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ZARQA RIVER CONVEYANCE STUDY

SELECTION OF CONCEPTUAL ALTERNATIVES

(DRAFT)

Contents

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SELECTION OF CONCEPTUAL ALTERNATIVES (DRAFT)

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ZARQA RIVER CONVEYANCE STUDY

SELECTION OF CONCEPTUAL ALTERNATIVES (DRAFT)

1 Qualitative Screening

Task 1 10 (Phase A), to be lead by Consolidated Consultants within the Zarqa River Conveyance Study scope of work relates to the selection of the alternatives to be developed at the conceptual design stage In relation to this activity and based on previous investigations and completed materials (Inception Report, Comprehensive Draft Report), on consultations with local engineers and specialists, as well as on site visits to existing power and irrigation facilities within the Zarqa River Basin, a series of qualitative recommendations are made herein with the aim to define and consolidate development alternatives

Some of the alternatives and concepts listed in the scope of work of Task 1 10 will have to be discarded based on technical feasibility considerations and / or necessity within the development scheme They include using a pipeline over the entire 23 km reach between the King Talal Dam and the Abu Zeighan Weir, improving the river channel, and using a deep cutoff wall within the study reach

It is a known fact that most of the channel losses and the totality of the salinization of river flows occur downstream of the Tal Al Dahab Weir, with the stretch Hwaret Weir - Abu Zeighan Weir being the most critical Consequently, the river itself can be considered an acceptable conveyance between King Talal Dam and Tal Al Dahab Weir, and perhaps even down to Hwaret Weir (although there are concerns related to the potential of losses along the reach between Tal Al Dahab and Hwaret Weirs) This reduces the stretch to be treated or by-passed to a maximum length of 7 km and obviously, a 23 km-long pipe intaking at King Talal dam is not necessary

Channelization of the river bed within this reach would not solve the problem of the losses and / or of saline contamination during the low flow season, precisely when irrigation water requirements are significant Also, trying to recover losses during low flow season by constructing a cutoff wall could very well have an adverse effect on the saline contamination potential by putting the saline springs under pressure and forcing their flow back into the conveyance

Constructing an open conveyance in canal along various reaches could probably represent a feasible solution However, this type of alternative needs careful consideration, as it might not eliminate completely the potential of losses and / or of saline intrusion Even in the case of a concrete lined canal (trapezoidal or rectangular cross section), the expansion joints will provide ready access to the artesian saline flows during the low flow season Moreover, such an open conveyance might cost as much as a closed conduit under some circumstances Building (or rehabilitating) a canal from Hwaret to Abu Zeighan under a maximum acceptable slope of 0 5 percent for instance, would imply solving the problem of a 38 m drop along a 3 5 to 4 km-long alignment or about 10 m per km Up to four drop structures may be required for

each 1000 m, which will result in a rather expensive solution An alternative with a combined conveyance (part canal, part pipe) between Hwaret and Abu Zeighan is retained for cost comparison, but for various reasons mentioned above it is recommended to approach it with caution

Other solutions listed represent feasible concepts that need to be consolidated into viable development alternatives to be further assessed for economic attractiveness They include installing pipelines within certain sub-reaches of the river, including power generation in the development, and providing a re-regulation reservoir upstream of Abu Zeighan Weir Finally, there are existing conveyance facilities in the Zarqa Valley that are operated for irrigation supply They include intakes at weirs, settling basins, canals and pressurized pipes These existing structures will have to be integrated within the proposed development alternatives

An alternative developed for irrigation will basically have a different configuration than one developed for power as described in the following There are however some staging possibilities with the power facilities being implemented at a later stage, provided that some features are incorporated from the very beginning in the irrigation development

2 Irrigation Alternatives

These alternatives will incorporate the existing power facilities at King Talal Dam that currently generate secondary energy and releasing a maximum of 6 4 cms (plant design discharge) for existing irrigation users whenever water is available Three irrigation alternatives described below are recommended to be developed at a conceptual level for a final selection based on a direct construction cost comparison

Alternative IRR1

A closed conveyance (a ductile iron pipe with ID 1500 mm would be sufficient) will be added along the reach from the Tal Al Dahab settling basins, to the Abu Zeighan intake This may require the expansion of the settling basins at the Tal Al Dahab location, although the current consumers along the Abu Zeighan Canal have settling basins at the corresponding pumping stations (whether their capacity is sufficient is not clear at the present) If no settling basin is considered necessary, the new pipe could initiate at the Tal Al Dahab existing intake and by-pass the desanders at Tal Al Dahab If there is a need of additional settling facility at the intake, preliminary computations based on the control of a minimum size sand particle of 0 2 mm show that a new separate basin (connected to the existing forebay and having its own upstream and downstream controls), would have to have a cross section of about 4 0 to 5 0 m width per 3 5 m depth (the length of 48 m of the existing desanders is more than adequate) Site inspection indicated that there is enough space to add this new basin on the left side (looking downstream) of the existing ones A new ID 900 mm (or even ID 1500 mm) pipe connecting the Tal Al Dahab intake to the settling basins forebay will have to be installed, together with its own controls at the intake The two

existing ID 900 pipes will continue to feed the basins for the needs of ZC I and ZC II (a maximum of about 2 5 cms) Conveyance capacity from weir to desander (intake and connecting pipes between intake and desanders) will have to be checked, including verification of the vortex submergence for the pipe that connects to the new desander (maximum flow of about 4 cms, maximum velocity of about 2 3 mps if the ID 1500 is installed) The 7 km-long ductile iron pipe will operate under a net head of about 103 3 m and will have a maximum capacity of some 4 cms It will require a minimum thickness of about 10 mm At the Abu Zeighan outlet, the pipe will require an energy dissipation valve, before releasing into the Canal As with the ZC II pipe, the new pipe will be mostly buried and might have syphon stretches, depending on the selected route The preliminary pipe alignment is shown in Attachment 1 on 1/10000 topographic maps, together with the location of the existing structures (as-built), and with the new scheme component locations For the costing and alternative comparison purpose, it is proposed to incorporate a settling basin expansion at Tal Al Dahab

Alternative IRR2

This alternative is based on the use of the existing ZC II pipe to convey up to the maximum of 6 4 cms down to the junction with the pumping station, and to connect at this point a new 2 km-long ductile iron pipe that would discharge into the Abu Zeighan Canal a maximum of 4 cms From the same junction point, the ZC II pipe would continue as is today, to serve the existing consumers Because current ZCII consumers do not have desanders, this alternative requires the expansion of the settling basins at the Tal Al Dahab Weir up to a total capacity of 6 4 cms and conveyance capacity of waterways from the Tal Al Dahab intake into the expanded desanders should be verified Additional booster pumps will have to be installed at a new pumping station built downstream of the existing junction This alternative also implies a longer interruption of irrigation water delivery to consumers currently served by the ZC II conveyance, than under the previous alternative Attachment 2 presents this alternative arrangement on 1/10000 topographic maps, together with the location of the existing structures (as-built), and with the new scheme component locations

Alternative IRR3

This alternative considers the possibility of constructing a conveyance (pipe or combination canal/pipe) to by-pass only the Hwaret - Abu Zeighan critical reach As mentioned previously, the implementation of such a scheme with closed or open conveyance, should only be promoted after a careful consideration of the losses and / or contamination potential upstream of the Hwaret Weir (at this stage, losses seem to be higher along the reach Tal Al Dahab - Hwaret, than along the reach downstream of the Hwaret Weir) A scheme with intake at Hwaret and partially in open conveyance might face the additional risk of contamination of the canal water by artesian saline springs

Under both sub-alternatives (ductile iron pipe or canal/pipe conveyance), the scheme implementation implies the rehabilitation of the Hwaret Weir and of the intake with the corresponding controls The open conveyance sub-alternative requires rehabilitating a 1 5 km-long stretch of canal currently deteriorated and adding a 2 0 km stretch of pipe after crossing the river in aqueduct (a canal in this stretch is difficult to build and will imply incorporating at least 12 drop structures along a 2 km alignment, raising significantly the cost of the alternative)

As in the case of Alternative IRR1, settling facility addition may be required at the Hwaret intake in both sub-alternatives, if current installations along the Abu Zeighan Canal have insufficient capacities If required, the settling basin at the Hwaret intake will have preliminary dimensions of 40 m-long, 5 m-wide, 3 5 m-deep, and will include a flushing path back to the river The 48 5 m head (43 9 m after friction losses) in the canal/pipe sub-alternative, will be dissipated through a dissipation valve installed at the end of the pipe at the initiation of the irrigation canal at the Abu Zeighan Weir

For a preliminary design of this alternative and of the corresponding rehabilitation works, a complete survey of the in-situ structures in their current state will be required Such survey will still be necessary even if the as-built drawings of the Hwaret weir and of the conveyance canal are located Attachment 3 presents this alternative schemes (both closed and open conveyances) on 1/10000 topographic maps, together with the location of the existing structures (as-built), and with the new scheme component locations

3 Multi Purpose Alternative (Alternative POW)

Power addition could be considered for the alternatives that incorporate closed conduits In order to take advantage of the full 120 m gross head between the settling basin take-off and the Abu Zeighan location (and to obtain a larger installation that could have more chances to be economically attractive), it is recommended to consider power addition only to the alternative with intake at Tal Al Dahab Weir A power installation harnessing the 56 m gross head between Hwaret and Abu Zeighan would only develop 1 8 MW, an installed capacity most probably too small to justify the investment

The multi purpose alternative could perhaps result feasible only if both the existing King Talal power facility (about 5 8 MW), and the new plant added at the end of the conveyance pipe (some 3 6 MW for a 0 86 conveyance efficiency and a design discharge of about 4 cms), will generate on peak for an energy selling price high enough to make the power addition attractive But to implement such a development, the investment would be quite significant, particularly when incorporating a re-regulating pond at the Abu Zeighan site (some 150 m upstream of the weir), provided with a spillway large enough to release the Zarqa River design floods This pond should be able to retain only fresh water discharged through the tailrace To this end, low and average Zarqa River flows should be diverted around the pond Only Zarqa River floods will discharge into the pond, with the understanding that irrigation

requirements are minimal during the floods period Annual maintenance and cleaning will be required to preserve the pondage at the new power plant tailrace

Before even assessing the economic attractiveness of such a 9 4 MW total peaking facility as compared to the thermal alternative, a power market investigation should be completed together with the national utility (Jordan Electric Authority) to determine the necessity of incorporating at this stage in the grid a peaking installation of this rather limited capacity

The conveyance installations are similar to those incorporated into the Alternative IRR1, with the comment that the new "pipe" should be this time a penstock built out of pressure vessels malleable steel that is more expensive than the regular ductile iron pipe (ID 1 5 m could be acceptable and thickness should probably be at least 10 mm) The new plant could be equipped with one horizontal shaft Francis unit similar to, and slightly larger, than the one currently operated at the King Talal Plant The new plant could be located on the bank of the re-regulating reservoir with the tailrace submerged properly against the minimum operating level of the lake Attachment 4 presents the features of this alternative on 1/10000 topographic maps, together with the location of the existing (as-built) structures

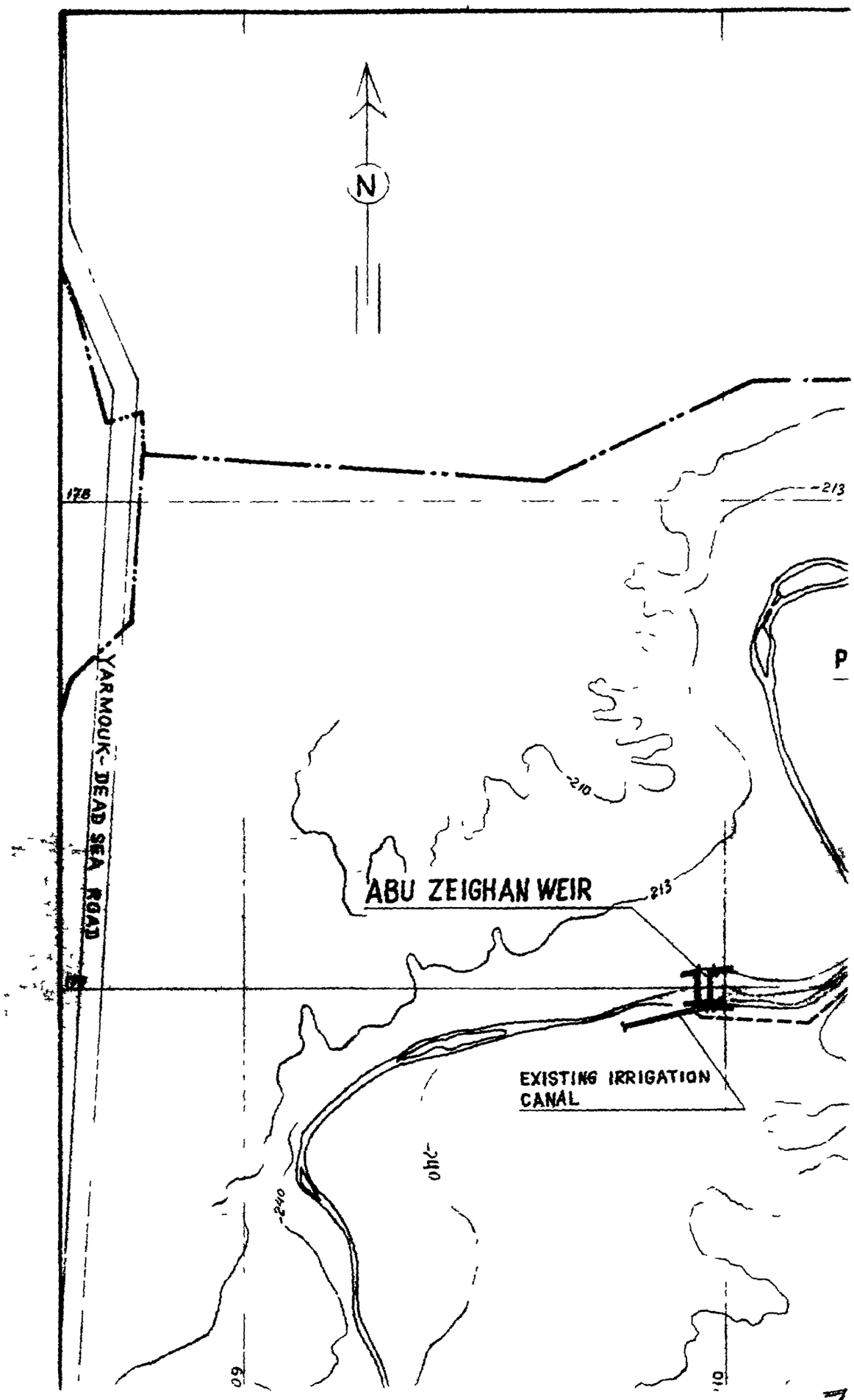
4 Staged Development

The alternatives IRR1 and POW could represent stages of the same development with the power development installed at a latter stage, when and if required In this case, the irrigation development is the one with a totally new by-pass pipe along the reach Tal Al Dahab Weir - Abu Zeighan Canal, with the comment that this conveyance should be installed as a penstock from the very beginning (that is, manufactured of malleable, special pressure vessels steel) Of course, this would represent a higher initial investment with a temporarily non-performing component

ALTERNATIVES FOR THE ZARQA RIVER CONVEYANCE STUDY

Alternative	Purpose	CONVEYANCE					Settling Basins		Power		Special Features
		Pipe/Penstock			Canal						
		Type	Length (KM)	Capacity (CMS)	Length (KM)	Capacity (CMS)	Expansion (CMS)	New (CMS)	Secondary (MW)	Firm (MW)	
IRR1	Irrigation	Ductile Iron	7 0	4 0	-	-	4 0[1/]	-	5 8[3/]	-	* Dissipation Equipment (valve) at Pipe Downstream End
IRR2	Irrigation	Ductile Iron	2 0	4 0	-	-	4 0[1/]	-	5 8[3/]	-	* Bifurcation from ZCII * Increase of ZCII discharge (5 8 cms) over First 5 km * Short interruption of ZCII consumers * Dissipation Equipment at Pipe Downstream End
IRR3a	Irrigation	Ductile Iron	3 5	4 0	-	-	-	4 0[2/]	5 8[3/]	-	* Rehabilitation of Hwaret Weir & Intake * Dissipation Equipment at Pipe Downstream End
IRR3b	Irrigation	Ductile Iron	2 0[5/]	4 0	1 5	4 0	-	4 0[2/]	5 8[3/]	-	* Rehabilitation of Hwaret Weir and Intake * Rehabilitation of 1 5 km Existing Canal * 300 M Aqueduct
POW	Irrigation and Power	Pressure Vessel Steel	7 0	4 0	-	-	4 0[1/]	-	-	9 4[4/]	* Re-regulating dam and fresh water pond at the Abu-Zeighan site * Diversion of low and average average flows of Zarqa R Upstream of Abu-Zeighan Weir

Notes.
1/ At Tal Al Dahab Weir (if required)
2/ At Hwaret Weir (if required)
3/ Existing Plant at King Talal Dam
4/ Includes new 3 6 MW Plant at the Abu-Zeighan Site
5/ Includes Aqueduct Length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178
YARMOUK- DEAD SEA ROAD
ABU ZEIGHAN WEIR
EXISTING IRRIGATION CANAL
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-210
-213
-240
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60
70

PROJECT LOCATION

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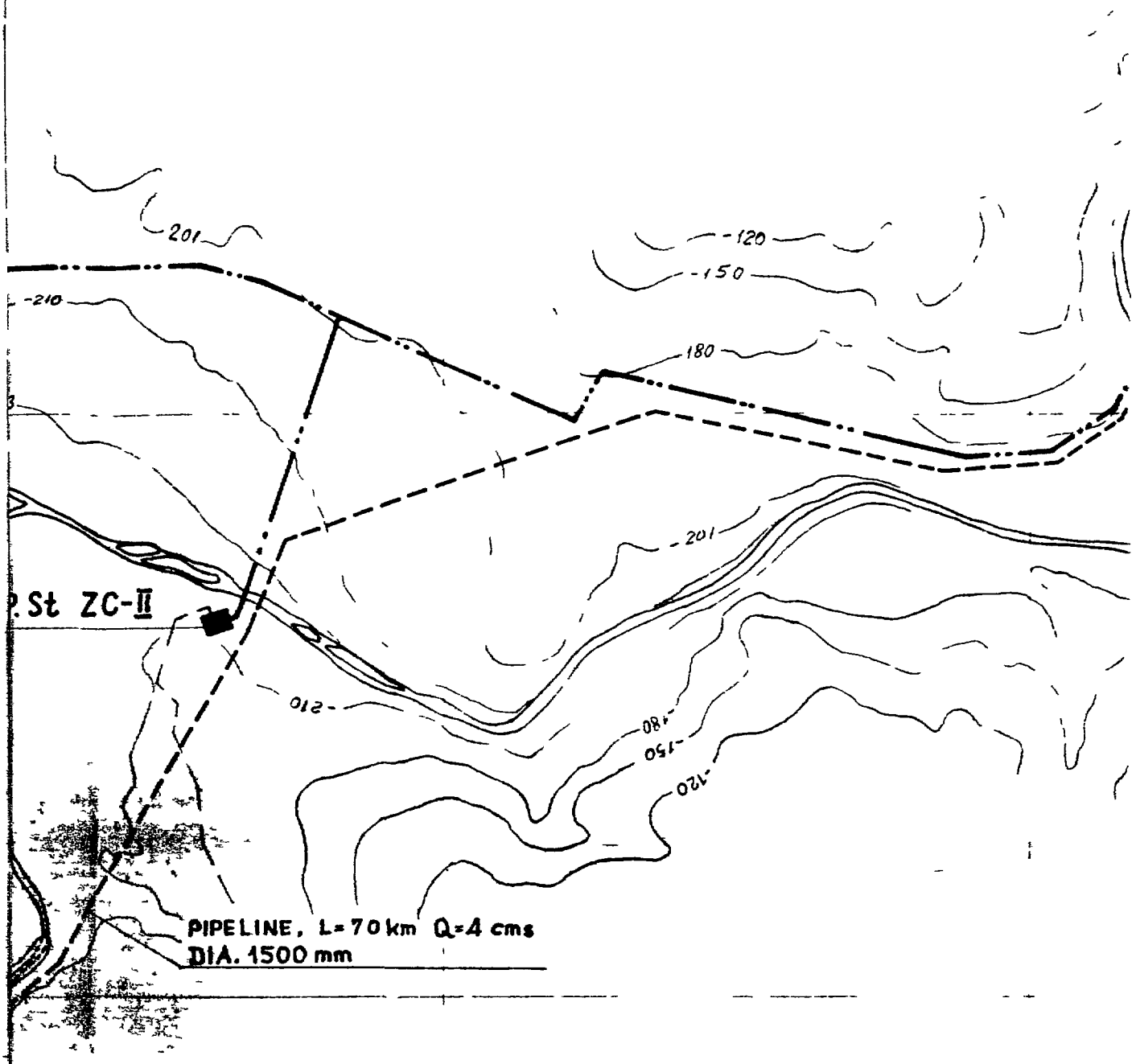

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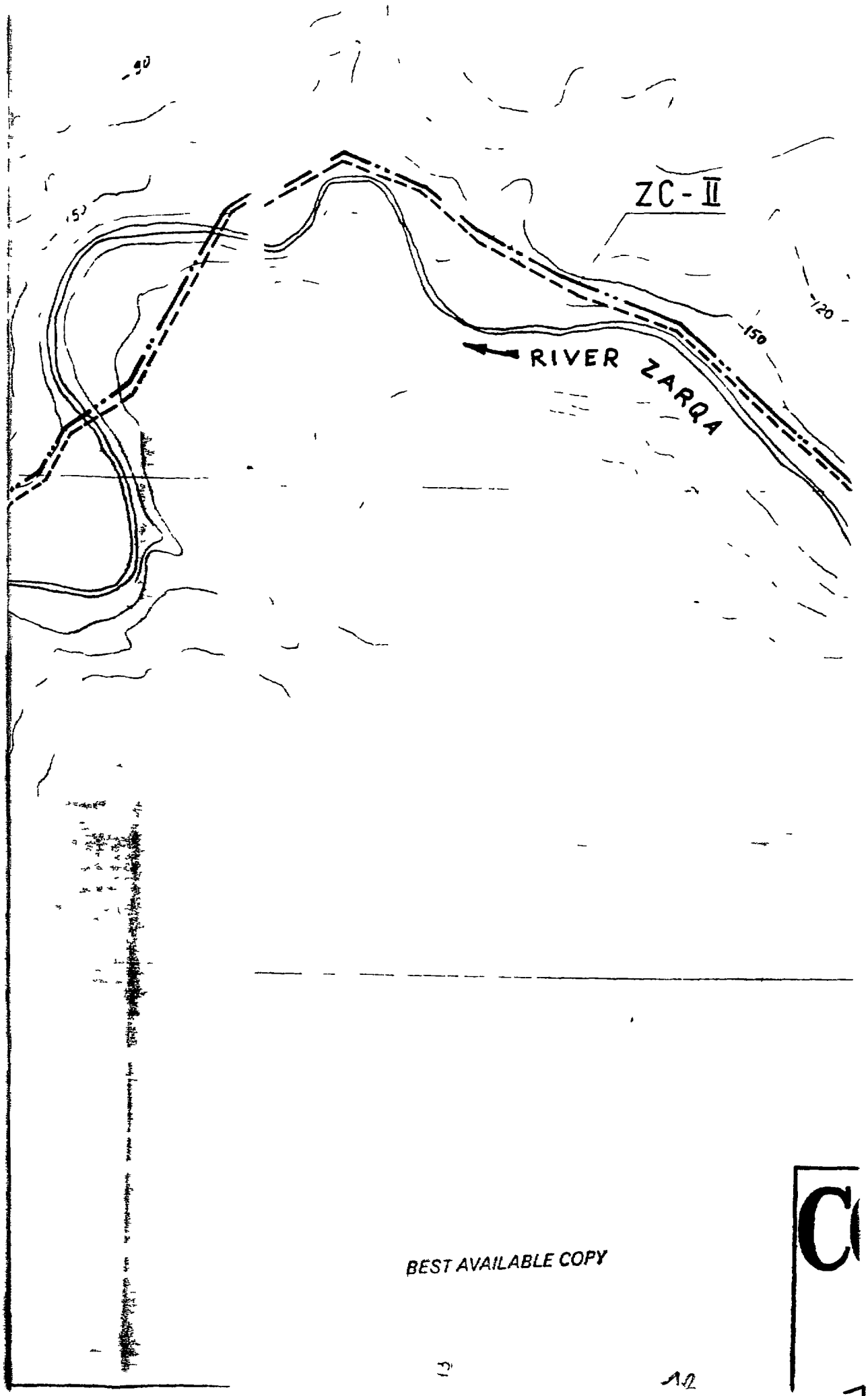

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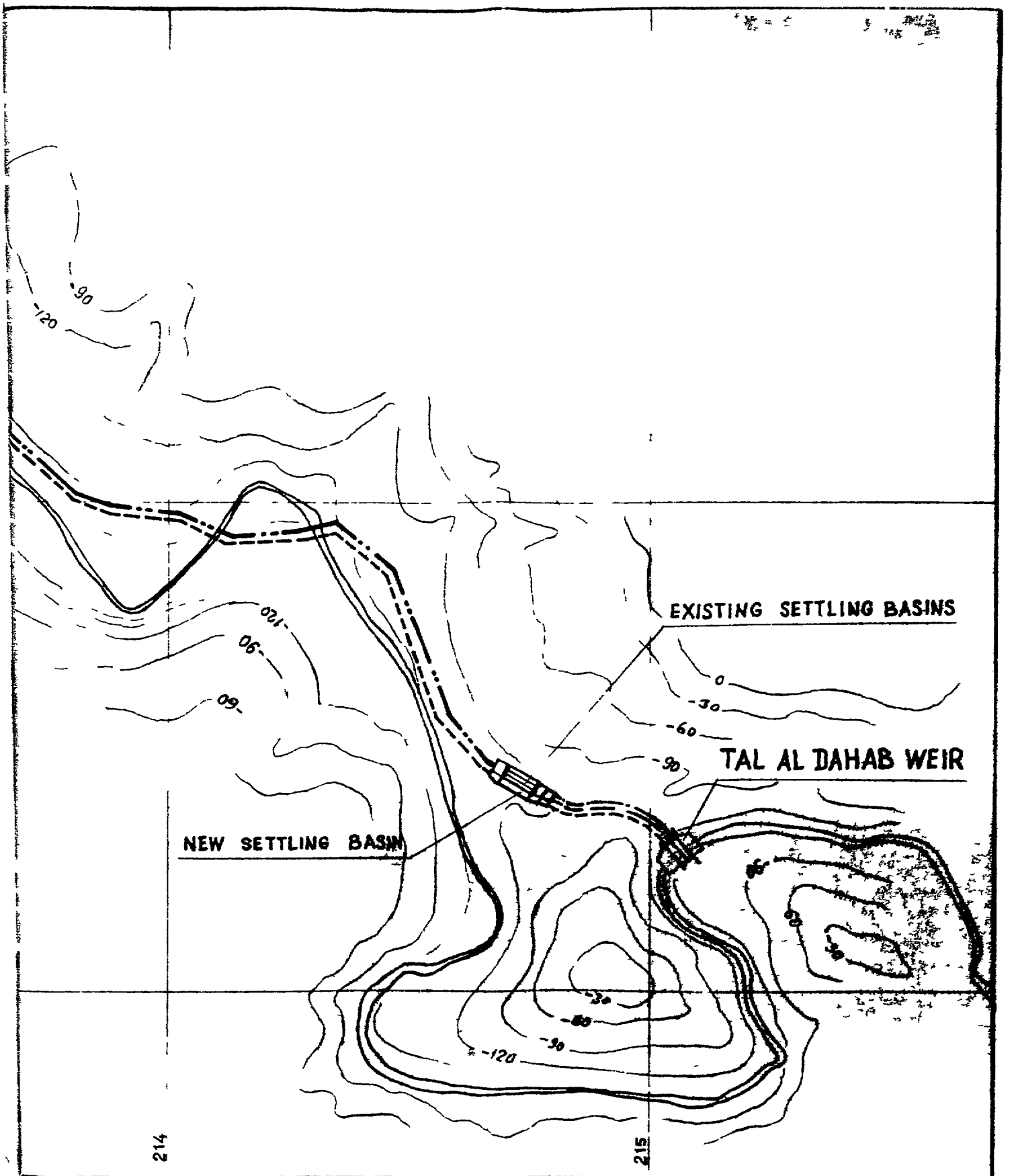

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ZARQA RIVER CONVEYANCE STUDY

ALTERNATIVE SELECTION

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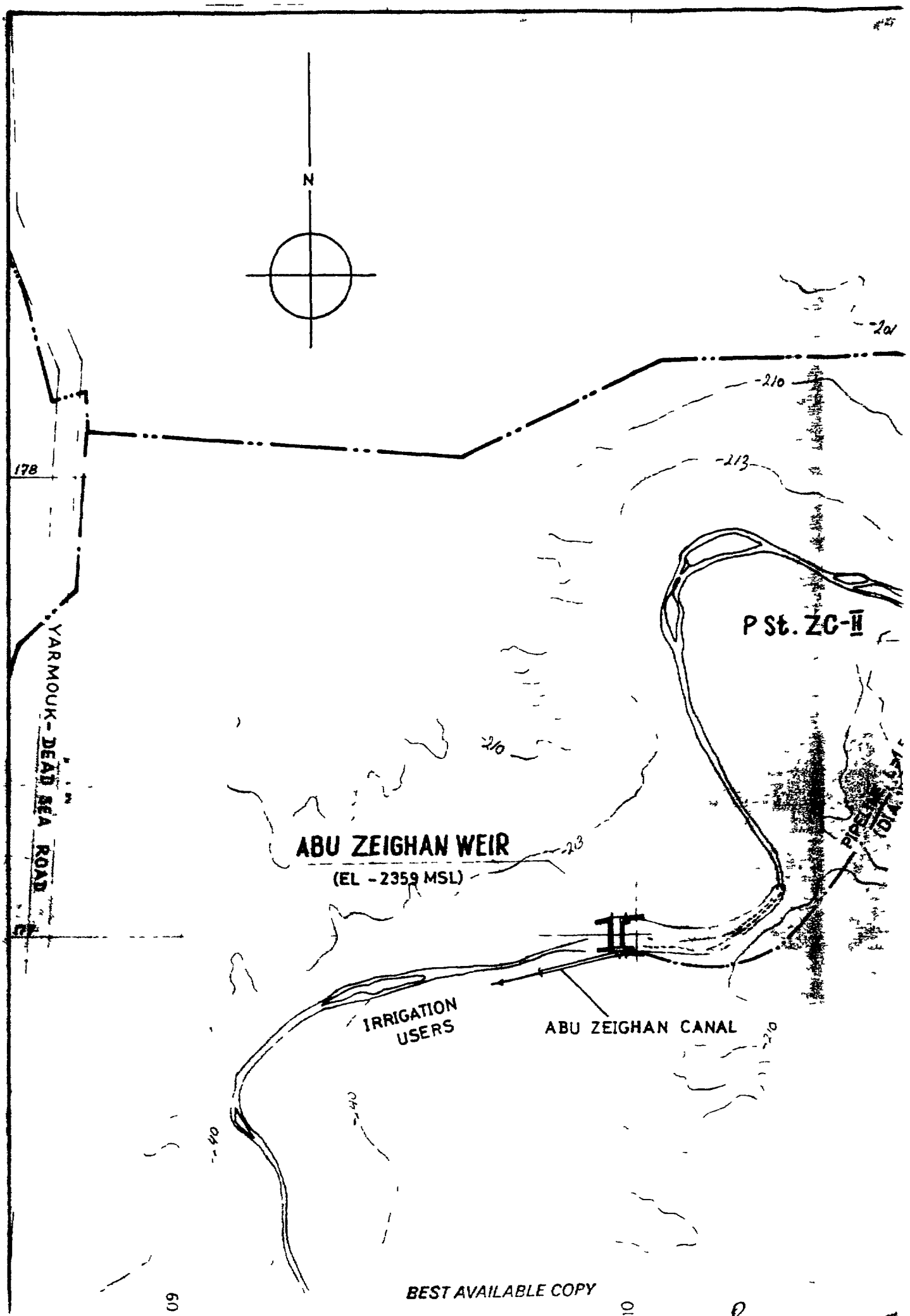
ATTACHMENT (1)



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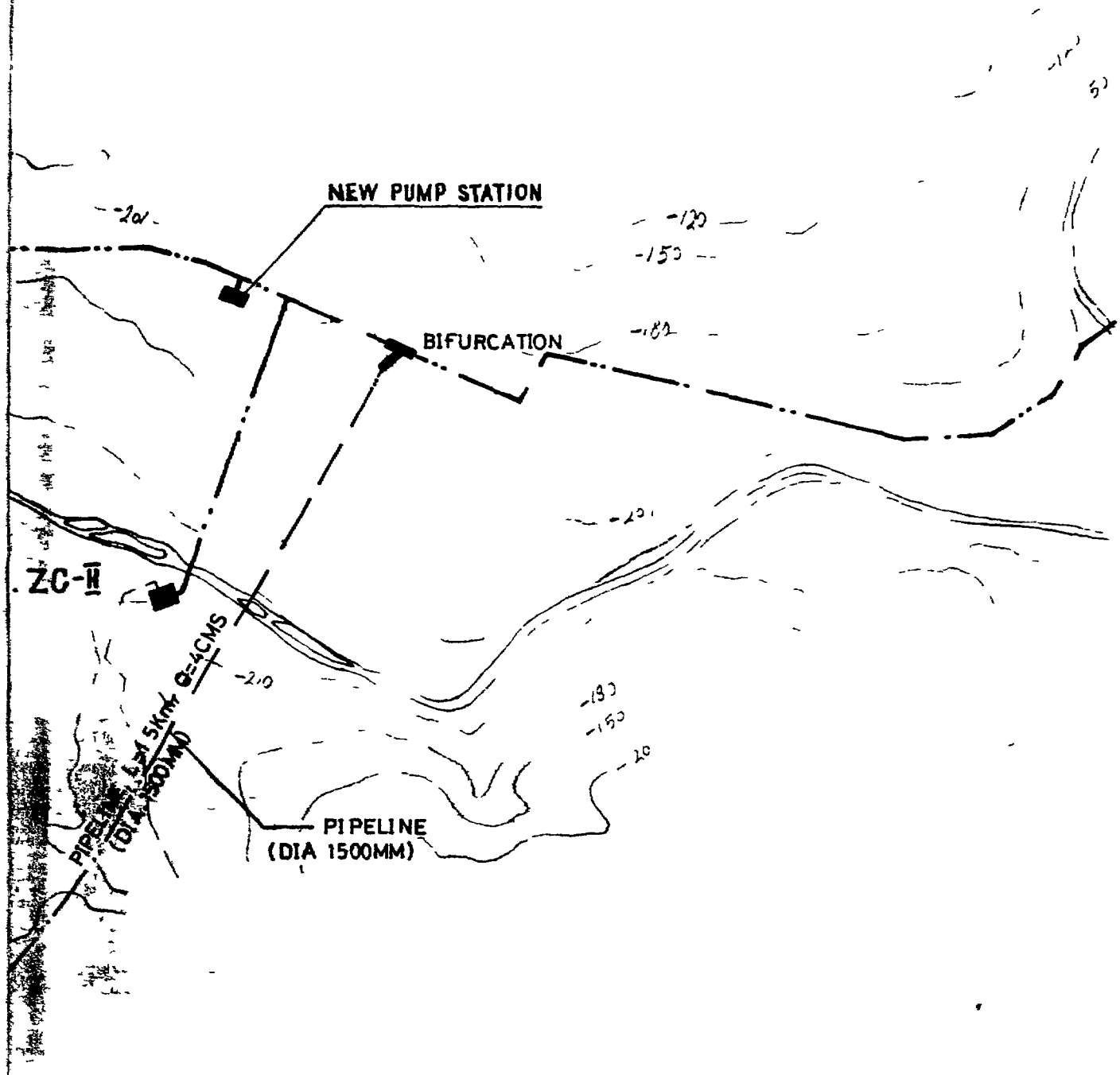

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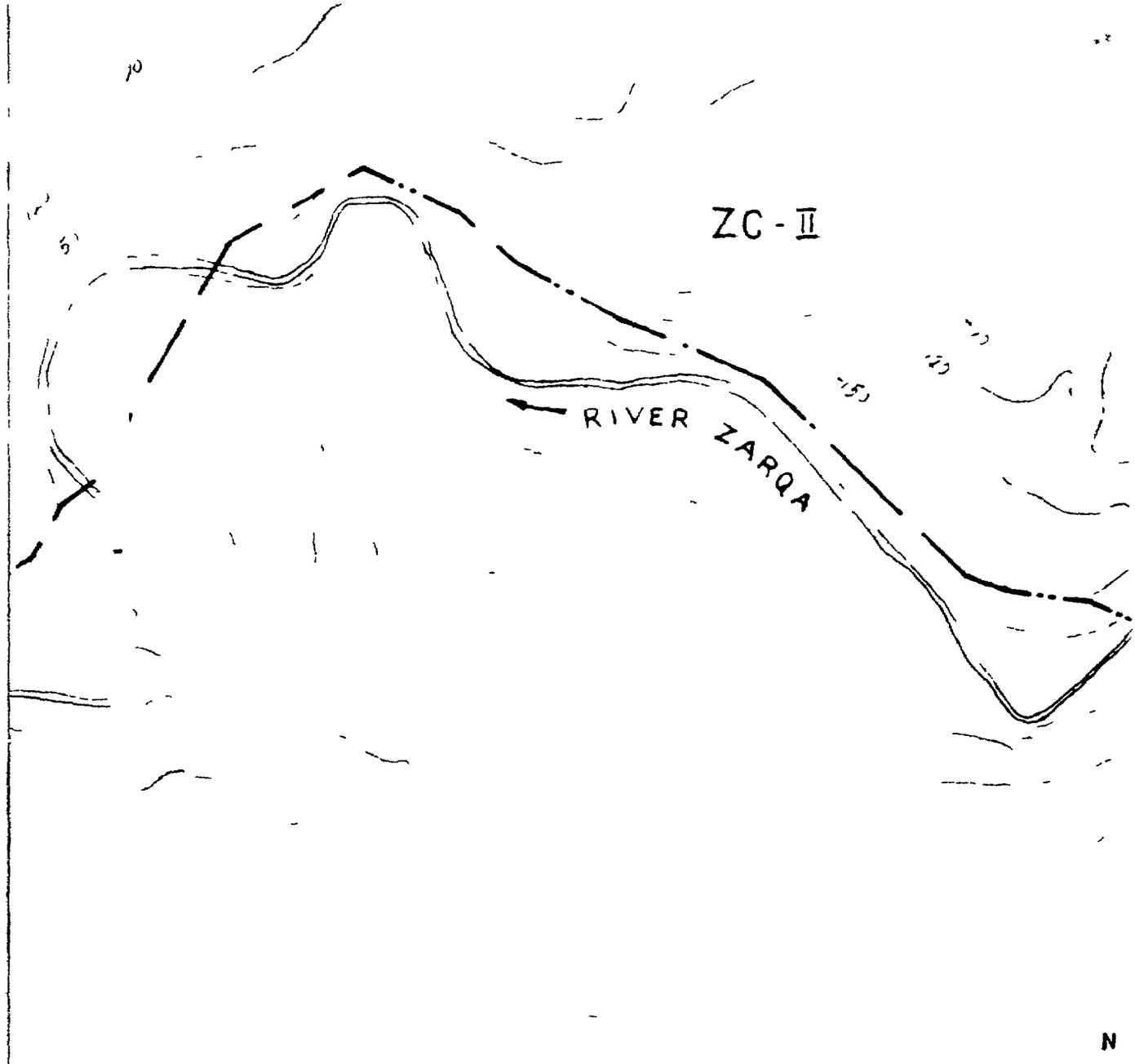

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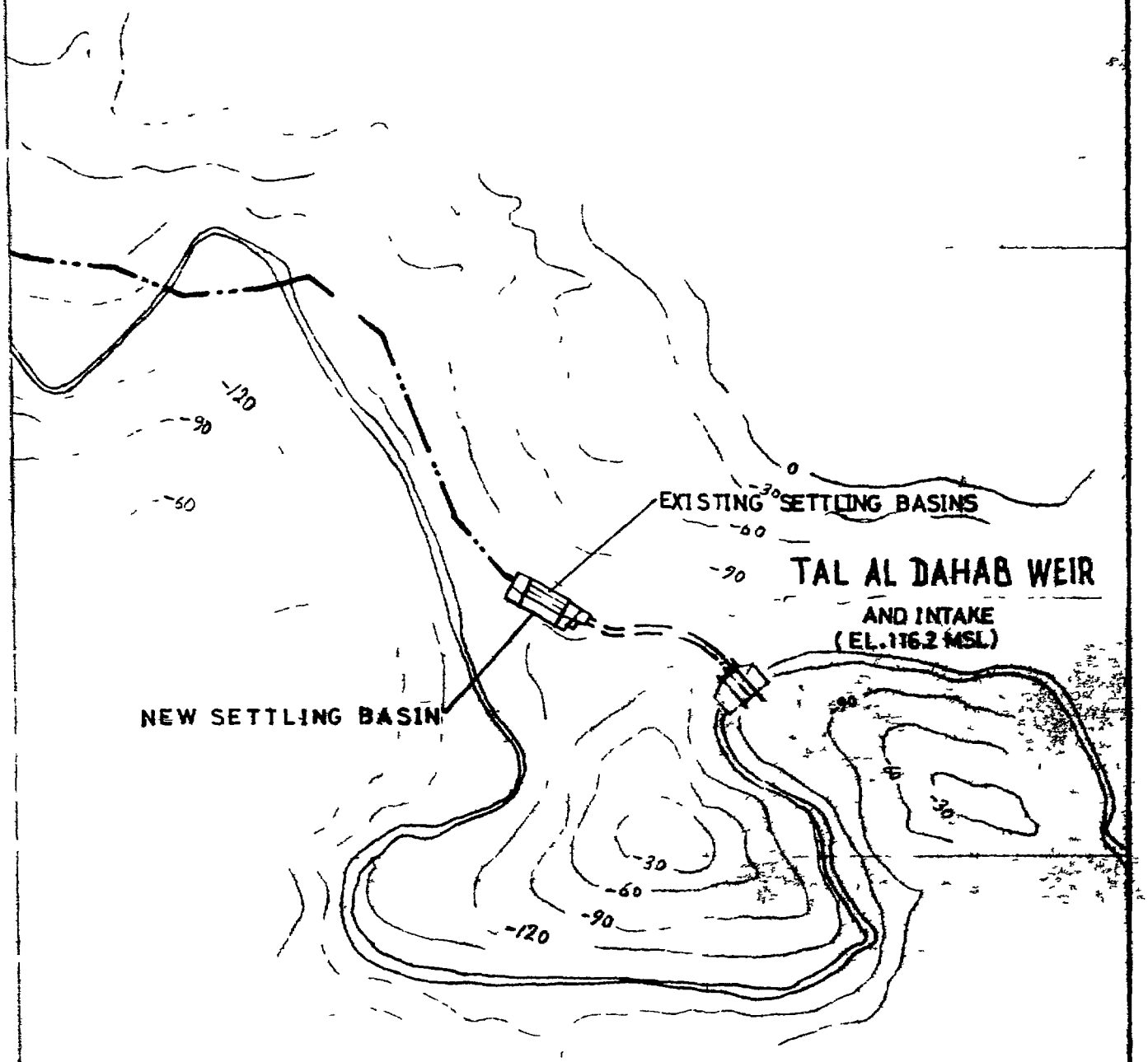

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ZARQA RIVER CONVEYANCE STUDY
ALTERNATIVE SELECTION

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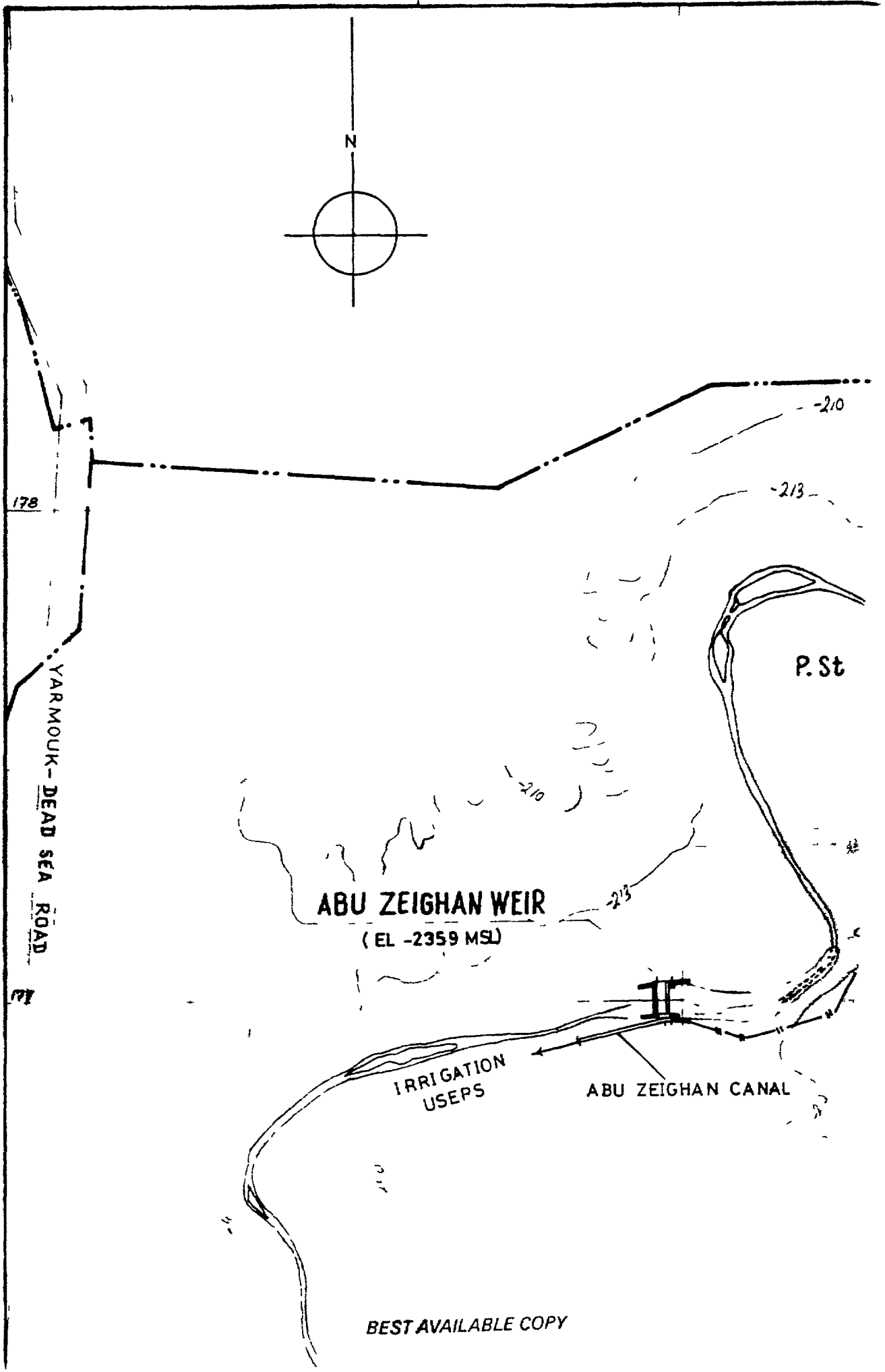

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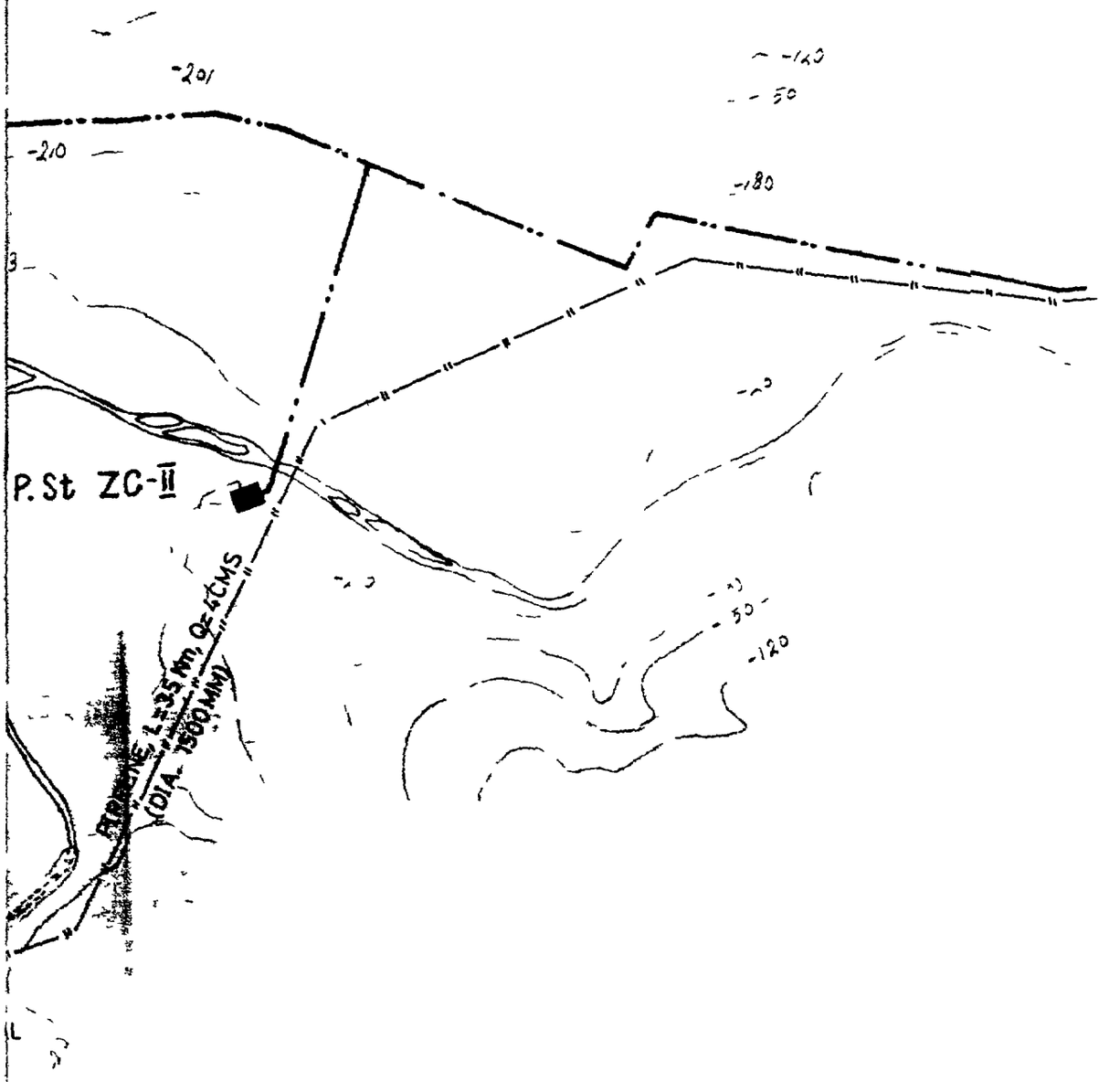

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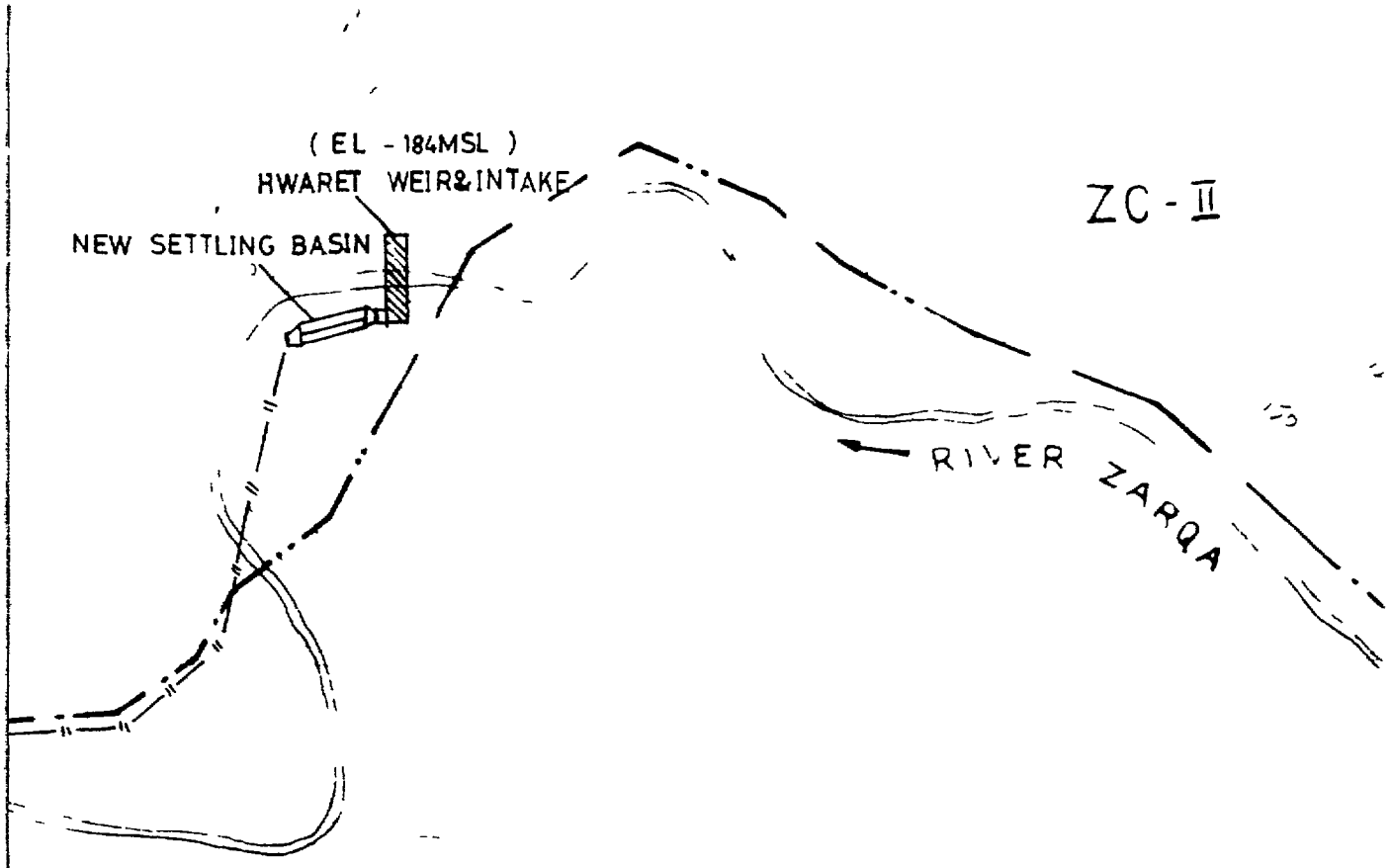

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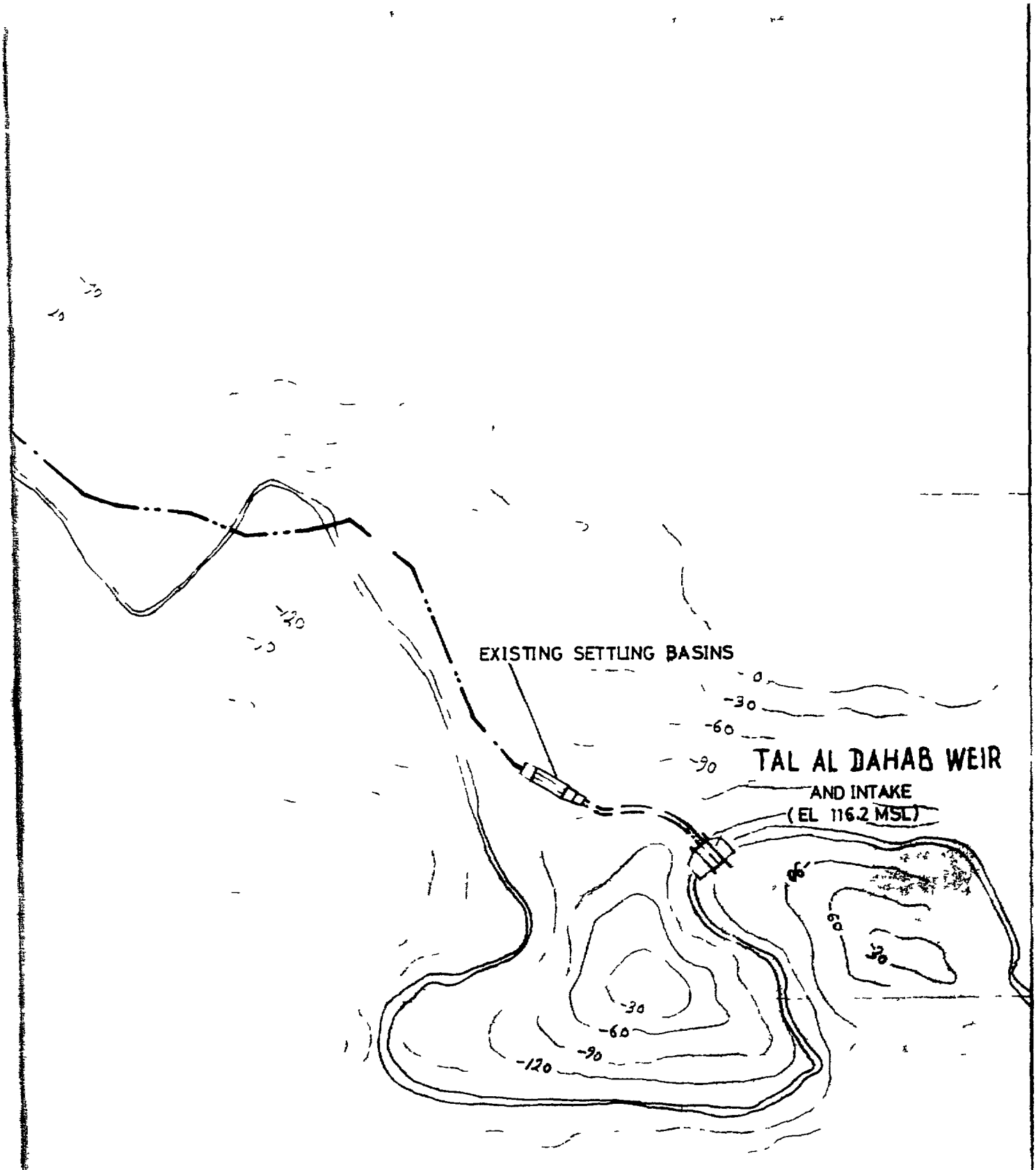

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ALTERNATIVE SELECTION

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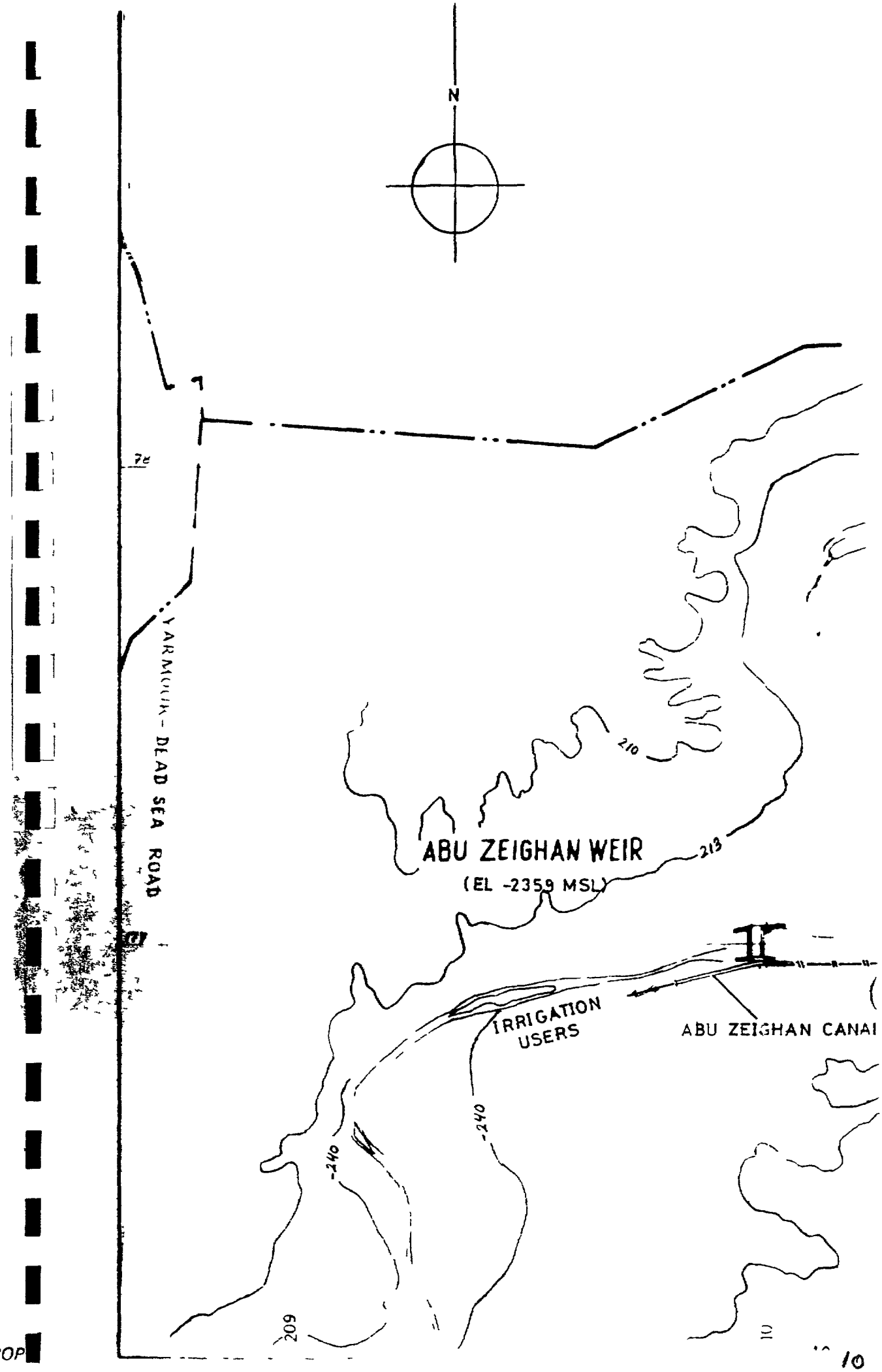

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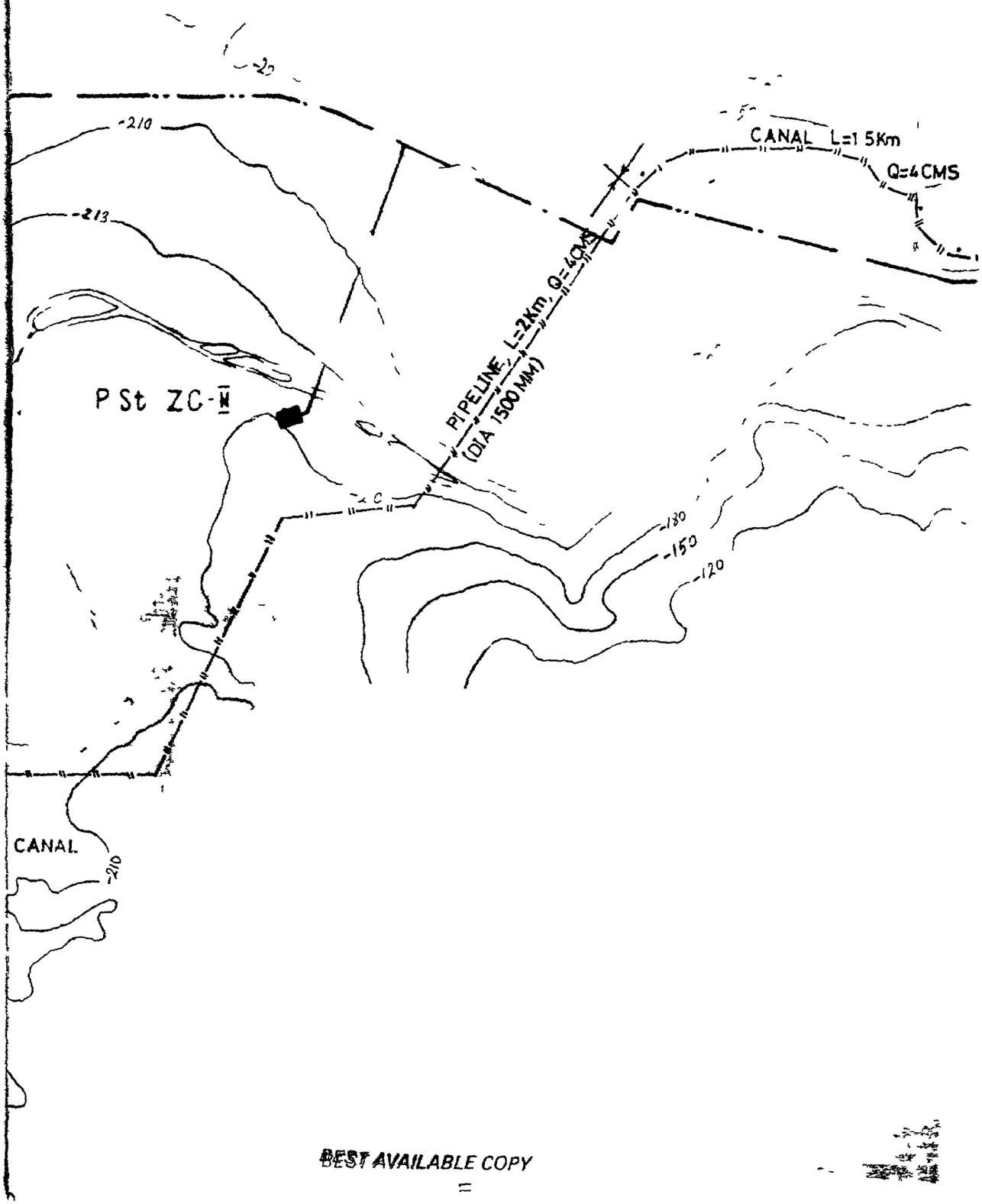

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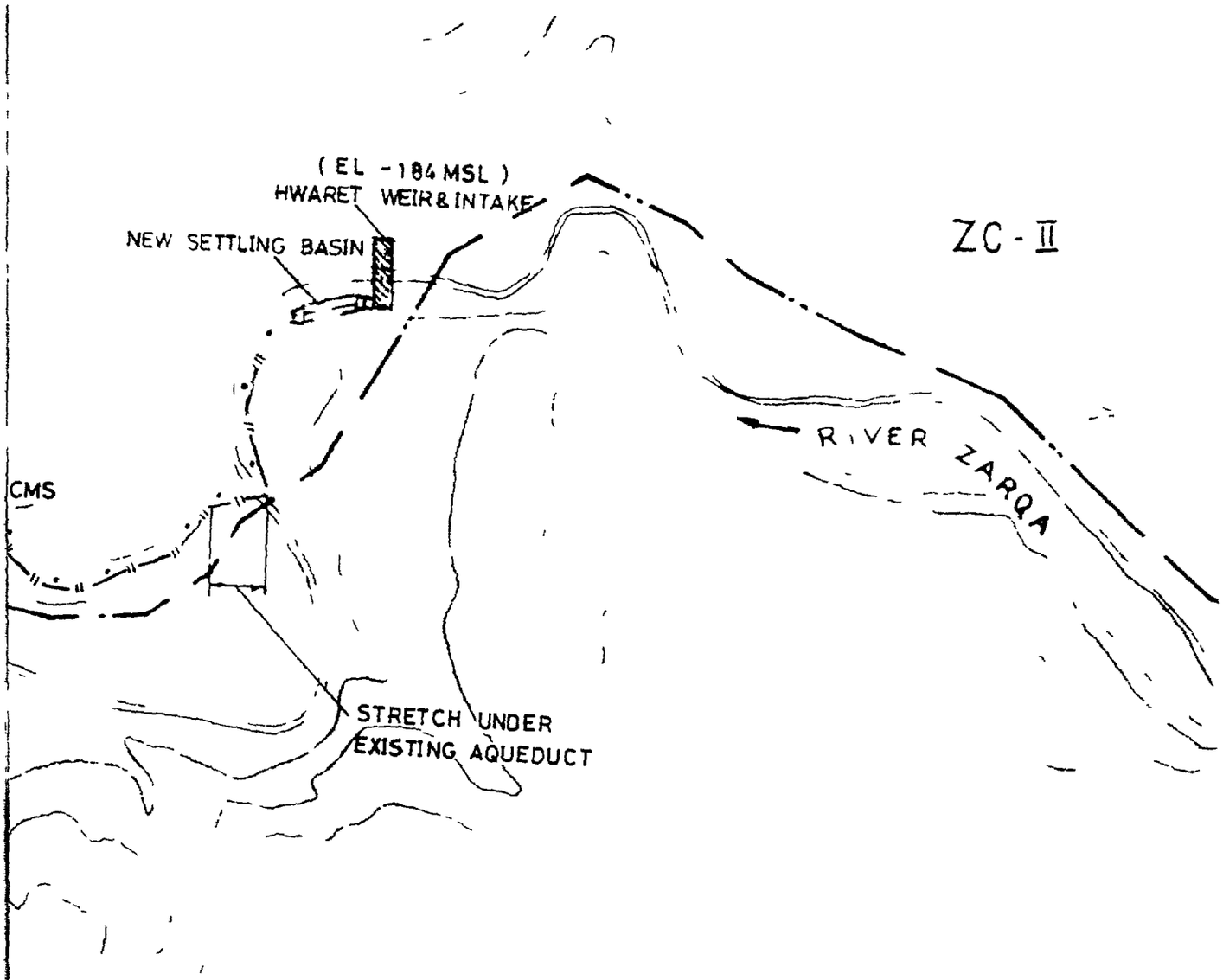

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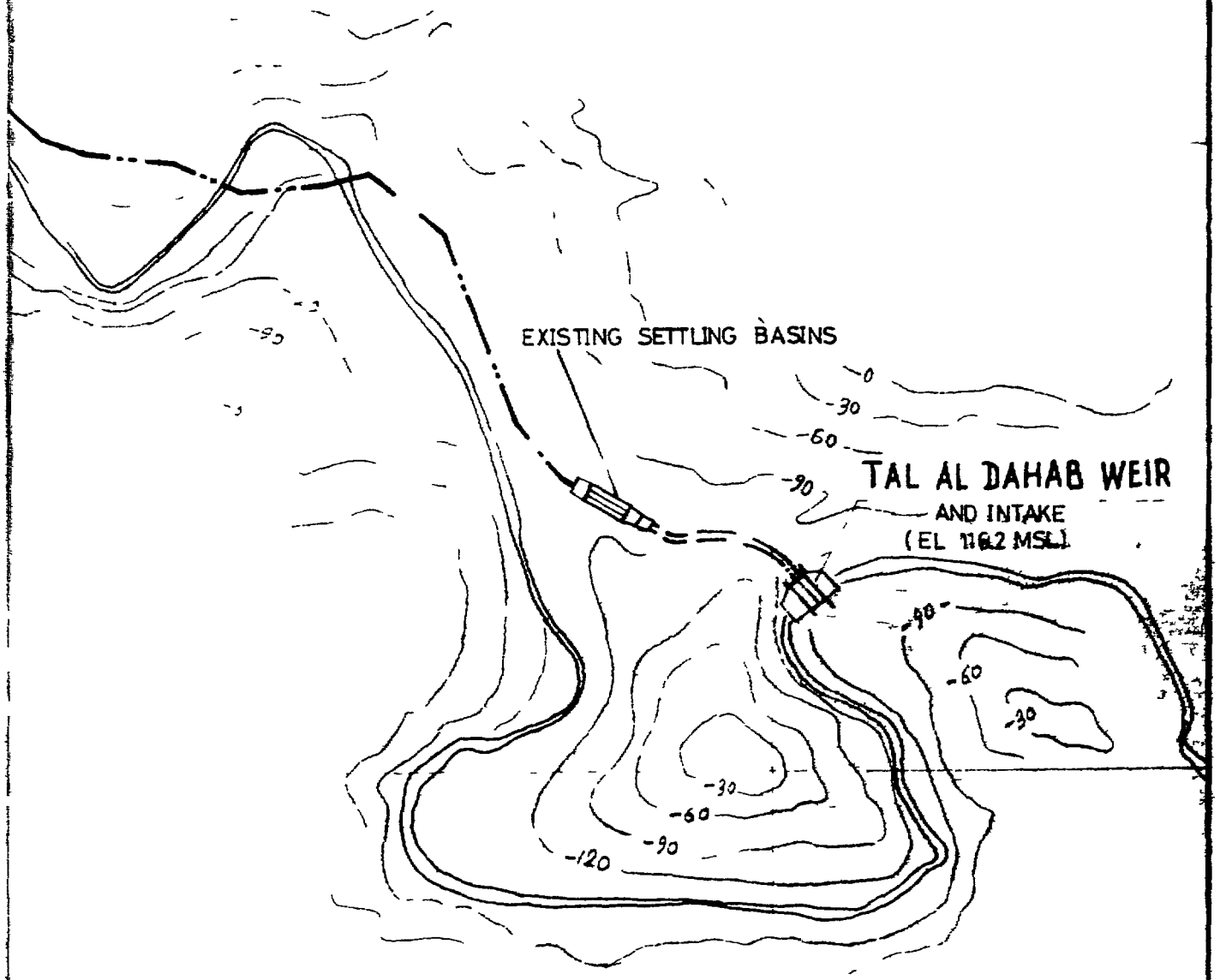

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ALTERNATIVE SELECTION

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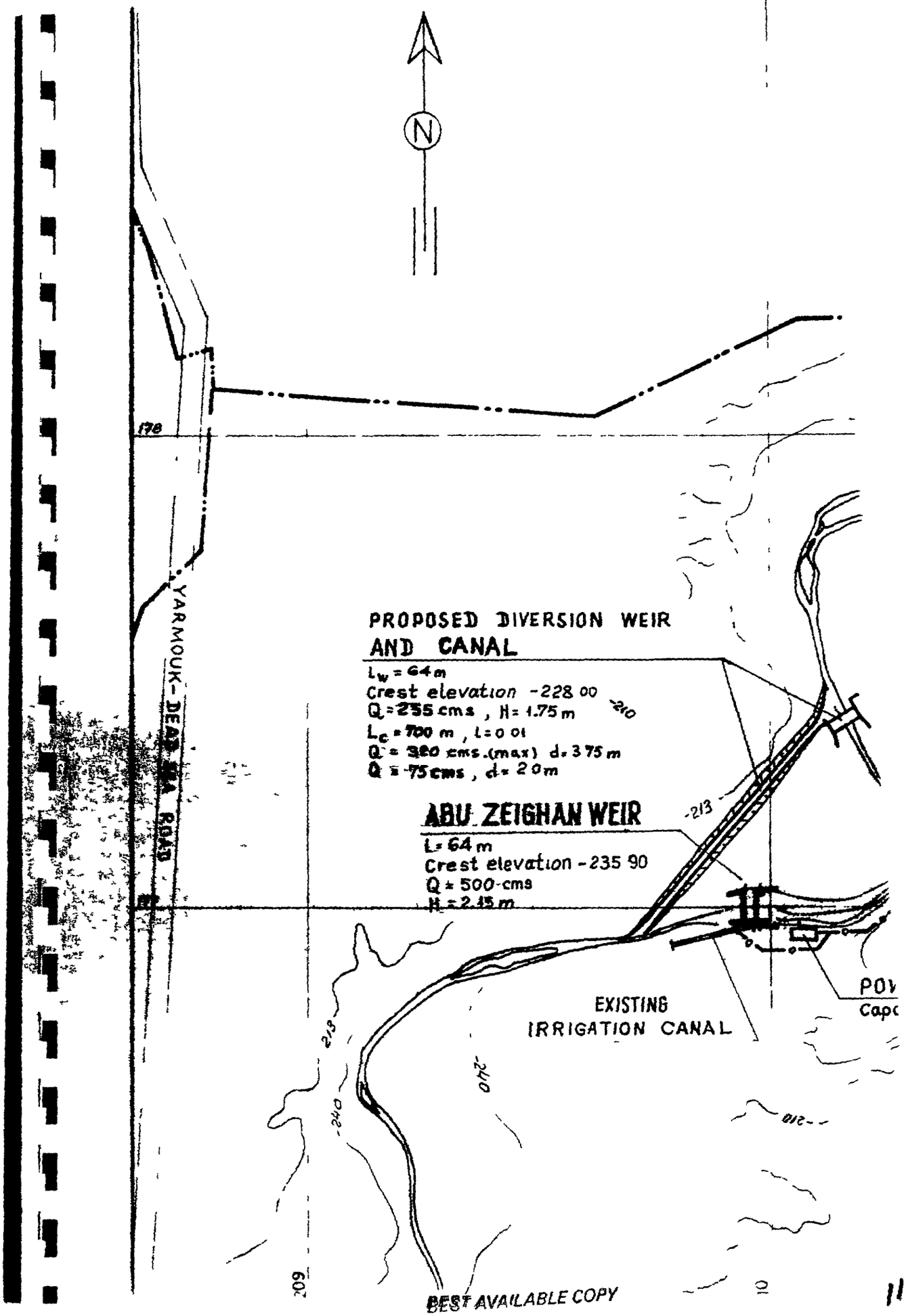

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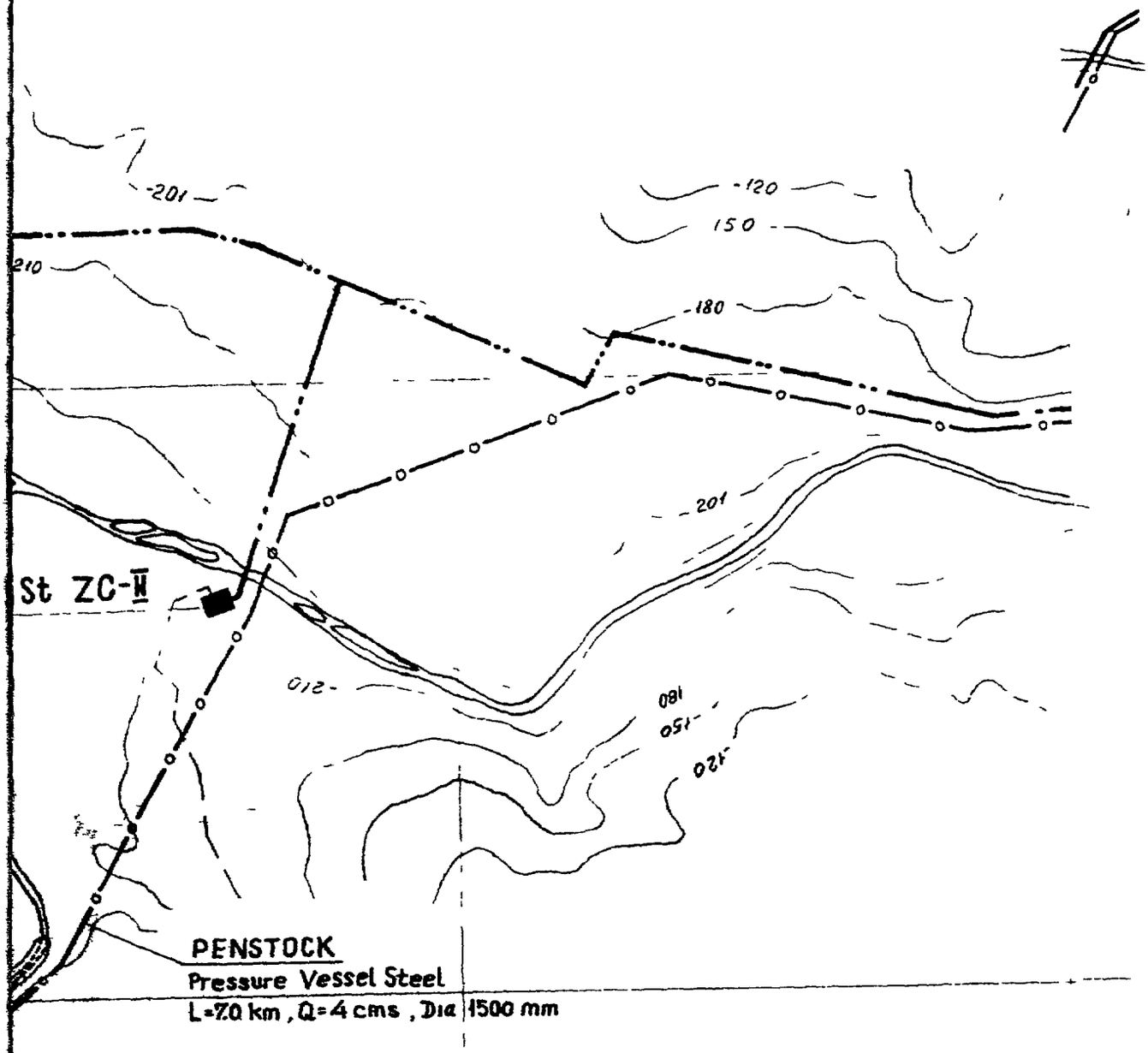

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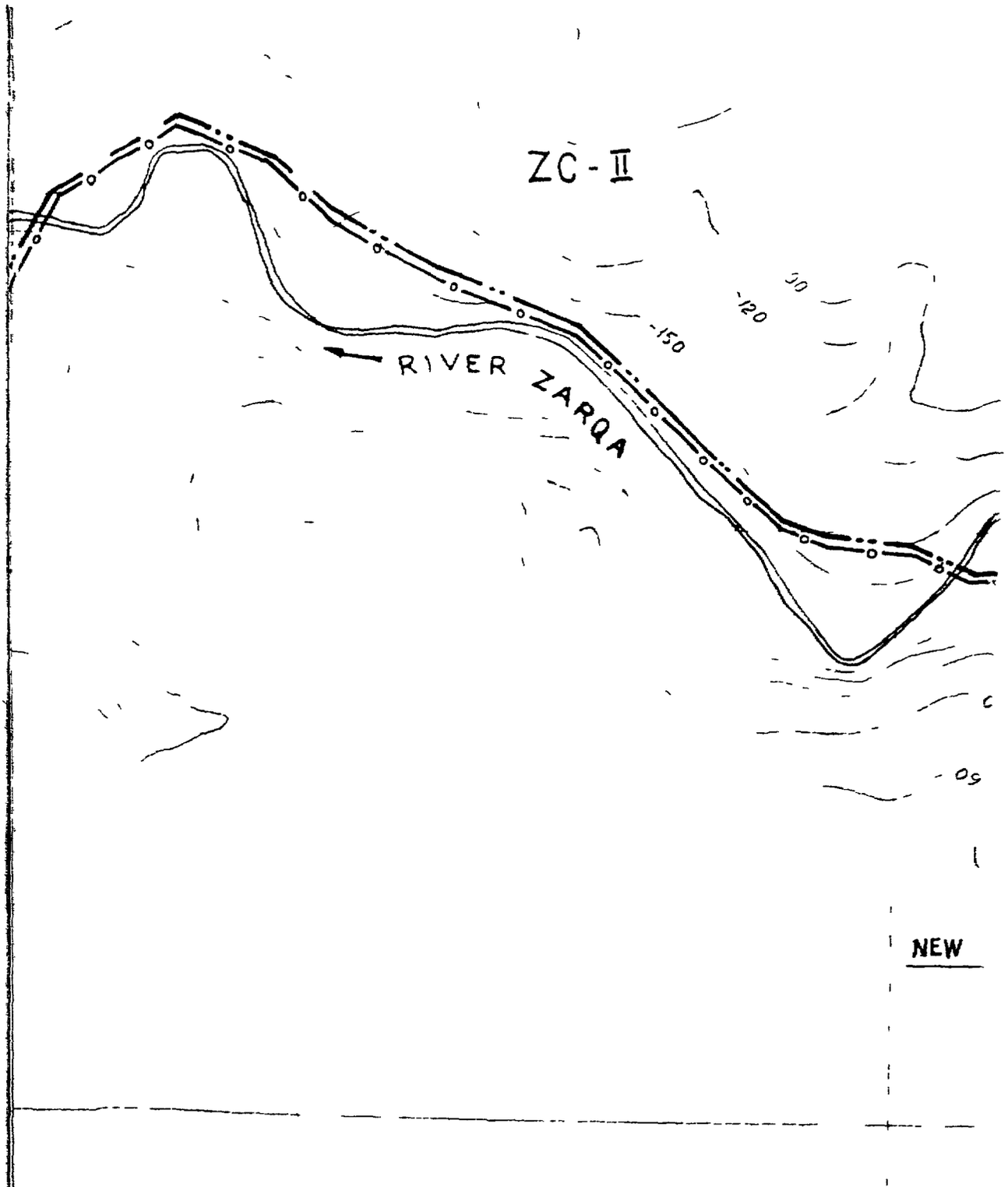

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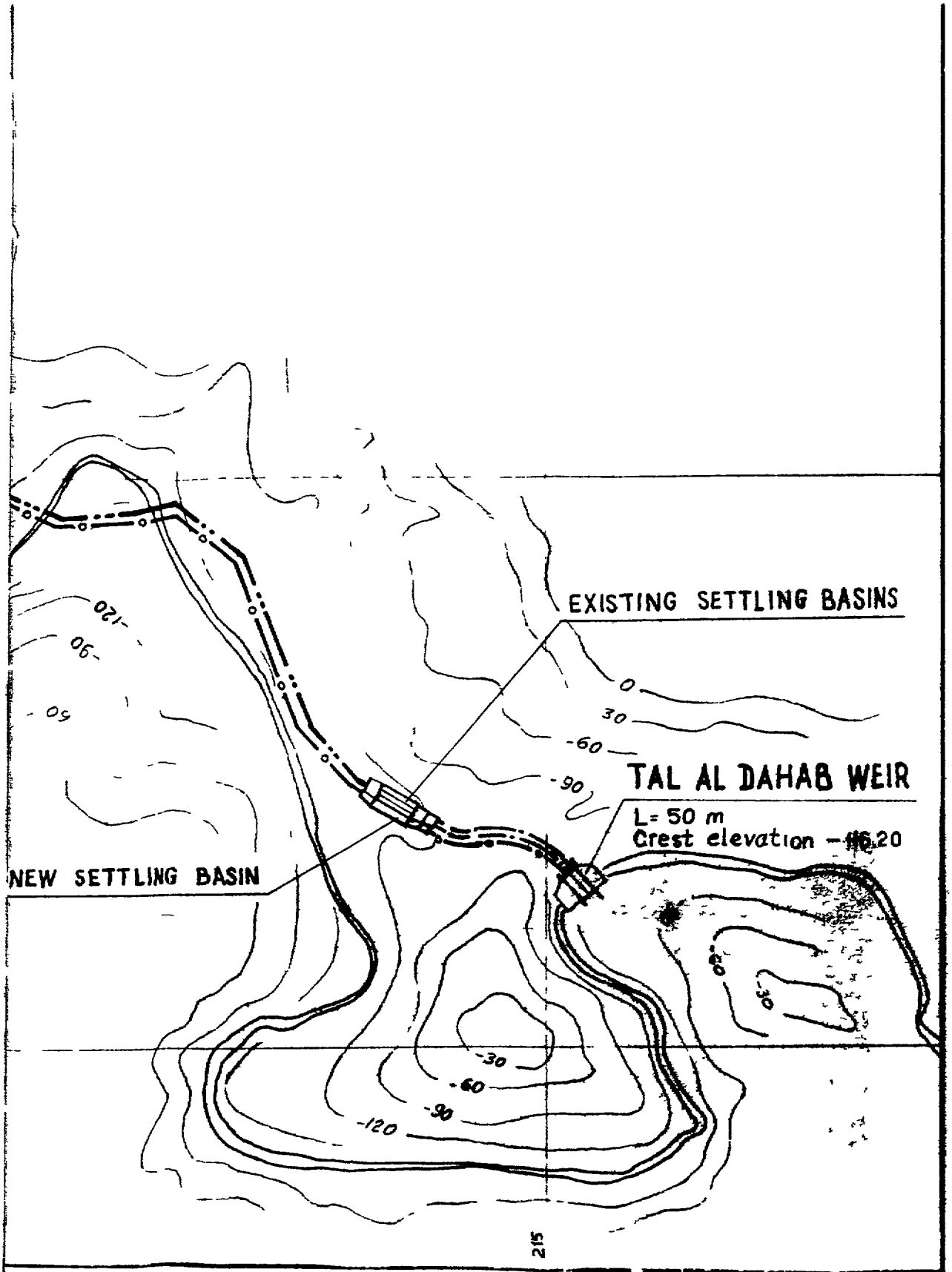

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ALTERNATIVE SELECTION

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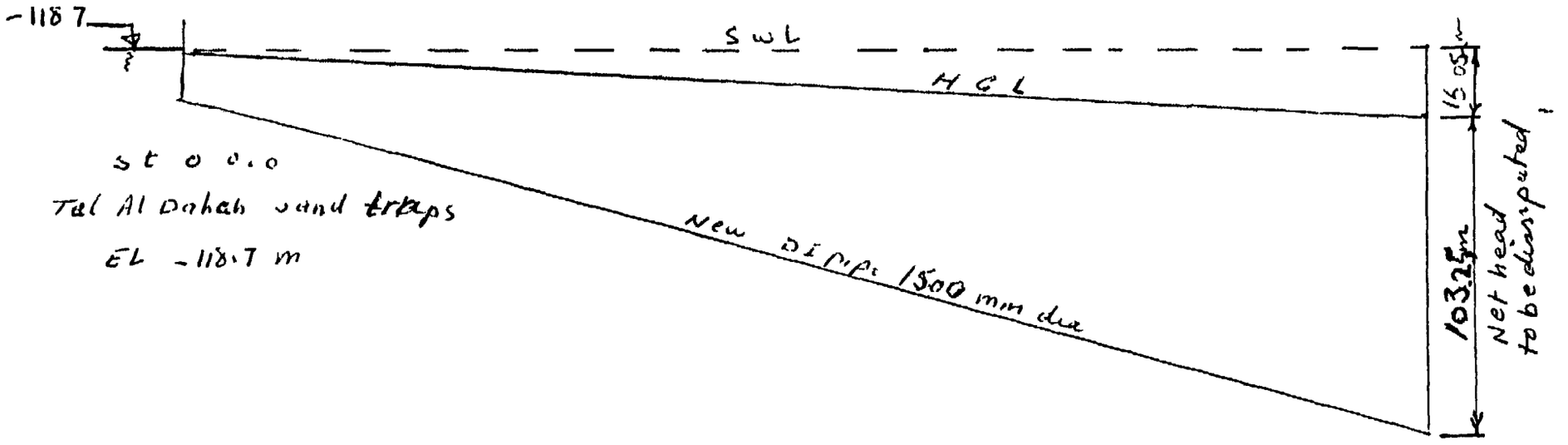

Alternative IRR1 (Irrigation)

Q = 4 CMS

Ductile iron pipe

Dia = 1500 mm

J = 2.084 m/km (head loss, m/km)

Length = 7 km

Total head loss = 2.084 x 7 x 1.1 = 16.05 m

Net head at outlet = 103.25 m

Required:

- One additional sand trap at Tel Al Dahab
- Pressure dissipator at Abu Zeyhan weir (Pressure reducing valve)
- One additional pipe from weir to sand traps at Tel Al Dahab
- Possibly vortex inhibitor at Tel Al Dahab weir

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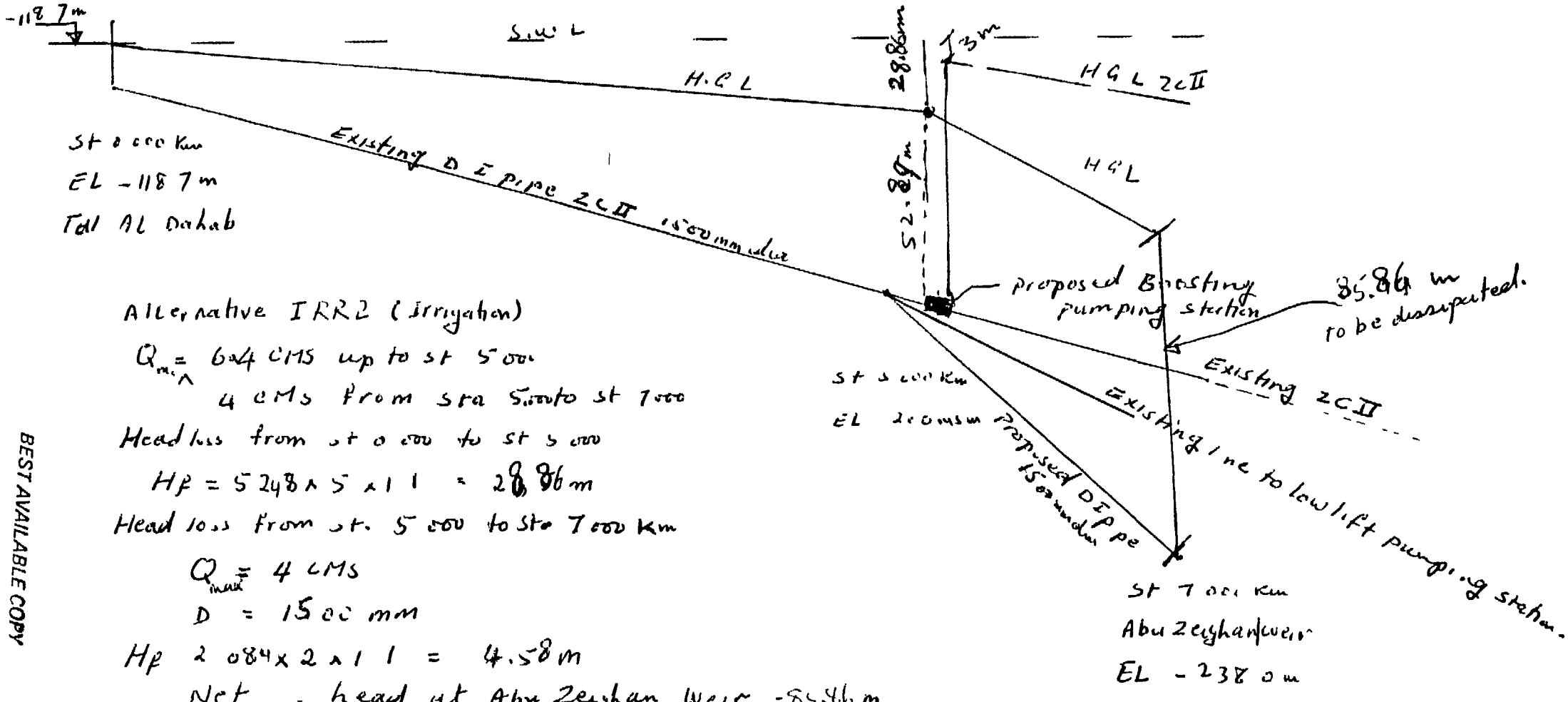

Alternative IRR2 (irrigation)

Q_{max} = 6.4 CMS up to st 5.000

4 CMS from sta 5.000 to st 7.000

Head loss from st 0.000 to st 5.000

$H_f = 5.248 \times 5 \times 1.1 = 28.86$ m

Head loss from st. 5.000 to sta 7.000 Km

$Q_{max} = 4$ CMS

$D = 1500$ mm

H_f 2.084 x 2 x 1.1 = 4.58 m

Net head at Abu Zeyhan Weir -85.86 m

Head loss at st 5.000 before the extension to Abu Zeyhan

$Q = 2$ CMS , $L = 5$ km , $J = 0.548$ m

$H_f = 0.548 \times 5 \times 1.1 = 3.0$ m

Difference in friction loss = 28.86 − 3 = 25.86 m

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TRR2 CONT.

Needed:

- One additional sand traps at Tell Al Dahab
- Pressure dissipator at Abu Zeighan weir (Pressure reducing valves)
- One additional pipe from weir to sand traps at Tell Al Dahab
- Possibly Vortex inhibitor at Tell Al Dahab WEIR
- Boosting pumping station at sh 5 000 to bring back the head to the existing value (or to add 26.5 m head to 2000 l/s at the junction to satisfy irrigation head requirements.

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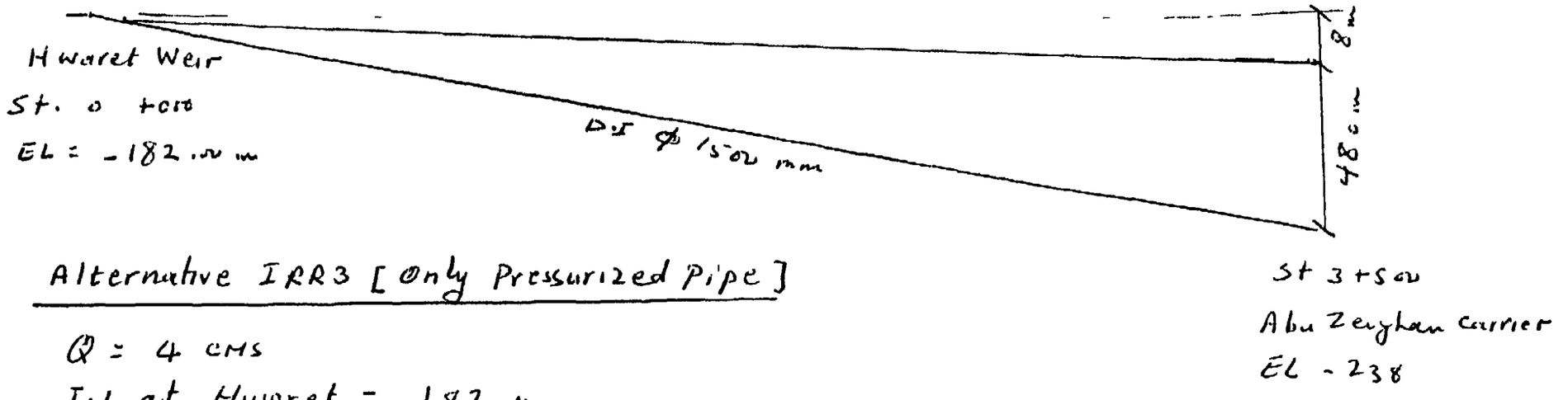

Alternative IRR3 [Only Pressurized Pipe]

Q = 4 CMS
I.L at Hwaret = -182. m.
I L at Abu Zeyhan = - 238 m
Friction loss in pipe
2.084 x 3.5 x 1.1 = 8 m
Net head to be dissipated at Abu Zeyhan carrier = 48 m

Required
- One scend trap 40 m long at Hwaret intake
- Rehabilitation of the existing Hwaret Weir and intake
- Pressure dissipator at Abu Zeyhan carrier (pressure reducing valves)

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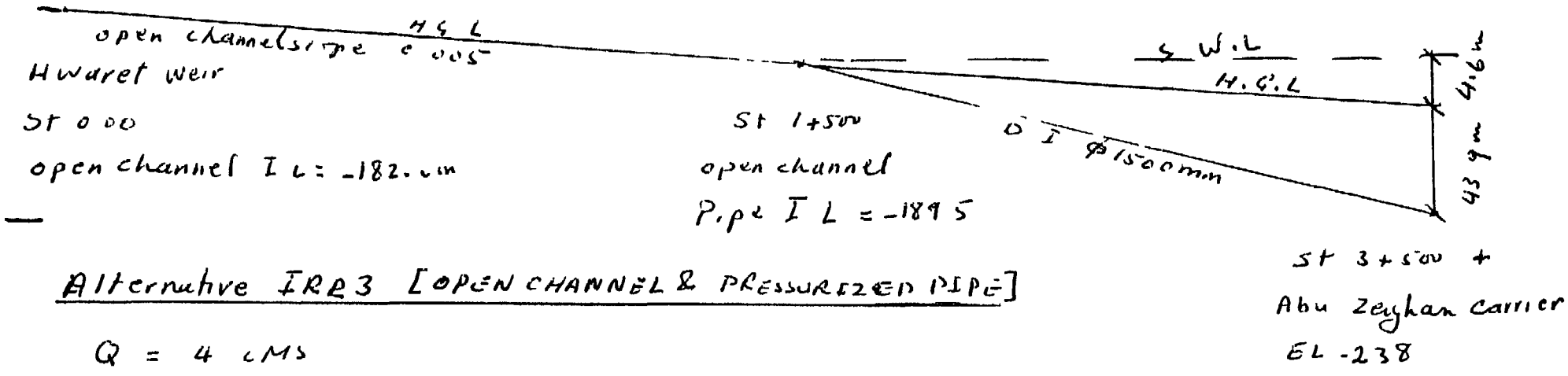

Alternative IRR3 [OPEN CHANNEL & PRESSURIZED PIPE]

Q = 4 cms

Open channel . Length 1.5 km, width 1.5 m

depth of flow = 1.0 m, Manning's n = 0.015

I.L at Hwaret = -182.0 m

I.L at pipe inlet = -189.5 m

Friction loss in pipe = 2.024 x 2 x 1.1 = 4.6 m

Net head to be dissipated at Abu Zeyhan carrier = 43.9 m

Required.

- One sand trap 40 m long at Hwaret intake.
- Rehabilitation of the existing open channel. (Only 1.5 Km), Hwaret Weir, and intake
- Pressure dissipator at Abu-Zeyhan Weir (Pressure reducing valves)

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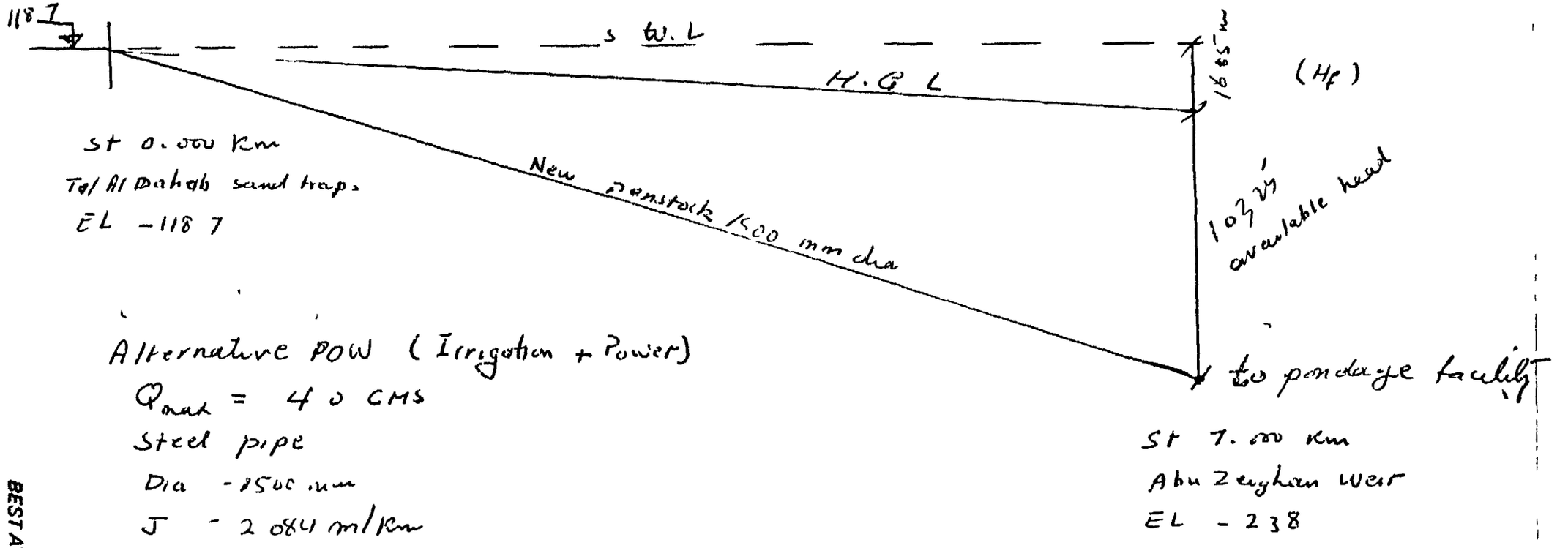

Alternative POW (Irrigation + Power)

Q_{max} = 40 CMS

Steel pipe

Dia - 1500 mm

J - 2.084 m/Km

Length = 7 Km

Total head loss - 2.084 × 7 × 1.1 = 16.05 m

Available head at outlet = m

Required

- ~~[illegible]~~ additional sand trap at Tel Al Dahab
- possibly vortex inhibitor at Tel Dahab weir
- Power plant Equipment (1 unit) and civil works
- Pondage facilities at Abu Zeyhan
- Diversion Works of saline water to Zarka river

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