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OBSERVATIONS AND RECOMMENDATIONS
FOR
SALMON HABITAT ENHANCEMENTS
IN SELECTED ICELANDIC RIVERS

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January 1989

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INTRODUCTION

An investigation of ten rivers in Iceland was performed between August 23 and September 14, 1988 to determine habitat enhancements for juvenile and adult Atlantic salmon (*Salmo salar*). Habitat enhancements include juvenile rearing areas, adult pools and spawning areas, flow diversity, current shelter, and fishpasses.

The rivers were selected by Veithimalastofnun, the Iceland Institute of Freshwater Fisheries. Selections are based on a need for increased stocks and improved catch areas.

Habitat structure recommendations are made at sites specifically desired by river owners or fisheries managers. Where structures could be built within a given reach of river, it is indicated in the text.

Channel profile surveys were taken when time and flow conditions permitted to determine optimum structure locations.

Hydrologic data is provided where it is available and structure designs are based on these flow conditions. Additionally, site observations and personal accounts regarding floods have been used for developing structure specifications.

LEIRVOGSA

Three sites on the lower reach of the river Leirvogsa were examined on August 26, 1988 for potential adult salmon habitat improvement. See figure 1.

The observed sites are of two types: 1) one bank of bedrock and the other of unconsolidated gravel and cobbles, and 2) both banks of unconsolidated gravel and cobbles.

Precast concrete weirs are recommended to develop scour pools and provide flow diversity for adult salmon. Two-piece removable weirs are recommended for use and are to be removed prior to the anticipated flood season. This recommendation is based on the readily moveable substrate, large quantity of gravel bedload, and high flood flows.

Figure 2 illustrates the weir placement.

Figure 1.

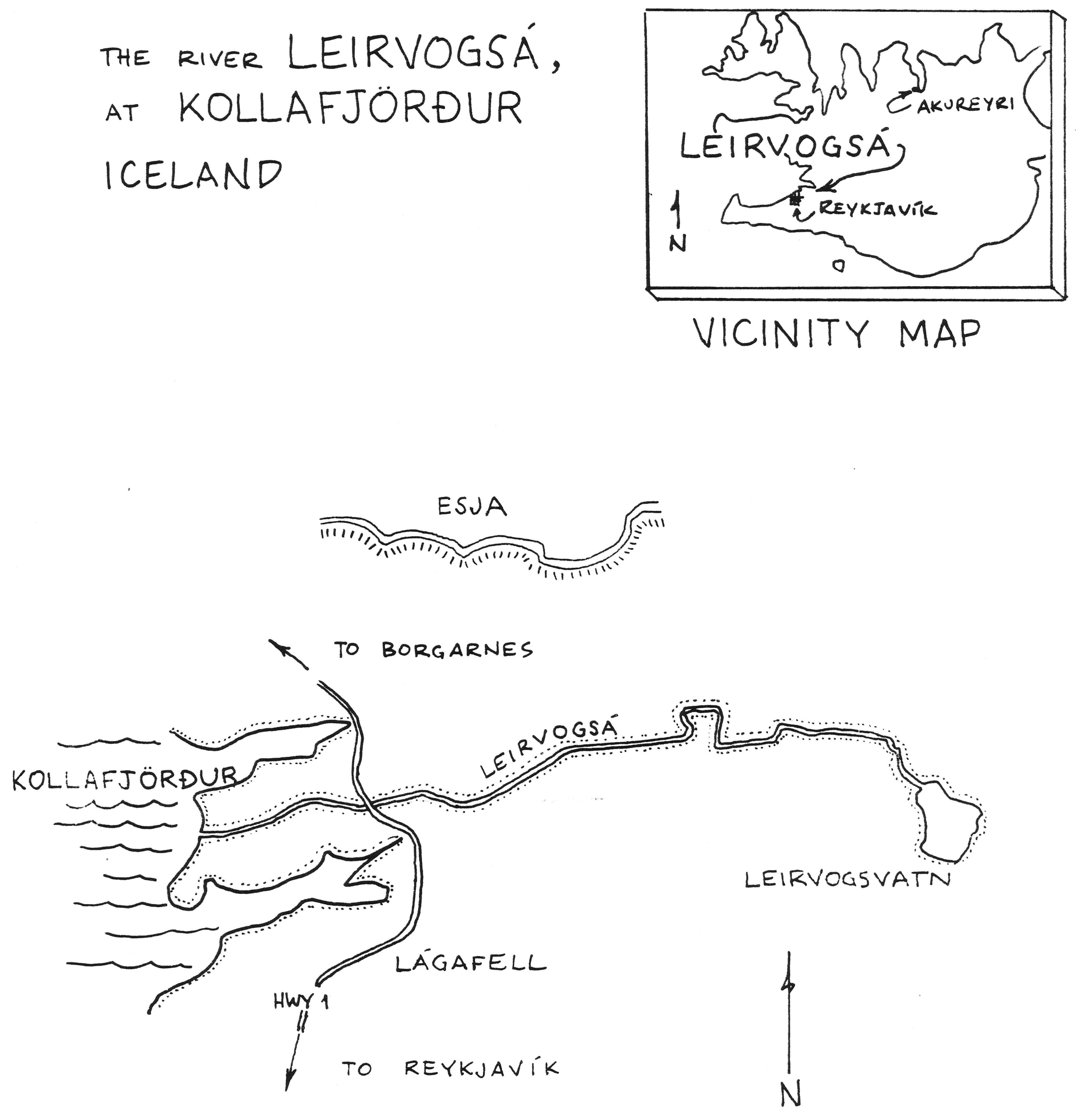
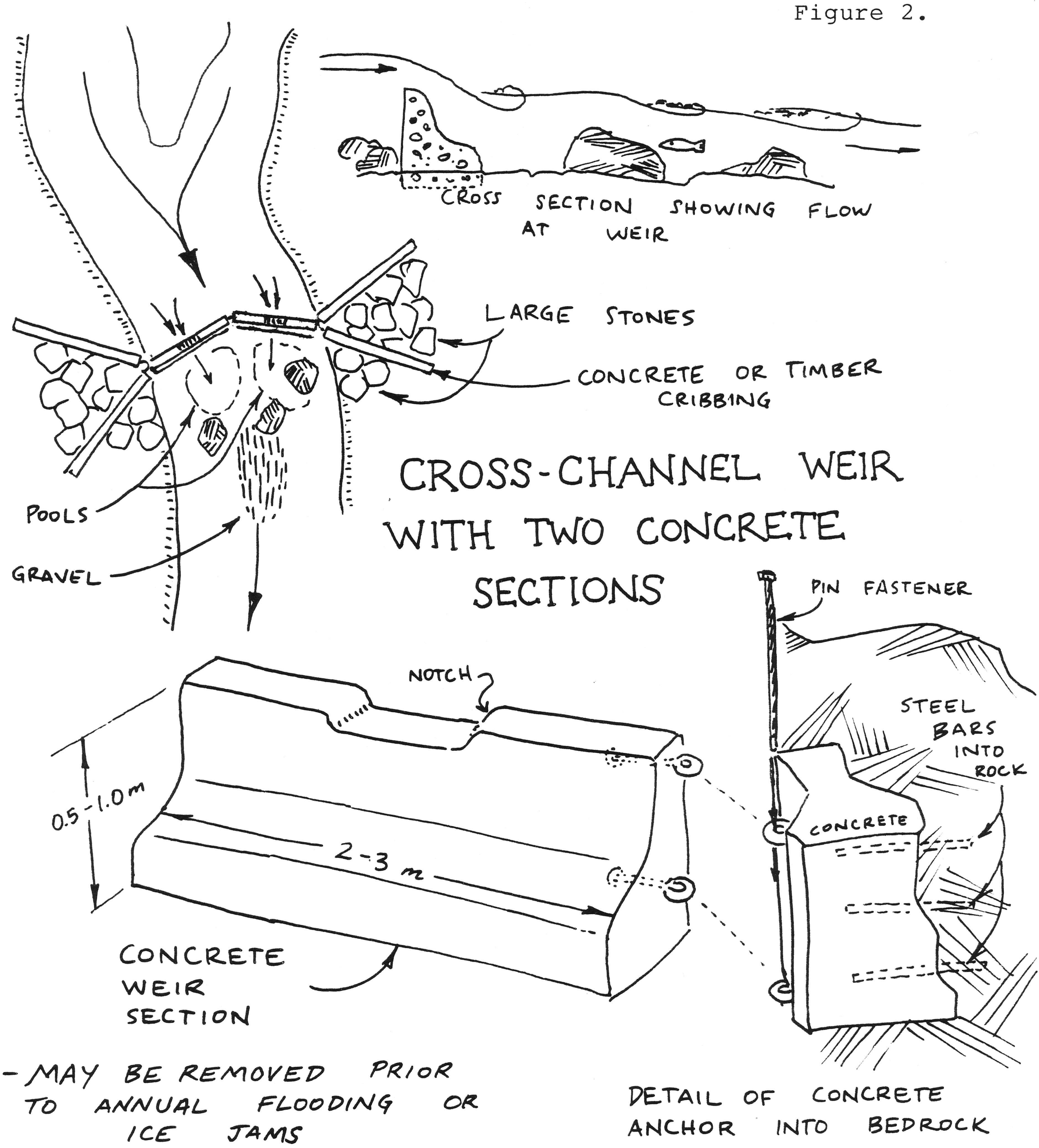

THE RIVER LEIRVOGSÁ,
AT KOLLAFJÖRÐUR
ICELAND
LEIRVOGSÁ
AKUREYRI
REYKJAVÍK
N
VICINITY MAP
ESJA
TO BORGARNES
KOLLAFJÖRÐUR
LEIRVOGSÁ
LEIRVOGSVATN
LÁGAFELL
HWY 1
TO REYKJAVÍK
N

Figure 2.



NOTES :

1. A SOLID BANK ANCHOR IS CRUCIAL.
2. WEIR SECTIONS ARE PLACED SO THAT THE STRUCTURE POINTS UPSTREAM.
3. NOTCH IN TOP OF WEIR SECTION FOR LOW FLOWS.

SVARTA

The reach of the river Svarta surrounding the tributary Fossar was observed on August 27, 1988 for siting of juvenile salmon habitat improvemnts. Salmon up to four years old are considered juveniles in this case.

In the observed reach, Svarta is bordered by a gravel and cobble dike on one bank and a high bank on the other. The high bank is either solid rock or unconsolidated cobbles, and gravel. The dike has been constructed to protect roads and a sheep fold which lie within the limits of a two-year flood.

Svarta is apparently reacting to recent diking and channelization as evidenced by increased flow velocities, substrate transport, and bank erosion. A combination of these factors has limited the available juvenile salmon habitat. Figure 4 illustrates the principles described above and shows how dikes can be set back from the river banks to allow flood flows to pass.

Habitat enhancement in Svarta requires the stabilization of the river through dissipation of stream energy by using stepped weirs and elevation controls embedded in the substrate. See figure 5. Weir spacing and weir heights are determined by a channel survey and flow analysis.

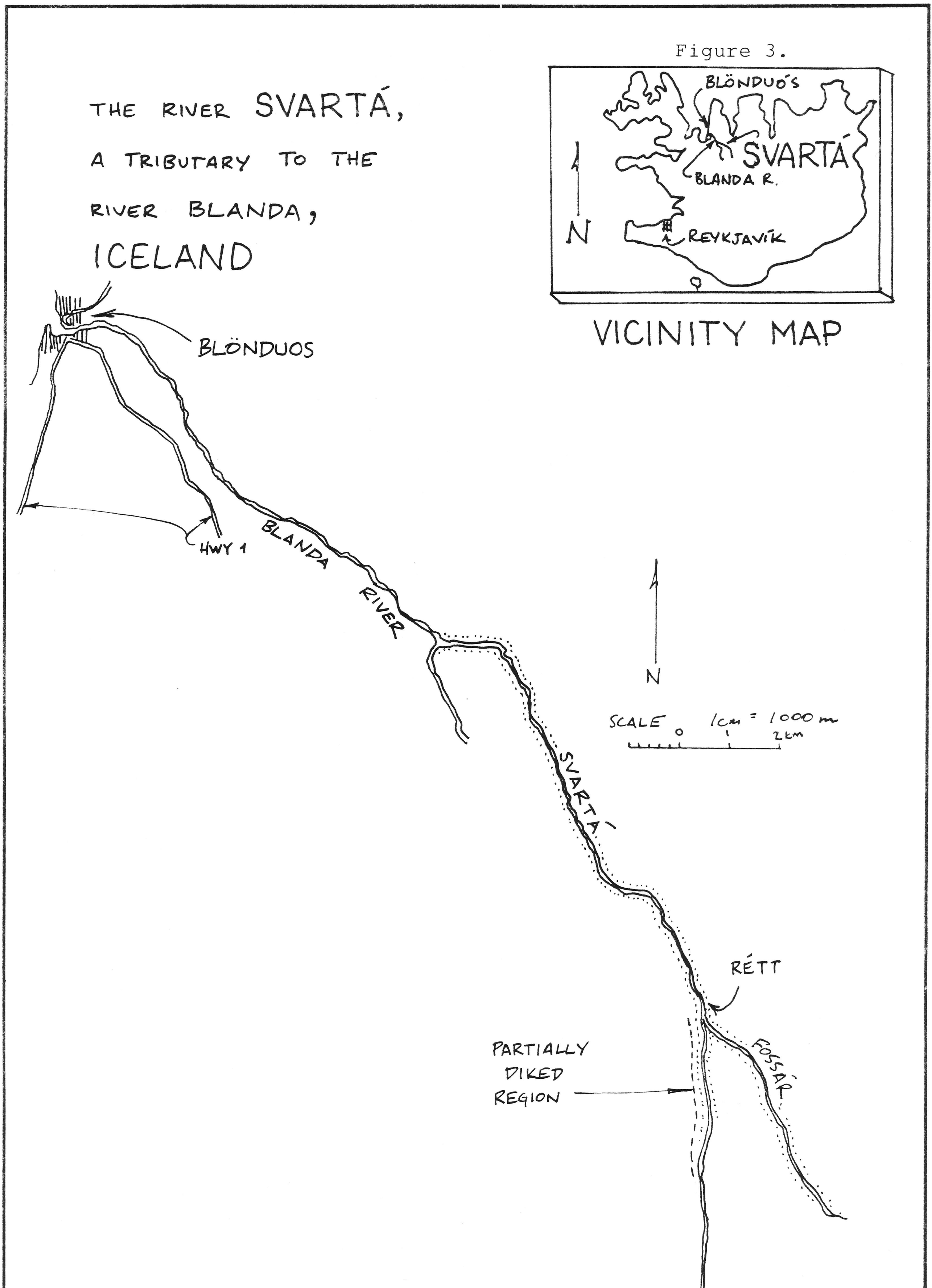

THE RIVER SVARTÁ,
A TRIBUTARY TO THE
RIVER BLANDA,
ICELAND
BLÖNDUOS
HWY 1
BLANDA RIVER
SVARTÁ
RÉTT
FOSSÁR
PARTIALLY DIKED REGION
BLÖNDUOS
SVARTÁ
BLANDA R.
REYKJAVÍK
N
VICINITY MAP
N
SCALE 1cm = 1000 m
0
2km
© 1988 S.Wenger
Figure 3.

Figure 4.

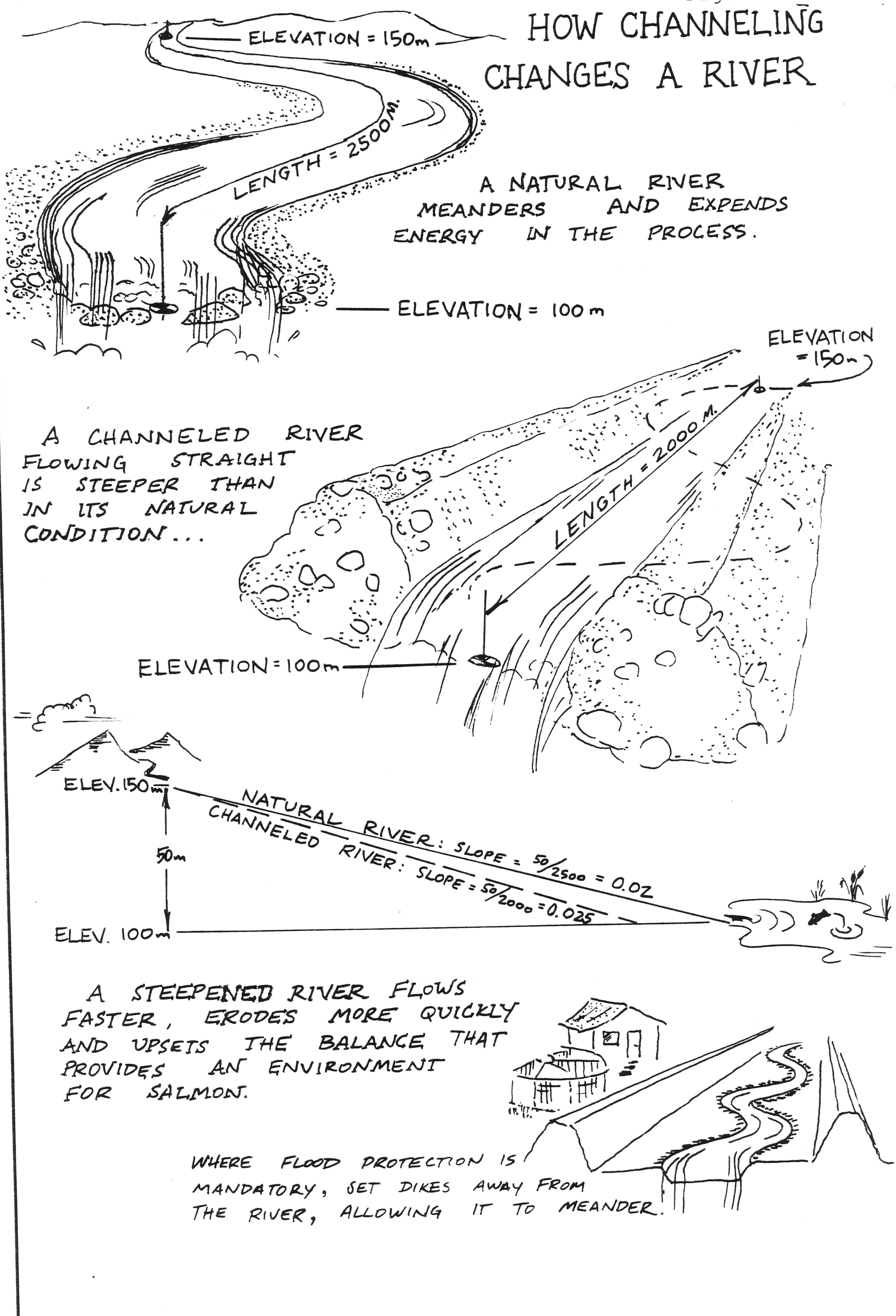
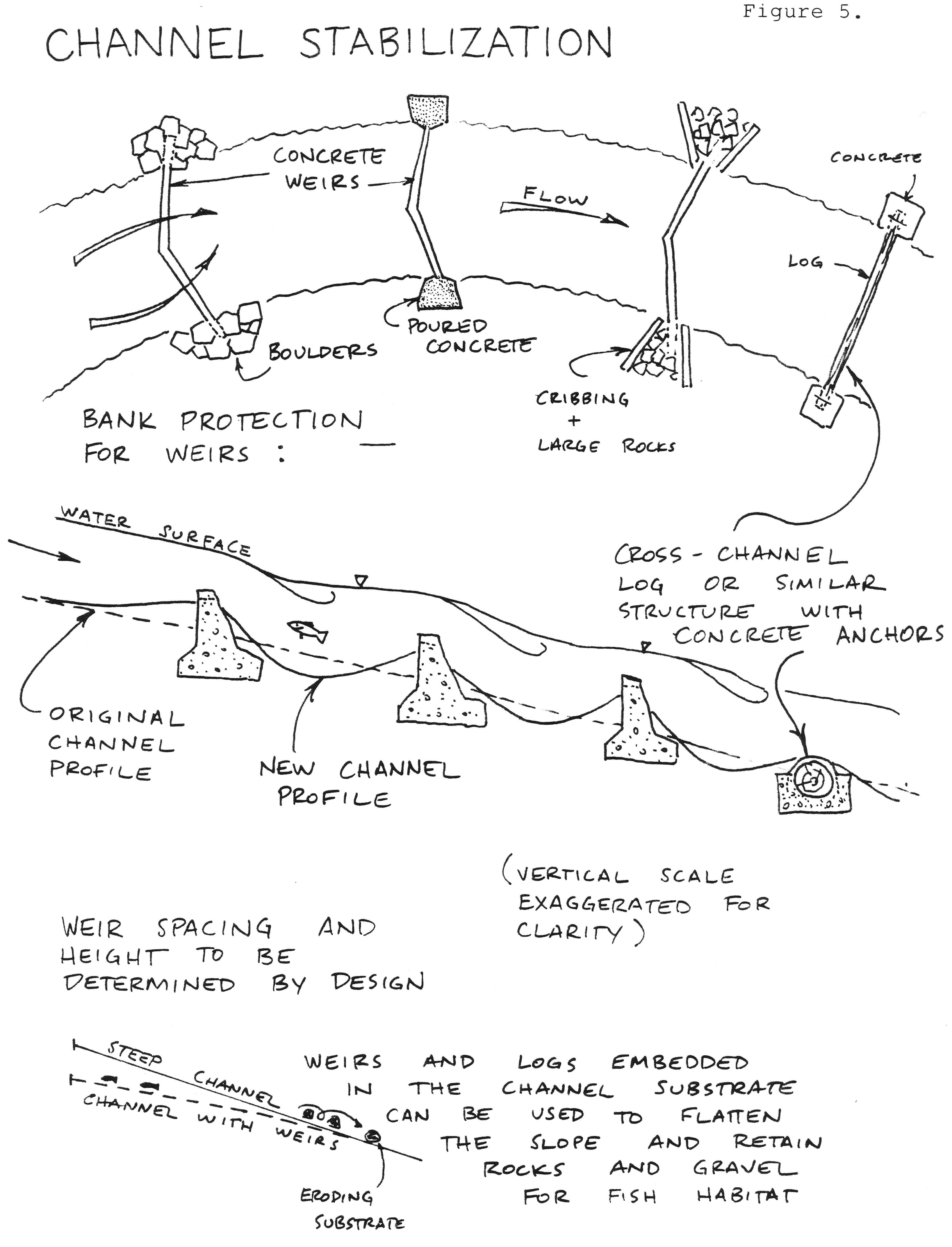

HOW CHANNELING CHANGES A RIVER
ELEVATION = 150m
LENGTH = 2500M.
A NATURAL RIVER MEANDERS AND EXPENDS ENERGY IN THE PROCESS.
ELEVATION = 100m
ELEVATION = 150m
LENGTH = 2000 M.
A CHANNELED RIVER FLOWING STRAIGHT IS STEEPER THAN IN ITS NATURAL CONDITION...
ELEVATION = 100m
ELEV. 150m
50m
ELEV. 100m
NATURAL RIVER: SLOPE = 50/2500 = 0.02
CHANNELED RIVER: SLOPE = 50/2000 = 0.025
A STEEPENED RIVER FLOWS FASTER, ERODES MORE QUICKLY AND UPSETS THE BALANCE THAT PROVIDES AN ENVIRONMENT FOR SALMON.
WHERE FLOOD PROTECTION IS MANDATORY, SET DIKES AWAY FROM THE RIVER, ALLOWING IT TO MEANDER.

Figure 5.


CHANNEL STABILIZATION
CONCRETE WEIRS
FLOW
CONCRETE
LOG
BOULDERS
POURED CONCRETE
CRIBBING + LARGE ROCKS
BANK PROTECTION FOR WEIRS :
WATER SURFACE
CROSS - CHANNEL LOG OR SIMILAR STRUCTURE WITH CONCRETE ANCHORS
ORIGINAL CHANNEL PROFILE
NEW CHANNEL PROFILE
(VERTICAL SCALE EXAGGERATED FOR CLARITY)
WEIR SPACING AND HEIGHT TO BE DETERMINED BY DESIGN
STEEP CHANNEL
CHANNEL WITH WEIRS
ERODING SUBSTRATE
WEIRS AND LOGS EMBEDDED IN THE CHANNEL SUBSTRATE CAN BE USED TO FLATTEN THE SLOPE AND RETAIN ROCKS AND GRAVEL FOR FISH HABITAT

VATNSDALSA

The river Vatnsdalsa was visited on August 27, 1988 to determine habitat improvements for adult salmon. The reach of Vatnsdalsa from the lake Flodid upstream is considered.

Currently, adult salmon tend to pause in their migration before entering the downstream end of the lake. Upstream migration could be stimulated by regulating the flow from Flodid with a gated weir as illustrated in figure 7.

The water level in Flodid would be raised 30 centimeters (a preliminary estimate) which would create a reserve impoundment of approximately 848,000 cubic meters. By gating this impounded water, the flow would be increased to stimulate upstream migration.

Sites upriver from Flodid were investigated for adult habitat enhancement. See figure 6.

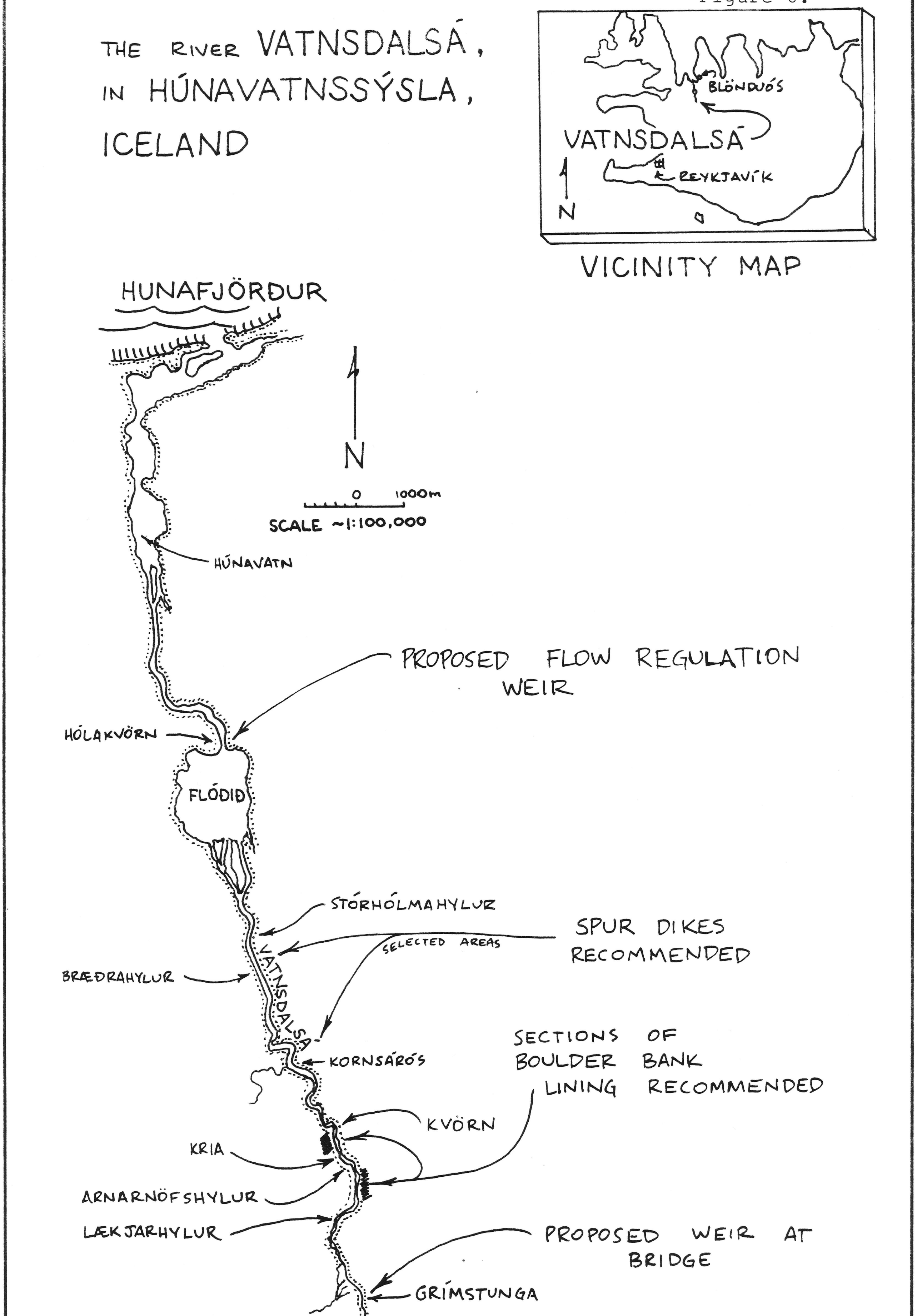
Pools and rock cover can be made by constricting the channel with spur dikes as shown in figures 8 and 9. Boulders, one to two cubic meters each, provide cover and flow diversion when placed downstream of the spur dikes. Between Storholmahylur and Brædrahylur and at Kornsaros are sites where these structures are recommended.

Increased pool depths and bank stabilization are desired in the two reaches: 1) between Kvorn and

Kria, and 2) between Arnarnofshylur and Lækjarhylur. This can be accomplished by lining portions of the river banks with boulders (0.7 - 1.5 cubic meters each) as indicated in figure 8. Specific location of this type of structure is recommended following a site survey and structure design.

An adult salmon pool in the Grimshylur area could be built using the existing road bridge piers. See figure 9.

figure 6.



THE RIVER VATNSDALSÁ,
IN HÚNAVATNSSÝSLA,
ICELAND
BLÖNDUÓS
VATNSDALSÁ
REYKJAVÍK
N
VICINITY MAP
HUNAFJÖRÐUR
N
0 1000m
SCALE ~1:100,000
HÚNAVATN
PROPOSED FLOW REGULATION WEIR
HÓLAKVÖRN
FLÓDID
STÓRHÓLMAHYLUR
SPUR DIKES RECOMMENDED
SELECTED AREAS
BRÆÐRAHYLUR
VATNSDALSÁ
SECTIONS OF BOULDER BANK LINING RECOMMENDED
KORNSÁRÓS
KVÖRN
KRIA
ARNARNÖFSHYLUR
LÆKJARHYLUR
PROPOSED WEIR AT BRIDGE
GRÍMSTUNGA

Figure 7.

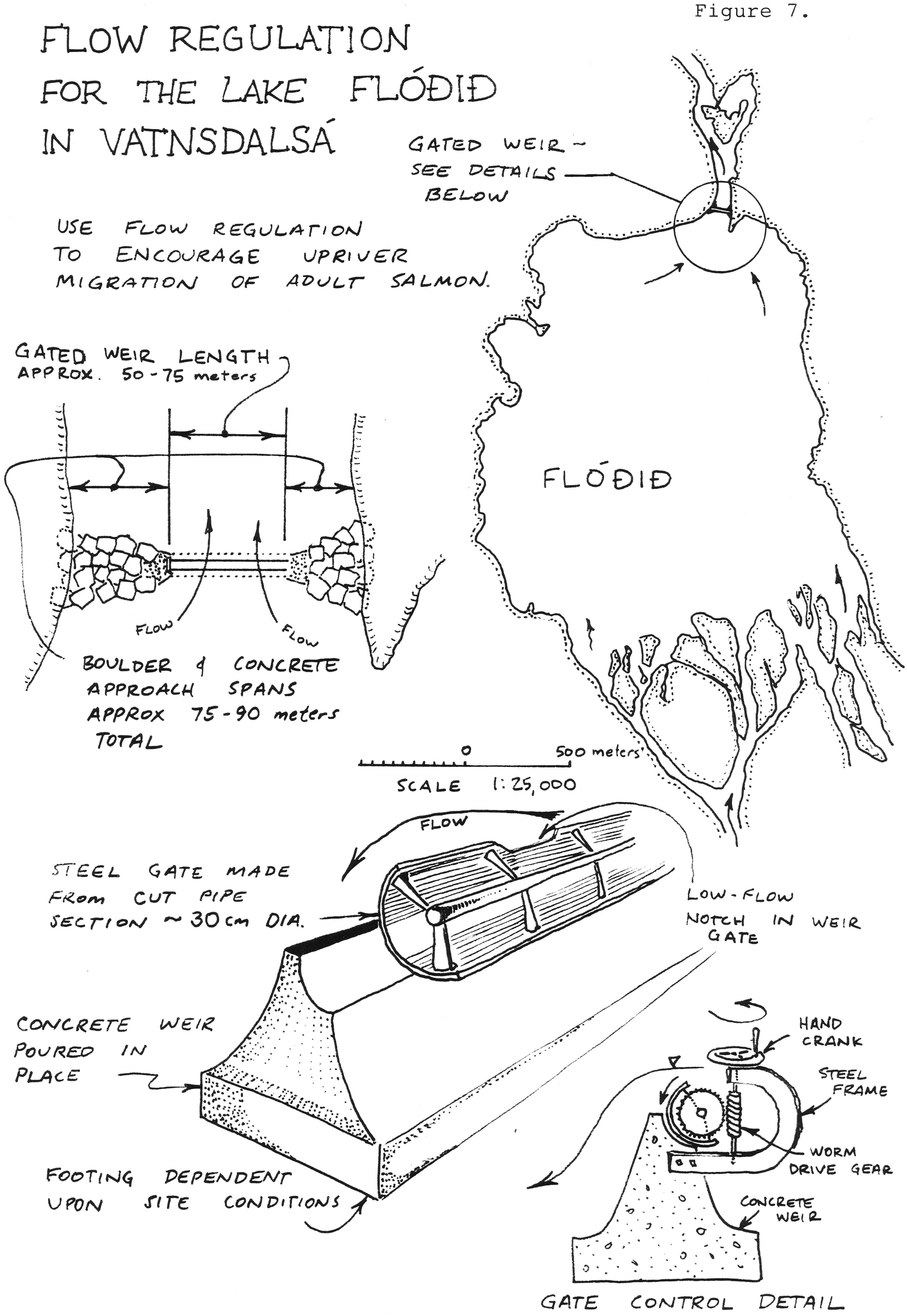

FLOW REGULATION
FOR THE LAKE FLÓÐIÐ
IN VATNSDALSÁ
GATED WEIR - SEE DETAILS BELOW
USE FLOW REGULATION TO ENCOURAGE UPRIVER MIGRATION OF ADULT SALMON.
GATED WEIR LENGTH APPROX. 50-75 meters
FLOW
FLOW
BOULDER & CONCRETE APPROACH SPANS APPROX 75-90 meters TOTAL
FLÓÐIÐ
0
500 meters
SCALE 1:25,000
FLOW
STEEL GATE MADE FROM CUT PIPE SECTION ~30 cm DIA.
LOW-FLOW NOTCH IN WEIR GATE
CONCRETE WEIR POURED IN PLACE
FOOTING DEPENDENT UPON SITE CONDITIONS
HAND CRANK
STEEL FRAME
WORM DRIVE GEAR
CONCRETE WEIR
GATE CONTROL DETAIL

Figure 8.

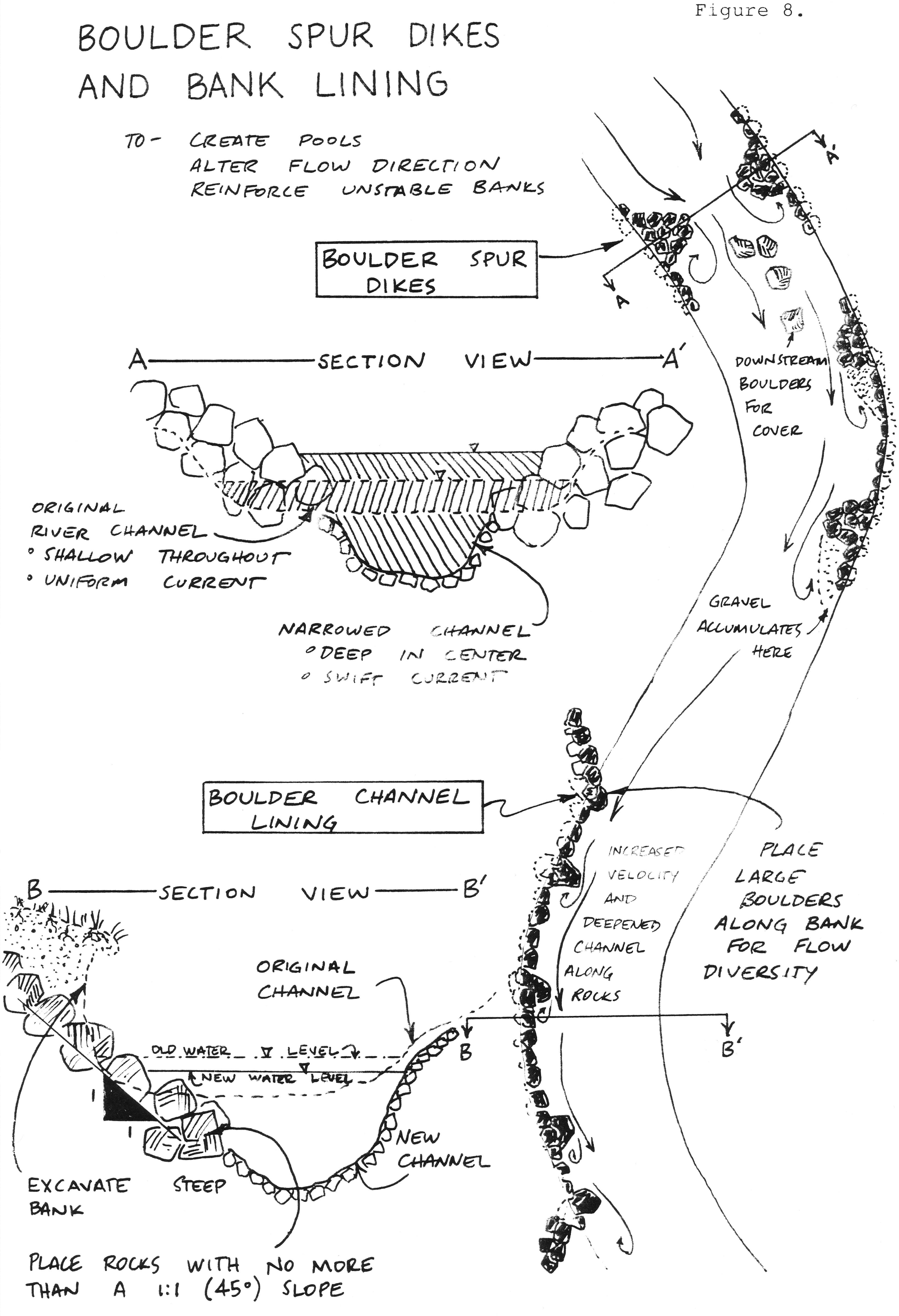
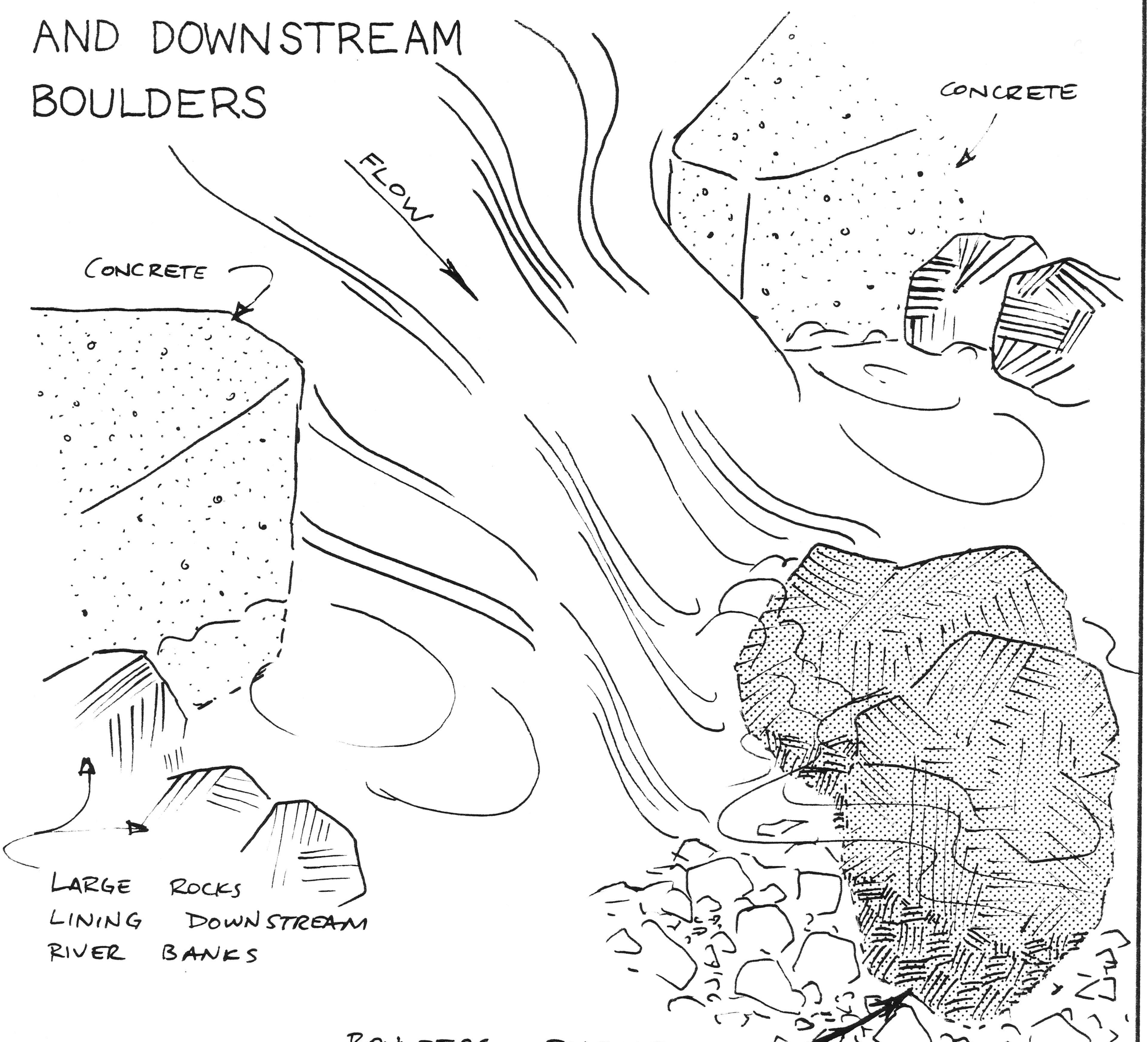
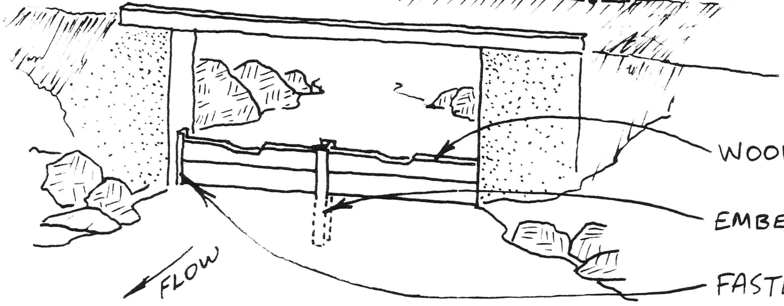

BOULDER SPUR DIKES AND BANK LINING
TO- CREATE POOLS
ALTER FLOW DIRECTION
REINFORCE UNSTABLE BANKS
BOULDER SPUR DIKES
A
A'
A — SECTION VIEW — A'
ORIGINAL RIVER CHANNEL
° SHALLOW THROUGHOUT
° UNIFORM CURRENT
NARROWED CHANNEL
° DEEP IN CENTER
° SWIFT CURRENT
DOWNSTREAM BOULDERS FOR COVER
GRAVEL ACCUMULATES HERE
BOULDER CHANNEL LINING
INCREASED VELOCITY AND DEEPENED CHANNEL ALONG ROCKS
PLACE LARGE BOULDERS ALONG BANK FOR FLOW DIVERSITY
B — SECTION VIEW — B'
ORIGINAL CHANNEL
OLD WATER LEVEL
NEW WATER LEVEL
1
1
NEW CHANNEL
B
B'
EXCAVATE STEEP BANK
PLACE ROCKS WITH NO MORE THAN A 1:1 (45°) SLOPE

Figure 9.

DETAIL OF CONCRETE SPUR DIKES AND DOWNSTREAM BOULDERS



WEIR CONSTRUCTION USING BRIDGE PIERS AT GRÍMSHYLUR



HITARA

The river Hitara was investigated on August 28 and 29, 1988 for juvenile salmon habitat enhancement and for the development of adult salmon pools.

Hitara can be divided into four areas defined by changes in the channel gradient and general site conditions, as shown in figure 10.

The farthest downstream reach extends from tidal influence to Oddafljot, approximately 1.5 km downriver from Bruarfoss. The channel is broad and relatively flat (approximately 0.1% slope) with few scattered boulders which provide the only cover for juvenile salmon. Because of the flat gradient, this area is where much of the sediment is deposited in the river. Also, during large discharges and ice flows, the current readily moves most rocks and small boulders downriver.

From Oddafljot to Bruarfoss the gradient increases to approximately 0.2% slope. Some boulders are present and the substrate is less covered with sediment than downriver.

Above Bruarfoss to approximately 1.5 km downriver from Kattarfoss the gradient is approximately 0.3% slope. Many rocks and boulders are present in the channel and pool and riffle areas are well developed.

Upstream to Kattarfoss the gradient increases to approximately 0.4% slope. Many rocks and boulders are present in the channel except along a diked portion of the river. The channel consists of cascading flow over rocks, with pools throughout.

Habitat enhancement for juvenile salmon consists of providing adequate cover where sufficient flow is present (greater than 0.3 meters/second). The portion of Hitara downstream from Bruarfoss is of particular interest. Presently there are few juvenile salmon in this area except for the tributary stream Fiskilækur.

Conditions in Fiskilækur provide a great potential for salmon rearing and could be improved by adding additional rocks and small boulders to the channel. A stream crossing which would protect the channel at the farm access is recommended.

Within the main river channel of Hitara, sufficient flow is present for juveniles, although the substrate is uniform and embedded in sediment. Cover could be provided by adding rocks and boulders to the river from the surrounding hillsides. Boulder groupings are more stable than individual rocks. See figure 11.

There is a structure at Kotdalsfljot which can be strengthened as shown in figure 12.

At Hraunsnef, boulders have been placed in the channel which provide juvenile and adult cover. The rocks were placed three to five years ago and have been stable, although maintenance is desireable. Adding boulders to form groups of three to five boulders with smaller rocks surrounding provides good habitat for juvenile salmon rearing.

Downstream from Kattarfoss, flow conditions are ideal for mid-channel boulders to provide cover for adults and juveniles. The boulders present along the banks could be used.

Cross-channel weirs may be placed within the reach upstream of Bruarfoss where the banks are stable as shown in figure 13.

Figure 10.

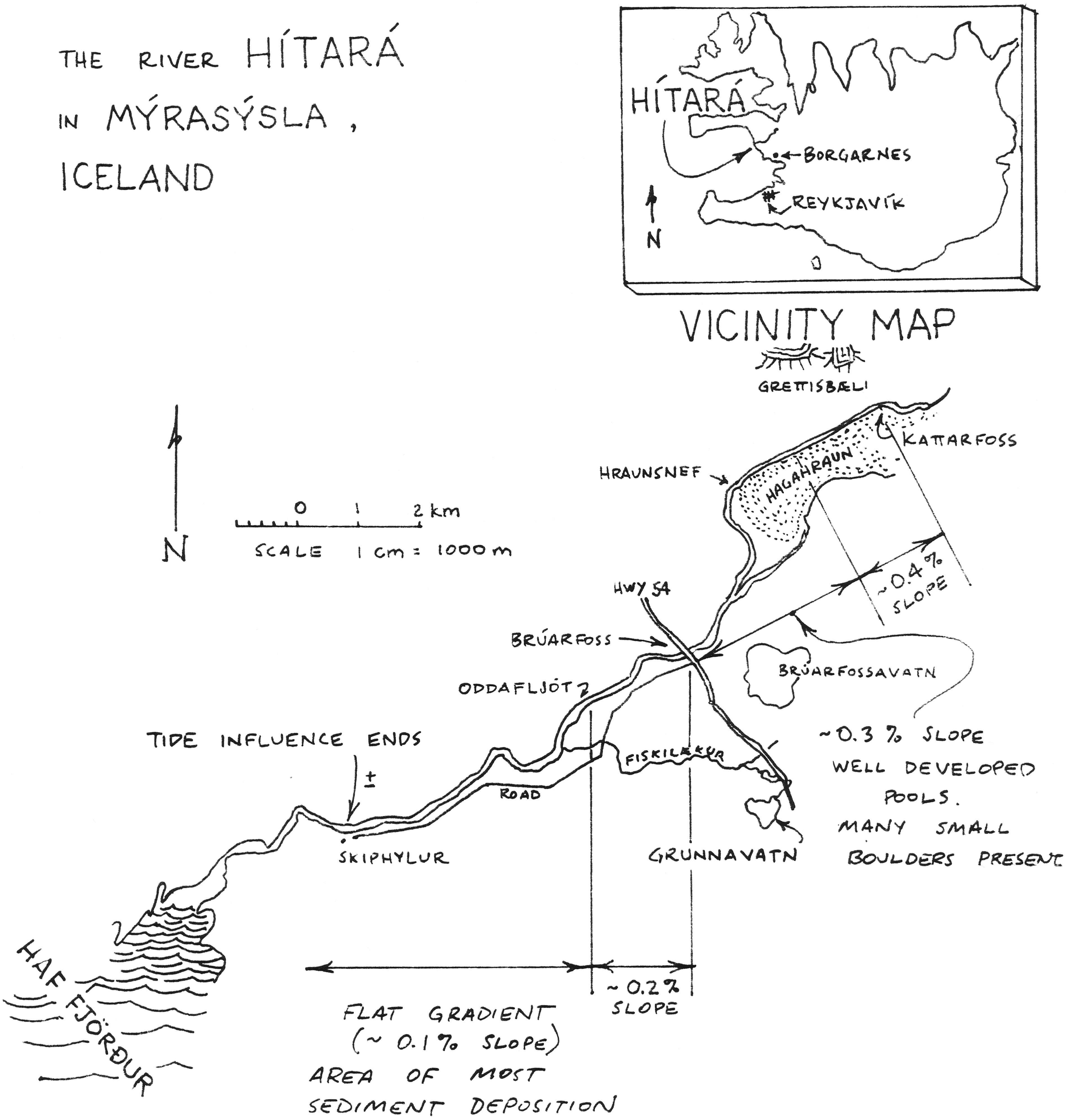
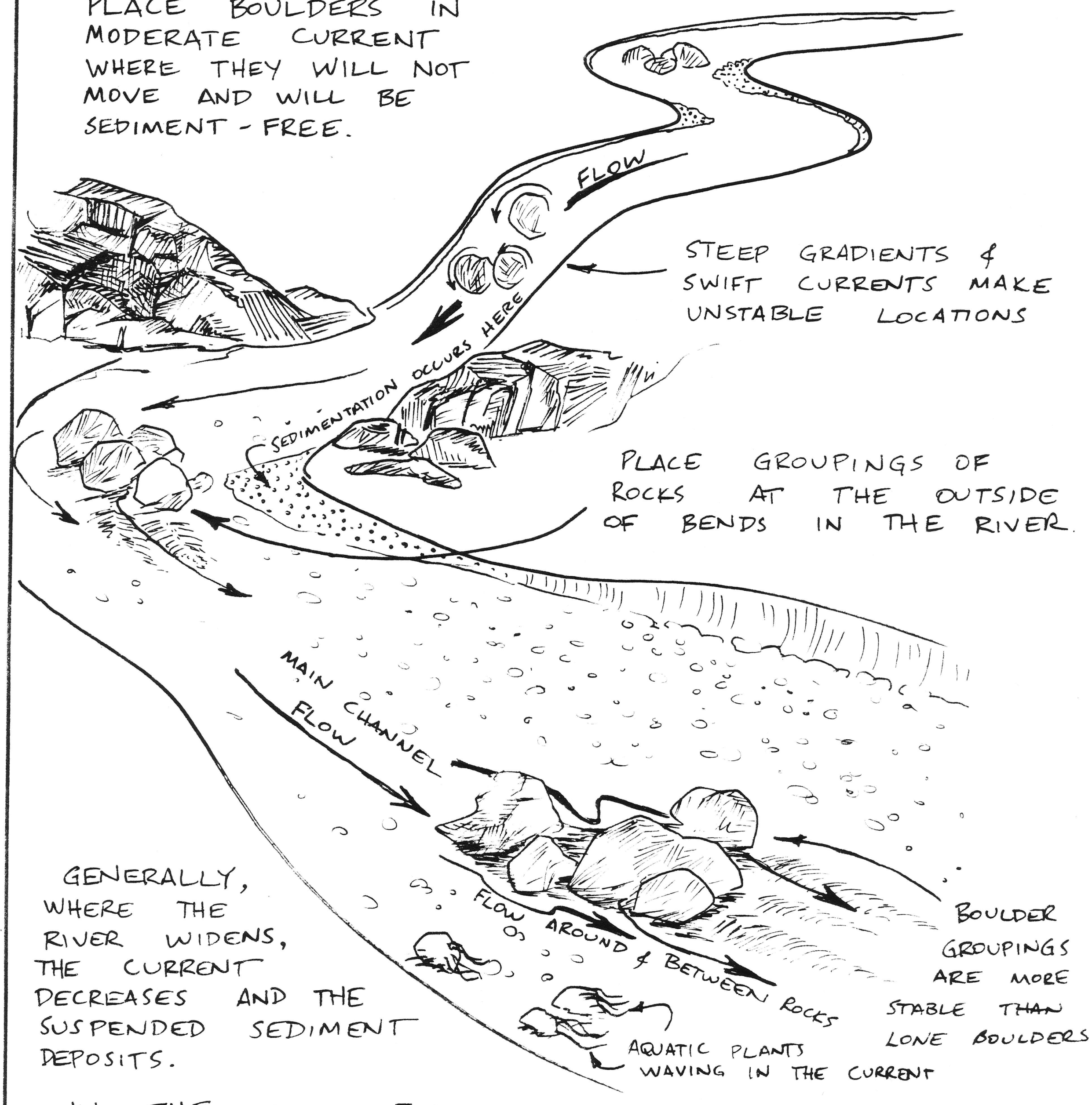

THE RIVER HÍTARÁ
IN MÝRASÝSLA,
ICELAND
HÍTARÁ
BORGARNES
REYKJAVÍK
N
VICINITY MAP
GRETTISBÆLI
KATTARFOSS
HRAUNSNEF
HAGAHRAUN
0 1 2 km
SCALE 1 cm = 1000 m
N
~0.4% SLOPE
HWY 54
BRÚARFOSS
BRÚARFOSSAVATN
ODDAFLJÓT
TIDE INFLUENCE ENDS
±
FISKILÆKUR
ROAD
~0.3 % SLOPE
WELL DEVELOPED POOLS.
MANY SMALL BOULDERS PRESENT
SKIPHYLUR
GRUNNAVATN
HAF FJÖRÐUR
~0.2% SLOPE
FLAT GRADIENT
(~ 0.1% SLOPE)
AREA OF MOST
SEDIMENT DEPOSITION

Figure 11.

BOULDER PLACEMENT FOR JUVENILE SALMON HABITAT



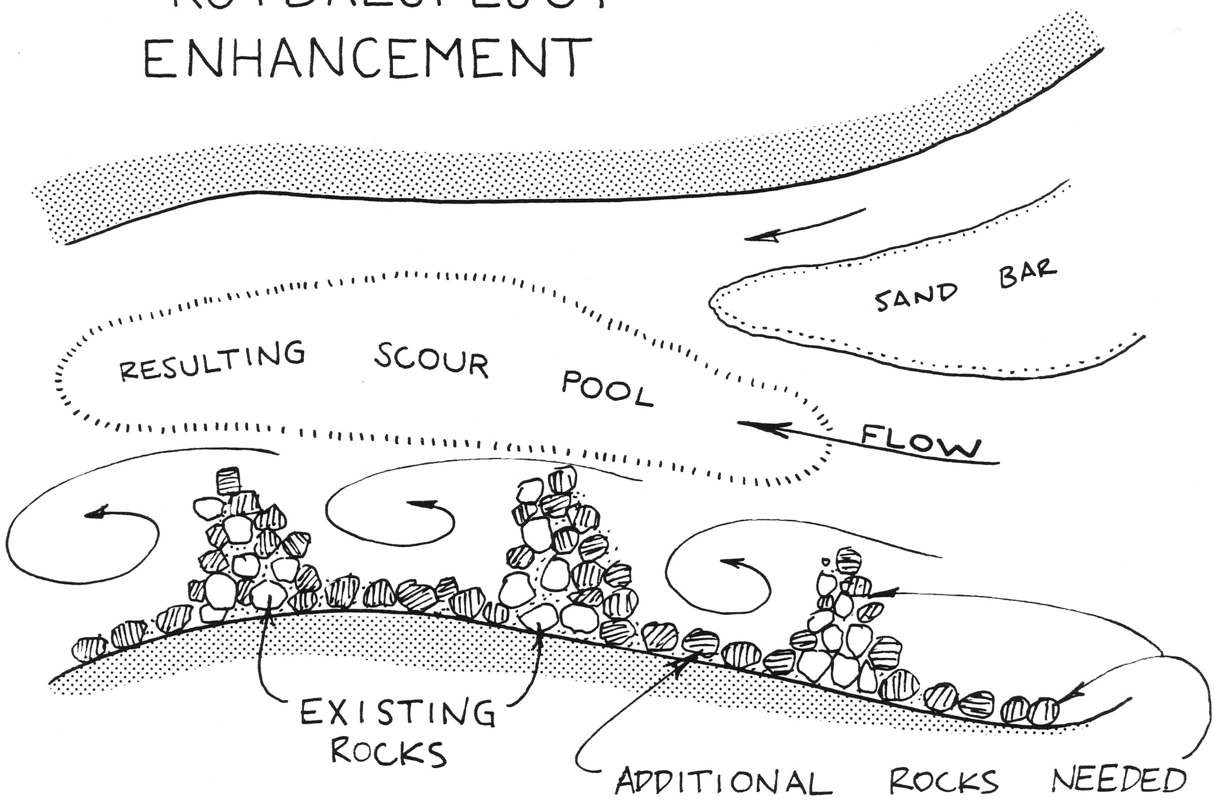
IN THE WIDE, FLAT PORTIONS OF THE RIVER PLACE ROCKS WHERE THERE IS A VISIBLE CURRENT.

THESE ROCKS WILL NEED TO BE MOVED AROUND TO RELEASE THE SEDIMENT WHICH ACCUMULATES - ONCE EACH SPRINGTIME OR AS NEEDED. OR -

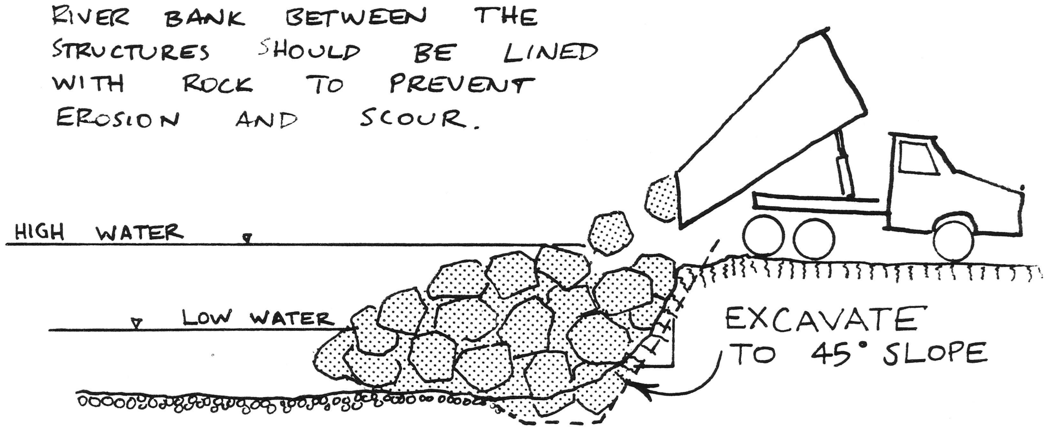
ADD MORE BOULDERS AS THE EARLIER BOULDERS ARE SEDIMENTED.

Figure 12.

KOTDALSFLJÓT ENHANCEMENT

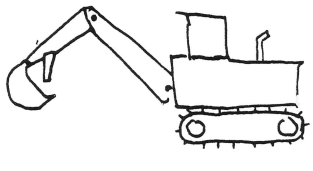


THE EXISTING ROCK STRUCTURES NEED TO BE STRENGTHENED. THE RIVER BANK BETWEEN THE STRUCTURES SHOULD BE LINED WITH ROCK TO PREVENT EROSION AND SCOUR.



CONSTRUCTION NOTES :

- BEST TO HAVE THE ABILITY TO PLACE ROCKS AS WELL AS DUMP THEM

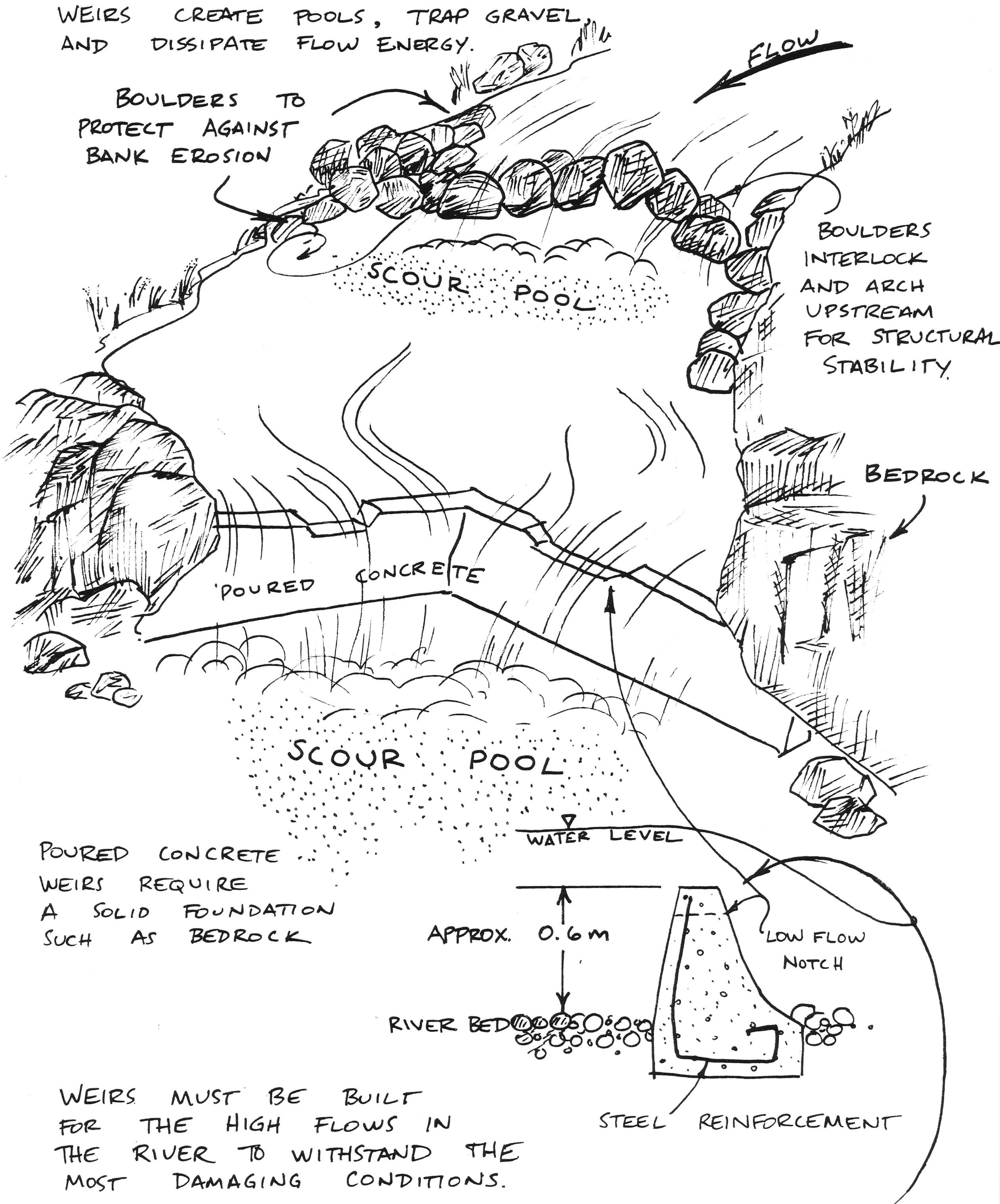


CAT 235 , FIATALLIS FE20LC OR SIMILAR

Figure 13.

CROSS-CHANNEL WEIRS

WEIRS CAN BE USED TO CREATE A DIVERSE HABITAT FOR ADULT AND JUVENILE SALMON.



WEIRS MUST BE BUILT FOR THE HIGH FLOWS IN THE RIVER TO WITHSTAND THE MOST DAMAGING CONDITIONS.

LOW FLOW NOTCHES ALLOW FISH PASSAGE

LANGA

The river Langa was visited on August 28 through 31, 1988, to examine existing habitat structures and recommend additional habitat structure placement.

The river reach from the sea to Bugurinn was investigated for adult salmon pool enhancement and in-channel cover. The in-stream structures between Bugurinn and Fljotandi (gravel and rock spur dikes) were examined and noted for maintenance or improvement. Between fishing spot number 3 and the rock weir at site C, adult pools and channel modifications were examined.

Although Langa has been modified with adult salmon structures, the principal interest is to develop more adult pools and holding areas in the form of mid-channel cover.

A channel profile and cross section survey was performed between the highway 54 bridge and Bugurinn to determine optimum structure locations. Pool enhancement and flow diversion are desired in this reach. See figure 15.

Spur dikes made of boulders are recommended to direct flow and shape the channel at Kvorn, as shown in figure 16. The spur dikes are located so that bank erosion will be minimal and so that the upstream water depth will be increased no more than 30 cm during mean flow.

At Fljotandi and Pjotandi, spur dikes provide shelter and flow diversity. Downstream of the spur dikes, boulders have been placed in the scour pools, which has resulted in productive fishing spots.

A spur dike at Eyarsund has developed a scour pool, although adult salmon have not been observed there. Placement of two or three boulders (.7 - 1.5 meters diameter each) in the scour pool is recommended.

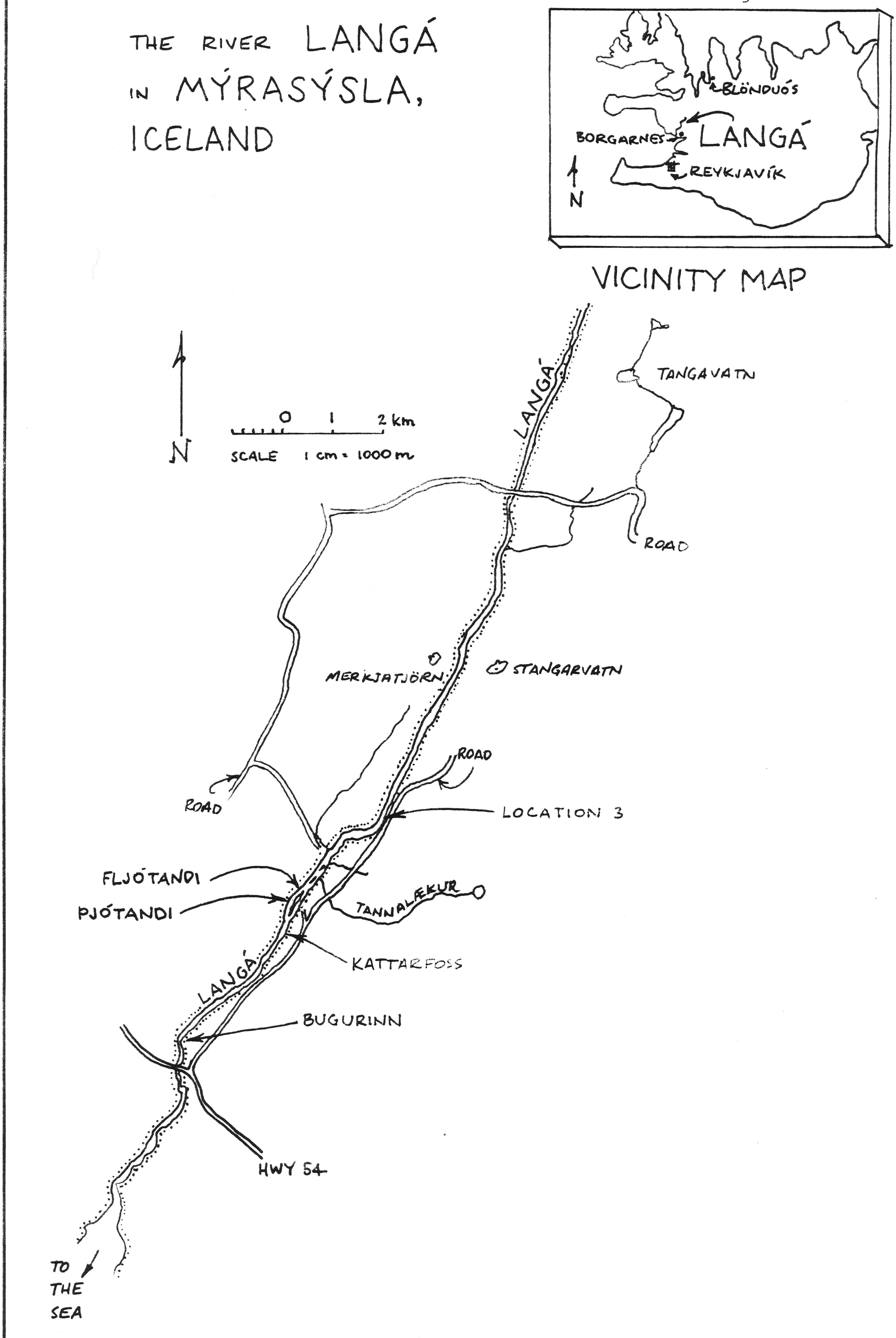
A pool can be developed upstream of Kattarfoss by concentrating the flow with a spur dike upstream of the location for the desired pool. Figure 8 shows a typical spur dike.

The diked portion of Langa (starting near fishing spot 3) is confined to a mean-flow channel which has contributed to bank erosion and subsequent pool filling along the undiked bank. Flood control dikes can be set back from the active river channel to allow flood flows to pass without excessive erosion. Figure 4 illustrates this configuration.

Boulder weirs have been built from fishing spot 11 upstream to fishing spot C. The weirs have formed productive fishing locations and a variety of habitat conditions. Annual maintenance could be lessened and the pool and flow quality enhanced by adding sacked concrete to mortar the boulders together as shown in figure 17.

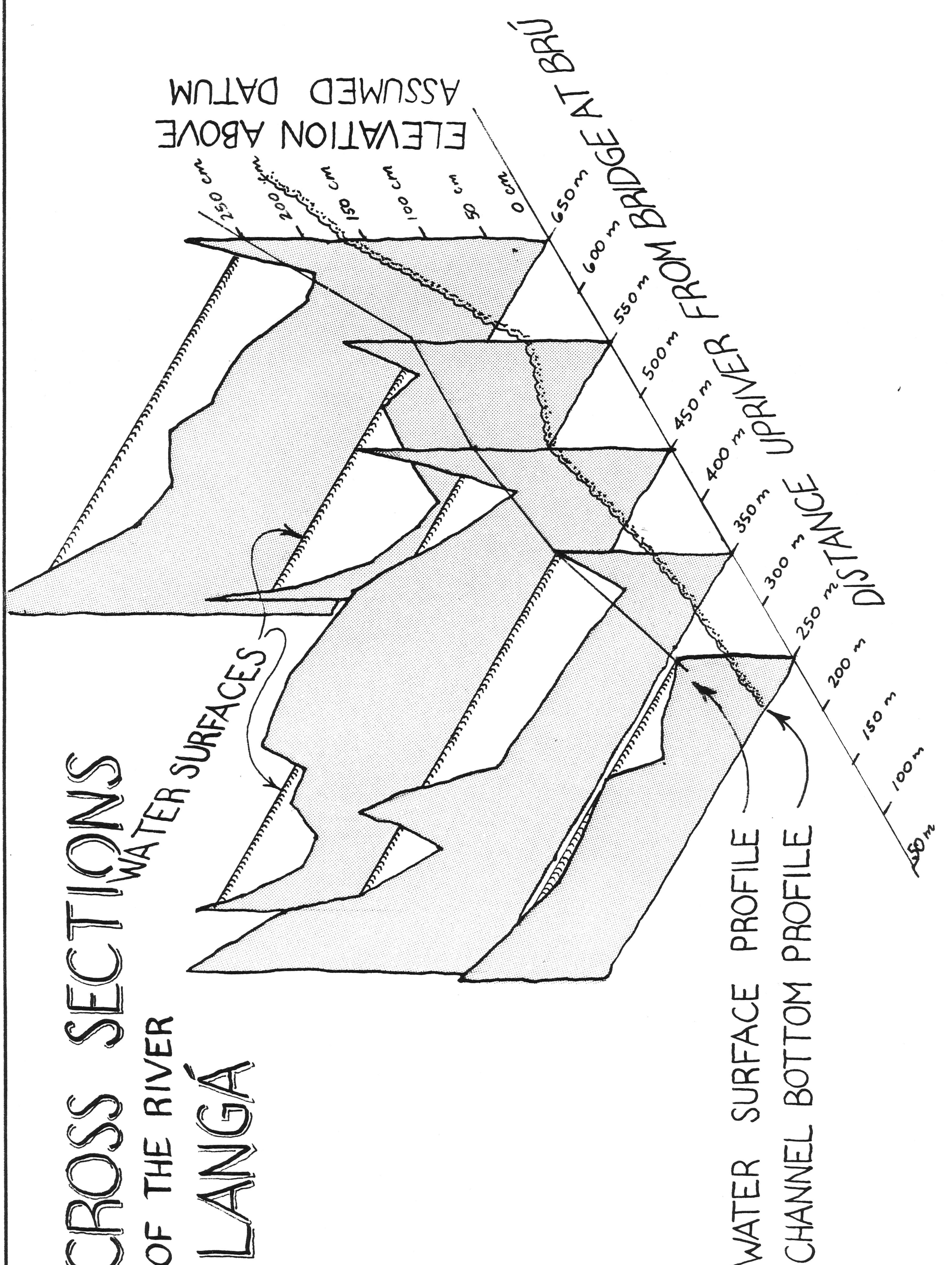
Figure 18 illustrates the dynamics of flow variation and its effects on the channel shape. In summary, it may be best to allow for natural variations in the river structure in some cases.

Figure 14.



Bestell-Nr 643 315 80185 gkm

Figure 15.


CROSS SECTIONS
OF THE RIVER
LANGÁ
WATER SURFACES
WATER SURFACE PROFILE
CHANNEL BOTTOM PROFILE
DISTANCE UPRIVER FROM BRIDGE AT BRÚ
ELEVATION ABOVE ASSUMED DATUM
0 cm
50 cm
100 cm
150 cm
200 cm
250 cm
50 m
100 m
150 m
200 m
250 m
300 m
350 m
400 m
450 m
500 m
550 m
600 m
650 m

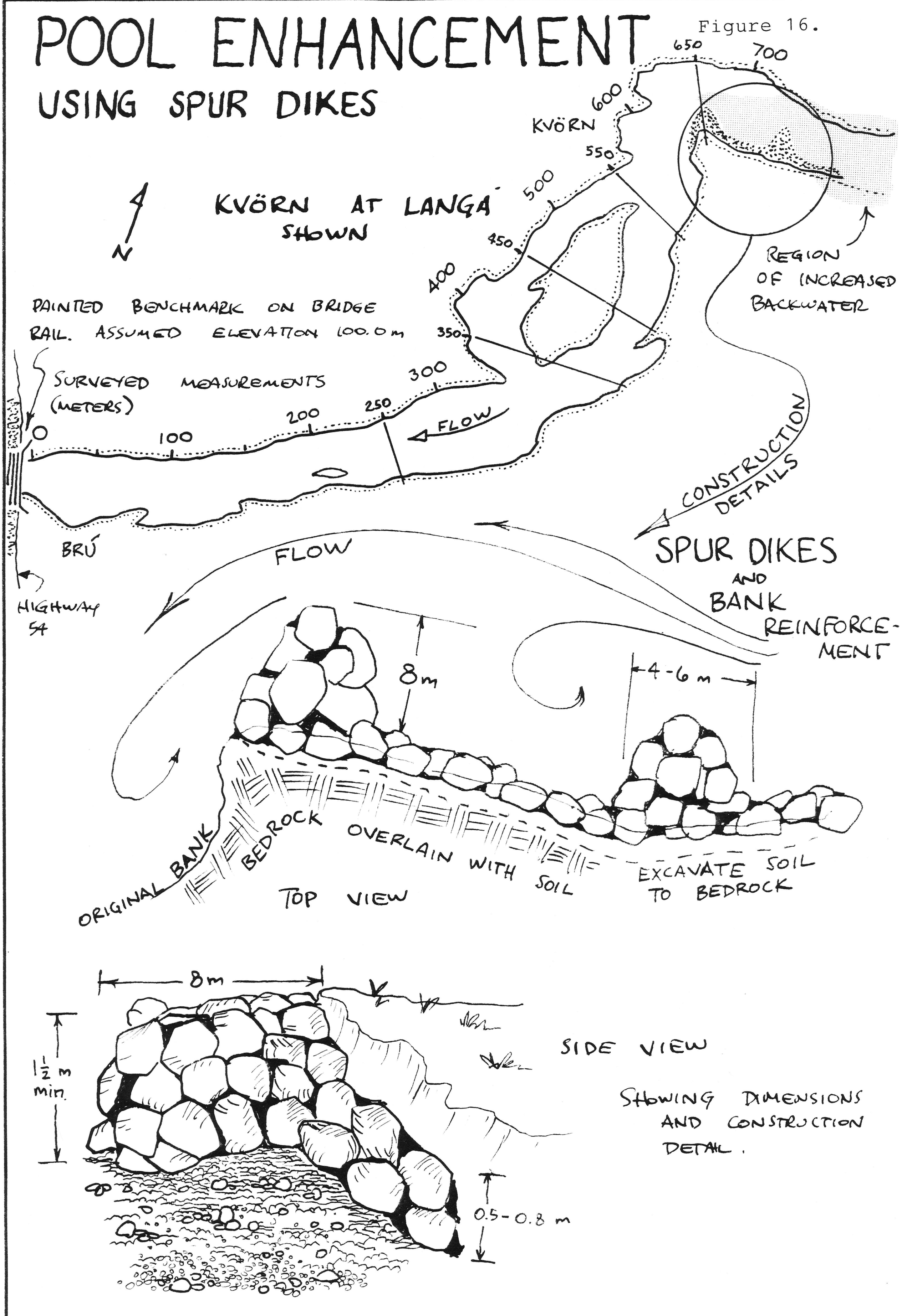
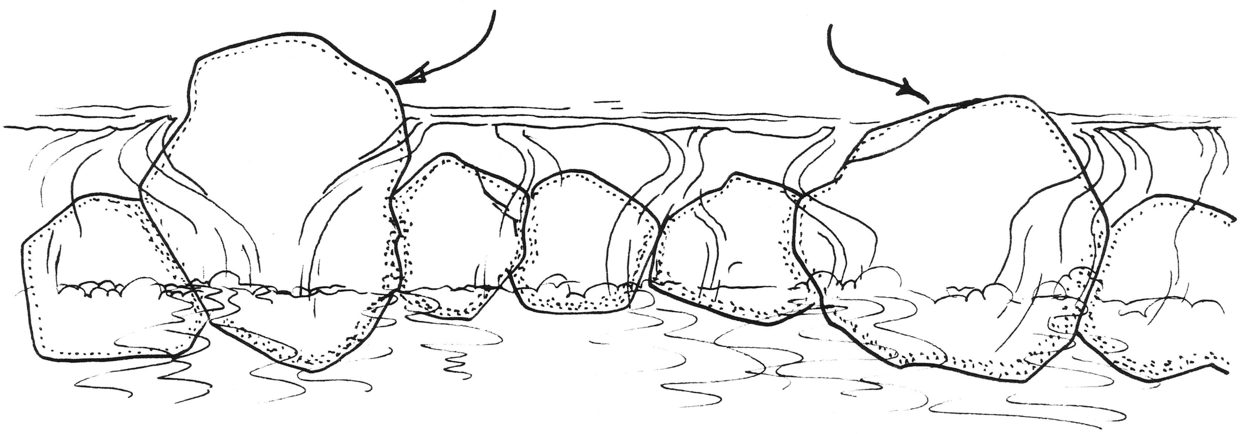

POOL ENHANCEMENT
USING SPUR DIKES
KVÖRN AT LANGÁ SHOWN
N
650
700
600
KVÖRN
550
500
450
400
350
300
250
200
100
0
PAINTED BENCHMARK ON BRIDGE RAIL. ASSUMED ELEVATION 100.0 m
SURVEYED MEASUREMENTS (METERS)
FLOW
BRÚ
HIGHWAY 54
REGION OF INCREASED BACKWATER
CONSTRUCTION DETAILS
SPUR DIKES AND BANK REINFORCEMENT
FLOW
8 m
4-6 m
ORIGINAL BANK
BEDROCK OVERLAIN WITH SOIL
EXCAVATE SOIL TO BEDROCK
TOP VIEW
8 m
1½ m min.
0.5-0.8 m
SIDE VIEW
SHOWING DIMENSIONS AND CONSTRUCTION DETAIL.

Figure 16.

Figure 17.

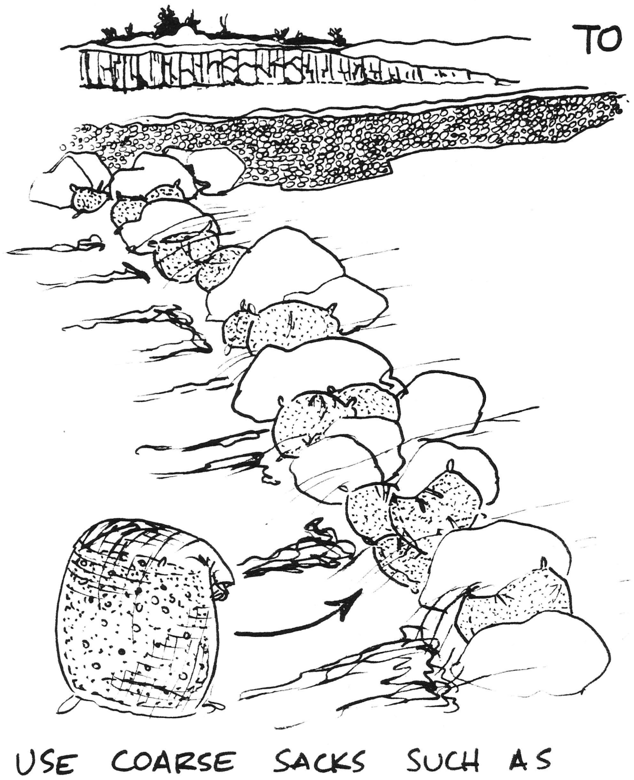
ROCK WEIR REINFORCEMENT

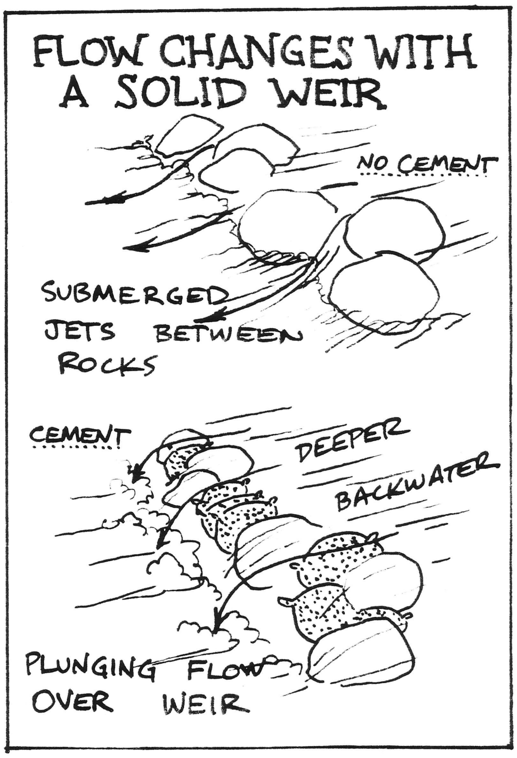
PLACE DOUBLE-SIZE BOULDERS TO HOLD SMALLER ROCKS IN PLACE



USE SACKS OF DRY CEMENT

TO "MORTAR" ROCKS IN PLACE



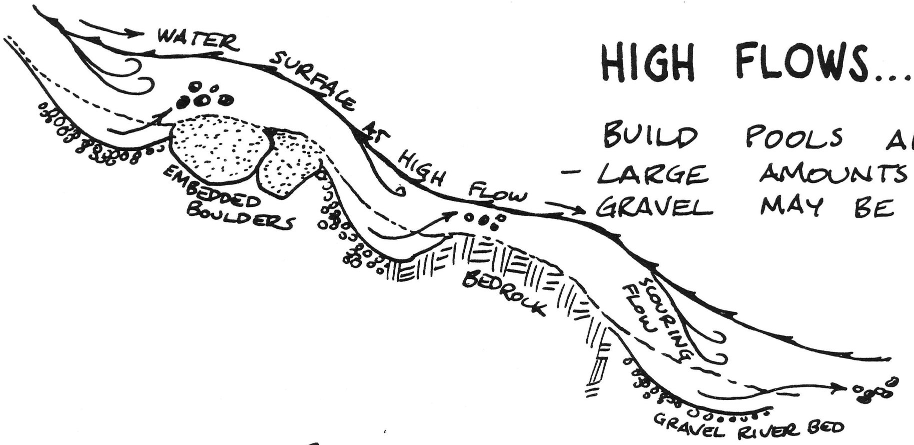


USE COARSE SACKS SUCH AS BURLAP AND COARSE AGGREGATE WITH THE CEMENT FOR A NATURAL APPEARANCE.

- THE DRY CEMENT HARDENS UNDERWATER.

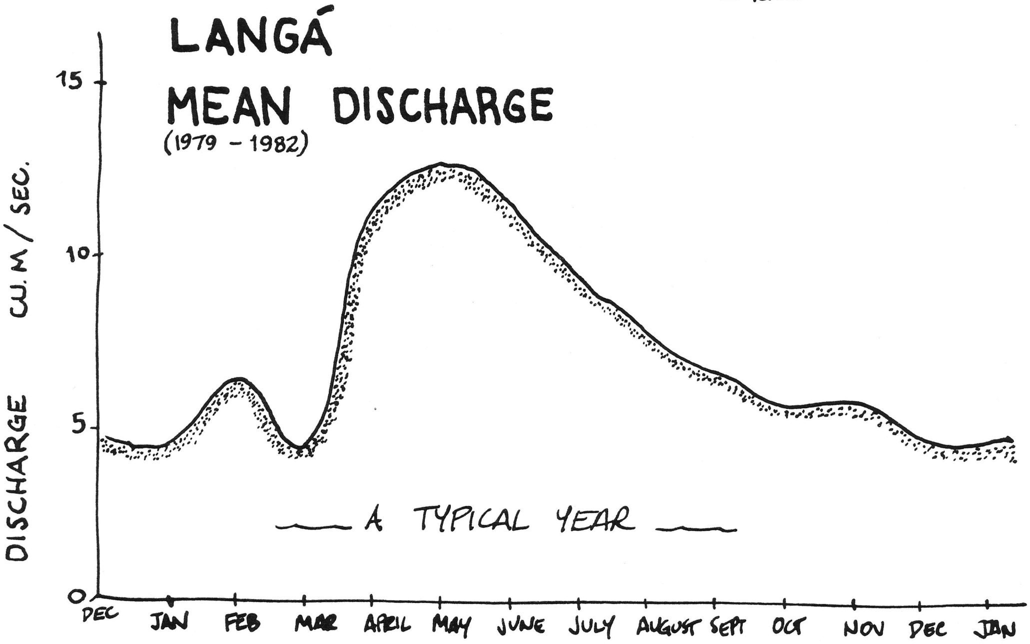
Figure 18.

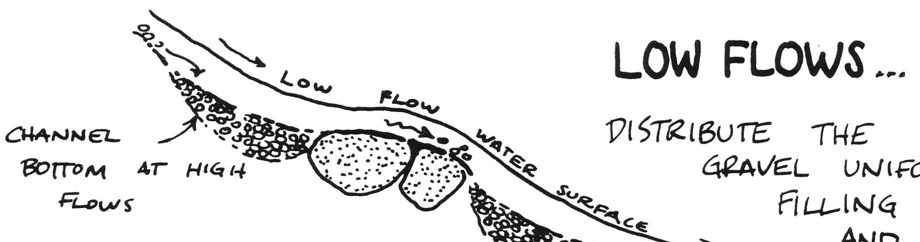
FLOW & CHANNEL VARIATIONS



HIGH FLOWS...

BUILD POOLS AND RIFFLES.
– LARGE AMOUNTS OF GRAVEL MAY BE TRANSPORTED.





LOW FLOWS...

DISTRIBUTE THE SUBSTRATE GRAVEL UNIFORMLY, FILLING POOLS AND LOWERING RIFFLES.

RIVER STRUCTURE CHANGES ACCORDING TO MONTHLY AND YEARLY CYCLES.

HAFNARA

The lower reach of Hafnara was investigated on September 1, 1988 to determine a layout for salmon producing facilities.

Channel elevations were measured from the abandoned dam site to the sea. See figure 19. Structure recommendations are shown in this figure also.

Figure 20 is a plot of pipe diameter vs. discharge for sizing the freshwater inlet pipe to the smolt lagoon. Computations are based on the continuity equation employing a Moody diagram. Concrete pipe is made with varying degrees of roughness and a median roughness is assumed. For coarsely finished pipe, use a larger diameter than indicated by the graph; 10-20% greater.

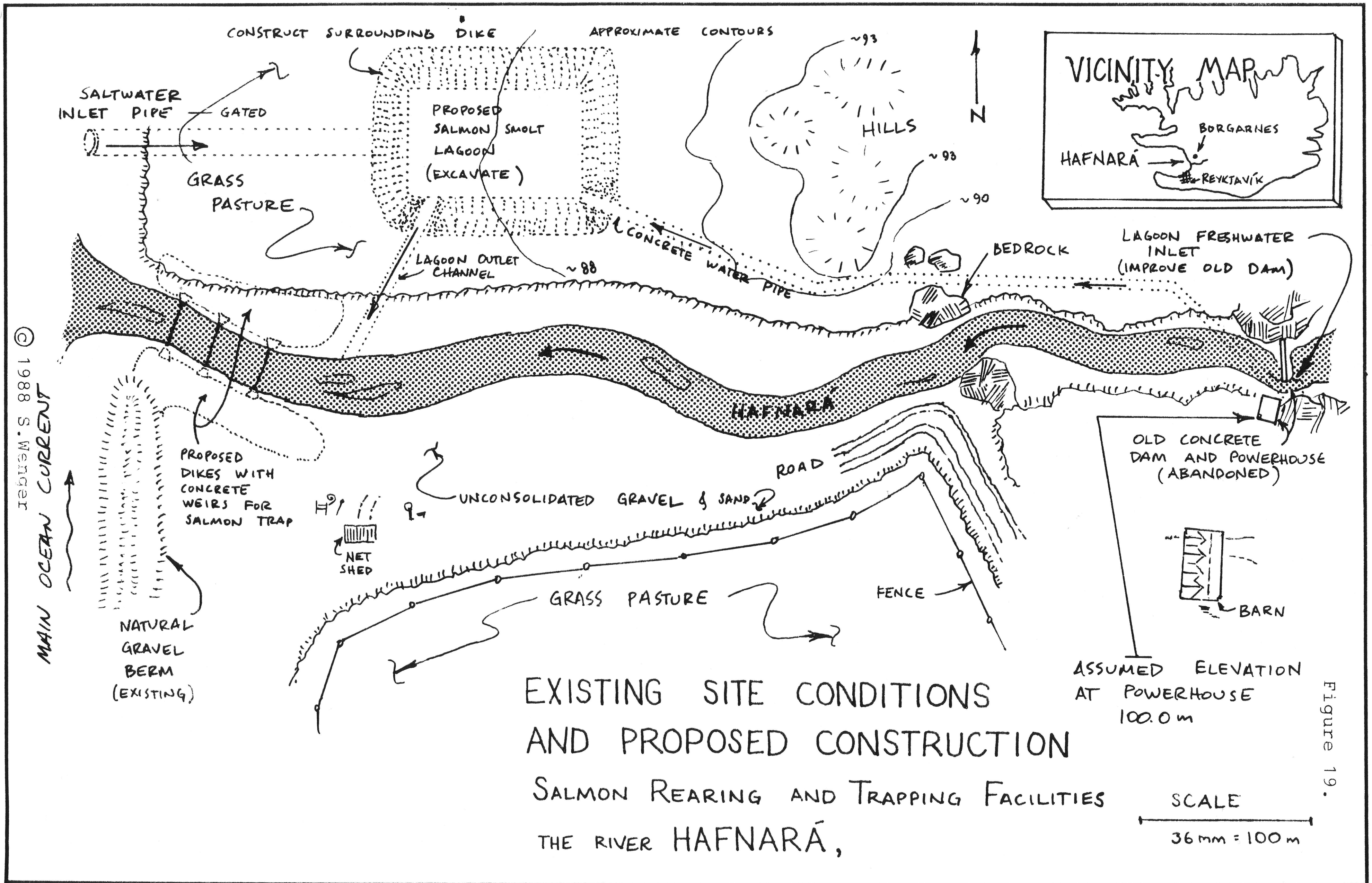

EXISTING SITE CONDITIONS AND PROPOSED CONSTRUCTION
SALMON REARING AND TRAPPING FACILITIES
THE RIVER HAFNARÁ,
VICINITY MAP
BORGARNES
HAFNARÁ
REYKJAVÍK
N
CONSTRUCT SURROUNDING DIKE
APPROXIMATE CONTOURS
SALTWATER INLET PIPE
GATED
PROPOSED SALMON SMOLT LAGOON (EXCAVATE)
GRASS PASTURE
HILLS
~93
~93
~90
~88
CONCRETE WATER PIPE
LAGOON OUTLET CHANNEL
BEDROCK
LAGOON FRESHWATER INLET (IMPROVE OLD DAM)
HAFNARÁ
PROPOSED DIKES WITH CONCRETE WEIRS FOR SALMON TRAP
UNCONSOLIDATED GRAVEL & SAND
ROAD
NET SHED
OLD CONCRETE DAM AND POWERHOUSE (ABANDONED)
BARN
FENCE
GRASS PASTURE
NATURAL GRAVEL BERM (EXISTING)
MAIN OCEAN CURRENT
ASSUMED ELEVATION AT POWERHOUSE 100.0 m
SCALE
36 mm = 100 m
© 1988 S.Wenger

Figure 19.

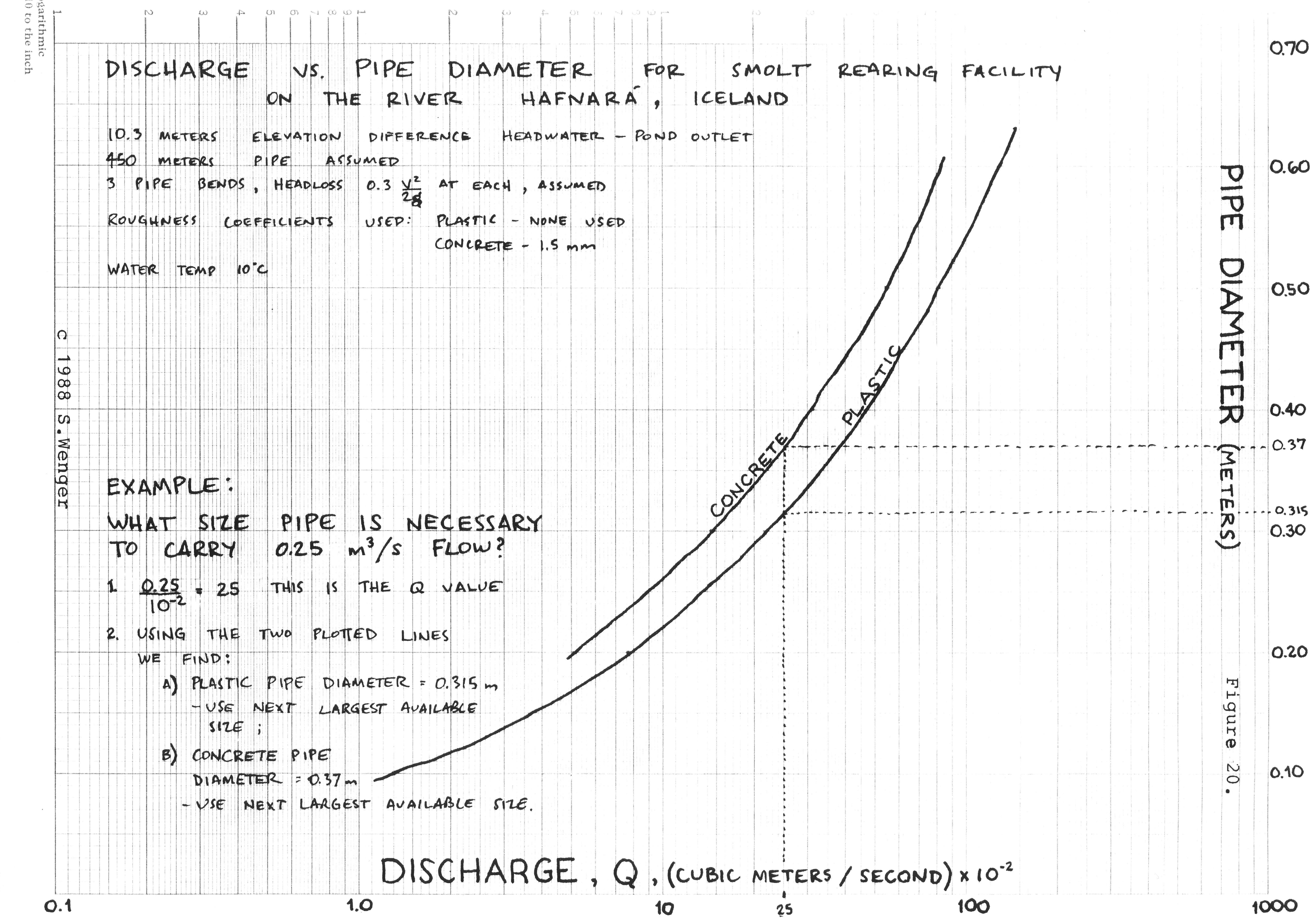

DISCHARGE VS. PIPE DIAMETER FOR SMOLT REARING FACILITY
ON THE RIVER HAFNARÁ, ICELAND
10.3 METERS ELEVATION DIFFERENCE HEADWATER – POND OUTLET
450 METERS PIPE ASSUMED
3 PIPE BENDS, HEADLOSS 0.3 V²/2g AT EACH, ASSUMED
ROUGHNESS COEFFICIENTS USED: PLASTIC – NONE USED
CONCRETE – 1.5 mm
WATER TEMP 10°C
EXAMPLE:
WHAT SIZE PIPE IS NECESSARY TO CARRY 0.25 m³/s FLOW?
1. 0.25/10⁻² = 25 THIS IS THE Q VALUE
2. USING THE TWO PLOTTED LINES WE FIND:
A) PLASTIC PIPE DIAMETER = 0.315 m
– USE NEXT LARGEST AVAILABLE SIZE;
B) CONCRETE PIPE DIAMETER = 0.37 m
– USE NEXT LARGEST AVAILABLE SIZE.
CONCRETE
PLASTIC
PIPE DIAMETER (METERS)
0.70
0.60
0.50
0.40
0.37
0.315
0.30
0.20
0.10
DISCHARGE, Q, (CUBIC METERS / SECOND) x 10⁻²
0.1
1.0
10
25
100
1000
c 1988 S.Wenger
Semi-Logarithmic
4 Cycles x 10 to the inch

Figure 20.

HVALSA

The river Hvalsa was visited on September 3 and 4, 1988 to determine suitable modifications to enhance adult salmon habitat. Lack of channel depth during low flow and gravel instability are the principal areas of concern.

Hvalsa is a direct runoff river, subject to seasonal floods. A large volume of coarse bedload is carried during floods, which leaves many areas scoured to bedrock. During low flows, the river is so shallow as to be nearly discontinuous, thus stranding upstream migrating salmon in pools.

Gradient changes in Hvalsa are shown in the channel profile of figure 22. Downstream from the highway 68 bridge, the channel is relatively flat with a coarse gravel and rock substrate. Upstream from the bridge, the channel is lined by a bedrock canyon. Gravel and rocks are transported continuously so that few stable gravel areas exist. The falls,Fossinn are impassable to salmon and no natural salmon production occurs beyon this point. See map, figure 21.

Habitat enhancements on Hvalsa are desired to develop a stable channel through which salmon can migrate during low flows. Channel-forming can be accomplished using spur dikes and cross-channel weirs.

Channel structures for the farthest downstream reach of Hvalsa are shown in figure 23. The three spur dikes and bank reinforcing will define a channel during high flows which will be sustained during low flows. The spur dikes may be built out of boulders (1 meter diameter each), concrete, or a combination of both. Structural strength to withstand flood flows must be accomplished, for this is when the channel forming occurs.

Cross-channel weirs may be constructed upstream to trap gravel and concentrate flow. Figures 2, 13, and 24 show possible weir types. Concrete weirs are recommended because they are most stable on the bedrock substrate. Rock structures are generally too difficult to anchor so that they will withstand flood flows.

Figure 22 contains a table of maximum weir heights for given reaches along the upstream portion of Hvalsa. These heights are calculated so that the overall channel slope is maintained at 0.004. This insures sufficient flow velocities for optimum salmon habitat. Individual weir heights should be kept below 0.8 meters to maintain a passable channel and ease constuction.

Concrete may be made more natural appearing by using techniques illustrated in figure 24. Variations on these methods are possible, although any surface alteration should not reduce the concrete overlying the steel reinforcing to less than the design specification (approx 25 cm). Likewise, specified weir thickness should be maintained.

Figure 21.

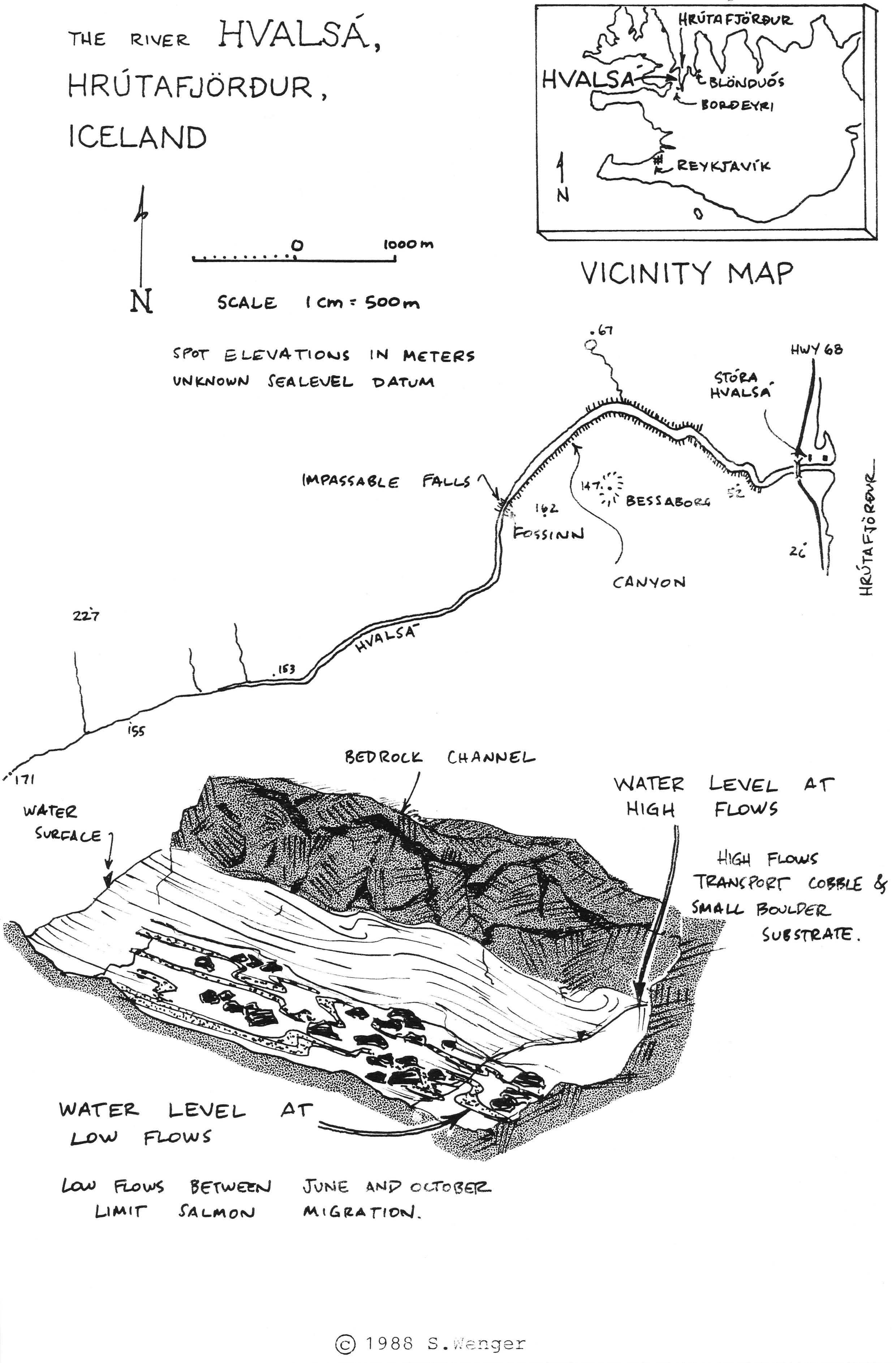

THE RIVER HVALSÁ,
HRÚTAFJÖRÐUR,
ICELAND
N
0
1000m
SCALE 1cm = 500m
HRÚTAFJÖRÐUR
HVALSÁ
BLÖNDUÓS
BORÐEYRI
REYKJAVÍK
N
VICINITY MAP
SPOT ELEVATIONS IN METERS
UNKNOWN SEALEVEL DATUM
67
HWY 68
STÓRA HVALSÁ
IMPASSABLE FALLS
147
BESSABORG
52
162
FOSSINN
26
HRÚTAFJÖRÐUR
CANYON
227
HVALSÁ
153
155
171
BEDROCK CHANNEL
WATER LEVEL AT HIGH FLOWS
WATER SURFACE
HIGH FLOWS TRANSPORT COBBLE & SMALL BOULDER SUBSTRATE.
WATER LEVEL AT LOW FLOWS
LOW FLOWS BETWEEN JUNE AND OCTOBER LIMIT SALMON MIGRATION.

Figure 22.

HVALSÁ CHANNEL PROFILE

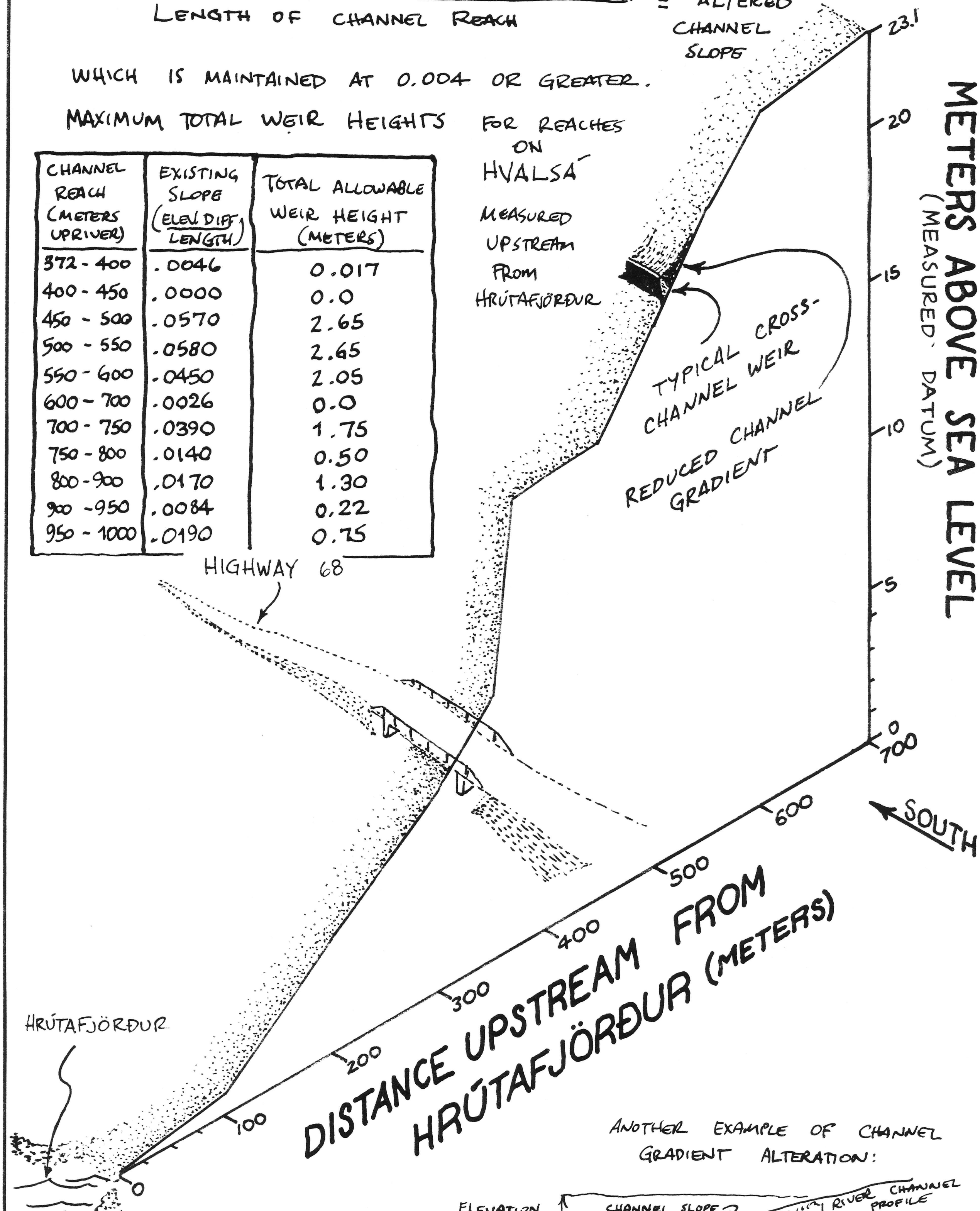
WEIR PLACEMENT: WEIRS REDUCE THE EFFECTIVE CHANNEL SLOPE AS INDICATED BY:

$$\frac{\text{ORIGINAL ELEVATION DIFFERENCE} - \text{WEIR HEIGHT}}{\text{LENGTH OF CHANNEL REACH}} = \text{ALTERED CHANNEL SLOPE}$$

WHICH IS MAINTAINED AT 0.004 OR GREATER.

MAXIMUM TOTAL WEIR HEIGHTS FOR REACHES ON HVALSÁ MEASURED UPSTREAM FROM HRÚTAFJÖRÐUR

CHANNEL REACH (METERS UPRIVER)	EXISTING SLOPE (ELEV. DIFF. / LENGTH)	TOTAL ALLOWABLE WEIR HEIGHT (METERS)
372 - 400	.0046	0.017
400 - 450	.0000	0.0
450 - 500	.0570	2.65
500 - 550	.0580	2.65
550 - 600	.0450	2.05
600 - 700	.0026	0.0
700 - 750	.0390	1.75
750 - 800	.0140	0.50
800 - 900	.0170	1.30
900 - 950	.0084	0.22
950 - 1000	.0190	0.75



ANOTHER EXAMPLE OF CHANNEL GRADIENT ALTERATION:

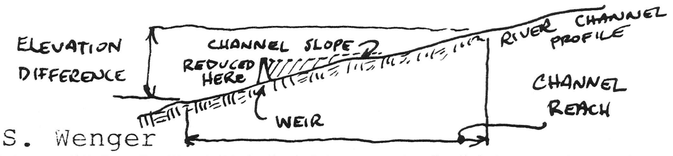


Figure 23.

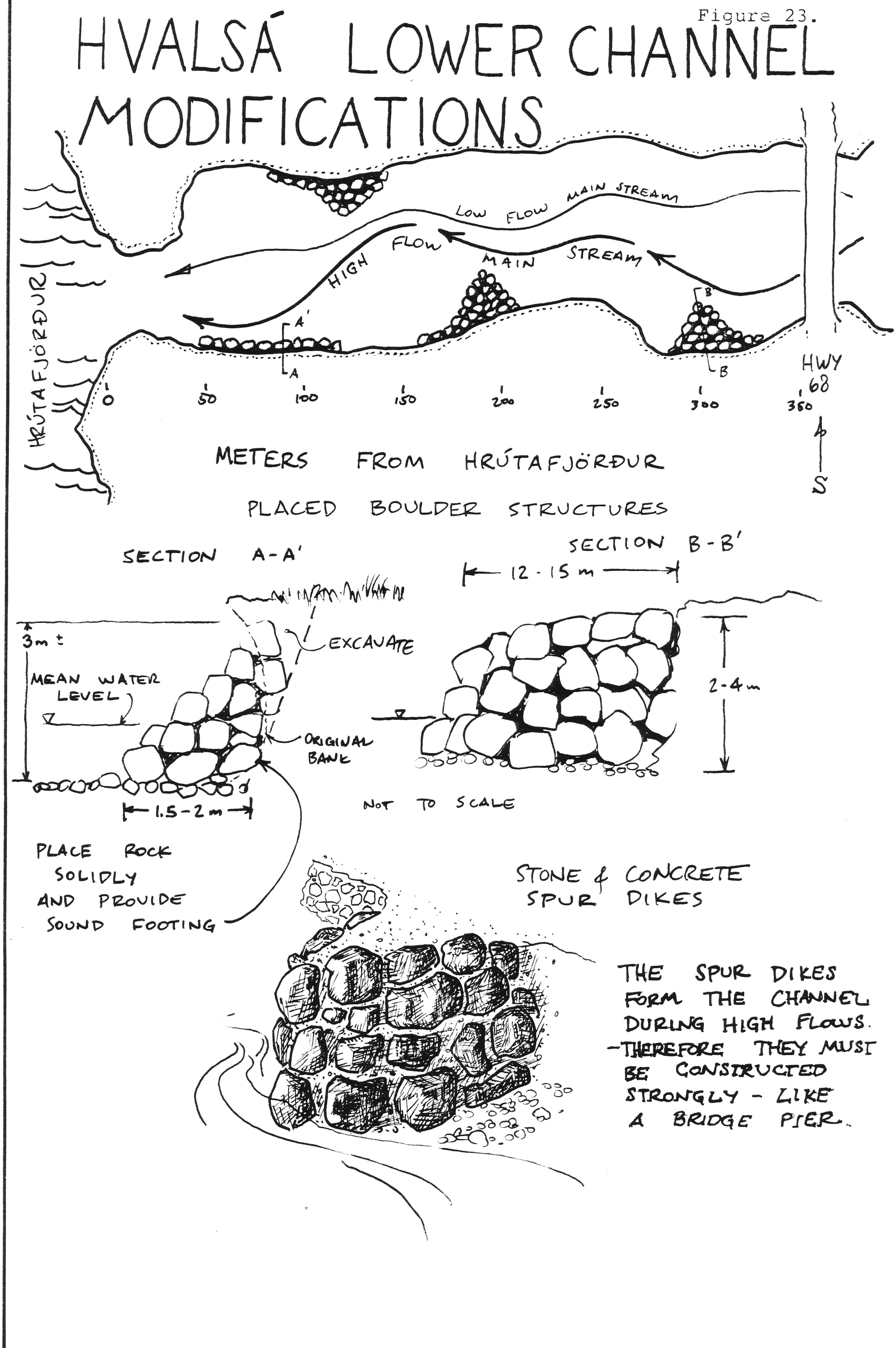
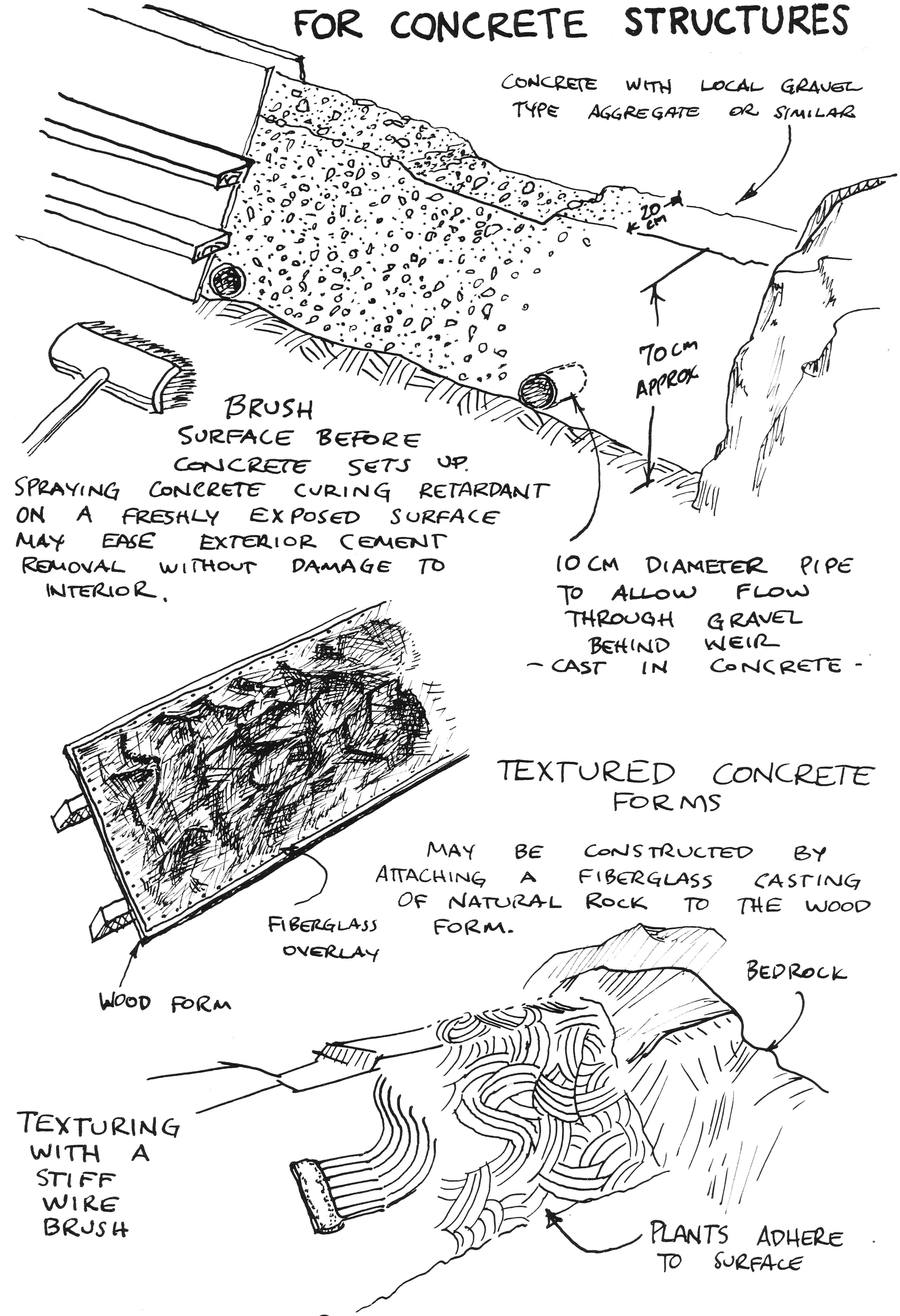

HVALSÁ LOWER CHANNEL MODIFICATIONS
LOW FLOW MAIN STREAM
HIGH FLOW MAIN STREAM
HRÚTAFJÖRÐUR
A'
A
B
B
HWY 68
0
50
100
150
200
250
300
350
S
METERS FROM HRÚTAFJÖRÐUR
PLACED BOULDER STRUCTURES
SECTION A-A'
SECTION B-B'
12-15 m
3m ±
MEAN WATER LEVEL
EXCAVATE
ORIGINAL BANK
1.5-2m
2-4m
NOT TO SCALE
PLACE ROCK SOLIDLY AND PROVIDE SOUND FOOTING
STONE & CONCRETE SPUR DIKES
THE SPUR DIKES FORM THE CHANNEL DURING HIGH FLOWS. -THEREFORE THEY MUST BE CONSTRUCTED STRONGLY - LIKE A BRIDGE PIER.

Figure 24.

AESTHETIC ENHANCEMENTS
FOR CONCRETE STRUCTURES



GRIMSA

The river Grimsa was visited on September 7, 1988 to review existing channel structures and recommend improvements. Both adult and juvenile salmon habitat enhancements are desired.

The reach of Grimsa between Homavath (spot 7) and Husbreitha (spot 16) was examined to review existing channel modifications which consist of excavated and plowed cobble and gravel dikes. The dikes contain Grimsa to a defined channel and attempt to promote scour pools for adult salmon. Generally, the cobble dikes seem to be located stragically, although they are not durable enough to resist seasonal flooding. These flood flows, when interacting with a permenent dike, could create the desired scour pools and flow patterns. Dikes can be made more durable by placing boulders on the upriver faces or by constructing gabion basket structures. See figure 26. Gabions could take advantage of the large quantities of smaller rocks available in the channel, although the construction technique is labor-intensive.

Along Thingnesstrengir, holding places for adult salmon were requested. These may be provided by placing boulders (1-1.5 meters diameter each) in the main channel flow. Angular rocks tend to be more stable than rounded rocks.

Hellufljot (spot 31) was examined for adult holding locations within the channel. The current along this 750 meter reach is approximately 0.3 m/s at mid-channel. Narrowing the channel by placing a spur dike on the east bank, and placing boulders along the resulting scour pool is recommended. See figure 27.

Ferjupollur (spot 36) is a site of a gravel and rock berm opposite a rock weir which has created a scour pool. This has been a successful structure and similar structures are desired 80 meters downstream. A construction technique using precast concrete sections is shown in figure 28. Similar structures are recommended at Strengur (spot 39) and at Tangi (spot 47).

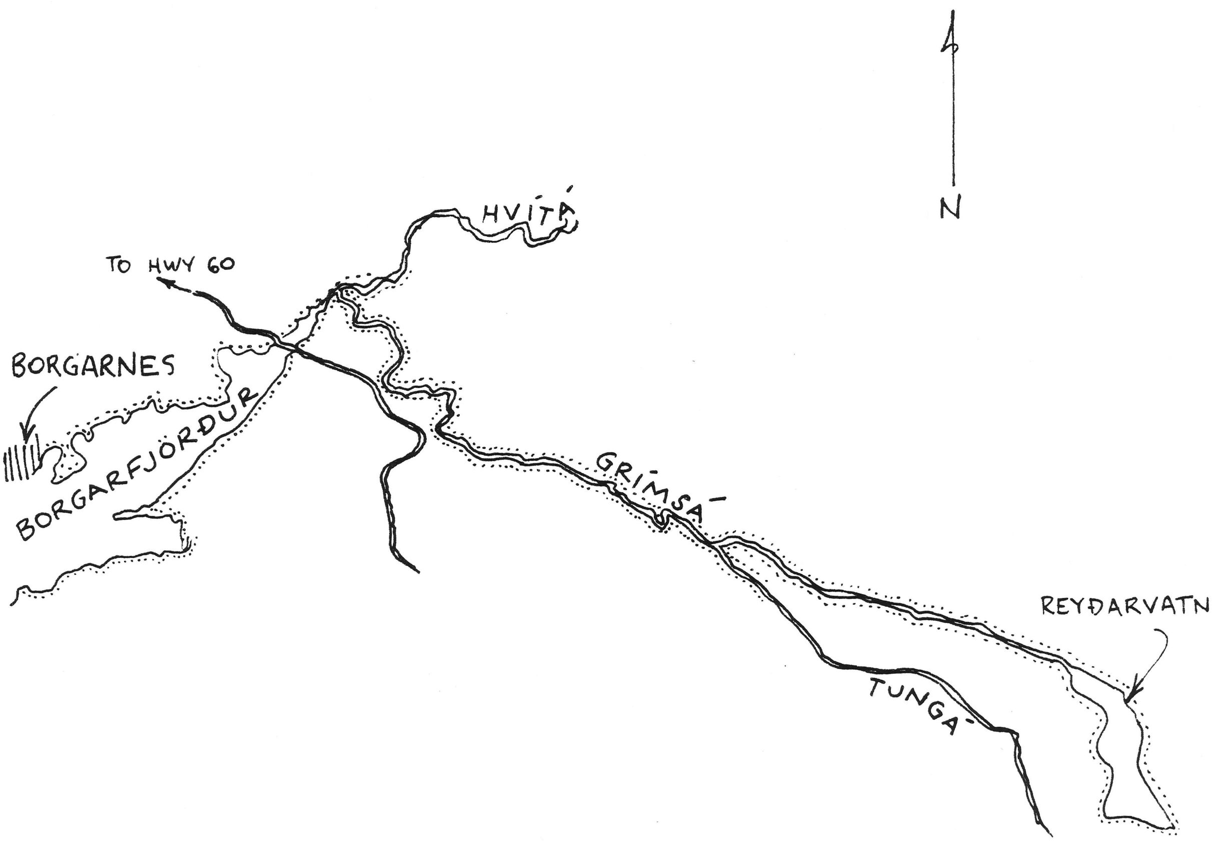
At many locations the banks are overhanging and collapsing into the river. Fencing the top of the banks is a method to stabilize the vegetation and retain the bank.

Stekkjarstrengur (spot 33) consists of boulders placed from the north bank, which can be fortified with additional rocks as shown in figure 28.

Figure 25.

THE RIVER GRÍMSÁ, IN LUNDAREYKJADALUR ICELAND

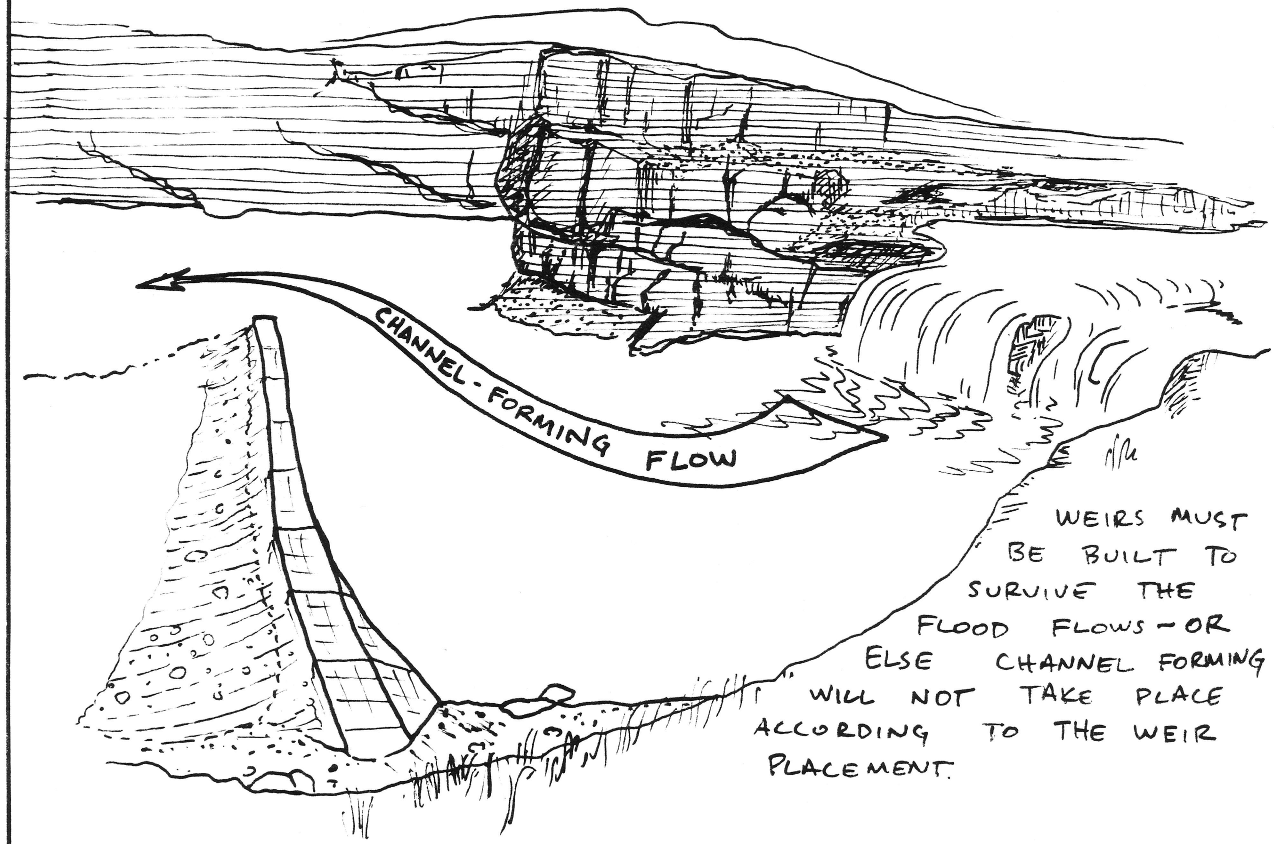
VICINITY MAP



GABION WEIR REINFORCING

FOR GRAVEL DIKES ON GRÍMSÁ Figure 26.

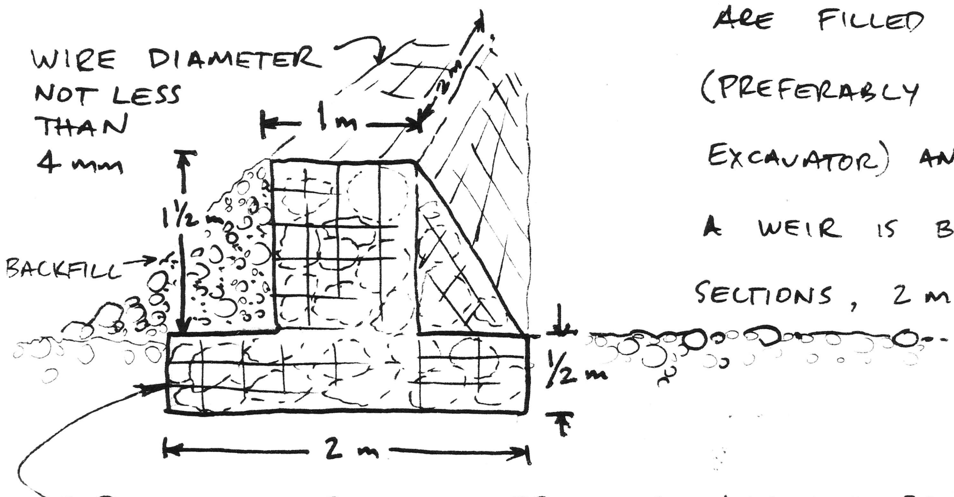
TYPICAL WEIR - STÓRLAXAFLJÓT SHOWN BELOW



WEIRS MUST BE BUILT TO SURVIVE THE FLOOD FLOWS - OR ELSE CHANNEL FORMING WILL NOT TAKE PLACE ACCORDING TO THE WEIR PLACEMENT.

GABION DETAIL

WIRE MESH BASKETS ARE FILLED WITH STONES (PREFERABLY WITH AN EXCAVATOR) AND WIRED SHUT. A WEIR IS BUILT OUT OF SECTIONS, 2 m LONG EACH.

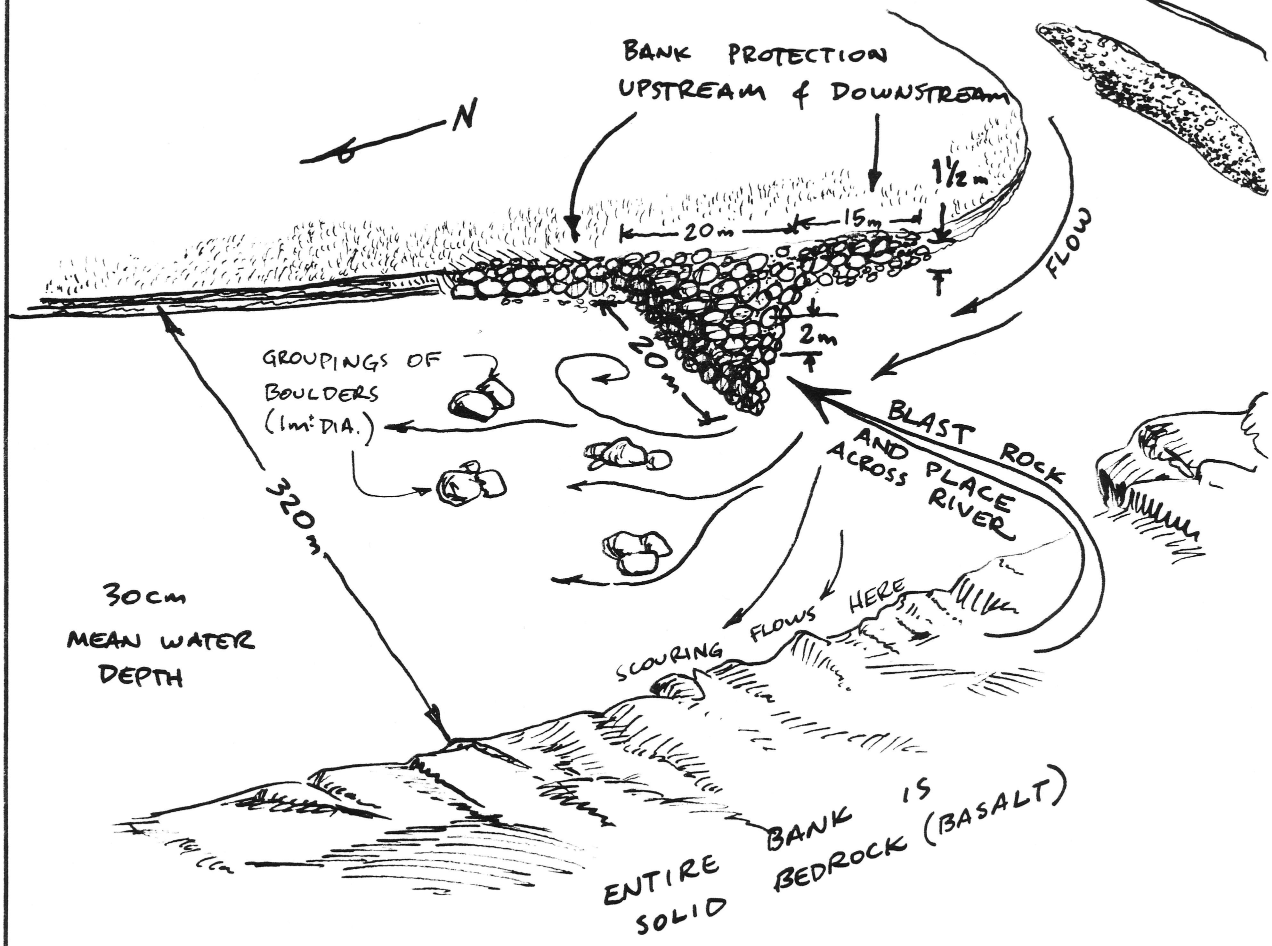


EMBEDDED SECTION PROTECTS AGAINST SCOUR

Figure 27.

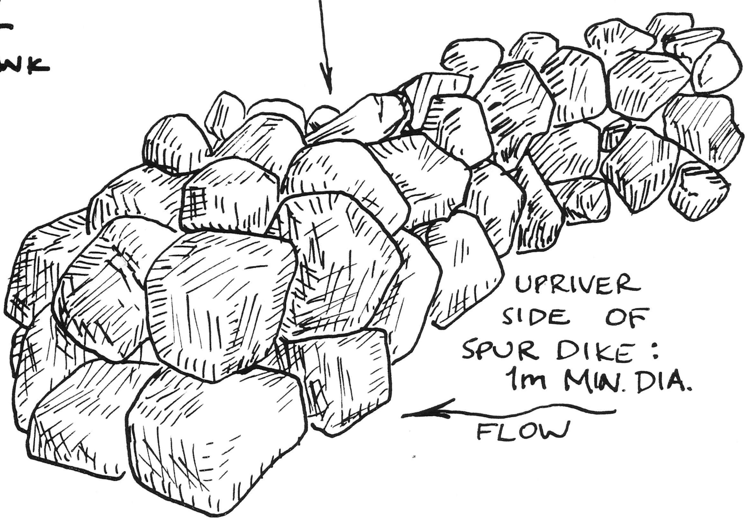
FLOW DIVERSITY AT HELLUFLJOT

USING A BOULDER SPUR DIKE AND MID-CHANNEL BOULDERS



THE SPUR DIKE IS OPTIMALLY LOCATED ON EAST BANK SO THAT SCOURING FLOWS ARE CONCENTRATED AGAINST THE BEDROCK WEST BANK

BOULDER SIZES



BOULDERS UPRIVER AND DOWNRIVER OF SPUR DIKE ALONG BANKS: 0.7 - 1 m AVERAGE DIAMETER

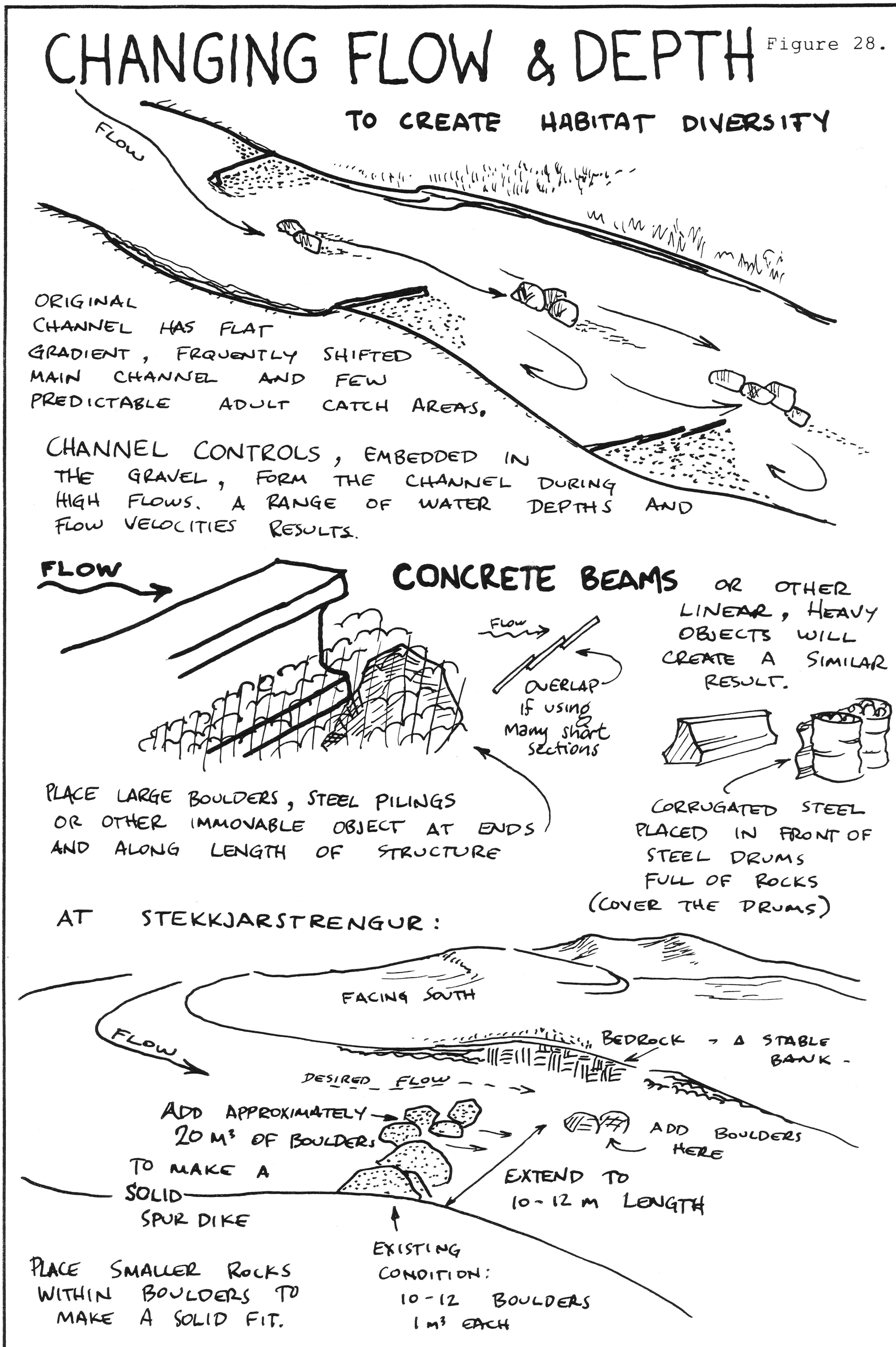

CHANGING FLOW & DEPTH
TO CREATE HABITAT DIVERSITY
FLOW
ORIGINAL CHANNEL HAS FLAT GRADIENT, FREQUENTLY SHIFTED MAIN CHANNEL AND FEW PREDICTABLE ADULT CATCH AREAS.
CHANNEL CONTROLS, EMBEDDED IN THE GRAVEL, FORM THE CHANNEL DURING HIGH FLOWS. A RANGE OF WATER DEPTHS AND FLOW VELOCITIES RESULTS.
FLOW
CONCRETE BEAMS OR OTHER LINEAR, HEAVY OBJECTS WILL CREATE A SIMILAR RESULT.
Flow
OVERLAP if using Many short sections
PLACE LARGE BOULDERS, STEEL PILINGS OR OTHER IMMOVABLE OBJECT AT ENDS AND ALONG LENGTH OF STRUCTURE
CORRUGATED STEEL PLACED IN FRONT OF STEEL DRUMS FULL OF ROCKS (COVER THE DRUMS)
AT STEKKJARSTRENGUR:
FACING SOUTH
FLOW
BEDROCK → A STABLE BANK.
DESIRED FLOW
ADD APPROXIMATELY 20 M³ OF BOULDERS TO MAKE A SOLID SPUR DIKE
ADD BOULDERS HERE
EXTEND TO 10-12 m LENGTH
EXISTING CONDITION: 10-12 BOULDERS 1 m³ EACH
PLACE SMALLER ROCKS WITHIN BOULDERS TO MAKE A SOLID FIT.

Figure 28.

LAXA

The river Laxa in Athaldalur was examined on September 9, 1988 for enhancement of adult and juvenile salmon habitat. Existing structures were examined for durability and effectiveness.

Starting at the downriver lake, Myravatn, adult habitat structures to encourage fish congregation in specific areas are desired. Presently, salmon are caught at Mjosund and Hraunholn at the most downriver portion of the lake. Additional catch sites are desired within 30 meters of the shore along Myravatn.

The current within 10 meters of the bank is estimated at 0.3-0.5 m/s at a site 200 meters upstream of Mjosund. See map, figure 29. At other locations in the lake, shoreline velocities range from 0.3-0.7 m/s.

Given the observed velocities in the lake, (relatively swift for a lake, as such) boulder placements in water depths greater than 2 meters are recommended to encourage salmon groupings. Figure 30 illustrates a typical boulder stack, as well as a vane device which has been used in lakes and saltwater for attracting fish.

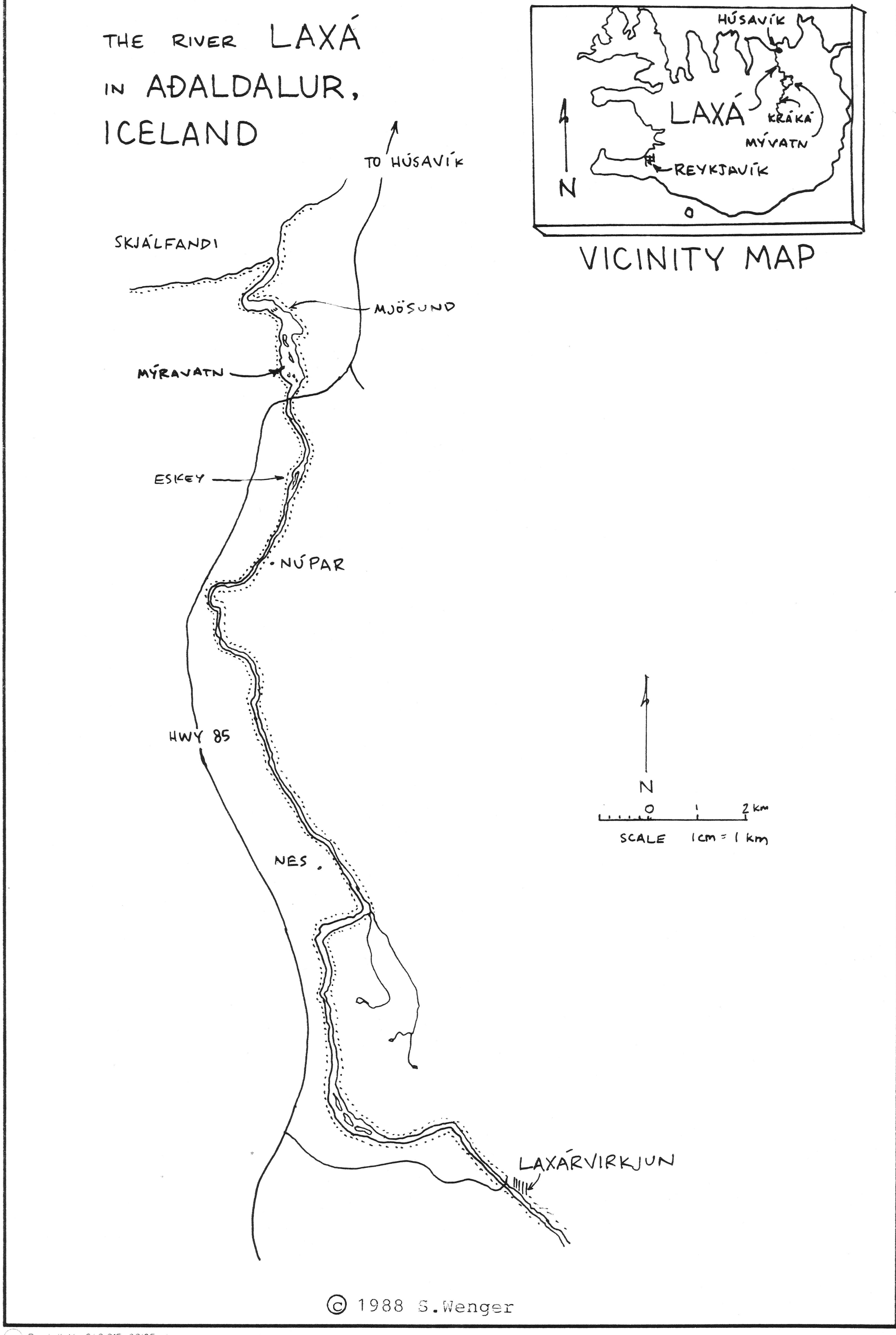
At Eskey (see figure 29) the channel was examined for juvenile habitat enhancement. Boulders and rocks (0.3-0.7 meter diameter each) can be placed within the shallow regions to create cover and feeding areas. Since thereis a large volume of bedload sediment in Laxa, stones placed in the river should be maintained as needed to compensate for sedimentation into the substrate. Addition of rocks periodically or agitation of sedimented stones are possible methods.

At Straumall, the channel is approximately 35 meters wide with a shoreline current of 0.5 m/s. A mid-channel pool and adult holding area can be made here by constructing a spur dike and downstream boulder groupings. Figures 8, 12, and 27 show example structures.

Throughout Laxa, adult catch areas are desired and can be most easily made with mid-channel boulders. The local rock is hraun which is a relatively lightweight lava (specific gravity approximately 1.7) which is unstable in the river channel, regardless of boulder size. Since maintenance of the natural river appearance may be essential, hraun may be an exclusive construction rock. Anchoring methods for using hraun are illustrated in figure 30 employing concrete and screw type anchors.

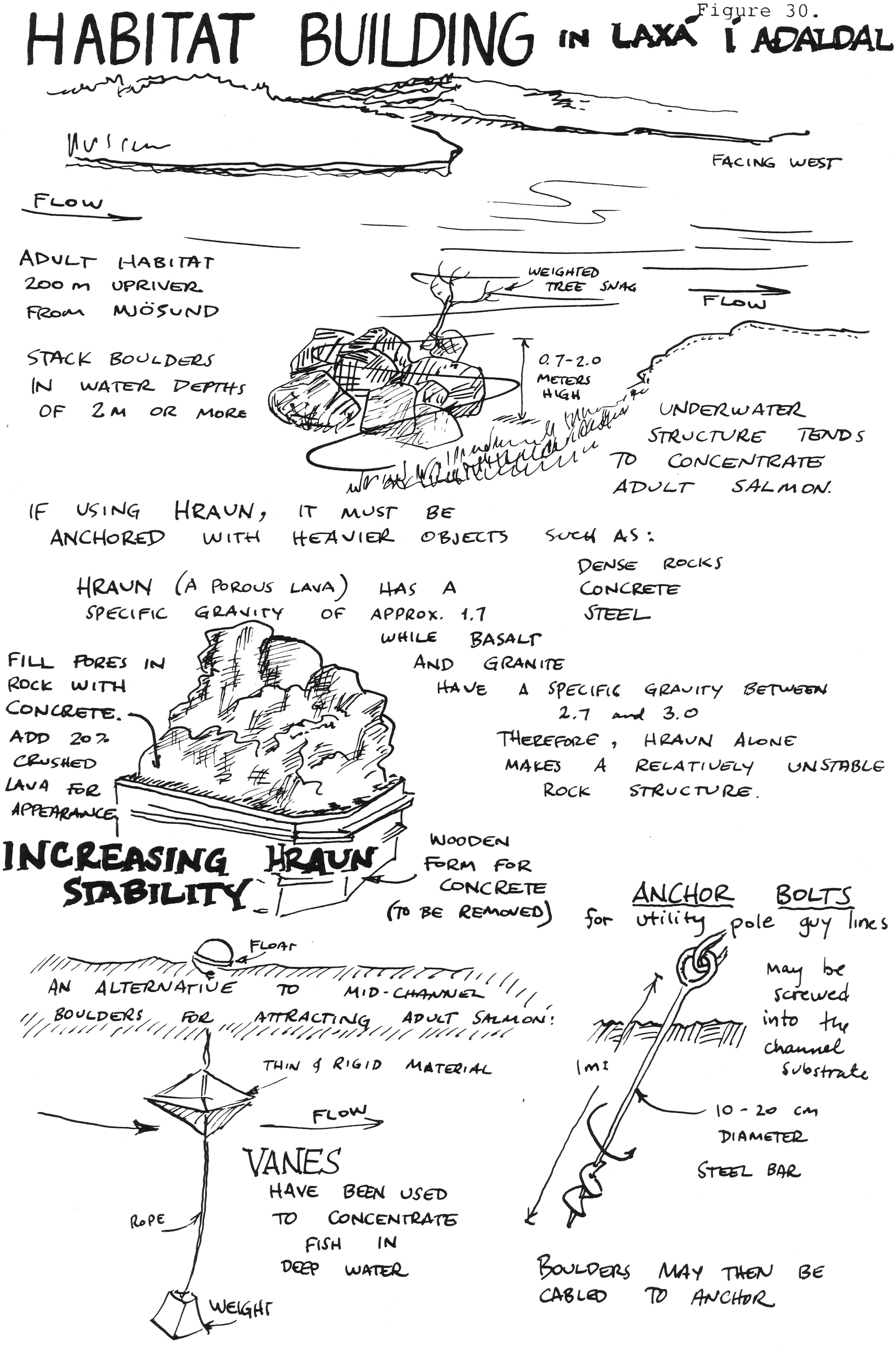
Newly constructed weirs and boulder placements at Holmavist, Starholmi, and downstream of Fornafluth were examined for effectiveness and stability. Annual monitoring is recommended for future construction guidelines.

Figure 29.



THE RIVER LAXÁ
IN AÐALDALUR,
ICELAND
TO HÚSAVÍK
SKJÁLFANDI
MJÓSUND
MÝRAVATN
ESKEY
NÚPAR
HWY 85
NES
LAXÁRVIRKJUN
HÚSAVÍK
LAXÁ
KRÁKÁ
MÝVATN
REYKJAVÍK
N
VICINITY MAP
N
0
1
2 km
SCALE 1cm = 1 km
© 1988 S.Wenger

Figure 30.


HABITAT BUILDING IN LAXÁ Í ADALDAL
FACING WEST
FLOW
ADULT HABITAT 200 M UPRIVER FROM MJÖSUND
WEIGHTED TREE SNAG
FLOW
STACK BOULDERS IN WATER DEPTHS OF 2 M OR MORE
0.7-2.0 METERS HIGH
UNDERWATER STRUCTURE TENDS TO CONCENTRATE ADULT SALMON.
IF USING HRAUN, IT MUST BE ANCHORED WITH HEAVIER OBJECTS SUCH AS:
DENSE ROCKS
CONCRETE
STEEL
HRAUN (A POROUS LAVA) HAS A SPECIFIC GRAVITY OF APPROX. 1.7 WHILE BASALT AND GRANITE HAVE A SPECIFIC GRAVITY BETWEEN 2.7 and 3.0
THEREFORE, HRAUN ALONE MAKES A RELATIVELY UNSTABLE ROCK STRUCTURE.
FILL PORES IN ROCK WITH CONCRETE.
ADD 20% CRUSHED LAVA FOR APPEARANCE
INCREASING HRAUN STABILITY
WOODEN FORM FOR CONCRETE (TO BE REMOVED)
ANCHOR BOLTS for utility pole guy lines
FLOAT
AN ALTERNATIVE TO MID-CHANNEL BOULDERS FOR ATTRACTING ADULT SALMON:
THIN & RIGID MATERIAL
FLOW
VANES HAVE BEEN USED TO CONCENTRATE FISH IN DEEP WATER
ROPE
WEIGHT
May be screwed into the channel substrate
1 M
10 - 20 CM DIAMETER STEEL BAR
BOULDERS MAY THEN BE CABLED TO ANCHOR

GLERA

The river Glera was visited on September 2, 1988 to survey the waterfall site upriver from the highway 60 bridge for a fishpass. See figure 31 for a map.

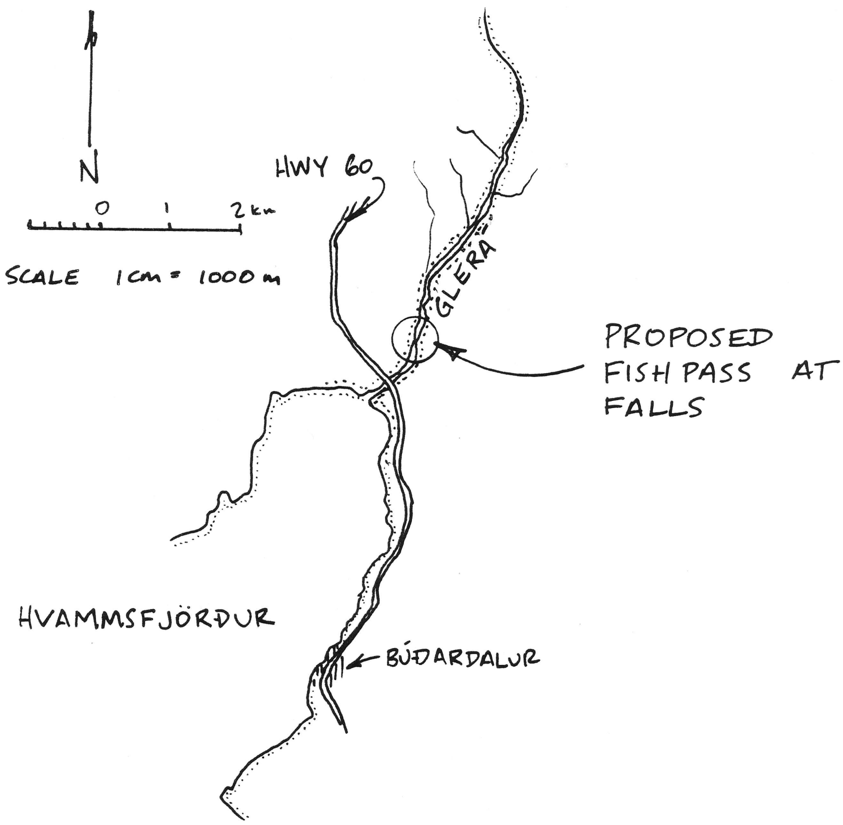
Fishpass designs and site topography are pending and are available from the author.

The reach of Glera downriver from the highway 60 bridge was examined for possible structures to maintain a defined channel during low flows. The channel consists of unconsolidated cobbles and gravel which are typically unstable building materials. Concrete spur dikes or weirs as shown in figures 2, 9, and 13 may be used in this reach. A gabion weir may also be applicable here as shown in figure 26. Further site measurements are necessary for specific recommendations.

Figure 31.

THE RIVER GLERÁ, HVAMMSFJÖRÐUR, ICELAND

VICINITY MAP



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