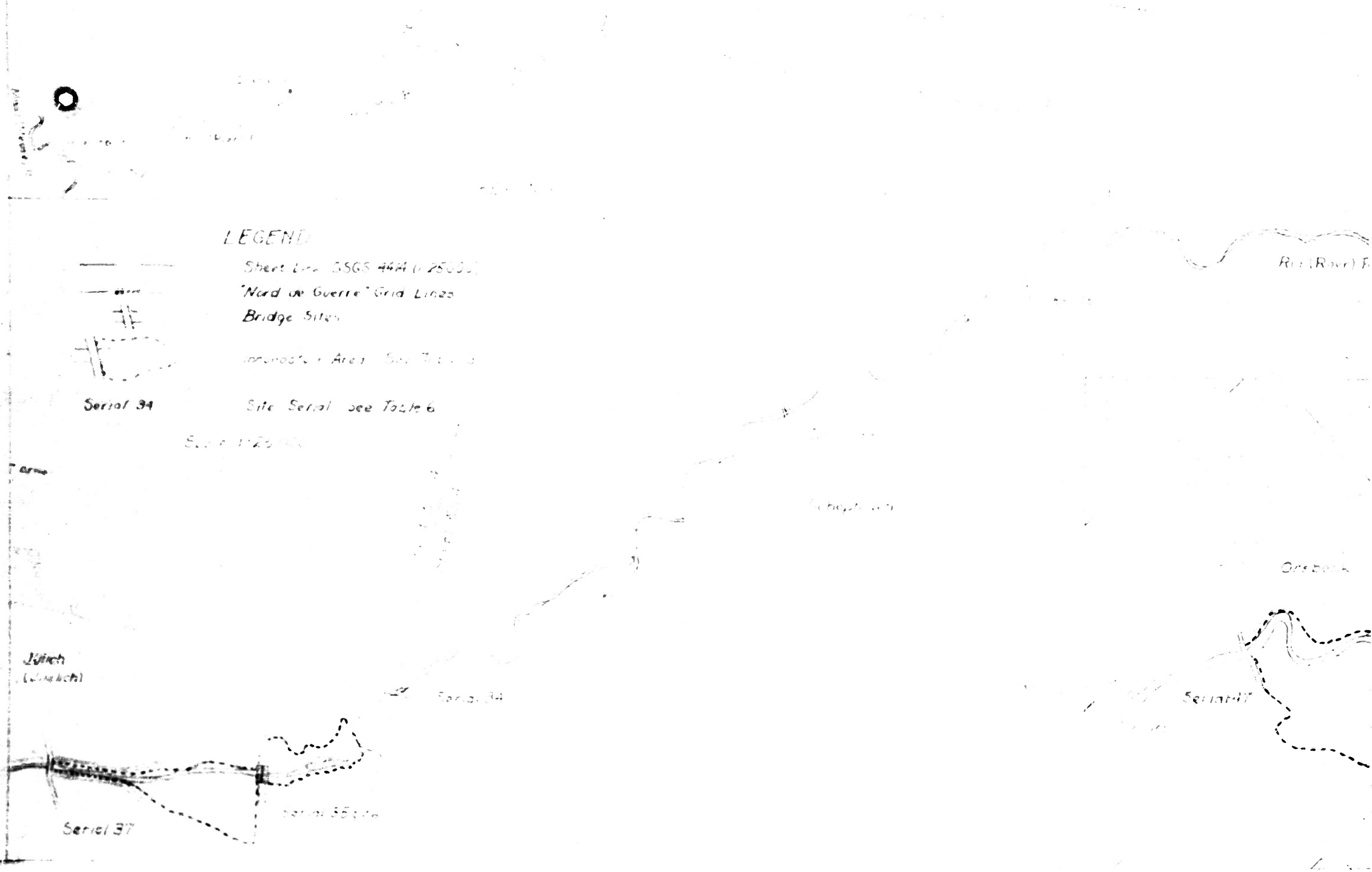
RUR (ROER) RIVER

DISCHARGE & VELOCITY RATING CURVES

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by ___ Date Oct 52
Drawn by ___

PLATE 13

CONFIDENTIAL



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SECURITY INFORMATION

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SECURITY INFORMATION

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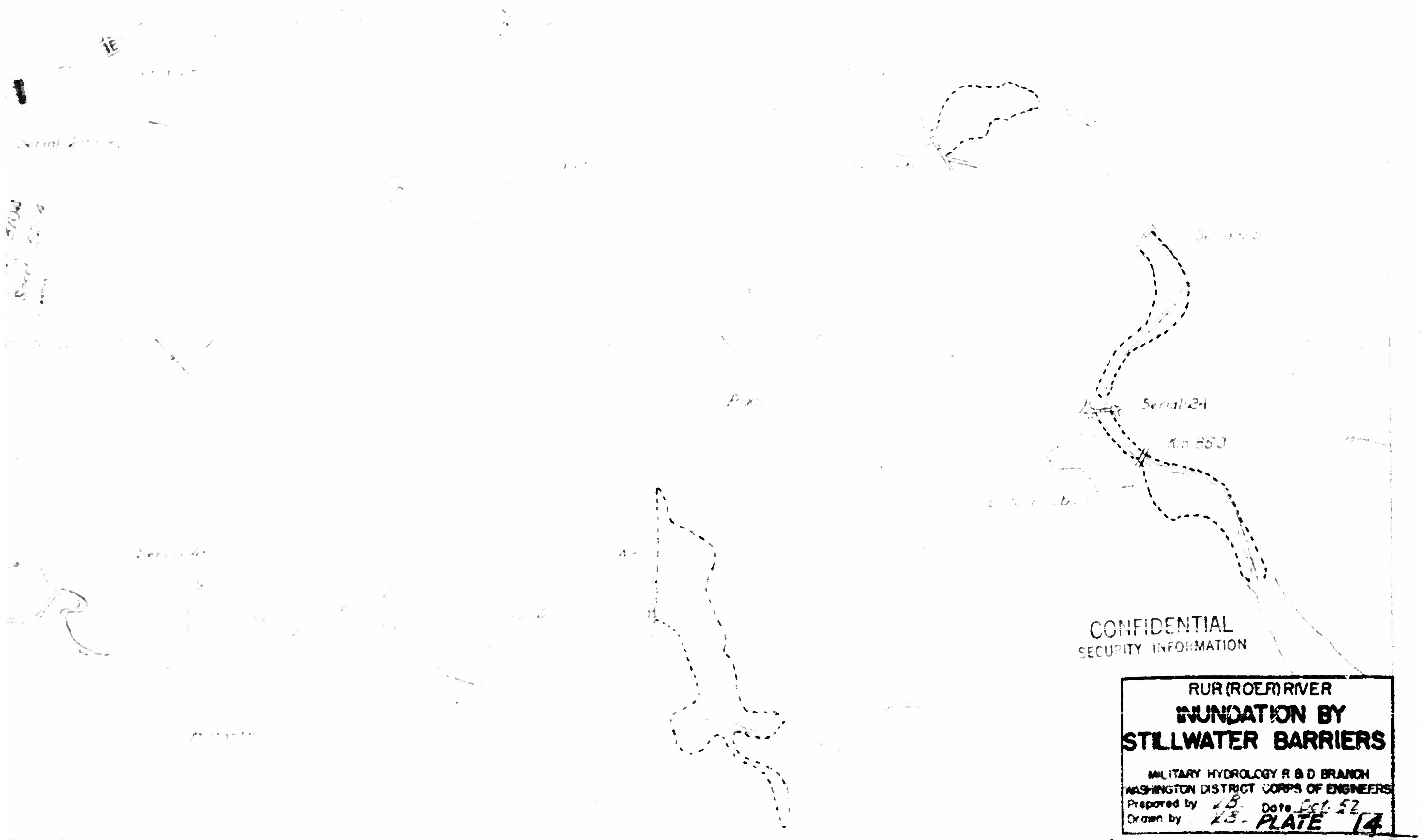
SECURITY INFORMATION



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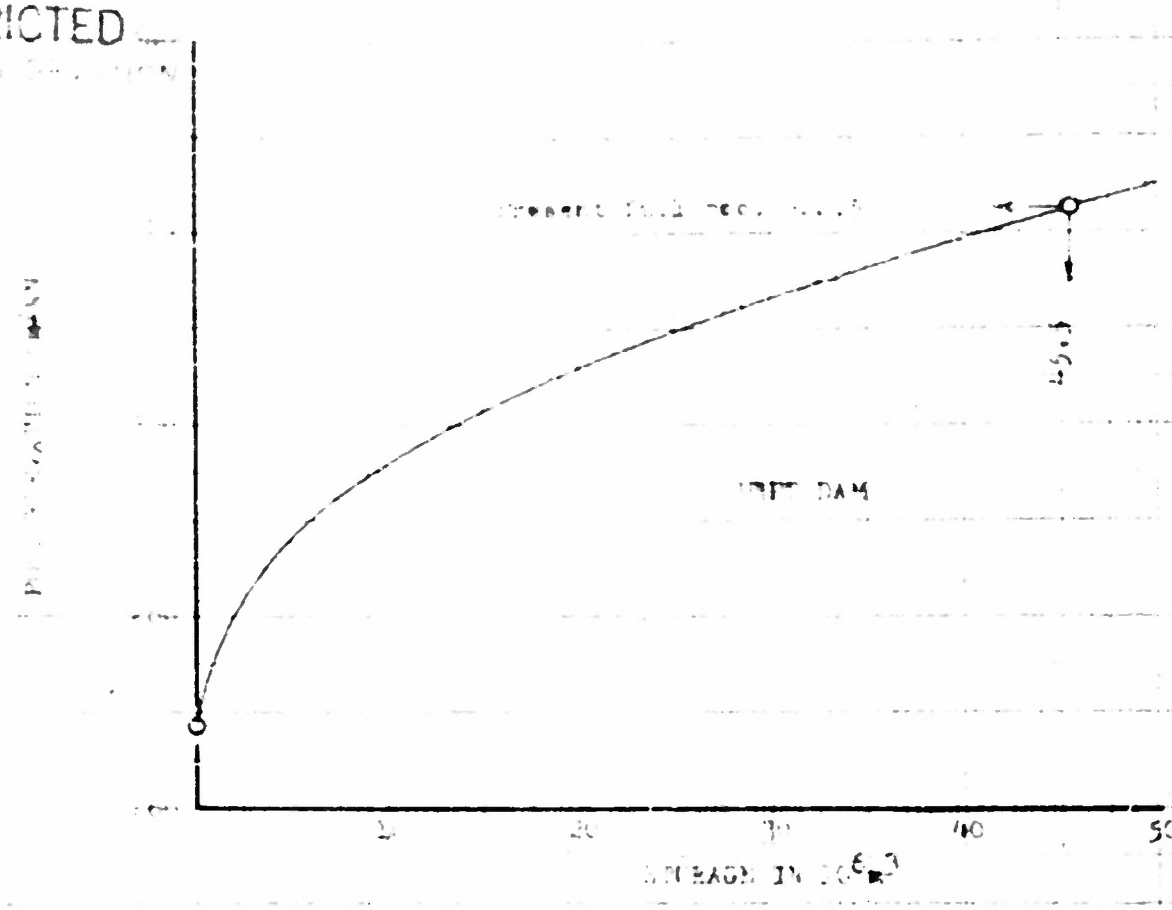
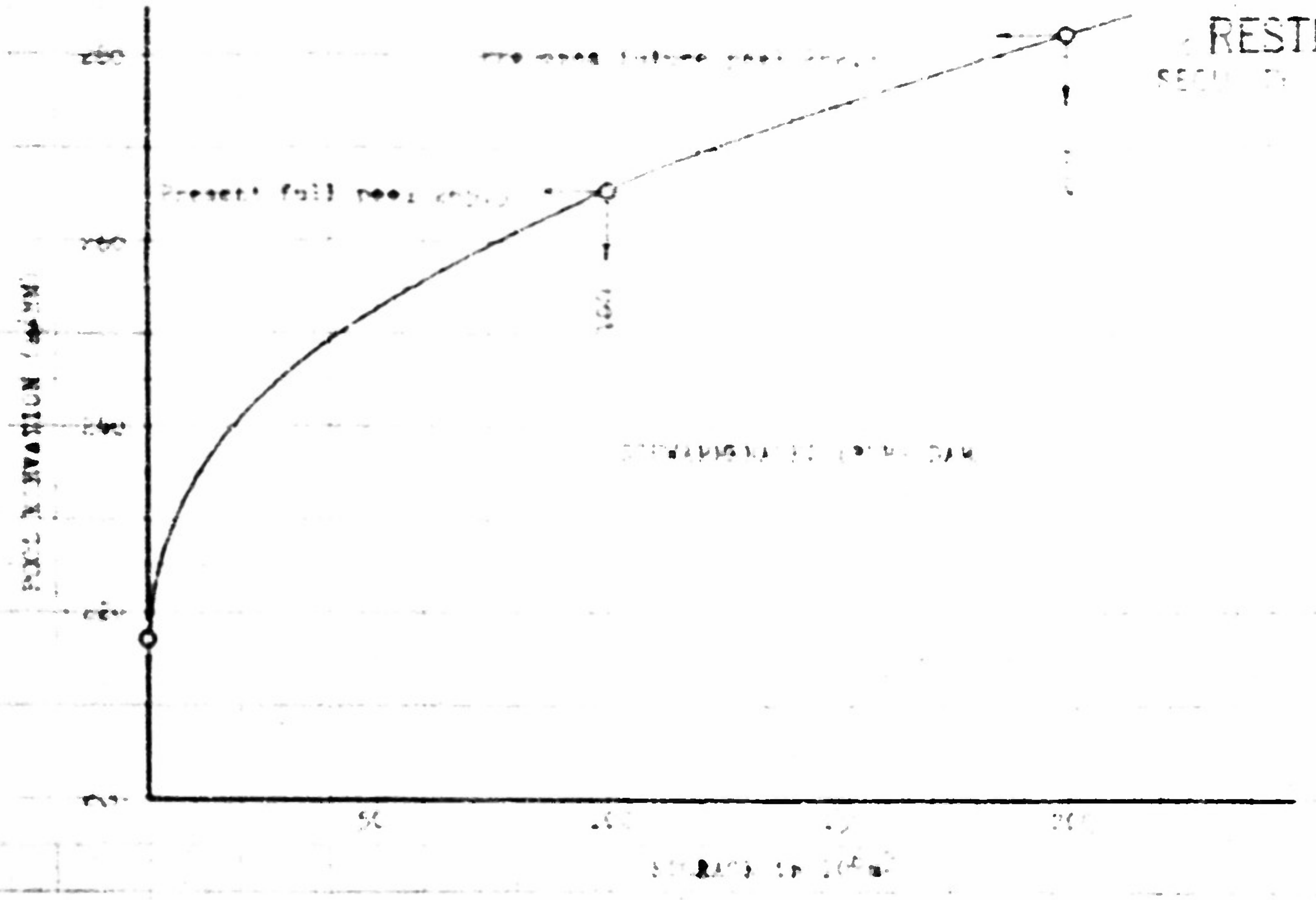
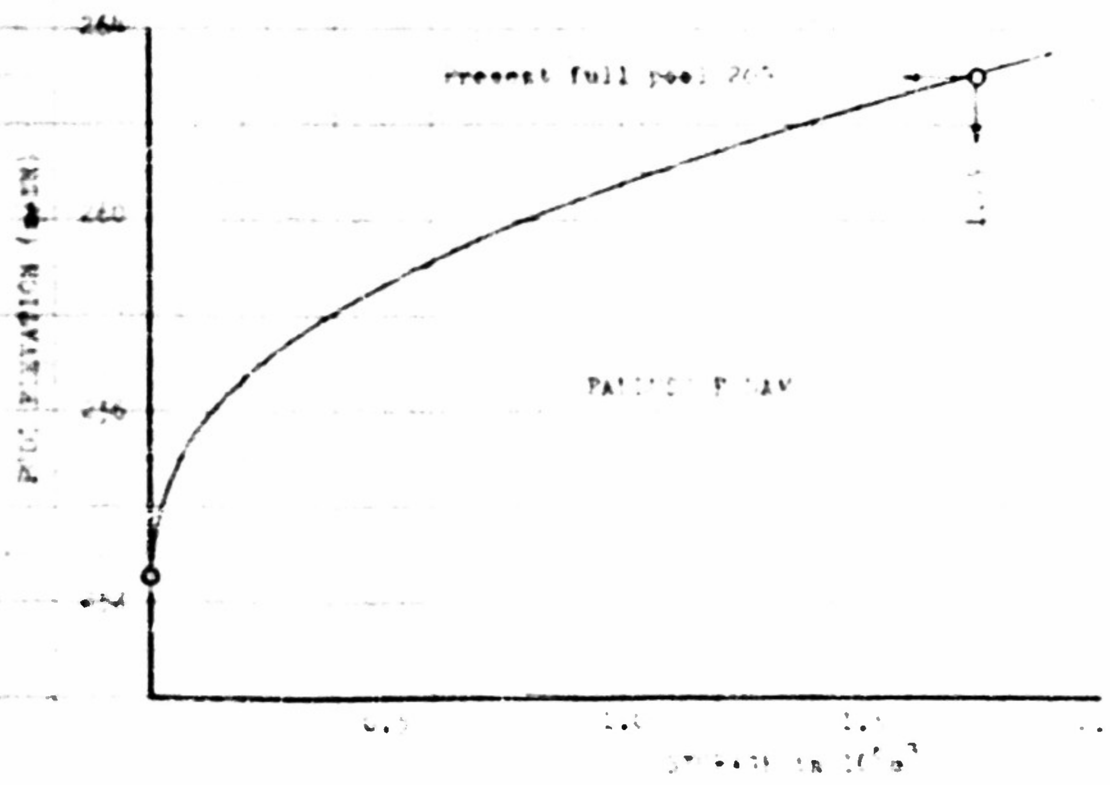
RUR (ROER) RIVER
INUNDATION BY STILLWATER BARRIERS

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by LB. Date Oct. 52
Drawn by LB. PLATE 14

RESTRICTED







NOTE: Storage curves were estimated by the method described in para. [illegible] are based on data cited in technical publications and designated as O

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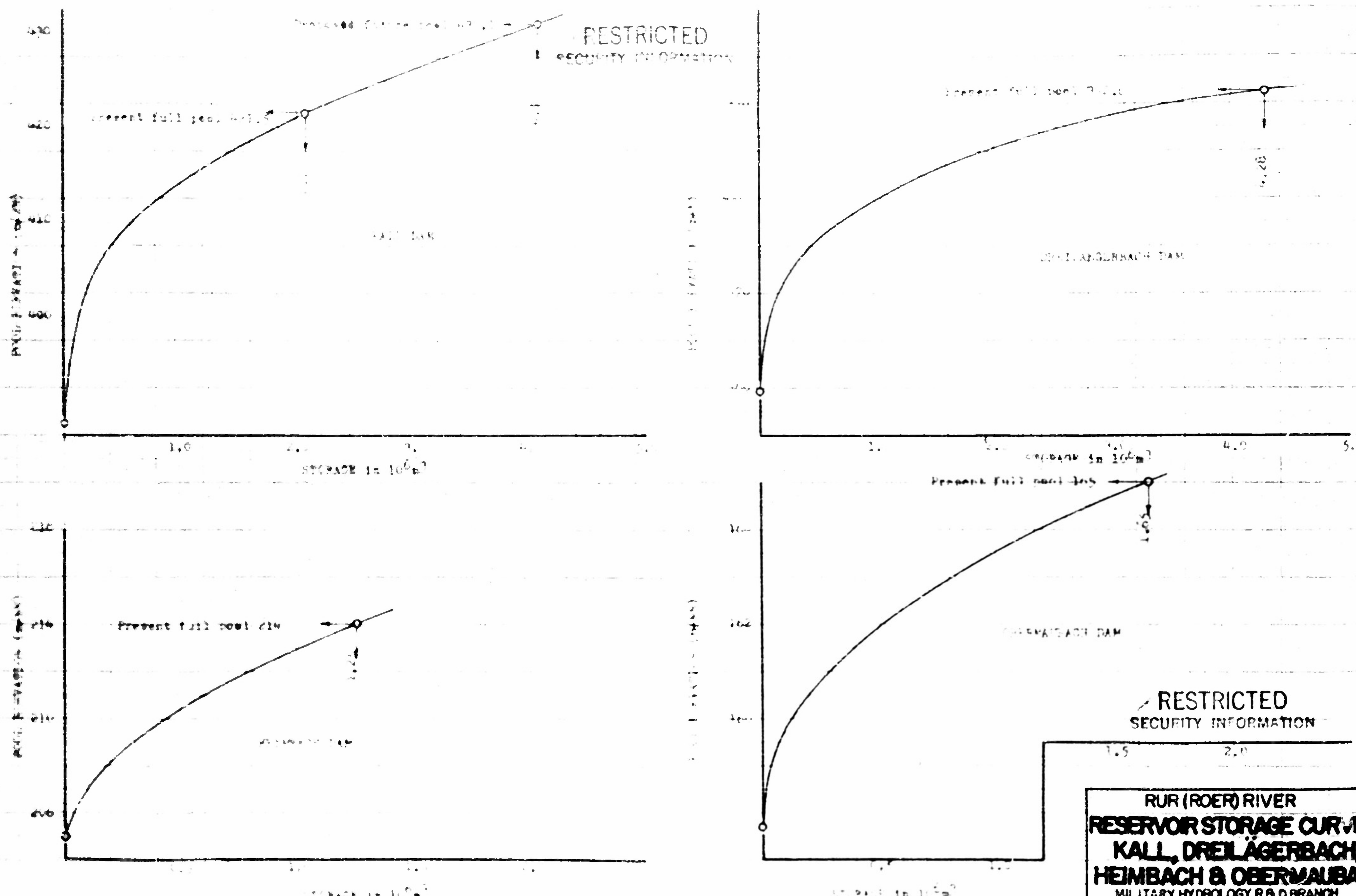
RUR (ROER) RIVER
RESERVOIR STORAGE CURVES
RUR, URFT & PAULUSHOF
MILITARY HYDROLOGY R&D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by ____ Date ____
Drawn by ____

PLATE 15



NOTE: Storage curves were estimated by the method [illegible] and are based on data [illegible] and indicated as O

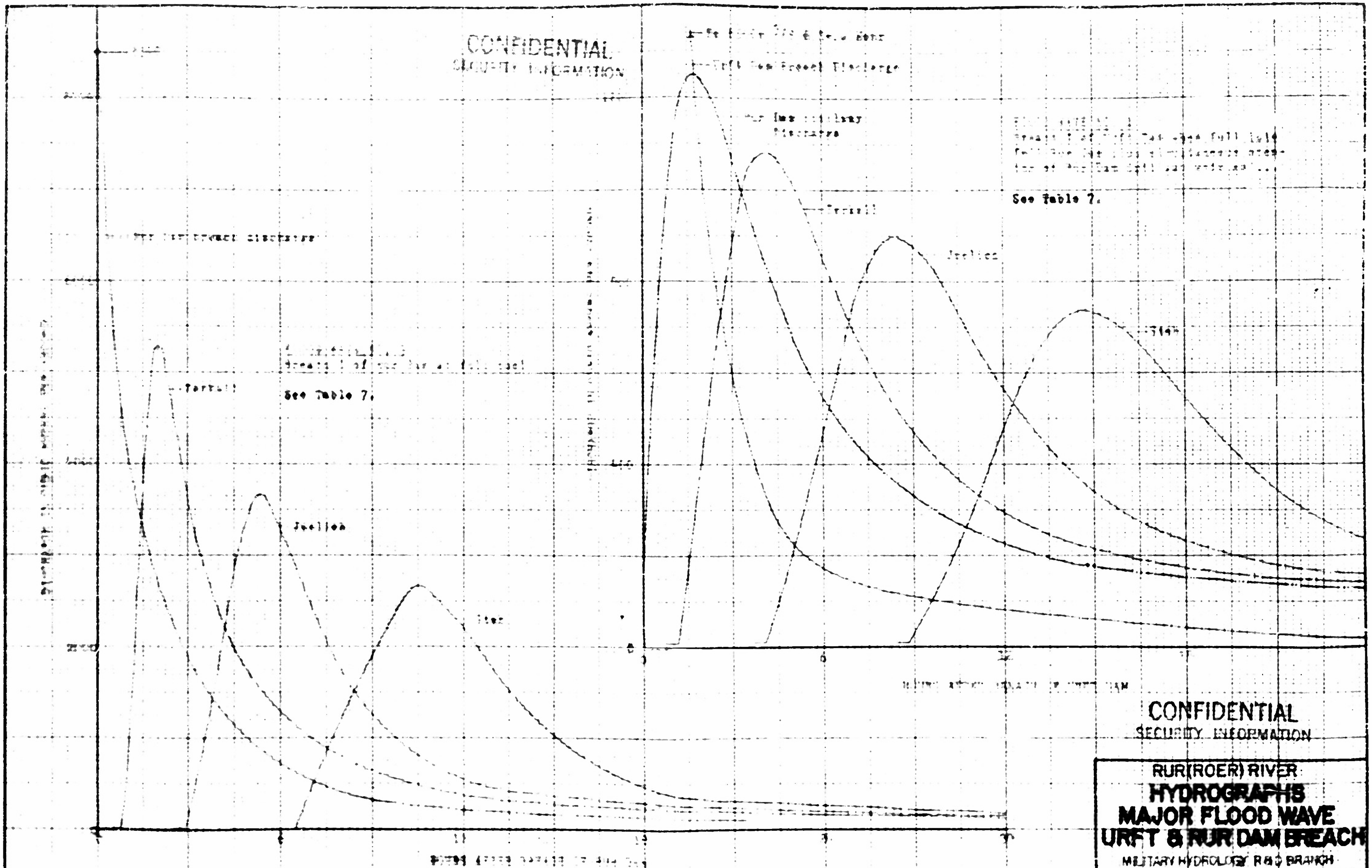
RUR (ROER) RIVER

RESERVOIR STORAGE CURVES KALL, DREILÄGERBACH, HEIMBACH & OBERMAUBACH

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS

Prepared by ______ Date ______
Drawn by ______

PLATE 16



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SECURITY INFORMATION

RUR(ROER) RIVER
HYDROGRAPHS
MAJOR FLOOD WAVE
URFT & RUR DAM BREACH

MILITARY HYDROLOGY R&D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by............ Date............
Drawn by............

PLATE 17

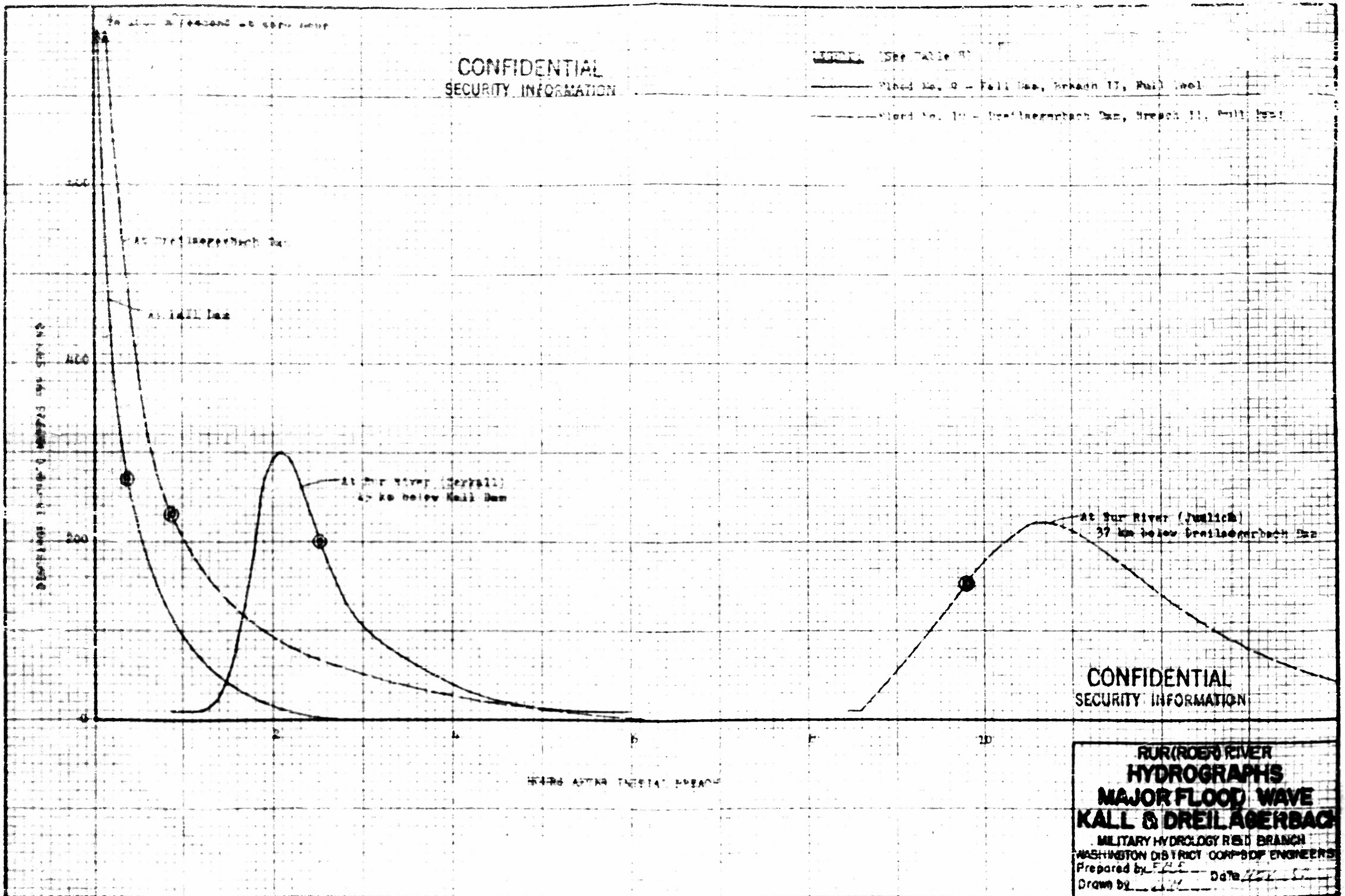

CONFIDENTIAL
SECURITY INFORMATION
At Kall Dam
At Rur River (Jeulich)
CONFIDENTIAL
SECURITY INFORMATION
RUR (ROER) RIVER
HYDROGRAPHS
MAJOR FLOOD WAVE
KALL & DREILAGERBACH
MILITARY HYDROLOGY R&D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by
Date
Drawn by

PLATE 18

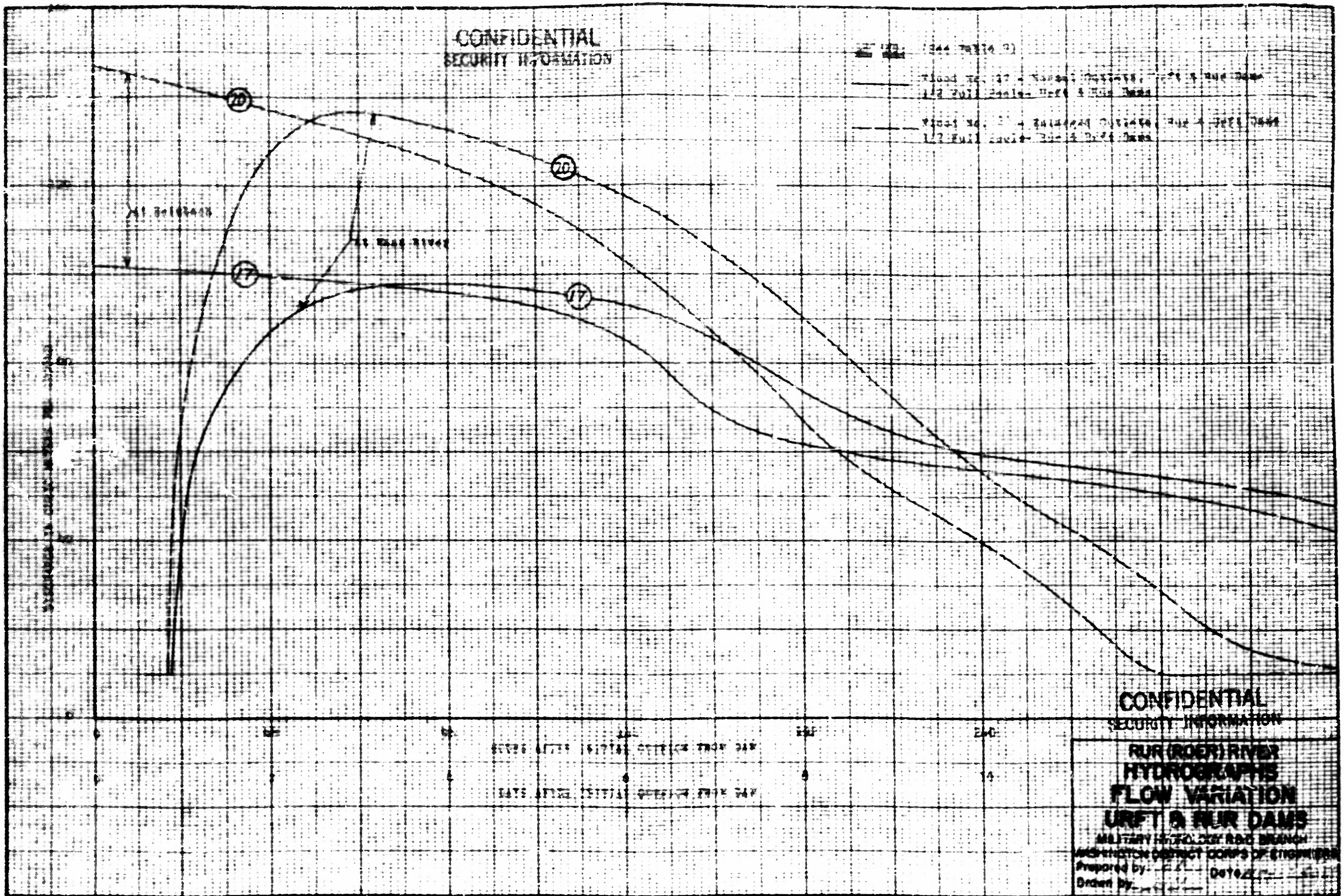
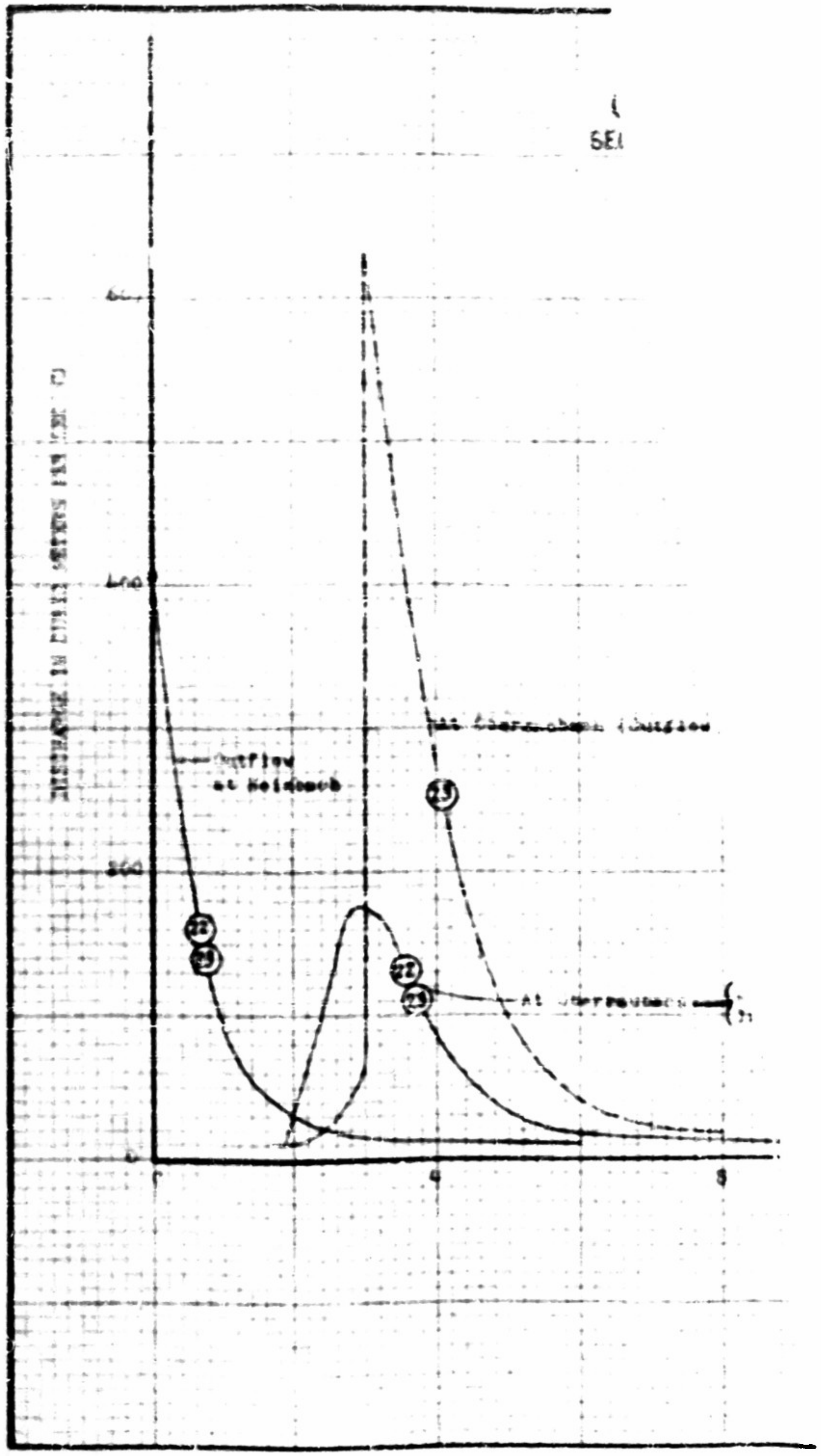
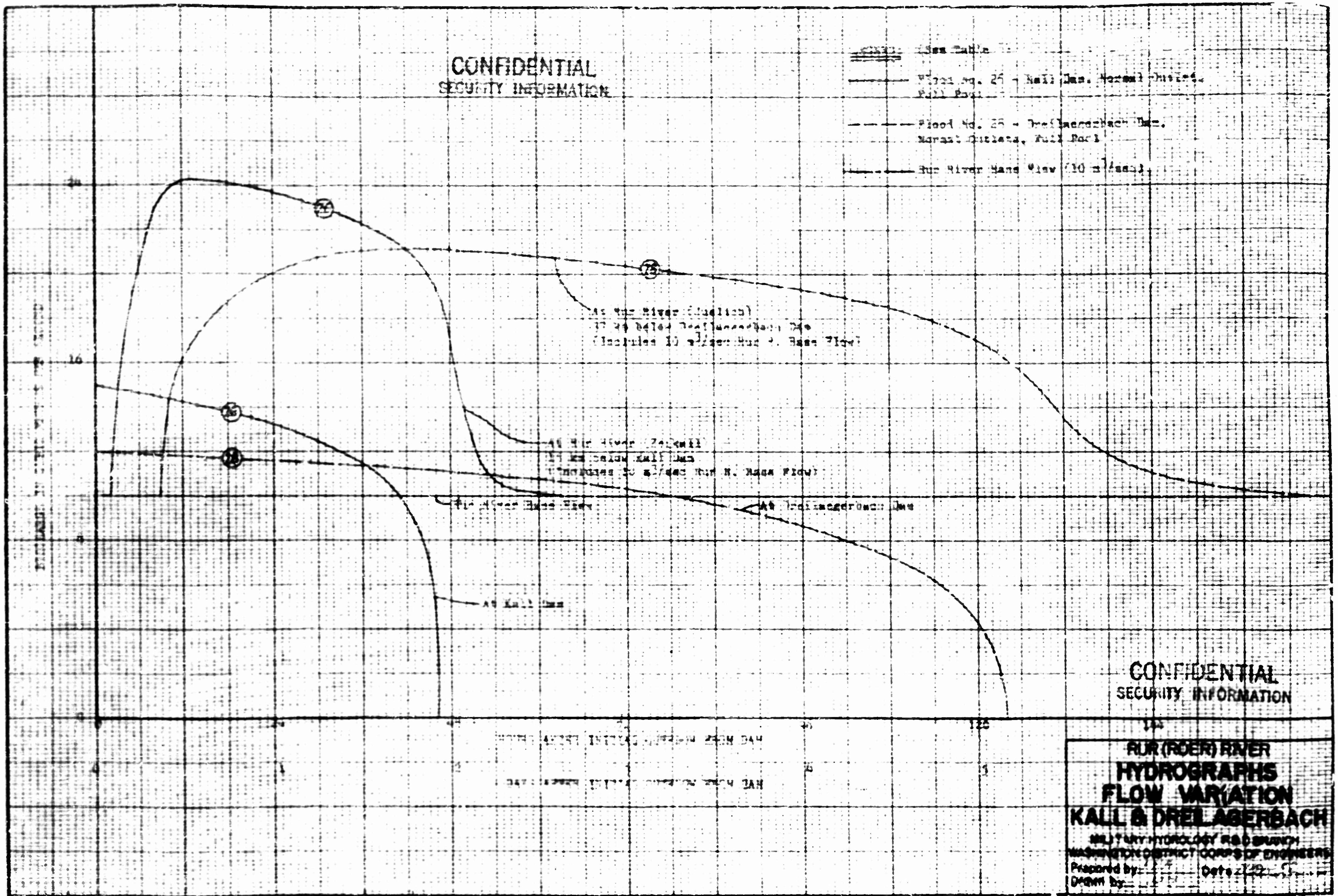

CONFIDENTIAL
SECURITY INFORMATION
(See Table 3)
CONFIDENTIAL
SECURITY INFORMATION
RUR (ROER) RIVER
HYDROGRAPHS
FLOW VARIATION
URFT & RUR DAMS
Prepared by:
Drawn by:
Date:

PLATE 19



Outflow
22
23
23
22
23
0
4
8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SECURITY INFORMATION
24
16
8
0
120
144
CONFIDENTIAL
SECURITY INFORMATION
RUR (ROER) RIVER
HYDROGRAPHS
FLOW VARIATION
KALL & DREILAGERBACH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by:
Date:
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PLATE 27

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EXHIBIT A

DESCRIPTION OF WATERCOURSE AND CONTROL STRUCTURES

THE RUR (ROER) AND URFT RIVERS*

*Abstracted and translated by Military Hydrology Branch, Washington District, Corps of Engineers, from "Stromgebiet des Rhein, Einwirkung auf die Wasserfuehrung" (Rhine River Basin, Influence of Flow). Military Geography ("Mil-Geo") Training Manual H. Dv. g. 34a. General Staff of German Army Section VI, Muenster 1939.

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12. THE RUR (ROER) AND URFT RIVERS

Stretch of river from the source to confluence with the Maas (Meuse) River.*

I. Short Description of the Watercourse.

The Rur (Roer) River rises in the Hocheifel (Hohes Venn) and flows as far as Kreuzau south of Dueren in mountain country, from there to Juelich in hilly country, and then to the German-Netherlands border in flat country. At Roermond in Dutch territory it empties into the Maas (Meuse) River. In the mountain country at low and mean water levels, wherever the Rur River is not dammed, it constitutes no obstacle because of its low discharge; the same is true in the hills and in the flat country as far as Linnich, because water is withdrawn into lateral industrial channels. Downstream from here to the border, mean water (MW) does not reach more than about 1m depth. The current velocity is considerable, since the fall amounts to 0.29% declining to 0.16%. At high water (HW) in the spring, the Rur River is a considerable obstacle because of its rushing current and bank overflows. Water depths at summer HW are at Zerkall 1.48m (70.9 m^3/sec), at Juelich 1.75m (130 m^3/sec), and at Stah 3.10m (140 m^3/sec); highest high water (HHW) at Zerkall is above 5.0m (567 m^3/sec), at Juelich 3.80m (400-500 m^3/sec) and at Stah 3.75m (400-500 m^3/sec). The larger tributaries are the Urft, the Kall, the Inde and the Wurm Rivers. At the mouth, the high water of the Maas River under certain circumstances, backs up 15 km into the Rur River. The normal length of the retention pond of the Maas River lock at Roermond is about 7.5 km.

II. Peacetime Regulation and Utilization of Discharge

The Rur River and its tributaries are not navigable — except for a short stretch in the retention basin of the Maas River at the mouth at Roermond harbor. The river is used for domestic and drinking water in the industrial region on the left bank of the Rhine River (Rur, Inde and Wurm River Basins, and the Aachen local district). The Urft Dam (No. 189) with 45.5 million m^3 storage capacity and the Rur Dam (No. 251) with 100 million m^3 storage capacity impound the flood water and release uniformly about 9 m^3/sec into the Rur River for power generation. In the equalizing basins at Heimbach (No. 242) with 1.25 million m^3 capacity and at Obermaubach (No. 234) with 1.5 million m^3 capacity, the water is again impounded and is supplied according to need to the downstream industries. In industrial canals (ponds) the water flows on both sides of the Rur River to the plants. Waste water returns to the channels and thus to the Rur River.

Independent of this water storage dam system, are the Kall Dam (No. 232) with 2.1 million m^3 capacity, and the Dreilaegerbach Dam (No. 66). The latter has a 4.3 million m^3 capacity and is connected with the former by means of a tunnel. These reservoirs supply the Aachen local district with industrial and drinking water. The fore-basin at Paulushof, (No. 394), has no practical significance. Building of additional water storage dams is planned (1939).

*NOTE: See plate 2 for geographical locations.

III. Wartime Changes in Discharge

1. Utilization for Warfare.

a. Reinforcement as an Obstacle.

The water supply of the reservoirs can be used to raise the level of the Rur River so high that it will have high water for a long time and will overflow its banks in places and become unfordable. The extent of the high water will depend on the available water supply in the reservoirs and the inflow from the tributary streams at the time. The reservoirs are generally only about 1/2 full from August to December, 4/5 full from April to June, and in the other months filled to 2/3 of their capacity. Only after a heavy rain or in time of melting snow do the dams run over. Since the Rur has a great fall and at high water levels a great velocity, fording becomes difficult even at a depth of 1.50m. Such a depth exists at summer high water with a discharge of 75 m^3/sec at Zerkall (mouth of the Kall River), river km 73.3; at a discharge of 100 m^3/sec at Juelich, river km 115; and even at 30 m^3/sec at [illegible]h, river km 154. Therefore, to produce a continuous water obstacle from the reservoirs to the Maas River a supply of 100 m^3/sec from the basins would be sufficient. The total volume of the reservoirs named amounts to about 160 million m^3. If half of this (80 million m^3) is available, then the flow of 100 m^3/sec would last about 9-1/2 days. With this discharge, bank overflows would occur over practically the entire [illegible]th. The depth in the river would then be 2.0m at Zerkall, 1.50m at Jue[illegible]h, and 2.70m at Stah. The flood will last longer if the reservoirs have been completely filled previously by well-timed closure of the outlets. The effect can be increased by closing the industrial channels or by short diversions into the Rur River and by barriers at the bridges. To release a discharge of about 100 m^3/sec from the basins, the following is necessary: release of about 22 m^3/sec into the Rur River from the fully feathered turbines of the Heimbach power plant of the Urft Dam (this water flows into the Heimbach Equalizing basin below the Rur Dam at Schwammenauel). The remaining water (78 m^3/sec) will be obtained from the Rur Dam which can furnish 90 m^3/sec.

The Kall Dam and the Dreilagerbach Dam will then have to be utilized only for increasing the duration of the flood. The equalizing basins at Heimbach and Obermaubach, and sometimes also the 4m high sluice-gate on the Rur Dam at Schwammenauel, can be opened suddenly in order to produce a short but high flood wave (500 m^3/sec) after complete filling of the basins. The effect of such a wave could be catastrophic. If the sudden release from the full equalizing basin at Obermaubach is synchronized to follow the entry of the flood wave from the basin at Heimbach, then the effect will be further increased. Such a wave lasts only a few hours, but can desolate the Rur valley entirely.

The foregoing measures can be executed only if the dams are not already in enemy hands, or if reclosing the opened discharges is prevented on abandonment of the dams (jamming of valves, or blasting of conduits).

By blasting one of the walls of the Rur and Urft Dams (possible in the inspection galleries), considerably greater destructive waves occur which would destroy everything in the densely industrialized valleys as far as the Maas River and on into Holland, endangering the population. The demolition of the Kall and Dreilagerbach Dams would cut off the drinking water supply to the entire Aachen district.

This threat (as described above) presented by the full reservoirs in enemy hands can only be obviated by timely release of water from the dams.*

b. Removal as an Obstacle.

The obstacle represented by the dammed stretches can be eliminated by releasing the water from the storage dams and basins. With a strong natural discharge in the Rur River by cutting off all discharge outlets of the valley dams and basins, the water level of the Rur River can be lowered for a time depending on weather conditions.

*Translator's note: i.e., prior to capture by the enemy.

DESCRIPTION OF WATERCOURSE

River km	Location	Map Ref.*	Ave. Width m	Aver. Depth m	NNW m/NN	MNW Elev. m/NN	MNW Dischg. m³/sec	MNW Max. Vel. m/sec	MW** Elev. m/NN	MW** Dischg. m³/sec	MW** Max. Vel. m/sec	High Water Level (HochW) Elev. m/NN	High Water Level (HochW) Dischg. m³/sec	High Water Level (HochW) Max. Vel. m/sec	Elev. m/NN	Stream Bed Data	Banks, Levees, Dikes, etc.	Remarks
0 to 12.8	1100 m east of Meste Rigt in Belgium to the German border		3.0 to 6.0	0.5	500.0	500.2	0.120	0.2	500.4	0.360	0.3	501.4	6.3	1.5	501.6	Upper course in the Hohes Venn. River bed firm bottom, clayey in part.	Banks marshy for the most part.	
12.8 to 40.7	Border between Belgium and Germany to north of Einruhr, end of pond of the Paulushof fore-basin		10.0	0.6	275.0	275.4	1.2	0.3	275.6	2.40	0.4	276.6	58	2.5	277.0	Mountain country River bed rocky, otherwise firm, with detritus.	Banks mostly vertical & firm; in the city of Monschau quay walls at both sides; narrow valley mostly steep slopes, high water overflows banks except at Monschau.	
40.7 to 44.9	North of Einruhr to the embankment and dam installation at Paulushof	394	Level raised from ±263.0 to ±265.5 NN. The Paulushof retention basin is the fore-basin for the Rur (Roer) dam at Schwammenauel, No. 251. Content 1.75 mill. m³													Mountain country.	Adjoining the basin, in which the level is almost always at the normal stage are steep and in part wooded valley slopes.	At km 44.65, mouth of the Urft 4 km upstream is the Urft dam from which most of the water is conducted to Heimbach by way of the power galleries of the Rur (Roer).

*See River Basin Map (Plate 2)
**See Table 2 for Definition of Terms

DESCRIPTION OF WATERCOURSE

River Km	Location	Map Ref.*	Aver. Width m	Aver. Depth m	NNW m+NN	Elev. m+NN	Dischg. m/sec	Max. Vel. m/sec	MW** Elev. m+NN	Dischg. m³/sec	Max. Vel. m/sec	High. Wat. level (Höchst) Elev. m+NN	Dischg. m³/sec	Max. Vel. m/sec	Elev. m+NN	Stream Bed Data	Banks, Levees, Dikes, etc.	Remarks
46.9 to 59.9	Embankment and dam installation of the fore-basin at Paulushof, to the embankment for the dam at Schwammenauel (at the foot of this embankment the contact of the Heimbach retention basin is to reach +214.00 mNN	251	17.0	0.5	215	215.4	1.4	0.3	216.0	3.6	0.6	216	90	3.0	218.5	Mountain country. River bed with firm bottom, partly rocky.	Banks in part vertical; in part sloping, but firm. Steep and mostly wooded valley slopes, with vertical rock formations reaching in places to the Rur (Roer). High water overflows the banks.	This stretch within the retention reach of the large Schwammenauel dam. Additional installations probably have been built.
59.9 to 63.3	Schwammenauel embankment to Heimbach dam wall and weir installation	262				Planned retention level +214.00 m+NN										Mountain c[illegible]. Pond area [illegible] the Heimbach equalizing basin.	Adjoining retention level, mostly wooded slopes.	See also list of dams and similar installations. Capacity to be 1.15 mill. m³. Into this retention basin the power galleries of the Urft dam empty at the right, at the Heimbach power plant.

*See River Basin Map (Plate 2)
**See Table 2 for Definition of Terms

River km	Location	[illegible]	Stream Bed Data	Banks, Levees, Dikes, etc.	Remarks
[illegible] to [illegible]	[illegible] to [illegible]	[illegible]	Mountain country. River bed firm [illegible] partly rock. Gravel deposits.	Banks partly vertical, partly sloping. Revetted at the Rur (Roer) railway embankment. Meadows, densely wooded slopes, occasionally steep. H.W. inundates the low-lying fields.	The Rur (Roer) is fordable at certain places if the water of the Rur is held back at Heimbach. On this river stretch the Kall empties at the left at Zerkall (km 78.3), on the upper course of which is the Kall dam. Discharge of the Rur below the mouth of the Kall can be increased by increasing the supply of water from the Kall dam. See list of dams and similar installations. No. 232.
[illegible] to [illegible]	about [illegible] north of [illegible], end of pond of the [illegible] retention dam, to the [illegible] retention dam and weir installation	[illegible] retention level [illegible]	Mountain country. Pond area of the [illegible] equalizing basin.	Adjoining the retention level at west and south, steep and wooded slopes, at east RR with steeply rising wooded slope, at north high farmland with RR.	See also list of dams and similar installations. Capacity 1.65 mill. m³.

[illegible]
[illegible]

River km	Location	Map Ref.*	Aver. width m	Aver. depth m	[illegible] mnh	Elev. mnh	Dischg. m³/sec	Max. Vel. m/sec	Elev. mnh	Dischg. m³/sec	Max. Vel. m/sec	Elev. mnh	Dischg. m³/sec	Max. Vel. m/sec	Elev. mnh	Stream Bed Data	Banks, Levees, Dikes, etc.	Remarks
83.9 to 89.3	[illegible] embankment and weir installation to the Kreuzau highway bridge		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.5	[illegible]	Mountain country. River bed: firm bottom, gravel.	Banks partly sloping, partly vertical with gravelly subsoil. Railway embankment in places reaching to the Rur (Roer) resetted. Adjoining flood area 100-[illegible] m is wooded and cultivated.	The Rur (Roer) is fordable at some places at low water.
89.3 to 92.8	Kreuzau highway bridge to Lendersdorf bridge		18 to 20	[illegible]	[illegible]	[illegible]	3.5	0.3	[illegible]	6.6 (without feed from the industrial channels)	[illegible]	[illegible]	244	2.5	[illegible]	Hilly country. River bed gravel, but firm.	Banks partly sloping, partly vertical, with firm gravelly subsoil. Flood area in the upper portion narrow, in the latter half, as much as 300 m wide.	At low water the Rur (Roer) is fordable. The industrial channels, 3 to 4 m, lying at both sides, have a disturbing effect.
92.8 to [illegible]	Lendersdorf bridge to the bypass of the [illegible] district [illegible] (east of Wiesemann factory)		26 to 30	0.5	117.2	117.3	3.5	0.3	117.5	6.8	[illegible]	119.0	247	2.0	119.5	Hilly country. River bed bottom gravel [illegible]. Bank slopes worn down, both firm.	Banks sloping with gravelly subsoil. Rur (Roer) regulated. High water does not overflow banks. At km station 96 + 600, a needle weir producing a rise of 1.20 to 1.50 m backs the water to km station 96.05.	The Rur (Roer) is fordable up to M.W. level. Industrial channels 4 m wide on both sides have a disturbing effect.

*See River Basin Map (Plate 2)
**See Table 2 for definition of Terms

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River km	Section	Max [illegible]	Aver [illegible]	Aver [illegible]	[illegible]	[illegible]	[illegible]	Max [illegible]	[illegible]	[illegible]	Max [illegible]	Elev.	[illegible]	Max [illegible]	Elev.	Stream bed Rur	Banks, terrain, dikes, etc.	Remarks
[illegible] to [illegible]	[illegible] to [illegible] bridge	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Hilly country. [illegible] bed bottom firm, gravelly.	Banks sloping or vertical, irregular and unstable. The Rur (Roer) flows through debris with scanty grass and old deposits. Below the Heven RR bridge the Rur is regulated to NW of Hirkesdorf. In this stretch high water does not over-flow the banks, else-where the flood area is about 400-500 m wide.	The Rur (Roer) is fordable at most places. The industrial channels 4 m wide at both sides have a disturbing effect. At km 113 & 150 at the left is the mouth of the tributary Inde.
113.2 to 126.0	Juelich-Kirchberg RR bridge to the [illegible] Rur bridge	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Hilly country. River bed bottom firm, gravelly banks irregular in part, gravel deposits	Banks partly slop-ing, partly steep. Banks are very ir-regular. From the Juelich-Kirchberg RR bridge to about 1 km below the Juelich highway bridge, the Rur (Roer) is regulated and on the right bank has a flood protection dike farther downstream of the Rur over-flows the banks for 300-500 m. At [illegible], dikes on both sides	Fordable at many places at MW level. On the left bank there is an in-dustrial channel 4 m wide.

[illegible] River Basin [illegible]
[illegible] Table [illegible] of Terms

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River km	Location	Map Ref.*	Aver. Width m		Levees, etc.	Remarks
126.0 to 146.5	Linnich Nur Bridge to Orsbeck Bridge		17 to 20		...tly steep. ...subsoil ...k col- ...k over- ... at dis- ...00 m³/sec. ...flood area ...-600 m ...Brachelen ...w the about wide.	On the left bank is the industrial channel from Linnich to Hilfarth. At Hilfarth is the left Nur (Roer) dike.
14[illegible].0 to 159.7	Orsbeck Bridge to the German-Dutch Border	230		0.[illegible] to 2.0	-	Fords in places at low water.

*See River Basin Map (Plate 2)
**See Table 2 for Definition of Terms

River km	Location	Bed	Banks, levees, slopes, etc.	Remarks
	River Urft			
0 to 14.0	West of [illegible] to [illegible] Bg. [illegible] of Hetterscheid	[illegible] with [illegible] covered [illegible]	Banks mostly vertical. Bank slopes of the Urft revetted with paving at the railway embankment. Narrow meadowland valley up to 100 m wide, adjoining gradually rising slopes. Meadow valley flooded at HW.	The Urft is fordable in places.
14.0 to [illegible]	Keller Bg., south of Hetterscheid, to north exit from town of [illegible]	[illegible] with [illegible] for [illegible] part [illegible] also [illegible], depth to [illegible] m.	Banks mostly vertical. Bank slopes of the Urft revetted with paving at the RR embankment. Adjoining the narrow meadowland valley are steep and mostly wooded slopes. HW overflows the banks.	Fording difficult
26.0 to [illegible]	North exit from [illegible] to [illegible] south of the [illegible]	[illegible] with [illegible] stone, deposits, [illegible] m.	Banks partly sloping, mostly vertical. The bank slopes of the Urft are revetted with paving at the RR embankment. In [illegible] there are [illegible] walls in places, otherwise meadows about 200-300 m wide, adjoining mostly wooded steep slopes, below [illegible] HW floods low-lying meadowland.	

[illegible] River [illegible] Map [illegible] Table [illegible] for definitions [illegible]

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River km	Location	[illegible]	[illegible]	[illegible]	[illegible], Levees, Dikes, etc.	Remarks
96.75 to 97.0	Town of Gemünd (mouth of the Olef) to end of pond of the Urft dam, about 500 m west of Malsbenden		10 [illegible]		[illegible] walls in Gemünd. Otherwise banks mostly vertical, irregular. The valley of the Urft as far as Malsbenden is fairly [illegible]. In [illegible] west of Malsbenden, [illegible] overflows the banks	At a few places above and below Malsbenden the river is fordable up to [illegible]
[illegible] to [illegible]	End of pond of the Urft dam to the dam wall	[illegible]	Planned retention level [illegible]		Pond area of the Urft dam. Adjoining retention levels are steep wooded and in part rocky slopes. No roads of vehicular access to the dam.	Capacity 45.5 mill. m^3. From the northernmost angle of the retention basin, the tunnel (2 km long) to the Heimbach power plant branches off (No. 180).
[illegible] to [illegible]	Dam wall to mouth into the Rur [illegible] of Paulushof.			Bed of the Urft [illegible]	Adjoining retention water levels are steep wooded slopes.	This stretch is flooded by the Paulushof fore-basin the level of which is [illegible] mm (No. [illegible]).

*See River Basin Map [illegible]
**See Table [illegible] for Definition of Terms
(1) As transcribed from original

LIST OF WEIRS AND DAMS

Place River km	Item No.	Installation Name & Purpose	A. Length of Head B. Altitude (Above SN) C. D. Width, Depth	Type of Structure & Dimensions A. Lock B. Dam C. Crossing	Effect: A. Fully closed B. Fully open C. Effect of A & B	Remarks
a. Below Gemünd in the Eifel b. River km [illegible] of the Urft, tributary of the Rur (Roer), mouth at km 50.96 of the Urft, km [illegible] of the Rur	105	a. Urft reservoir dam [illegible], power generation, regulation of discharge	a. [illegible] km b. [illegible] m c. Up to [illegible] m d. 55 m depth at the dam Content 51 mill. m^3, duration of emptying 12 hours, duration of refilling 1 year.	a. b. Curved wall of quarry stone, 300 m long, 5.15 m wide, 100 m wide at the bottom, bottom outlet 4 pipes. Capacity 30 m^3/sec to the Urft. In the galleries 2 pipes 1.5 m diameter, capacity 34 m^3/sec to the Heimbach power plant on the Rur (Roer) (No. 180). c. Highway bridge, Class II, 1.20 m, 2.5 m and 1.45 m.	a. Filling to overflow b. Emptying c. Consequences of (a): Power plant stops. Lack of water for the Duren industries. The Urft and the Rur cease to be obstacles below dam. Consequences of (b): During emptying, Urft and Rur obstacle effect increased, discharge 60 m^3/sec. After emptying, the basin and river are no obstacle. For emptying and refilling time, see Item 4.	With regard to Item 6b. On blasting of the full dam in the accessible discharge galleries: catastrophic flood as far as the Meuse. Arrival of the flood wave at the German frontier in about 20 hours. Destruction of all cities and crossings in the river valley, the Heimbach power plant (No. 180) (8 turbines, 13,400 kw) and the Juelich gas pipe line.
a. Fore-dam at Paulushof b. 64.9	[illegible]	a. Paulushof fore-dam b. Solely for enhancing beauty of landscape	a. b. c. 132 m d. 10.50 m at the dam	a. b. Earth embankment with 4 flood openings at NN+263.0 m, each [illegible] m long, and 1 shutter opening at NN+261.2 m, 5 m long, bottom outlet 1.5 x 1.0. c. Highway bridge, Class II, 0.75 m, 3.0 m and 0.75 m.	a. Filled: local obstacle. Emptied: no obstacle.	

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LIST [illegible] WEIRS AND DAMS

Place River km	Obj. No	Installation Name & Purpose	A. Length of Head B. Altitude (Above NN) C. D. Width, Depth	Type of Structure & Dimensions A. Lock B. Dam C. Crossing	Effect: A. Fully closed B. Fully open C. Affect of A & B	Remarks
a. Schwammenauel west of Hasenfeld b. 59.8	[illegible]	a. Rur reservoir dam at Schwammenauel b. Regulation of discharge, power generation, flood protection	a. [illegible] m b. Crown of dam [illegible] m Flood spillway [illegible] m wide c. [illegible] to [illegible] m d. 50 m at the dam Content [illegible] mill. m^3 duration of emptying [illegible] days, duration of refilling 14 years.	a. b. Earth embankment with concrete and steel core, [illegible] m long, width of crown [illegible] m, width at bottom as much as 298.05 m, with bottom discharge galleries outside the embankment, with gate on headwater side, 5.0 x 4.0 m, tailwater tubular closures [illegible] m diameter, [illegible] m diameter and 2,0 m diameter. Discharge 90 m/sec. In the embankment are inspection galleries 2.0 x 1.2 m and drainage galleries. Flood channel is cut off by shutters at NN261.50 m, therefore 4 m below the overflow spillway. c. Service bridge, [illegible] 1.5 m, 6.0 m and 1.5 m.	a. Filling to overflow. b. Emptying. c. Consequences of (a): Power plant stops. Shortage of water for the Dueren industries, if the Urft dam (No. 182) is also closed. The Rur is then no obstacle. Consequences of (b): During emptying the Rur becomes a reinforced obstacle, discharge 90 m^3/sec, then the emptied basin is no legal obstacle.	With regard to Item 3: Schwammenauel dam under construction, to be finished 1,37. Planned second improvement: increasing the height of the Schwammanetal dam by 18 m. Capacity then will be 200 mill. m^3. Power plant to begin service in 1939, 1 turbine, 10,000 kw, has the function of a peak load plant. The water from the dam can be used if necessary for filling small obstacles in the Rur valley. With regard to Item 6b On blasting the dam in the inspection galleries, catastrophic flood as far as the Meuse destruction of the cities of Dueren, Linnich, Juelich and Roermond, all bridges as far as the Meuse, destruction of the pipe line at Juelich, flood in the Meuse. On sudden opening of the gates of the flood run-off channel when the dam is completely filled, there is a discharge of 200-250 m^3/sec (Highwater discharge) for about 7 hours.

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LIST OF WEIRS AND DAMS

Place River km	Obj. No.	Installation (Name & Purpose)	A. Length of Pond B. Altitude (Above NN) C. D. Width, Depth	Type of Structure & Dimensions A. Lock B. Dam C. Crossing	Effect: A. Fully closed B. Fully opened C. Effect of A & B	Remarks
a. West of Heimbach b. 63.4	242	a. Equalizing basin at Heimbach b. Regulation of the discharge of the Rur	a. 3.4 km b. ∮214.0 m c. Up to 170 m d. 9.0 m at the dam Content 1.25 mil. m^3, duration of emptying 2 to 3 hours, duration of refilling 4 to 5 days under natural inflow.	a. 18.0 x 5.5 m b. Weir with large shutter opening 18.0 x 5.5 m and automatic steel flaps. In the first pier of the weir is a bottom outlet 1.5 x 0.8 m c. Footbridge 1.25 m	a. Filling to overflow b. Emptying c. Consequences of (a) and (b): No regulation of discharge; Dueren industries without adequate water.	With regard to Item 6: On demolition of the structure or sudden dropping of the gates by blasting the operating rods of the filled dam: catastrophic flood wave as far as the Meuse, 400-500 m^3/sec, tempered somewhat if the Obermaubach retention basin (No. 234) is empty, reinforced if the Obermaubach dam is suddenly opened at the time of entry of the wave. For effect in the Rur valley, see No. 251.
a. North of Hollenkreiten b. km 7.4 of the Kall, left tributary of the Rur (mouth) into the Rur, km 78.3)	232	a. Kall reservoir dam b. Drinking water supply, together with the Dreilaegerbach dam (No. 66)	a. 1.0 km b. ∮421.50 m c. 250 m d. 31 m at the dam Content 2.1 mill. m^3; duration of emptying 2 days, duration of refilling 4 to 6 months.	a. b. Earth embankment with concrete core, bottom outlet of 2 pipes 0.65 m + 1.0 m diameter, and inspection gallery in the embankment. c. Highway bridge, Class I, 4.50 m and 1.0 m wide.	a. Dam runs over b. Dam runs dry c. Consequences of (a) and (b): Run-off into the Kall without damage, Drinking water supply in the Aachen local district complicated.	With regard to Item 6: On blasting the full dam in the inspection gallery: catastrophic flood in the Kall and Rur valleys from Zerkall to the Meuse, duration 24 hours (No. 251). The flood wave is influenced by the Obermaubach dam (No. 234). The water from the dam can be used if needed for filling small obstacles in the Rur valley.
a. Between Obermaubach and Zerkall b. 83.9	234	a. Obermaubach retention lake b. Regulation of discharge	a. 3.4 km b. ∮165.0 m c. 390 m d. 7.33 m at the dam Duration of emptying 4 to 5 hours, duration of refilling 4 to 5 days with natural inflow.	a. b. Earth embankment with clay packing, 2 flaps 18.0 m and 8.0 m, 4 m high, at 161.0 m above sea level, bottom outlet 1.0 x 1.5 m. c. Highway bridge, Class II, 3.50 m and 0.75 m.	a. Dam runs over b. Dam runs dry c. Consequences of (a) and (b): No regulation of discharge. Interference to the water supply of the Dueren industries.	With regard to Item 6: On blasting the operating rods of the flaps of the full dam or sudden dropping of the flaps: catastrophic flood wave as far as the Meuse, 500 m^3/sec, reinforced if the Heimbach dam (No. 242) or the Kall dam (No.65) are so destroyed as to make the flood waves coincide; duration about 20 hours. For effect in the Rur valley, see No. 251. Water from the dam can be used if needed for filling small obstacles in the Rur valley.

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LIST OF WEIRS AND DAMS

Place River km	Obj. No.	Installation (Name & Purpose)	a. Length of Pond b. Altitude (above NN) c. Width, Depth	Type of Structure & Dimensions A. Lock B. Dam C. Crossing	Effect A. Fully closed B. Fully open C. Effect of A & B	Remarks
a. North of Roetgen b. km 5.7 of the Dreilägerbach, tributary of the Vicht, which is a left tributary of the Inde, which is a left tributary of the Rur (mouth into the Rur, km 112.86)	66	a. Dreilägerbach reservoir dam b. Drinking water supply together with the Kall dam (No. 232) for the Aachen local district waterworks.	a. 2.0 km b. 432.60m c. up to 400m d. 21.6m at the dam Content 4.[illegible] mill. m³, duration of emptying 48 days, duration of refilling 6 to 10 months.	a. b. Solid concrete wall with quarry-stone facing. Bottom outlet: 1 pipe of 1 m diameter; driving conduit, 1 pipe of 0.50m diameter. Inflow from the Kall dam (No. 232).	a. Dam runs over b. Dam runs dry c. Consequences of (a) and (b): Drinking water supply of the Aachen local district interrupted. Damage considerable.	With regard to item b: On blasting the full dam in the outlet galleries catastrophic flood wave through the Vicht, Inde and the Rur to the Meuse, duration a few hours, destruction of communities and all bridges. Aachen local district without water supply for a long time. The water from the dam cannot be used for filling small obstacle ponds in the Rur valley.

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EXHIBIT B

ABSTRACTS OF GERMAN TECHNICAL LITERATURE

ON

RUR VALLEY DAMS*

PAGE

*Abstracted and translated by Military Hydrology Branch, Washington District, Corps of Engineers from German technical literature cited by number in the Bibliography at the end of the text in the main body of the report.

RUR RIVER DAMS

1. General (References 5, 6, 11, 12, 13 and 16)*

The flow of the Rur River is regulated and controlled by the following storage dams and hydraulic installations, located on the Rur River and on its tributaries, Urft, Kall and Vicht Rivers.

a. Schwammenauel Storage Dam, capacity 100 x 10^6 m^3, built 1935-1937

b. Paulushof Auxiliary Dam

c. Urft Valley Dam, capacity 45.5 x 10^6 m^3, built 1904

d. Heimbach Equalizing Pond, capacity 1.25 x 10^6 m^3,** built 1933-35

e. Obermaubach Equalizing Pond, capacity 1.65 x 10^6 m^3,** built 1933-35

f. Dreilaegerbach Storage Dam, capacity 4.28 x 10^6 m^3, built 1909-11

g. Kall Storage Dam, capacity 2.1 x 10^6 m^3, built 1934-36

The dams are sometimes called collectively "Eifeltalsperren" (Eifel Valley Dams).

The four installations (Schwammenauel, Urft, Heimbach, and Obermaubach Dams), located on Rur and Urft Rivers, are interlocked into one hydraulic system, serving to protect the Rur River Basin against damaging flood high water, as well as providing water supply to the industrial region between Dueren-Juelich, during dry summer months.

The Dreilaegerbach and Kall Dams are interlocked in a separate hydraulic system, the primary purpose being to provide the drinking and industrial water supply for the industrial district of Aachen. In addition, their water storage can be exploited independently by the release through Kall and Vicht Rivers to influence the flow of the Rur River.

*Reference numbers listed in the Bibliography of report.
**Capacities quoted in various sources for d. and e. vary from 2.80 x 10^6 to 3.50 x 10^6 m^3 for the combined capacities of the two ponds.

The hydrologic conditions of the drainage areas of the Rur and Urft Rivers are characterized by the density of forests and the intensity of precipitation.

The balance sheet of precipitation, runoff, and losses for the watershed of Rur River, including Urft, referred to Heimbach, is outlined in Figs. 1, 2, 3, of Reference 6.

On the average, the precipitation in this area is evenly distributed throughout the year and amounts to 30.7 liter/sec/km^2 in the period November-April, and 30.0 liter/sec/km^2 between May-October. The evaporation and percolation losses average 13 liter/sec/km^2, but vary considerably throughout the year. In the winter period, the losses are very small and in some instances reach a negative magnitude. This is probably due to release of storage from the extensive moorland region in the headwaters, and to the frequent snowfalls. Conversely, during the growing season, due to the large extent of the forested areas, the losses will vary sharply and will reach (usually in July) the highest average value of 28.2 liter/sec/km^2.

In the winter months, the runoff greatly exceeds the limits of required needs and possible utilization, and damaging floods do then occur. In the summer months, runoff is only 6-7 liter/sec/km^2, which is not enough to cover the industrial needs of the area.

It was established that approximately 9 m^3/sec are needed in the industrial regions below Heimbach. This corresponds to a needed storage capacity of 150 x 10^6 m^3, which is approximately 42 percent of the average yearly inflow. This storage is supplied by the Schwammenauel and Urft Dams and by the equalizing ponds at Heimbach and Obermaubach, described above.

2. SCHWAMMENAUEL (RUR) DAM
(References 5, 6, 7, 8, 11, 12, and 13)

a. Structure of the Dam.

Originally the dam was planned for a storage capacity of 200 x 10^6 m^3. Actually it was built for only 100 x 10^6 m^3, but it may at any time be extended as planned. (See Plate 7 in report and Reference 6).

The dam is a gravity earth dam. This type of dam was chosen because of considerable loam deposits near the selected location of the dam. The quarries which could supply the concrete ingredients, gravel and rubble were lacking. The cross-section of the dam is very diversified as to the structural material used. The most important part of the dam structure is a very solid loam apron, 40 m wide at the bottom, which has the role of sealing the dam.

The dam is constructed without a rigid core reaching up to the crest as is usually the case of most combined gravity dams. The idea of the planners was to make the structural components of the dam pliable, as far as possible, in order to achieve the greatest possible adjustment of various materials used for the dam construction. They reasoned at the same time that the rigidity of a concrete core would prevent the balancing of the enormous forces inside the dam necessary for settlement of the varieties of structural layers forming the dam.

The only part rigidly connected with the ground is the foundation "socle," which extends 5 m into the solid rock. The rock is supposed to create an impermeable hydraulic water seal. The rock is built up to the normal terrain level. (Reference 12).

An inspection gallery, 1.40 m wide and 2 m high runs through the rock and serves for observations of possible water seepage and for any required repairs of the sealing material.

On the "socle" is a 12 m high concrete wall separated from it entirely by a joint. This joint consists of 0.002 m thick iron sheet between two bituminous layers. (Reference 12). The construction of the joint is such as to permit the shifting, as well as possible tipping, of one body (socle) against the other (core), during the settling of the various materials forming the dam.

Joined to the top of the concrete core is a dividing wall of steel sheet piles consisting of horizontal strips welded longitudinally together out of 12 m long elements. (See Plate 7 and Reference 12). The lock joints of the strips are filled with a bituminous material and the surface of the steel wall covered with bitumen to prevent leakage.

b. <u>Operating Installations of the Dam</u>.

(1) These installations consist of:

(a) <u>Pressure Tunnel</u> - with appropriate closing mechanisms and fittings for utilization of flow for power generation, water supply, etc.

(b) <u>High water Spillway</u> - (See Plate 7 of report and Reference 6).

(2) <u>The pressure tunnel</u>, 360 m long, served as a by-pass conduit during the period of the dam construction. The circular cross-section of the tunnel has [illegible] m clear diameter.

The mountain rock, through which the tunnel was drilled, is predominantly solid Devonian schist, with inlaid greywacke strata of varied thickness. Inside, the tunnel is reinforced by 0.30 m concrete masonry for protection against the natural rock and also to secure the smooth operation of the flow. Along an approximately 50 m long portion of the conduit, where it passes through a greatly depressed clay slate, the protective concrete masonry is reinforced to 0.60 m thickness. In addition, a 0.05 m thick "torkret" coating with steel netting is added in order to avoid possible water seepage. (See Plate 7 of Report).

The entrance to the tunnel is equipped with a gate, 4 m wide, 6 m high, which may be rolled on a sloped track. This is an emergency closure in case the conduit would require inspection while the reservoir is filled.

When open, the gate is located above the reservoir stage and can be lowered into closed position along the track, sloped along the reservoir embankment. The rollers of the gate and the hoisting mechanism are so dimensioned that the closure and opening of the 24-ton heavy gates can be achieved only when the pressure on both sides of the gate are nearly in equilibrium. Consequently, the valves in the downstream portion of the tunnel must be closed and the penstock filled in order to operate the entrance gate.

Two valves, fitted in the upper part of this emergency gate, permit some flow to enter the tunnel when the gates are closed. The opening of the valves is accomplished by a slight pull on the gate pulling cord. The closure is then affected by means of a spring mechanism.

The fine rack with 0.04 m clear width between the bars, has a movable upper part which may be lifted by hooking it on the gate. (Reference 6). The rack weighs 21 tons. By rolling a separate truck on wheels with very wide flanges, the rack may be lifted above the open portion of the gate. By means of either the gate or the rack truck, the rack may be moved in its operating closed position in front of the gate. For operation of the gate and rack, a power-hoisting mechanism and an auxiliary hand mechanism are provided.

On the outlet side, the tunnel ends in a 50 m long concrete plug into which are fitted the pipelines. A 20 m long transition of 3.80 m diameter joins a "Y" piece with 2.0 m and 2.50 m diameter branches equipped with built-in Venturis. (See Plate 7). From the left (*) pipeline, branches another 2.30 m diameter pipe leading to the turbine and powerhouse. All 3 pipelines are equipped with butterfly valves for emergency closure. The two water supply lines have the flow controlled by ring valves. Both lines are of 2.00 m diameter.

*Apparently from the 2.50 m diameter pipe

The outlets have, together, a capacity of 80 m^3/sec according to Reference 6. However, Reference 13 cites a capacity of 2 x 35 m^3/sec for the 2 ring valves at 45 m head.

(3) The highwater spillway, constructed as a fixed overflow weir, has a capacity of 450 m^3/sec at 1.50 m head on the crest. This capacity is considerably greater than any known floods on the Rur River. The spillway capacity corresponds to 1500 liter/sec/km^2 runoff from the 300 km^2 drainage area of the Rur River at the dam. The drainage area of the Urft River, which is controlled by the Urft Dam, is not included in that runoff value. (Reference 13). At the 267.00 m/NN elevation (265.50 m/NN normal stage plus 1.50 m head) the surface area of the reservoir is slightly over 5 x 10^6 m^2. An additional 2 m head, up to 269.00 m/NN (the elevation of the crest of the dam) is available.

The spillway has a "hairpin" form, in order to achieve the required overflow crest length of 95.0 m. Adjacent to the overflow, there is a 9.00 m wide weir opening provided with a double tapered gate 5.5 m high. By means of this gate, the 23 x 10^6 m^3 flood protection storage of the reservoir can be released even when the main outlet of the reservoir would be inoperative because of failure of the tunnel release mechanisms. The gate is automatically opened when the stage reaches 0.50 m above the fixed spillway elevation of 265.5 m/NN.

The weir opening has a capacity of 250 m^3/sec at a reservoir level of 265.5 m/NN (the elevation of the fixed spillway crest). This means that in the rare case in which the stage of the reservoir would rise over normal despite the gate being open, then at 1.50 m head on the spillway, the total discharge would amount to 750 m^3/sec.

The flow over the spillway and through the weir, passes down a 300 m long chute into the lower pool. A special stilling-basin structure, consisting of 2 basins, (one with +208.00 m/NN, and the other with +210.0 m/NN bottom elevations) dissipates the energy of the spillway flow. The normal stage of the lower pool has an elevation of 214.00 m/NN. The lower stilling basin has an end sill with 3 underwater openings. The combined flow through these openings and over the sill, braked down considerably by the water cushion of the basin may pass without turbulence over the downstream end of the concrete stilling basin. The crest of the basin sill is slightly higher than the bottom of the nearby Heimbach Equalizing Pond.

3. PAULUSHOF AUXILIARY DAM (References 5, 6, 11, 12, and 13)

The 30 km long Schwammenauel Lake is crossed at its upper part by a masonry overflow weir, known as Paulushof Dam.

It has not any special hydraulic purpose and was supposed to contribute to the natural beauty of the region. (See Plate 8).

However, this auxiliary dam was used extensively during the reconstruction period of the Schwammenauel Dam in the 1945-46 period.

4. URFT DAM (Reference 4).

The drainage area of the Urft River at the location of the dam is 375 km^2. According to 12 years of observations in the period 1888 to 1899, the mean yearly runoff of this area amounted to 160 million m^3, which corresponds approximately to 3 times the storage capacity of the dam.

In figure I of Plate 6 of the report and figure 2 of Reference 4, is shown an earth cofferdam which was used for damming of the Urft River during the construction period. This cofferdam diverted at the same time the flow of the Urft to a 140 m long tunnel, to keep the construction location dry. The discharge capacity of this tunnel was approximately 100 m^3/sec, corresponding to the maximum recorded HHW. This tunnel is retained in the present structure as a relief outlet as further described.

The dam has a maximum height above the foundation of 58 m, a crest width of 5.5 m, a maximum base width of 50.5 m. The crest length is 226 m, along an arch of 200 m radius. The maximum damming depth over the valley floor (elevation 270.0 mAHN) is 52.5 m (elevation 322.5 mAHN). The wall is protected on the reservoir side by an earth filled slope, paved on the surface, up to 34 m above the foot of the dam.

The dam structure is constructed out of clay-slate and has a graywacke facing 1 m thick on the reservoir side. On the inside of the graywacke facing, there is a 2.5 cm thick cement-trass coating and a bituminous coating for protection against leakage of water out of the reservoir. At intervals of 2.33 to 2.56 m, we find double drains of 6 cm diameter, made out of clay pipes which join the 15 cm diameter main drain, running along the wall.

The outlet structure of the dam consists of 2 bottom relief outlets constructed as vaulted masonry culverts. In these culverts is built a 60 cm diameter pipeline equipped with a valve operated through shafts which extend in towers to the elevation of the dam crest. The top of the towers are connected to the roadway on the crest of the dam by means of a service bridge.

The tunnel, which was used during the construction period, serves as an additional relief outlet and permits complete emptying of the reservoir. This tunnel is drilled in the rock and is provided with a concrete plug 24.35 m long through which pass 2 pipes each of 70 cm diameter, and equipped with valves. The tunnel is lined and has a masonry portal at both ends.

The spillway has cascaded steps on its downstream side, and is 90 m long and of particular and unique construction. (See Plate 6 and Reference 4). It consists of a fixed weir of a wave-shaped form in plan view. The crest is at 322.5 mAN which corresponds to the normal stage in the reservoir. The pillars carrying the bridge are 1.00 m wide and the clear width between them is 7.00 m. Some of the bays (number not given), are equipped with a sluice, which has a bottom elevation of 320.00 mAN. The sluices are closed by a gate operated from the service bridge and serve for release of small volumes of water.

The penstock tunnel is 2,800 m long and is pierced through a clay-slate rock. It has a 6.14 m^2 clear cross section area. The gradient of the 2800 m long tunnel towards Heimbach is 2 m. However, the total head brought to the turbines in Heimbach Power plant is approximately 110.00 m.

5. HEIMBACH WEIR (Reference 11).

The Heimbach control structure consists of an 80.0 m long and up to 14.0 m high concrete gravity dam and a movable weir. The weir structure (which is of the same type as the weir at Obermaubach) makes possible a very accurate control of flow for industrial purposes. It also provides an automatic, reliable and fast discharge for floodwater. The weir opening is 18.0 m wide. The closure is a submergible flap-gate hinged at the bottom of the of the opening, which may be dropped to the bottom for the release of high water, or raised to its normal position in which the damming head is 5.50 m. Structurally, the gate is developed as a movable, torsionproof, fishbellied flap, operated by means of a gear mechanism. The complete and fast opening for passing of flood water is achieved by a hydraulic device, operating automatically without any additional power or manual regulation when the stage in the upper pool reaches an established high water stage. (See Plate 8).

Besides the movable weir, a small bottom opening 1.0 x 1.50 m in the side pillar provides for releases of small quantities of water and emptying of the pool.

6. OBERMAUBACH WEIR (Reference 11).

The Obermaubach control structure consists of a 200.0 m long earth dam, of 5.0 m mean height plus a movable weir, built on the left side of the dam. (See Plate 8 of report and Figures 7-10 of Reference 11). The movable weir is of the same type as at

Heimbach and regulates the flow very accurately and provides for quick opening in the case of floods.

The weir opening is 36.0 m wide. The closure is a two-part, submergible flap gate (each part 18.0 m long) hinged at the bottom of the weir opening. Each half of the gate is movable by means of a gear mechanism located in each side pillar. Because of the considerable torsion stresses, the structure is built with a fish-bellied cross-section. The height of the gate is 4.0 m.

The complete opening of the gate, by dropping it over the crest of the weir, for passing the high water, can be achieved automatically, without additional power or manual regulation by means of a hydraulic device, which goes into operation at the moment the upper pool reaches the high water stage. Similar to Heimbach Weir, there is a bottom outlet 1.0 x 1.5 m in the left pillar permitting a release of small volumes of water and emptying of the pond.

The water discharge is regulated so that only approximately 3-4 m^3/sec are released during the period in which the downstream industrial plants are not in operation. During the operation period, the discharge is increased to at least 7 m^3/sec according to the water requirements.

7. DREILAEGERBACH DAM (References 9, 10, and 15).

The dam was built in the period 1909-1911 and placed into full operation in 1912. It was erected for the purpose of supplying water for the Aachen industrial district. In addition to the city of Aachen, this district contains numerous industrial settlements including the coal mines on the German-Holland border, as well as the Holland cities of Kirchrath and Vaals. The capacity of the dam is 4.28 x 10^6 m^3.

The natural drainage area of the Dreilaegerbach Dam is only 10.95 km^2. This was artificially increased in 1918 and 1920 to 22.93 km^2 by construction of 2 drainage channels, which intercept the flows of numerous small streams in an area of high precipitation. These channels are called the Schleebachhanggraben and Hasselbachhanggraben. The mean yearly precipitation of this drainage area is 1.026 m.

In 1924 to 1926, the drainage area of the Dreilaegerbach Dam was further artificially increased by means of the construction of the socalled "Kall Tunnel" (Kall Stollen). This is a 6,241 m long tunnel, having a clear cross-section area of 5.7 m^2, and which collects the discharges of the Upper Kall River. The drainage area of the Kall River above the site of the tunnel entrance is 28.6 km^2 and has a mean yearly precipitation of 1.053 m. The total drainage area of Dreilaegerbach Dam was thus increased to 51.53 km^2.

In order to secure the water supply out of the upper Kall River drainage area, it was decided to build a dam — (Kall Dam) near the entrance to the tunnel. This dam was built in the period 1934–1936. The capacity of the Kall Dam is 2.1 x 10^6 m^3. Provisions are made for future increase of capacity to 4 x 10^6 m^3. The Dreilaegebach Dam is a gravity type dam and is built in an arch form of 350 m radius. The crest is 3 m wide, and 240 m long. The crest elevation is + 393.00 mAP (33.0 m over the floor of the dam). At normal stage, the reservoir area is 0.4 km^2. (See Plate 9 of the report and Figure 2 of Reference 9).

On the south side, the dam extends over a ridge in the form of a dam wing, along which is located the spillway. The spillway is a Heyan type siphon. It has 5 openings, each 1.42 m wide. The entrance openings have staggered elevations; the difference in elevation between two adjacent openings is 0.01 m. The capacity of the siphon at 0.07 m head is approximately 14 m^3/sec. The free board of the spillway is 0.33 m while the dam itself has a free board of 0.98 m. In addition to the siphon, the release structure has a 3-part sluice gate 7.10 m wide and 0.60 m high. In an emergency this can carry 7 m^3/sec through a chute into the Schleebach. Plate 9 of this report and Figure 3 of Reference 9 show the connection of the dam with the release tower and bottom outlet.

The bottom outlet pipe is 1.0 m diameter. At full head, the discharge capacity is 12 m^3/sec. Actually, this discharge cannot be achieved on account of faulty construction of the wedge action valve. Dangerous vibration is generated at approximately 0.20 m opening.

The bottom outlet pipe has a cross-connection on the upstream side with an outlet conduit of 0.5 m clearance. The release tower has two operating mechanisms, the upper one being used as long as possible for withdrawal of drinking water.

The negative pressure is measured in the bottom outlet tunnels on the upstream side of the dam, at three locations 8.60 m, 12.20 m and 16.7 m from the foot of the wall. Taking into account the 37.10 m head on the foundation floor at the maximum stage, the negative pressure amounts to 9.0 m, 5.90 m and 5.60 m.

The auxiliary reservoir located above and connected with the main reservoir has a capacity of 70,000 m^3. That auxiliary dam is of the same type as the main dam. A 10.20 m wide spillway is located in the middle of the auxiliary dam.

8. KALL DAM (References 9, 10, and 15).

This dam has a capacity of 2.1×10^6 m^3. The crest is 5 m wide, 18.0 m long, and 34 m above the bottom of the valley floor. The elevation of the top of the dam is +423.50 m/NN. The dam consists of a concrete wall with a loam core on the reservoir side. Gravel fill is placed on both sides of the dam. The area of the reservoir is 0.178 km^2, which is rather small compared with other dams of the same size. This is due to the very narrow shape of the valley and to the steep gradient of the stream (as high as 1 on 40). The dashed line on Figure III of Plate 9 of this report and Figure 4 of Reference 9 shows the proposed increase of the dam by 9.35 m in height and 4.1 million m^3 capacity.

The bottom outlet of the dam is a concrete conduit. On the downstream side of the core, the outlet has two pipes, respectively 1.100 m and 0.600 m in diameter, at the control, discharge capacity of bottom outlets is 15.0 m^3/sec. For emergency closure of the outlets, there are two butterfly valves located at the point where the conduit passes through the core wall. In the event of breaking of the pipe, these valves close automatically by means of a float.

A small turbine 4.0-37.2 HP capacity, according to the head, utilizing the smaller bottom outlet is installed in the valve house. The generated power is used for illumination and heating of the buildings of the dam site. A small amount of the utilized water is released into Kall River.

The high water release structure consists of a spillway tower, and a flume, which passes through the dam by means of a tunnel and a transition. The structure is designed for 43.5 m^3/sec corresponding to 1.50 $m^3/sec/km^2$. Design was established and tested by model experiments made at the Technical University at Karlsruhe. The round spillway tower was selected in order to facilitate proposed future increase of the height of the dam. At the assumed highest high water, the overflow depth is 0.74 m. There is a free board of 2.26 m available. (See Plate 9 of the report).

9. THE KALL TUNNEL (References 9, 10, and 15).

The tunnel is reinforced by an inside concrete facing approximately 0.30 m thick to withstand the mountain pressure. In some places, this concrete is reinforced with steel. In some places, the floor also has to be reinforced against upward pressure. These reinforcements extend for approximately 1/3 of the length of the tunnel. The inside of the tunnel was provided by a "torcret" facing for protection against water seepage. Approximately 1.0 million m^3 of seepage water is accumulated in the tunnel in a year.

The entrance to the Kall tunnel is located on the left slope of the valley approximately 500 m upstream from the Kall Dam. This location was selected in order to avoid a long service bridge. The spillway tower has three outlet openings at high elevations in order to tap the layers of pure water.

Flow through the tunnel is regulated by a segment gate. A stop-log emergency closure is located outside the entrance. On opening all three inlets at full pool, the flow of water through the tunnel into Dreilaegebach Reservoir amounts to 8.0 m^3/sec.

10. RECONSTRUCTION OF WAR DAMAGES (Reference 14).

a. The Rur River valley was the center of a very intensive military operation in the last phase of the World War during the period November 1944-March 1945. The hydraulic installations of the Rur and its tributaries, controlling the water and power supply of the area were the target of Allied military actions, while at the same time they were used extensively by German Armed Forces for defense.

The Dreilaegerbach and Kall Dams were captured by American Army in practically intact conditions during the period September-November 1944, and immediately placed in operation, as a source of drinking water supply for the Aachen area.

All other dams (Schwammenauel, including the Paulushof auxiliary dam, Urft, Heimbach and Obermaubach) were seriously damaged, partly by Allied air raids, but most severely by the retreating Germans.

b. Schwammenauel dam was, on several occasions, subjected to heavy Allied bombing. The resulting craters were 20-40 m in diameter, but only few meters in depth, which was insufficient to endanger the structural safety of the dam.

In February 1945, shortly before surrendering the dam, the Germans blasted its main operating installations. One of the 2.0 m diameter bottom outlet pipe lines was blasted. This action caused the ring-valves and butterfly valves of both bottom outlets to be destroyed and swept away. Also the emergency gate at the upstream outlet entrance of the reservoir was destroyed by explosion.

c. The Allied air raids caused 5 breaches 1.3-3.50 m deep, on the crest of the Urft Dam. As the dam was filled to capacity at this time, a great amount of water flowed over, creating a flood wave. In addition, the air raids destroyed the upper part (20-24 m high) of the control tower and outlet conduit as well as the bottom outlet control mechanism. The lower part of these outlet conduits, on the reservoir side of the dam, was not affected by the bombing because of protection afforded by the earth fill on top of the conduit.

Upon their retreat, the German Armed Forces blasted the main valve of the 1.5 m diameter pressure pipe above the power-house near the surge tank.

d. The Obermaubach control structure was also blasted by the Germans, and the operating flap structure was put out of commission.

e. As the result of these destructions caused by the German Armed Forces, the reservoirs of both Schwammenauel and Urft Dams were emptied, creating flooding condition for weeks along the entire Rur River valley, destroying practically all installations which were not already destroyed by bombing or by blasting by the retreating Germans.

The reconstruction of all hydraulic installations started immediately after the occupation of the territory by Allied Forces in the latter part of 1945.

The present intention of the planners is to reconstruct all the above-mentioned hydraulic structures and pertinent installations into original operating conditions and improve them where possible.

Neither Schwammenauel nor Urft Dams were substantially endangered in their structural stability or impermeability, which facts were checked by subsequent tests.

f. Schwammenauel Dam ——— reconstruction 1945-1949.

Prior to 1949, only the emergency closing valve of 0,500 m diameter, flanged with the 2.00 m diameter outlet pipe, provided for controlled discharge out of the dam. The maximum capacity of this emergency control was 9.0 m^3/sec compared with the 80 m^3/sec capacity of the original outlet valves. Utilizing this emergency closure, the dam was filled in 1946 during the high water period up to 92.0×10^6 m^3.

This 1949 article (Reference 14), mentions the reconstruction of power generation to normal operating conditions. No mention is made concerning the reconstruction of other operating mechanism of the dam; however, it may be assumed that since 1949, progress was made towards normal operating conditions with new installed mechanisms.

g. Urft Dam —— reconstruction 1945-1949.

The wall of the dam which was hardly damaged by bombing and blasting was completely restored. Also the outlet operating towers were rebuilt in concrete.

The valve in the 1.5 m pressure pipe line, which was blasted by the Germans, was replaced by a valve of an improved construction but of the same size and capacity. Also the pressure tunnel was repaired. The velocity in the tunnel is 3-4 m/sec. In the pipe line, it is 8.0 m/sec. Consequently, it appears probable that the Urft Dam is now in normal operating condition.

RESTRICTED
SECURITY INFORMATION

EXHIBIT C

EXCERPTS

FROM

"ENGINEER OPERATIONS BY THE (U. S.) VII CORPS

IN THE EUROPEAN THEATRE

VOLUME VI

THE ROER RIVER CROSSINGS AND

ADVANCE TO THE RHINE"

RESTRICTED
SECURITY INFORMATION

THE CROSSINGS OF THE ROER RIVER AND THE ADVANCE TO THE RHINE

THE TACTICAL SITUATION PRIOR TO THE CROSSING

1. 12 September 1944 VII Corps entered Germany near Aachen. During the next three months the Corps completed the destruction of the Siegfried Line in its zone, captured Aachen, cleared the Germans from the difficult Hurtgen Forest, and reached the line of the Roer River between Obermaubach and Krauthausen on 19 December.

2. The German breakthrough which commenced on 16 December in the Ardennes resulted in the shifting of VII Corps and its Corps Troops initially to the area between Huy and Dinant in Belgium. Following the reduction of the breakthrough, the Corps was withdrawn from action on 25 January 1945 and on 5 February assumed the zone on the Roer River shown on map, Appendix No. 1.*

3. The area to the east of the Roer offered good defensive possibilities. The town of Duren and numerous built up communities lay within small arms range of the river. Field fortifications had been under construction for four months. The entire area was heavily sown with both antipersonnel and antitank mines. Heavy concentrations of artillery had been moved into the area.

THE TACTICAL PLAN FOR THE CROSSING

4. The tactical plan for the crossing of the Roer River provided for the attack by Ninth Army to cross the Roer and advance to the Rhine in the area opposite Dusseldorf. First Army, on the right of Ninth Army, would advance and cover the right flank of Ninth Army. It was felt necessary that the storage reservoirs on the Roer River system be seized prior to the beginning of the operation to prevent their use by the German army to flood the river and interrupt the crossing. The XVIII Airborne Corps and later the III Corps on the right of VII Corps was given the mission of seizing the Schwammenauel Dam while V Corps captured the Urft Dam. The capture of the former was a difficult tactical operation and while its capture was effected finally on 7 February, the Germans had opened the outlets from both dams and destroyed the operating mechanisms. The river rose rapidly and inundated areas along its low lying banks.

5. Due to the tactical situation, no accurate stream velocity measurements could be obtained; estimates placed it as high as 10-12 miles per hour. Reconnaissance established the fact that a crossing in the swift, turbulent stream with the standard equipment available would be extremely hazardous, and the operation was delayed until the velocity had moderated.

*Omitted

6. VII Corps, on the immediate right of Ninth Army, planned to cross the Roer with two Divisions at the same hour as Ninth Army. The 104th Infantry Division, on the left of the Corps, planned to cross two regiments abreast, each regiment crossing two battalions abreast, each battalion with two companies abreast. The 8th Infantry Division, on the right, followed the same general plan except that the extreme right battalion was to be crossed 40 minutes prior to H-Hour which was set for 0330 on 23 February. Division boundaries are shown on 1:50,000 map, Appendix No. 1.*

7. The plan of VII Corps provided also for the early passage of the 3d Armored Division across the river to break out on the front of the 104th Infantry Division, seize a crossing of the Erft River, and cover the flank of the advancing Ninth Army to the Rhine. This made the early construction of Class 40 bridges across the Roer a matter of urgency.

8. III Corps, on the right, was to cross the river on 25 February, two days after VII Corps. This factor was responsible to some degree for the difficulty of the crossing in the 8th Division sector. Terrain to the right of the 8th Division on the east side of the Roer provided excellent observation of the river in the entire 8th Division sector, and it was not until after the 25th when the 1st Division moved east of the river that accurately adjusted artillery fire was finally lifted from the bridge sites in the 8th Division sector.

THE ROER RIVER AS A MILITARY BARRIER.

9. The Roer River rises in the Eifel Region south of Monschau and flows in a northeasterly direction to Kreuzau where it leaves the foothills and enters the Rhine plain. Here it turns north, flows past Duren and Julich and joins the Meuse River at Roermond.

10. The river has a steep gradient, approximately 14' per mile until it reaches the area between Duren and Julich. To control the velocity and to provide water for manufacturing processes, low check dams had been installed in the river approximately every kilometer. During normal water stages the velocity of the river is moderate and the width within VII Corps sector approximately 125 to 150 feet. The river was fordable by foot troops at many points.

11. Two main reservoirs had been constructed by the Germans on the river as shown on map, Appendix No. 1.* The first and older of the two, the Urft Dam, has a storage capacity of 1,600 million cubic feet. This is a large concrete and masonry dam with a normal discharge through conduits to a power station at Heimbach. Between 1935 and 1940 the Schwammenauel Dam, a large earth structure capable of impounding 3,500 million cubic feet of water was constructed. The discharge from this reservoir passed through a power station located immediately below the dam.

*Omitted

12. Prior to the seizing of the Roer River line, attempts had been made by the Allied Air Forces to destroy these dams by aerial bombardment without satisfactory results. The bombardment did result in a reduction of the level in both reservoirs by the Germans. As the drive to capture the reservoirs was about to succeed, the outlet gates were opened to the obviously pre-determined amount required to obtain a maximum velocity in the stream. The river level rose 7-10 feet initially, then dropped about 1-1/2 feet and remained constant. The effect of the check dams was eliminated by the increased depth, and velocities rose to 12 miles per hour in a few places in the Corps zone. The width did not increase to any great amount, but for the most part it rose over the low banks and inundated areas on both sides of the river. The inundations were wider in the Ninth Army zone. Photos Nos. 1, 2, 3, and 4 were taken during the period of flood stage, and show the extent of flooding.*

13. The river reached a "stable maximum" height about 9 February; thereafter the elevation and velocities remained constant for a period of ten days. Data on velocities and a description of the operation of boats on the river are contained in Appendix No. 2, "Use of Assault Boats on the Roer River in Flood Stage." As the level in the Schwammenauel Dam approached zero, the river level and velocity began to decrease rapidly. Based upon engineer estimates, the assault crossing time was established at 0330 on 23 February. Velocities were still high, being over 8 miles per hour in the southern part of the Corps zone.

14. Essentially, the Roer River was an excellent switch position for the Siegfried Line. The south flank of the Roer rested in the extremely difficult forested terrain east of Monschau. The two reservoirs provided excellent barriers for long distances. The arrangement for controlled flooding provided a means of securing the river line for a limited period of time in view of the fact that no river crossing equipment available to our army will negotiate currents of 10-12 miles per hour. The German Army secured a delay of more than two weeks in our offensive to seize the Rhine. Appendix No. 3, "Study of Possible Flooding of the Roer River," contains a detailed analysis of the river control and the capabilities of the river as a barrier. This study was prepared in December 1944, and the capability outlined in paragraph 6 was put into effect. First Army Engineer estimates placed the actual discharge at 3500 to 4000 feet per second.

PREPARATORY WORK FOR THE CROSSING

Paragraphs 15-19 (omitted)

*Omitted

THE ASSAULT CROSSING BY THE DIVISIONS

20. The 104th Division crossed with two regiments abreast, two battalions abreast within each regimental zone. The left regiment crossed two rifle companies of one battalion and three of another in the assault. The right regiment crossed two companies of each of the two battalions abreast. A total of nine rifle companies were in the assault wave.

21. The division engineer placed one platoon of engineers with 16 assault boats in support of each rifle company, and reinforced the platoons to a strength permitting the use of three engineers per boat load of 10 infantrymen. One hundred forty-four boats were employed initially, with 60 in reserve at three different locations. Because of previous intensive training of the engineers, every boat in six companies reached the far shore safely and 15 boats landed safely in the seventh company. In the crossing of the eighth company, four enemy machine guns were adjusted on the site, and only four boats crossed safely. The balance of the force withdrew and crossed at the site of a previous successful crossing. The ninth company came under heavy mortar and artillery fire and successfully crossed only six boats, lost seven in the river, and had three damaged prior to entering the water.

22. Casualties were sustained by the engineers at all except one site; they ranged from a maximum of ten at one crossing, the result of small arms fire to one at an unopposed site. Casualties totaled 8 killed, 143 wounded, and 1 missing out of approximately 400 engineers actively engaged in the crossing sites; a rate of 38 per cent. See Appendix No. 4. *

23. Of the 204 assault boats available, 187 were used; 28 of these were destroyed and 108 were damaged. Due to the stream velocity, only 8 boats could be returned to the near shore from the original 144 used in the assault crossings; three engineer soldiers could not control the boats on the return trip.

24. It has been planned to construct footbridges to cross the reserve infantry companies, but the stream velocity would not permit. In lieu of footbridges, cable ferries were put into operation by five of the nine engineer platoons, using assault boats from reserves. Two platoons followed the infantry and gapped a minefield on the far bank.

25. Storm boats, and double assault boats powered with 22 HP outboard motors, although available, were not used in the 104th Division assault crossing.

*Omitted

26. The crossing of the 8th Division was similar in all respects to that of the 104th with the added handicap of an exposed right flank from which observation of the river within the Division zone was possible. Only two engineer companies were used for the assault boat crossings; the third company was assigned the construction of footbridges. One regiment was crossed in rowed half boats, the other in powered double assault boats supplemented by rowed boats. Casualties in both men and equipment were higher in this crossing than in the 104th Division. The rowed half boats could not be returned, the footbridge construction was impossible, and artillery fire damaged many of the boats before they could be launched.

CONSTRUCTION OF BRIDGES BY CORPS ENGINEERS

27. To support the operation of the Corps, the Corps Engineers were assigned the mission of constructing all of the bridges, leaving Division Engineers free to handle the assault crossing of the Infantry. Five bridges were planned for each Division Zone. Two of these were to be Infantry Support Bridges, Class 9, one in each regimental zone. One of the Treadway bridges was to be constructed with the conversion set to permit the passage of the new T-26 tank. Two sites were available in the entire Corps zone where Bailey Bridges could be constructed without technical difficulty, and it was planned to build at these two sites as rapidly as the tactical situation would permit.

28. Bridge construction was ordered to commence as soon as possible after the crossing of the infantry. On all previous river crossing operations of VII Corps, bridge construction had been started immediately after the assault infantry had secured a lodgment on the far bank, and the bridges had been finished within a few hours after the initial crossing. In the Roer crossing, the observation afforded the enemy by the buildings in Duren and from the high ground south of the 8th Division zone enabled him to keep the bridge sites under observed artillery fire for 24 to 56 hours and contributed to the relatively high number of casualties sustained.

29. Smoke to screen the operation had been requested. Smoke generators were not made available, but a few trained non-commissioned officers from a Chemical Smoke Generating Company were secured, and a small supply of smoke pots was moved up. Control of the use of smoke was delegated to Division Commanders, who decided against its use during the early hours of 23 February. When the intense artillery fire continued during the day, authority to use smoke in one Division zone was given, but it proved to be quite ineffective. The equipment and men had been committed to sites which had been observed and upon which enemy artillery fire had been registered.

30. During the night of 24-25 February, and thereafter, the water level in the river fell rapidly following the emptying of the Schwammenauel Dam. This added to the technical difficulties of construction of the floating bridges at sites 7, 9, and 10.

DETAILS OF EACH CROSSING

Paragraphs 31-45 (omitted)

APPENDIX 1 (omitted)

MAP SHOWING ROER CROSSING AREAS

APPENDIX 2

USE OF ASSAULT BOATS ON ROER RIVER IN FLOOD STAGE

During the night of 10-11 of February, the 329th Engineer Combat Battalion sent two patrols to the Roer River to attempt to cross in assault boats. The purpose of the patrol was to determine if an assault boat could be handled in the river at flood stage by fully equipped Infantry troops who had little or no training in assault boat crossings and to also determine if it were feasible to put a cable across the river to provide anchorage for a trail ferry. The results of the two patrols are as follows:

PATROL NO. 1

Two officers and ten men took an M-2 assault boat to the Roer River at the following coordinate (10054680), with the purpose of taking a light cable across the river. Upon reaching the river bank, the two officers decided that the water was too swift to do any more than attempt to paddle across the river without dragging the 1/4" cable that they had brought to the site. They loaded the boat with two officers and six enlisted men each equipped with a paddle. None of the men carried any equipment except for a carbine, which was on the bottom of the boat, and a rubber self-inflating life belt. All men were well trained in assault boat work and had worked together with the equipment for two years.

The current at the launching point was estimated at ten miles per hour and very turbulent due to the speed of the water, rather than to obstacles on the river bed. It also seemed to flow from the near to the far bank. After loading the boat, they headed upstream and paddled as rapidly as possible. When they reached the main channel, they lost control of the boat, but due to the current were swept to the far bank into relatively calm water. From there they paddled upstream and started rapidly back. Almost immediately after they started back, the men lost control and the boat was swept over a weir, which was approximately 150 yards downstream from the initial launching point. The boat filled with water until about four inches of the gunwhales were showing. As they went over the weir, one of the officers told the men to inflate their life belts. The current swept the boat with all the men in it near some bushes on the near bank. The men grabbed the bushes to stop the boat, but the current got into the rear of the boat and turned it end over end.

Lt. Field and three of the men held onto the bushes and pulled themselves ashore. One man was found 150 yards downstream, conscious, but unable to breathe due to the shock of the cold water. Another man was found 300 yards downstream in the same condition. A search was made by the other men in the boat and by the four men on the bank, but they were unable to locate Lt. F[illegible]thra or Pvt. Brannison.

Conclusions drawn by Patrol Leader:

1. A boatload of inexperienced Infantry troops with full load would have very little chance of crossing the river in assault boats at its present stage.

2. If a boat is tipped, the men would have a very difficult time reaching shore due to the cold and turbulent water, even if wearing life belts.

3. A 5/8" cable well anchored would probably hold an assault boat ferry, but great care would have to be taken or the boat would swamp due to the rapid current.

4. Obstacles in the water near the shores, such as barbed wire, stumps, etc., would prohibit the use of storm boats in this area.

5. An assault boat will be approximately 250 yards downstream from its starting point when it reaches the far bank.

PATROL NO. 2

Lt. McKain, with several men from Company C, attempted an assault boat crossing of the Roer River at (086510). The river at this point was four hundred yards wide and is divided into three channels. The first is about three feet deep, with shallow water over a bar that is about 100 yards from the near bank. The second channel is approximately four feet deep. The sand bar between this second channel and the main stream offers an obstacle to an assault boat.

Lt. McKain loaded four Engineer and eight Infantry soldiers, about half of whom were carrying rifles, into the boat; tied a rope to the gunwale and the men started paddling with the boat headed upstream. At the first bar, the men had drifted 200 feet downstream. At this point, half of the men unloaded and pushed the boat over the bar. They then climbed in and paddled to the middle of the main channel. They were being swept downstream so rapidly that the men in the boat pulled the boat back to the starting point. Ten men holding the rope on the near shore assisted in pulling the boat back with little difficulty.

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Conclusions drawn by Patrol Leader:

1. An assault crossing could be made at this point by Infantry troops.

2. The boat would have to start 200 to 300 yards upstream from the proposed landing site.

3. A rope tied to an assault boat makes a drag, at least equal to the drag of the boat.

4. Men are not able to wade in 3 feet of water on the secondary channels and keep their feet.

PATROL NO. 3

At 200030A February, a crossing of the Roer was effected by a 6-man Engineer patrol from Company C, 329th Engineer Combat Battalion.

The mission of the patrol was to reconnoiter the river at its present stage and also to transport a German PW who volunteered to obtain information for our forces of enemy disposition and identification in Duren and Birkesdorf.

The crossing was made in the vicinity of Hoven at coordinate (F093489) using an M-2 Assault Boat. It was originally planned to cross at 2200 but due to the extremely bright moonlight, the crossing was postponed until 0030 when visibility decreased. However, visibility was excellent up to 250 feet.

The width of the river at the crossing site was estimated at 250 feet. This is a decrease of 50 feet from previous reconnaissance reports of 12-13 February. The velocity of the current was estimated at 7-8 MPH. All patrol members agreed that the current was not as swift as recorded 12-14 February.

The boat was launched in shallow water 30 feet from the near shore. With 5 men paddling and 2 passengers, the crew experienced no difficulty in crossing and the drift was only 10 yards downstream. On the return, with 5 paddlers and 1 passenger, the drift was 40 yards downstream. This discrepancy in driftage was explained by the fact that the boat was purposely allowed to drift over a series of riffles in the main channel in order to determine the amount of drift if the boat were caught in the current. The boat (loaded) would not cross a gravel rise on the far side which was some 60 feet from the far shore. This gravel rise is the original east bank of the river. The PW debarked here and was observed wading in water about 1 foot in depth.

All observations indicate that the water is draining. However, the ground is soft and wet, and there is standing water on the far shore.

No hostile enemy action was encountered. The crew experienced no difficulty in crossing. No life belts were worn. The crew was armed with carbines. Crossing time was estimated at 6 minutes.

APPENDIX 3

STUDY OF POSSIBLE FLOODING OF THE ROER RIVER

1. The Roer River rises in the Eifel Mountains south of Monschau. It flows in a northeasterly direction through mountains to Kreuzau, where it enters the rolling Rhine Plain. Here it turns north and flows by Duren; thence northwest by Julich and empties into the Meuse River at Roermond.

2. There are two main storage dams on the upper reaches of the river - the Urft Dam (F0723) with 1,600 million cu. ft. capacity and the Schmidt (Roer)Dam (F0827) with 3,500 million cu. ft. capacity. In addition there are three regulating dams - one between the Schmidt and the Urft Dams (F046240) and two downstream from the Schmidt Dam at (F111262) and (F090360).

3. The normal discharge of the Schmidt Dam is 320 cu. ft. per second.

4. Independent of the Roer River Dam system is the Kall Dam (F0230) on the Kall River, a tributary of the Roer. This dam has a capacity of 74 million cu. ft. and has been secured by the V Corps.

5. To present a military obstacle the water supply impounded by the aforementioned dams can be used to raise the level of the Roer River so high that it will overflow its banks, wash out existing bridges and cause damage throughout the Roer River Valley.

6. Since the Roer River has a steep gradient (approximately 14 feet per mile) and at high water a great velocity, it is estimated that a continuous water obstacle from the Roer Dam to the Meuse River could be produced with a discharge of 3,500 cu. ft. per second from the dams mentioned. The total volume of the basins named amounts to about 5,600 million cu. ft. From the latest available photo coverage it appears that the reservoirs are about two-thirds full. Thus, a flow of 3,500 cu. ft. per second would last about 12 days. The estimated depth of the flood produced by this discharge would be 6-1/2 ft. at Zerkall (F093334), 6 feet at Duren (F109453), 5 feet at Julich (F027589).

7. The flood gates of the equalizing basins at Heimbach (F111262) and Obermaubach (F090360) can be opened suddenly to produce a short but high flood wave estimated at 15,000 cu. ft/sec, after complete filling of the basins. This wave can be considerably increased in volume and velocity if the level of the Schmidt Dam reservoir is above the spillway and the opening of the spillway gates is synchronized with the successive opening of the flood gates at the Heimbach and Obermaubach dams. Such a wave would probably not last more than eight hours but it would inundate the Roer Valley to an estimated height of fifteen feet above the normal stream level. This level could be raised further in the Duren area by the erection of barriers at the openings in the railroad and highway fills which extend across the river valley. It is estimated that about 30% of the town of Duren could be flooded in such a manner.

8. Captured German documents dated 3 April 1944 reveal that the maximum water contents of the Urft and Schmidt reservoirs have been limited to 3,885 million cu. ft., which is 1,715 million cu. ft. less than actual capacity. The proposed distribution is 2,330 million cu. ft. in the Schmidt reservoir and 1,585 million cu. ft. in the Urft Dam reservoir. This distribution would allow the contents of the Urft Dam reservoir to be caught and retained in the Schmidt Dam reservoir without undue strain on the Schmidt Dam, in case the Urft Dam, which has slender concrete walls, were blown (witness the case of the Moehne and Eder Dams).

9. The Schmidt Dam is of mass earth fill construction and does not lend itself to easy destruction by either blasting or bombing. The Urft and Schmidt Dams have been bombed by RAF and AAF several times without results, although numerous hits have been made.

10. Although it is not considered probable, it is possible that the Schmidt Dam will be destroyed by explosives. Attached is overlay showing elevations 5, 10, and 15 meters, respectively, above the stream bed of the Roer River. As a precautionary measure it is recommended that large bodies of troops and heavy equipment be kept above 10-meter line south of the Autobahn Highway; similarly that large bodies of troops and heavy equipment be kept above the 5-meter line north of this highway.

Incl:
Overlay (In 2 sheets) - Withdrawn from Report (i.e. from original VII Corps Report)

APPENDIX 4 (omitted)

CASUALTIES

APPENDIX 5 (omitted)

SUMMARY OF EQUIPMENT

APPENDIX 6 (omitted)

TABULATION OF STREAM CROSSING DATA

APPENDIX 7 (omitted)

MAP SHOWING ROAD NET AND ROER RIVER BRIDGE

APPENDIX 8 (omitted)

PHOTOS OF THE ROER CROSSINGS

APPENDIX 9 (omitted)

TABULATION OF STREAM CROSSING DATA

APPENDIX 10 (omitted)

PHOTOGRAPHS OF ERFT BRIDGES