フィリッピン共和国

アグノ川灌漑施設堆砂制御・補修計画

事前調査報告書

平成６年９月

社団法人　海外農業開発コンサルタンツ協会

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はじめに

本報告書は、平成6年8月7日から8月14日まで、フィリピン国パンガシナン州を中心に実施した「アグノ川灌漑施設堆砂制御・補修計画」に関する海外農業開発事業事前調査（現地調査）結果をとりまとめたものである。

アグノ川灌漑地区（The Agno River Irrigation System, ＡＲＩＳ）は、ルソン島中部パンガシナン州を貫流する島内第2の河川であるアグノ川（Ｃ．Ａ＝ 5,700km²、幹川流路延長： 275km）の下流部右岸に展開する島内屈指の水田地帯である。

1959年に完成した同灌漑システムは、アグノ川中流部のサン・マヌエル付近で取水された灌漑用水（最大86m³/s）を総延長 209kmの水路網により配水するもので、補助水源であるシノカラン川からの取水と併せて20,050haの計画受益地区を有するものである。しかし、その後アグノ川からの流入土砂による水路閉塞や取水堰上流に位置する金，銅鉱山からの廃サイ土砂の水田内への堆積、更には、シノカラン川の洪水氾濫や地震等により、受益地は急激に減少してきており、現在の受益地は当初計画の4割程度にまで減少をきたすに至っている。

このような状況に対し、国家灌漑庁（ＮＩＡ）では灌漑システムの維持管理に各種の対策を実施してきているが、主として予算上の制限から毎年の水路の維持浚渫の実施がせいいっぱいの状況であり、灌漑システムの抜本的な機能回復を行う事は極めて困難な状況にある。

一方、フィリピン国政府は取水堰上流にサンロケ多目的ダム（発電、洪水調節）の建設を予定しており、従って、ダム完成後には、取水地点における土砂流入の課題は解決することとなる。しかし、ダム建設はＢＯＴ方式による実施を前提としており、事業費規模（＄8億ドル）等からみて、事業実施までには今後多くの困難が予想される。

また、仮に今後サンロケダム建設計画が順調に推移した場合にあっても、ＡＲＩＳの機能回復までには、更に水路の修復、シノラカン川の治水対策を含む取水設備の改修及び放置水田の圃場整備等多くの課題が山積しており、ＮＩＡを初めとするフィリピン国政府はこれら課題の解決に我国の支援を強く求めている。

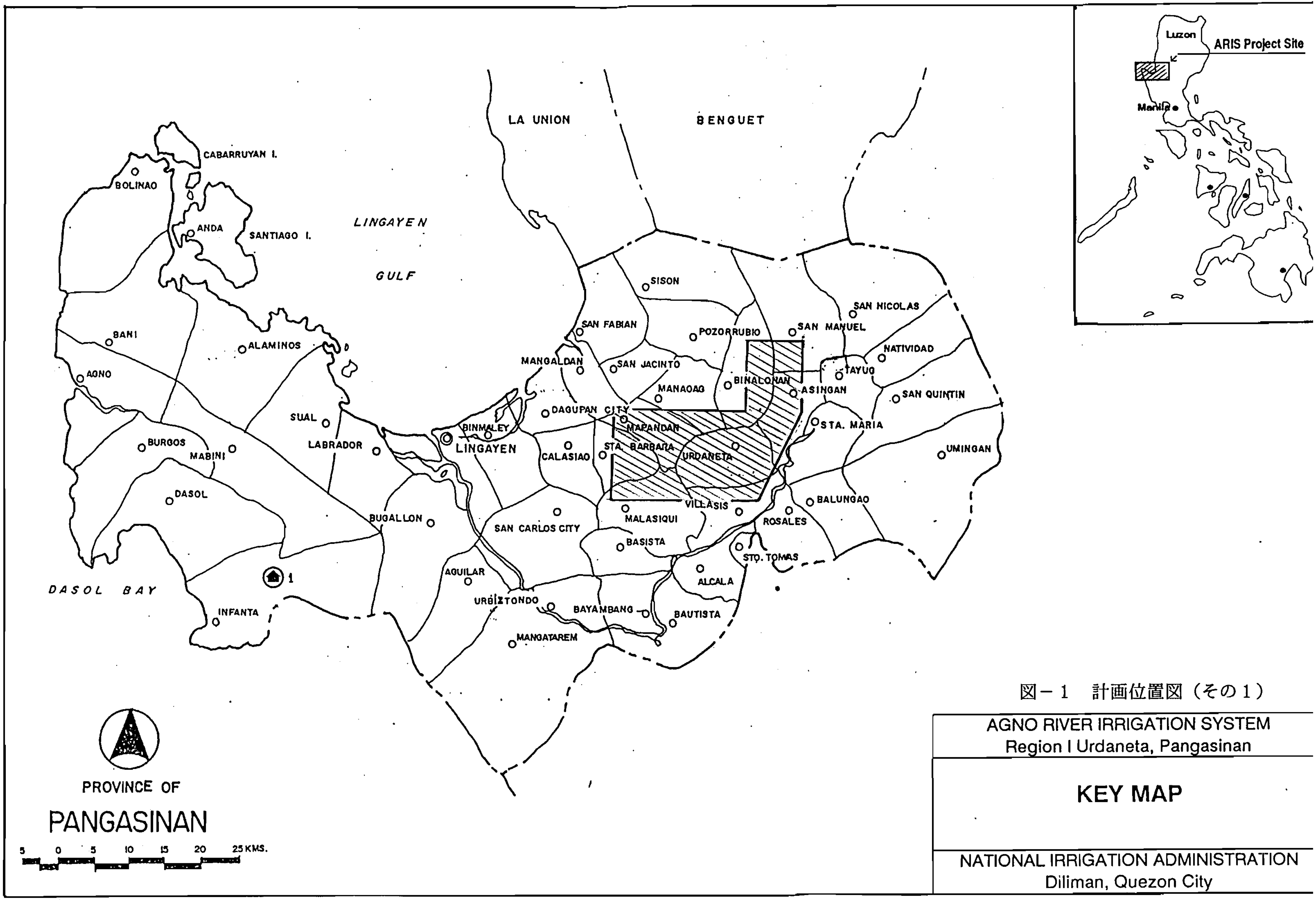
このような背景から、本案件はＡＲＩＳ（Agno River Irrigation System）の機能回復へ向けた以下の事業を実施せんとするものである。

o アグノ川頭首工の改修と流入土砂除去施設（沈砂池）の設置

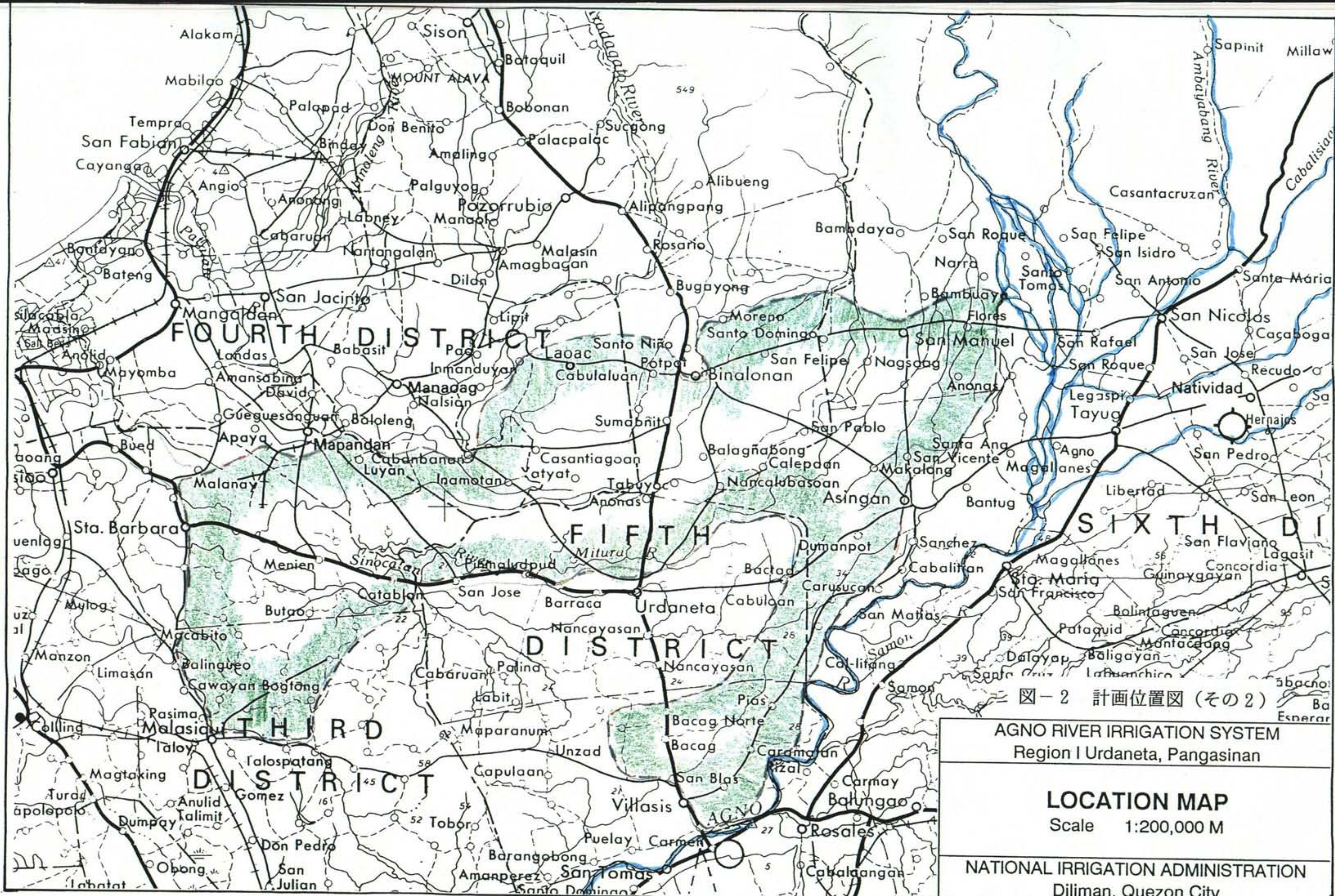
o シノラカン川の治水対策と取水施設の改築

o 用水路の修復と排水施設整備

o 荒廃圃場の再整備


Luzon
ARIS Project Site
Manila
LA UNION
BENGUET
CABARRUYAN I.
BOLINAO
ANDA
SANTIAGO I.
LINGAYEN
GULF
SISON
SAN NICOLAS
SAN FABIAN
POZORRUBIO
SAN MANUEL
BANI
ALAMINOS
NATIVIDAD
MANGALDAN
SAN JACINTO
TAYUG
AGNO
BINALONAN
MANAOAG
ASINGAN
SAN QUINTIN
SUAL
DAGUPAN CITY
BINMALEY
MAPANDAN
STA. MARIA
BURGOS
LABRADOR
LINGAYEN
CALASIAO
STA. BARBARA
URDANETA
UMINGAN
MABINI
DASOL
VILLASIS
BALUNGAO
BUGALLON
MALASIQUI
ROSALES
SAN CARLOS CITY
BASISTA
STO. TOMAS
1
AGUILAR
ALCALA
DASOL BAY
URBIZTONDO
BAYAMBANG
BAUTISTA
INFANTA
MANGATAREM
PROVINCE OF
PANGASINAN
5 0 5 10 15 20 25 KMS.
AGNO RIVER IRRIGATION SYSTEM
Region I Urdaneta, Pangasinan
KEY MAP
NATIONAL IRRIGATION ADMINISTRATION
Diliman, Quezon City

図－1　計画位置図（その1）


AGNO RIVER IRRIGATION SYSTEM
Region I Urdaneta, Pangasinan
LOCATION MAP
Scale 1:200,000 M
NATIONAL IRRIGATION ADMINISTRATION
Diliman, Quezon City
FOURTH DISTRICT
FIFTH DISTRICT
THIRD DISTRICT
SIXTH DI
Urdaneta
Binalonan
Asingan
Villasis
Rosales
Tayug
Mapandan
Manaoag
Pozorrubio
Sison
San Fabian
Mangaldan
Sta. Barbara
Malasiqui
San Manuel
San Nicolas
Natividad
Sta. Maria
Balungao
AGNO

図－2　計画位置図（その2）

1. 調査団構成

入江章演　㈱アイ・エヌ・エー　理事

本多和彦　㈱アイ・エヌ・エー　海外部長

Abelardo Almentia　ＮＩＡ計画部次長

Danny Swmaet　ＮＩＡ　RegionⅠ．技師

2. 調査日程

調査日程は平成６年８月７日より８月14日までであった。

詳細日程は以下のとおりである。

日順	月　日	行　　程	調　査　内　容
1	8／7 (日)	成田→マニラ	移　動
2	8／8 (月)		日本大使館・ＮＩＡ及びパンガシナン州知事 自宅訪問
3	8／9 (火)	マニラ→ダクパン	現地調査・ＮＩＡ Region Ⅰ事務所訪問
4	8／10 (水)	ダクパン→マニラ	現地調査・パンガシナン州政府訪問
5	8／11 (木)		ＮＩＡ・ＪＩＣＡマニラ事務所訪問 資料収集・打合せ
6	8／12 (金)		関係機関に調査報告、資料収集
7	8／13 (土)		資料収集、整理、本多団員帰国
8	8／14 (日)	マニラ→成田	移　動

3. 主要面談者

山内勝彦氏	在フィリピン日本大使館一等書記官
石田武士氏	在フィリピンＮＩＡ駐在専門家
吉田勝美氏	在フィリピンＪＩＣＡ事務所駐在
ＭR. Aguedo Ｆ. Agbayani	パンガシナン州知事
ＭR. Punzal	ＮＩＡ計画部長
ＭR. Almentia	ＮＩＡ計画部次長
ＭR. Qrlando Ｌ. Bulseco	ＮＩＡ Region Ｉ 事務署長
ＭR. Danny Sumaet	ＮＩＡ Region Ｉ 技師

4. 本格調査の概要

4.1 計画の名称及び位置

名称：アグノ川灌漑施設（ＡＲＩＳ）堆砂制御・補修計画

位置：パンガシナン州サンマニエル

4.2 相手国担当機関

国家灌漑庁（ＮＩＡ）

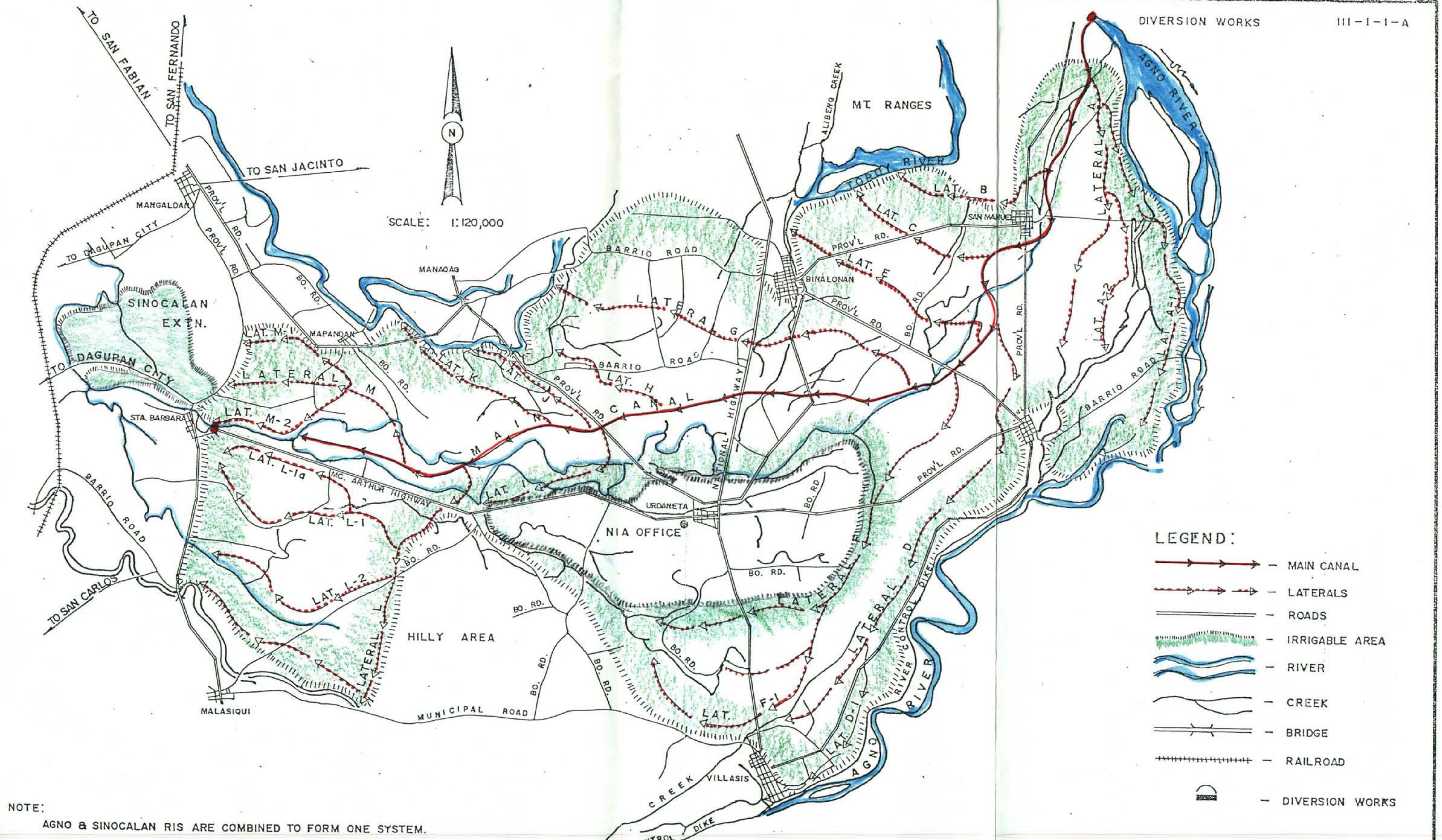
4.3 計画の目的

本計画は、多年にわたる土砂の流入、堆積等により、灌漑区域の減少が著しいＡＲＩＳ灌漑地区を対象として、灌漑可能区域を現状の 7,700haより当初計画の20,050haへと復旧することを目的として、流入土砂対策・治水対策及び水路復旧等、農業基盤諸施設の機能回復を計るものである。

4.4 ＡＲＩＳの現況と計画の背景

アグノ川灌漑システム（The Agno River Irrigation System・ＡＲＩＳ）は中部ルソン，パンガシナン州の水田18,500haを対象に計画された大規模灌漑システムである。

ＡＲＩＳはアグノ川中流部右岸に広がる10市の水田地帯を対象に、1950年代後半に建設された。その後1979年にはサンタ・バルバラ市を流れる支流シノカラン川を水源とする３集落の 1,550haの灌漑地区が追加され、受益農家数約10,000世帯、受益人口約40,000人と推定されるルソン島内屈指（総灌漑面積：20,050ha）の灌漑システムが完成した。（図－３参照）



図－3 アグノ川灌漑システム

SERVICE AREA: 20,054 Has. (AGNO & SINOCALAN EXTN.)

O & M STUDY PHASE III	DATE	CONSULTANTS	NATIONAL IRRIGATION ADMINISTRATION	REGION	AGNO RIVER IRRIGATION SYSTEM	APPENDIX A
	JAN. 1985	PRC/SGV		I		SHEET 1 OF 2

一方、アグノ川上流域は地被に乏しく、多量の侵食土砂が発生することに加えて、金,銅の採掘に伴う鉱滓の混入等により配水地点の浮遊砂の含有率は1,000ppm～3,000ppmにおよんでいる。

この為、ＡＲＩＳは1959年の竣工直後から水路内への大量の土砂流入により、水路の埋設、圃場内への鉱滓の沈澱等により多大の被害を被るところとなり、灌漑可能区域は減少の一途を辿るに至っている。

これに対処するため、ＡＲＩＳ管理事務所は1973～74年の間に 935,000㎥のシルトを浚渫したが、その後浚渫費用の高騰等により浚渫量は年間31,000～33,000㎥に低下するに至った。このような浚渫土砂量の低下と当地を襲った地震とにより、サイフオン箇所の殆どが閉塞されるところとなり、全長 209kmの支水路のうち71kmは通水不能となっている。

このような、用水路網の機能低下に伴う灌漑可能区域の減少と、流入土砂の圃場内への堆積とにより、灌漑面積は減少の一途を辿っており、1994年現在のＡＲＩＳ灌漑面積は 7,000haと当初計画の40%にまで減少するに至っている。（図－４）

更に、今後も有効な対策が実施されなければ、年間約 1,000haの割で廃田化が進行すると予想されている。

加えて、受益地のほぼ中央を貫流するシノカラン川の洪水氾濫により廃田化が一層加速されることが懸念されている。

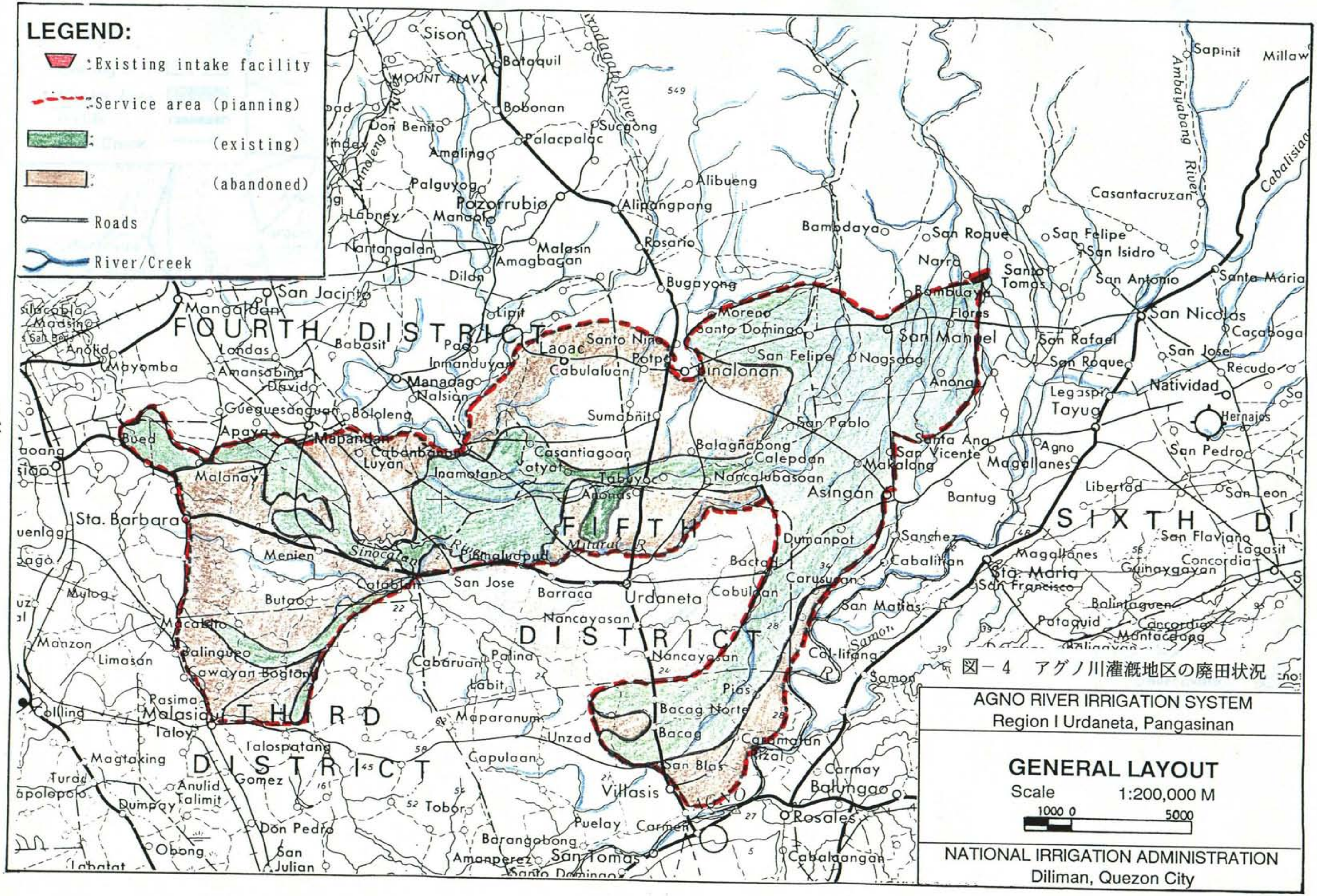
このようなＡＲＩＳ灌漑区域の荒廃を防ぐべく、ＮＩＡはVortex tube の設置(199年英国無償援助）等の対応策を実施してきているが抜本的な解決には至っていない。

ＮＩＡによるＡＲＩＳ補修計画は、当初フィリピン電力公社が取水堰上流に計画中のサン・ロケ多目的ダムが完成するという前提で計画された。

サン・ロケ多目的ダムは、総貯水容量11億５千万㎥の大ダムであり、これが完成すれば、上流より搬出される土砂は殆ど貯水池内に捕捉されることから、ＡＲＩＳにおける最大の課題である、土砂問題の抜本的な解決が画れることとなる。

発電、灌漑用水開発、治水に加えて大きな流送土砂対策効果を有するサン・ロケダム建設にはフィリピン政府も意欲的に推進を計っており、ＢＯＴ方式での建設を各国に働きかけている。

しかし、現在１～２ケ国が関心を示してはいるものの、総額８億ドルと推算される工事費や、治水や土砂対策を含む多目的ダム事業を対象とする投資であること等、幾つかの課題を内包しており、近い将来における事業の完成には疑問を提する声が多い。このような現況を考慮すると、ＡＲＩＳ灌漑地区の機能回復へ向けた各種対策事業の実施は、サン・ロケダムの完成を待つまでの猶予を有するものでは無く、早急な実施が強く望まれるところである。



図－4　アグノ川灌漑地区の廃田状況

4.5　調査計画の内容（Ｓ／Ｗ）

本調査の対象項目は大きく以下の６つに大別される。

(1)　ＡＲＩＳ灌漑地区現況調査

－1.　施設現況調査（取水施設，用配水路，圃場）

－2.　被害実態調査

－3.　水文環境調査

－4.　水質実態調査（既往調査の再レビューと追加調査）

(2)　堆砂制御施設の検討

－1.　地形・地質調査

－2.　堆砂制御方式の検討

－3.　取水堰改修計画及び設計

－4.　沈砂（排砂）設備の設計

－5.　水理模型実験

(3)　水路補修計画の検討

－1.　補修計画の立案

－2.　補修施設設計

(4)　シノカラン川治水対策検討

－1.　治水基本計画の検討

－2.　内水排除計画の立案

－3.　治水対策施設設計

(5)　圃場整備計画の立案

－1.　Abandon Aria　再整備計画の立案

－2.　シノカラン地区灌漑計画の立案

(6)　経済分析・評価

－1.　工事費積算

－2.　経済分析

－3.　財務分析

尚、上述の各調査の内、特に緊急を要する調査は(1)の現況調査によるＡＲＩＳ灌漑地区の内包する各種課題の定量化と、(2)の堆砂制御施設の検討である。

4.6　本格調査工程

前項で示した各調査項目を対象とする本格調査の工程は概ね図－５に示すとおりである。

図－５ 本 格 調 査 工 程

調 査 項 目	月											
	1	2	3	4	5	6	7	8	9	10	11	12
現況調査	━	━	━	━								
施設現況調査（取水施設，用配水施設，圃場設備）	━	━										
被害実態調査（土砂被害，洪水被害，内水被害）			━	━								
水文環境調査（雨量，流量）	━	━										
水質実態調査（取水地点水質，水路内水質）	■	■	■	■								
堆砂制御施設の検討		━	━	━	━	━	━	━	━	━		
地形・地質調査		━										
堆砂制御方式の検討			━									
取水堰改修計画及び設計				━	━	━				━		
沈砂（排砂）設備の設計				━	━	━				━		
水理模型実験							━	━	━			
水路補修計画の検討					━	━	━	━	━			
補修計画の立案					━	━						
補修施設設計							━	━	━			
シノラカン川治水対策検討			━	━	━	━	━	━				
治水基本計画の検討			━	━								
内水排除計画の立案				━	━							
治水対策施設設計						━	━	━				
圃場整備計画の立案				━	━	━	━	━				
廃棄地区再整備計画の立案				━	━							
シノラカン地区灌漑計画の立案						━	━	━				
経済分析・評価									━	━	━	━
工事費積算									━	━	━	
経済分析											━	━
財務分析											━	━

5. 収集資料リスト

本調査により収集したＡＲＩＳ灌漑地区の堆砂対策検討に関する基礎的資料は以下のとおりである。

(1) 計画地点1/50,000地形図

(2) ＡＲＩＳ一般平面図

(3) ＮＩＡ作成ＴＯＲ原案

(4) Sediment Control in the ＡＲＩＳ by Hydrulic Research Willingftrd, ＵＫ

(5) Vortex tube 関連資料

(6) サンロケ多目的ダム開発計画調査報告書（ＪＩＣＡ. 1985年）

(7) ＮＩＡ年次報告書（1993年版）

6. 参考資料

参考資料としてＮＩＡと協同で作成したProject Proposal及びVortex tubu による排砂対策提案書（Hydroulics Research, Wallingford, ＵＫ）を以下に添付する。

PROJECT PROPOSAL

I. Name & Location of Project :

Agno River Irrigation System (ARIS) Rehabilitation and Sedimentation Control Study
San Manuel, Pangasinan

II. Project Proponent:

National Irrigation Administration (NIA)

III. Proposed Financing Institution:

Japan International Cooperation Agency (JICA)
The Government of Japan

IV. Objective:

The project aims to **(1)** rehabilitate ARIS and improve the drainage system, **(2)** upgrade the Sinocalan Irrigation System in order to restore the service area of the former from 7,000 ha to the original 18,500 ha, and to increase from 700 ha to 1,500 ha the service area of the latter; and **(3)** save the huge maintenance cost.

V. Proposed Development Scheme:

A. Background

The Agno River Irrigation System was designed to irrigate some 18,500 ha of paddy fields in Pangasinan Province, in the Central Plain of Luzon. It was constructed in the late 50s to serve ten municipalities. In 1976, an extension area of 1,550 ha covering three towns was made possible with the construction of an auxiliary dam (check gate) across the Sinocalan River in the town of Sta. Barbara. The extension brought the potential service area of the Agno-Sinocalan RIS to 20,050 ha.

ARIS has long suffered from two ailments since its inauguration in 1959, i.e. sedimentation and siltation. Composed of geological formations vulnerable to erosion, the upstream valley of the Agno River produces a lot of sediment materials comprising mainly of coarse sand. Also, water released from mine tailings contains very fine particles. Previous studies revealed that suspended sediment at the ARIS headworks are about 0.1-

0.3% of water-sediment mixture. Yearly desilting works were conducted by the ARIS office and in 1973-74 some 935,000 cu m of silt were removed at a total cost of P2.8 million. During the 1980s, the volume of desilting decreased due to high costs. In 1984 and 1985, only 33,000 cu m and 31,000 cu m of silt, respectively, were removed at an annual expense of P500,000. Consequently, the main canal became shallow and its discharge capacity decreased from the design capacity of 38 cu m/s to only about 24 cu m/s. Siphons also lost their capacities due to clogging and some 71 km out of the total length of 209 km of secondary canals were abandoned due to siltation. To keep the canals free from silt at all times and maintain 100% conveyance capability, about P1 million is needed annually. Without this yearly allocation, the system will be decreasing its irrigated area by 1,000 ha every year. As of 1994, the irrigation area was already reduced to 7,000 ha from the designed area of 18,500 ha.

ARIS area frequently suffers from damages by flood because the Sinocalan River which traverse the area cannot accommodate the flood discharge and the local drainage systems are not sufficient. To improve this situation and irrigate 1,500 ha of paddy fields, NIA launched the Sinocalan Project. Due to some constraints at that time NIA finished only part of the construction works which included a concrete weir built across the Sinocalan River. However, the weir was never operated during rainy seasons because farmers opposed the raising of water level of the river above the crest level of the weir. The rehabilitation of the existing Sinocalan diversion dam to serve the designed area of 1,500 ha and the construction of flood protection dikes along both river banks will be included in a separate project proposal for grant aid assistance.

B. Proposed Development Scheme

The rehabilitation and improvement of ARIS was originally proposed with the condition that the San Roque Multipurpose Dam Project of National Power Corporation (NAPOCOR) would be implemented. This is to take advantage of the fact that an allocation for sediment storage in the dam was incorporated in the project. However, due to NAPOCOR's limited resources and the high cost of the 220m high dam project, estimated now at US$ 800 Million, it is deemed that the multipurpose dam project would not be implemented in the immediate future. At this instance, the improvement of ARIS must be reformulated on a "without San Roque" basis, which preliminary studies show that it would be possible to do so. For instance, to provide a sediment control measure in the period before longer measures become effective, a vortex tube was constructed sometime in 1991 by the Hydraulic Research Laboratory of England. This P6 Million structure is now being used by the National Irrigation Administration (NIA) Region 1 Office in Urdaneta, Pangasinan in its desilting efforts at the main canals of the ARIS Project. However, as this desilting facility is only effective during the wet season and flushing sediments at about 60% recovery efficiency, there is still the need to find other effective means to control the heavy sedimentation problem at Agno River.

This proposal involves the construction of settling basins at the banks of the main canals just downstream of the intake structure.

VI. Proposed Scope of the Study

1. Investigation of Water Quality
   - Investigation of suspended sediments at the Agno River and at the canal system
   - Particle size analysis

2. Design of Sedimentation Control Facilities
   - Topographic survey and geological investigation
   - Design of sand settling basin
   - Hydraulic model testing

3. Rehabilitation Plan for ARIS
   - Investigation of existing sediments in canals
   - Investigation of crop water requirements
   - Formulation of rehabilitation plan
   - Design of rehabilitation structures

4. Hydrological Study
   - Rainfall analysis
   - Flood analysis

5. Drainage Plan
- Investigation of flood damages
- River survey
- Formulation of drainage plan
- Design of flood and drainage facilities

6. Sinocalan Irrigation Project
- Irrigation plan
- Design of weir
- Design of irrigation facilities

7. Construction Schedule

8. Economic Analysis
- Cost Estimate
- Benefit estimate
- Project justification

9. Preparation of feasibility study report suitable for presentation to foreign funding institutions

VII. Study Schedule

A tentative study schedule is shown in Figure 1.

AGNO RIVER BASIN

Location — Western Part of Central Luzon (Benguet, Tarlac, and Pangasinan Province)

Catchment Area — 5,700 km^2

Total Length — 275 km

Mean Annual Precipitation
- **Upstream** — 4,000 mm
- **Downstream** — 2,000 mm

Precipitation Pattern
- **Wet Season** — May - October
- **Dry Season** — November - April

Mean Temperature
- **Upstream** — 19 ^0C
- **Downstream** — 27 ^0C

Annual Mean Discharge — 9,990 x 10^6 m^3

Duration

Month	1	2	3	4	5	6	7	8	9	10	11	12
Discharge	33.9	22.6	18.1	19.2	31.7	61.0	186.5	229.5	202.3	174.1	93.8	57.7
%	3.0	2.0	1.6	1.7	2.8	5.4	16.5	20.3	17.8	15.4	8.3	5.1

SEDIMENT CONTROL IN THE AGNO RIVER IRRIGATION SYSTEM

by

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SUMMARY

The note presents preliminary designs for sediment control structures that could be constructed in the ARIS irrigation system. Large quantities of river sediments and mine tailings are diverted to this system, resulting in high rates of sedimentation of the conveyance canals. At present canal bed levels are generally between one and two metres above design levels. The main canal, designed in the 1950's for a discharge of 38 m3/s has in recent years been operated at an average discharge of only about 6 m3/s.

The present low canal discharge capacity can only been maintained by annual desilting in the canal head reach, and at other critical points at syphons etc.. There is a massive backlog of sediment to be cleared if the canal is to be restored to design conditions. However this is now what is plannned as part of the IOSP programme. The canal system will be remodelled to new design cross sections, with a design discharge capacity in the main canal of 26 m3/s.

The additional water diverted to the canal will bring with it additional sediment, and effective sediment control facilities are necessary if the system is not to rapidly revert to its present silted condition. A number of options would be feasible, spanning a range of costs and expected performance. As there is the possibility that the construction of the San Roque Dam, and /or the implementation of other measures in the river catchment that will reduce the problem in the medium term, We have considered a relatively low cost interim solution. This will provide a measure of sediment control in the period before longer measures become effective.

We suggest that a vortex tube located at km. 1.7 in the main canal is used to divert sediment back to the river the wet season. In the dry season, when only low discharges can be diverted to the canal, and the additional flow required to operate the vortex tube is not available, the head reach will be operated as sluiced settling reach. This will require that the canal is closed for periods of up to 24 hours during sediment flushing, which would be carried out every two weeks. Fine sediments, that can not easily be controlled at the head of the system, would be trapped in small settling basins located at the heads of laterals.

The works that would be required are shown in figure 2 and consist of:

Removing the existing canal cross regulator at km 1

Constructing a new canal cross regulator at km 1.7

Constructing a vortex tube sediment extractor and low level escape at km 1.7

Constructing about 200 m of escape channel from km 1.7 to the flood protection bund at the edge of the river, and a conduit through the bund, controlled with flap gates to prevent reverse flows.

Forming and maintaining a channel from the bund to the river low flow channel.

Constructing small settling basins at the heads of laterals to trap sediments in the fine sand and silt size range.

Outline designs for these components are presented in the note in enough detail to allow preliminary costings to be prepared. Estimates of the performance that would be achieved have been made and indicate that of the estimated 280,000 tonnes of sand sized sediments that will enter the remoddelled system about 196000, tonnes will be divered back to the river at km 1.7. The remaining sediment, which will be finer than that presently settling in th system, can be carried by the upper sections of the main canal, but would be trapped in settling basins located at the heads of laterals.

Some sediment deposition would occurr in the lower reaches of the main canal, but at much lower rates than at present.

A significant proportions of sediments in the clay and silt size ranges is at present transported to the fields, and would continue to do with the new works. However about 40 % of the sediment larger than 10 microns that now settles in the smaller channels wouls be trapped by the settling basins located at the heads of laterals.

If NIA decide to preceede with the construction of some or all of the sediment control facilities described then further studies should be made to finalise the dimensions of the structures, and to optimise their operation, so as to achieve the highest possible rates of sediment removal from the canal system.

1 INTRODUCTION

This note sets out the options for improving sediment control at the Agno irrigation intake, located in Pangasinan Province in the Philippines. The study was carried out during a visit to NIA Region 1 irrigation office between 31 Oct and 7 Nov 1989 by P Lawrence and E Atkinson of Hydraulics Research, UK. Some additional performance simulations were carried out at Wallingford after the visit.

NIA and the Overseas Development Unit at Hydraulics Research are carrying out a collaborative study at two irrigation offtakes located in the Agno river system, both suffering from severe canal sedimentation problems. The study as originally conceived, Atkinson 1988, had four components:

* Field data collection at the two canal intakes

* Analysis of field data, and use of numerical modelling, to predict the performance of improvements to the intakes.

* Modification of the intakes, (If justified by the analysis)

* Field data collection to measure the benefits of the modifications, and to assist in the development of effective operational procedures.

Thus the project is assisting NIA by identifying solutions to canal sediment problems, and is providing Hydraulics Research with detailed field data. This is needed to verify the improved design and performance prediction procedures for sediment control structures at intakes that we are developing.

Data collection was initiated in August 1989. Because of the time constraints in NIA's construction programme it was necessary to prepare outline drawings of the modifications proposed for the Agno offtake by the end of November 1989, before field data was available for analysis, and before performance simulations of the proposed modifications at the intake could be carried out. The is note is concerned only with this aspect of the joint studies, ie improved sediment control facilities for the ARIS system. Other aspects of the project will be reported seperately.

2 THE PROBLEM

The area of land that can be irrigated by the ARIS system has been dramatically reduced by the effects of canal sedimentation. The original design discharge for the main canal, constructed in the 1950,s was 38 m3/s, but the average discharge in the period between 1978 and 1985 was reduced to about 6 m3/s. (data from Castencia, table 2). While some of this reduction is due to the shortage of water in the dry season, sediment deposits in the canal system make it now make it impossible to convey more than about 8 m3/s.

It is also reported that pollutants in the mine tailings, which form a substantial proportion of the sediment diverted to the irrigation system, are reducing crop yields.

Various measures have been proposed that would result in a reduction of the sediment loads transported by the Agno river system. These include, control of the sediments resulting from mining activities, improved soil conservation in the catchments, and construction of the San Roque multipurpose dam. It will take a number of years before improvements in the catchement can reduce the quantity of sediment diverted to the ARIS system, and we understand that no decision has been made on the construction of the dam.

Sediment control in the ARIS system at present relies on canal desilting, but resource constraints have restricted this mostly to the canal head reach and at some other critical points, such as syphons. Bed levels in the main canal are now 1m to 2m above design levels, and there is thus a massive backlog of desilting required to restore the system to design conditions.

Some funding for maintenance activities is being provided under the IOSP project, and a programme has been prepared for rehabilitating the main canal system. It is envisaged that the canal will be operated with flows of up to 26 m3/s in the wet season and 12 m3/s in the dry season, a very large increase over the average flow rates that have been supplied in the recent past.

The increase in the flows entering the canal will bring a proportionate increase in the quantities of sediment that enter, and thus the quantity of sediment settling in the rehabilitated system will be between two and three larger than at present unless effective sediment control is introduced. If this is not done the system will rapidly revert to its existing silted cross section, and will be incapable of irrigating the larger area that is targetted in the ISOP programme.

It is usually found that control of sediment at or near to the irrigation offtake, using sediment control structures, is more economical than attempting routine desilting of an entire canal sytem. Thus we have not considered the massively increased desilting effort that would be needed to maintain the canal at its new design bed levels as a viable sediment control option.

3 MODIFICATIONS TO THE INTAKE

At the start of the study is was envisaged that the construction of a tunnel sediment excluder in the existing sluiceway could provide a substantial reduction in the quantities of coarse sediment that are diverted to the canal. However the field data collected in 1989 shows that the existing intake is minimising the concentrations of sand size sediments that enter the canal. This is a result of a combination of the beneficial siting of the intake, and the way the sluice gates are operated, producing favourable flow curvature in the sluice pocket.

Figure 1 compares sediment concentrations in the upper half of the river flow at the bridge, located about 500m upstream from the intake, with the sediment concentrations entering the canal. It can be seen that the concentrations are similar. The sediment concentrations carried in the lower half of the river flow, also shown in figure 1, are about three and a half times larger. A tunnel excluder, which would prevent the flow near the bed of the river from entering the canal, would thus not provide any useful improvement over the existing situation.

The measurements do not cover either very high flood discharges, or low dry season river flows, when little water is available for sluicing. Thus we suggest that further consideration of an excluder should be postponed until the data collected over the dry season is available, and a mathematical model study of the effects of introducing an excluder on the performance of the intake at high flows has been completed. At this stage it appears that the benefits will probably be only marginal.

4 OTHER SEDIMENT CONTROL OPTIONS

In this section we briefly review the other sediment control options that are available for the ARIS system. These are:

4.1 A sluiced settling basin located near the intake.

A sluiced settling basin could trap both the sand sizes and a proportion of the finer sediments entering the canal. However the head that is available near the intake for gravity flushing is too small for effective flushing. This option would only be viable if the height of the existing weir was substantially increased.

4.2 A sluiced settling basin located further down the system

By removing existing cross regulators the canal slope downstream from the 1 km. long lined section could be increased, making it possible convey sediment to a settling basin located further down the system, where a larger head for flushing is available. The principal disadvantage of this option is the very high capital cost of the basin, flushing sluices, etc.

4.3 Mechanical desilting from a settling basin near the intake

A settling basin near the canal head could be considered, if sediments are removed by mechanical means. The desilting work previously carried out over the whole system would thereby be concentrated at one location. The basin would probably be considerably less expensive than a sluiced basin due to the lower hydraulic forces on the structure and the lack of a requirement for large gates. However a high recurrent cost for desilting and sediment disposal would still be incurred.

4.4 Sediment extraction from the canal head reach

As there is the possibility that the longer term measures mentioned in section 2 will be implemented, and the sediment concentrations entering the canal may eventually be much lower than at present, a less expensive options which would offer improved, sediment control have been considered.

A sediment extractor located in the canal head reach could provide a more economical means of sediment control, but would trap less sediment, particularly at the finer end of the size range, than a well designed settling basin. However in the option that we outline in the following sections the head reach would be used as a settling reach in the dry season, when canal flows are low, and thus the advantages of a settling basin will be obtained for the part of the year when canal discharges are low.

An extractor diverts the flow and sediment from the region near the canal bed to an escape channel, which returns the water and sediment diverted through the extractor to the river. As the largest sediment concentrations are transported near the bed, removal of say 20 % of the canal flow can divert about 60% of the sediment. A vortex tube extractor can be designed to operate at a much lower head than is required to flush a large settling basin. Both tunnel and vortex tube extractors have been used for many years in the Indian sub-continent and elsewhere. An outline design for a vortex tube extractor combined with a low level escape for flushing sediments from the head reach is presented in the next section.

5 VORTEX TUBE WITH HEAD REACH FLUSHING

In this section we explain the design of a vortex tube extractor and the arrangements for flushing the head reach in the dry season, and present a preliminary estimate of the performance that will be achieved.

5.1 Layout

The first suitable location for a vortex tube is at the end of the lined head reach section, about Km 1. However trapping efficiency calculations show that, at the new design discharge of 26 m3/s, the high velocities in the lined section will result in a low sediment trapping efficiency. The selected location is at about Km. 1.7, close to lateral A extra. Here a short, approximately 200 m, escape channel to the river flood protection bund is possible, and a larger head for operating the vortex tube and escape channel is available than at the upstream location.

The canal from km. 1 to the vortex tube location has insufficient slope to ensure that sediment is transported to the vortex tube. However by relocating the cross regulator at km 1 to a new position just downstream from the vortex tube the slope in the

700 metre reach between the lined section and the extractor can be allowed to steepen to the slope of approximately 0.0004 needed to transport sediment to the vortex tube. (Design water, bank and bed levels for this reach of canal should be recalculated on the basis of this new slope)

Figure 2 shows the general layout for the sediment handling facility that is proposed. The vortex tube would discharge to a short escape channel that will return the extracted sediment to the river. The existing cross regulator at km. 1 would be removed and replaced with a new gated regulator just downstream from the vortex tube. The escape channel would pass through the flood bund in a conduit, which would be provided with flap gates to prevent reverse flows in floods.

A low level escape would be included just upstream from the vortex tube, and would also discharge to the escape channel. The low level escape would be operated intermittently in the dry season to flush sediments that settle in the head reach.

5.2 Design conditions

The following conditions were assumed in order to carry out the design calculations.

5.2.1 Discharge

Canal design discharge of 26 m3/s in the wet season, 12 m3/s in the dry season, and a probable minimum discharge of 6 m3/s.

5.2.2 Mean sediment concentration

The concentrations of sediments larger than 0.063mm entering the canal in the 1989 measurements varied between 20 ppm and 2000 ppm, with an average of 431 ppm. This gives an indication of concentrations entering over the wet season, but for design a longer data record is needed, covering both wet and dry seasons. Data quoted in the Castencia report on mean total suspended load concentrations entering the canal over the years 1978 to 1985 has been used . The mean of the wet and dry season sediment concentrations, weighted to account for the different wet and dry season discharges, is 1387 ppm. This is for the total suspended load, and so includes the clay and silt sediment fractions. Some assumptions are required to estimate the proportion of this concentration that represents sediment in the sand size range. (According to JICA, 1989, about 90 % of the sediment that settles in the main canals and laterals is sand.)

Castencia reports that 70 % of the sediment that enters the canal is mine tailings, and JICA, 1989, state that less than 40% of mine tailings are in the sand size range. Thus, as a first approximation, 1387 * 0.7 * 0.4 = 388 ppm, represents sand sizes contributed by mine tailings. In other rivers with similiar characteristics to the Agno about 50% of the total suspended load is sand, thus sand from natural erosion processes represents about 1387 * .3 * .5 = 208 ppm. The mean concentration of sand entering is thus, approximately, 388 + 208 = 596 ppm. We have used a mean annual sand concentration of 600 ppm for design, a figure which can be revised if necessary in the light of the results of dry season sediment monitoring.

5.2.3 Bed sediment size grading curve

Figure 3 shows two size grading curves. The first is a bed grading curve for the canal head reach, derived from the measured sizes of the sediment entering the canal. The second is for a bed sample collected at the end of the canal head reach, at about km 1.0. The curves are similar, but we have used the first curve for trapping efficiency calculations, as it shows slightly smaller sediments at the fine end of the size range, and will result in smaller (conservative) estimates of vortex tube trapping efficiency. The second curve was used to estimate the sediment transporting capacity of the canal system.

5.3 Vortex Tube, predicted trapping efficiency

Sediment trapping efficiencies for the vortex tube have been predicted using the DACSE computer programs for the design of sediment extractors. They are:

CANAL DISCHARGE (upstream) m3/s	CANAL DISCHARGE (DOWNSTREAM) m3/s	TRAP EFFICIENCY %
32.5	26	61
9.6	8	63

These are conservative predictions, use of the slighty coarser sedimemt size grading curve 2 in figure 3 increases the predicted trap efficiencies by about 10 %.

5.4 Canal Sediment transporting Capacity

As the extractor will divert the coarser sediment fractions moving near the canal bed, the sediments passing over the vortex tube will be finer than sediments entering the main canal at present. Thus the sediment transporting capacity of the canal downstream from the extractor will increase. The result of DACSE computations of canal sediment transporting capacity, for the design slope and cross section in the reach to km 10.25 are tabulated below. The sediment concentrations entering the reach are based on the assumed average concentration entering the canal, 600 ppm, a water extraction ratio at the extractor of 20%, and the bed sediment grading curve 2 shown in figure 3.

DISCHARGE (m3/2)	SEDIMENT CONCENTRATION PASSING EXTRACTOR (ppm)	SEDIMENT TRANSPORTING CAPACITY (ppm)
26.0	172	276
12.0	150	187
6.0	135	132

Thus in the canal reach downstream from the extractor the sediment input is smaller than transporting capacity for discharges down to about 6 m3/s. Further down the main canal, where the discharges are reduced, the transporting capacity is also reduced. In the lower reaches some sediment deposition is predicted when the canal is operating a low discharges.

5.5 Hydraulic Design of vortex tube

An outline design for a vortex tube has been prepared, again using the DACSE package, and is shown in figure 4. Two tubes with a diameter of about 1.7 m, a length of 4 metres, and a slit width of 0.5 metres is suggested. Vortex tube discharges are controlled using vertical lift gates located at the end of each tube. The transition from the design canal bed level to the flumed section containing the vortex tubes is set at a slope of 1 to 5.

Until the survey being carried out at the vortex tube location is available levels can not be specified. Indicative levels, relative to the revised canal design full supply level at km 1.7 are listed below so that the likely cost of the structure can be determined. However levels must be reconsidered before the design is finalised.

Flume section containing the vortex tubes	-1.89m
Bed level of escape channel	-2.43m
Low level escape gate sills	-2.63m
Bed of the escape channel at the bund	-3.23m

A summary of the design calculation results, for a water extraction ratio of 20%, is given below:

CANAL DISCHARGE (Downstream) m3/s	TUBE DISCHARGE (Each tube) m3/s	HEAD LOSS m
26	3.25	0.87
8	0.80	0.07

5.6 Escape channel design

The escape channel will be operated at a range of discharges and sediment concentrations. As a "regime" channel can only be designed for one discharge and sediment concentration, the dimensions and slope are set initially for the steepest slope required and the largest width required. Some channel adjustment can be expected as the flows and sediment loads change through the seasons. The recommended initial design is tabulated below.

Bed Width	7.9 m
Side Slope	1 to 1.5
Depth	0.65 m
Bed slope	0.004 (Note 1)
Length (to flood bund)	about 200 m

(Note 1 This bed slope is set by the tranporting capacity needed when sediment is being flushed from the low level escape, see section 5.7)

The escape channel must pass under the flood bund. A rectangular section conduit, 6 metres wide and 1.5 metres high, with a bed slope of 1% is suggested. Flap gates will have to be installed at the downstream end of the conduit to prevent water passing through the bund in floods. On the river side of the bund a channel aligned at about 30% to the axis of the bund can be formed through the cobbles and boulders to connect the escape channel to the river low flow channel. Some routine clearance work may be necessary at this location to maintain a channel to the river.

5.7 Flushing from the Low level escape

A gated low level escape is proposed at the location shown in figure 4. The gate sill should be set at 0.2m below the canal design bed level.

In the dry season the canal would be operated at the full supply level at the cross regulator downstream from the vortex tube. This will result in a low sediment transporting capacity in the canal reach between km 1 and km 1.7. Initial calculations have been carried on the performance that can be expected, using the same assumptions as for the vortex tube calculations.

DISCHARGE	6.0 m3/s
TIME BETWEEN SLUICINGS	30 days
MEAN SEDIMENT CONCENTRATION PASSING km 1.7	53 ppm
APPROXIMATE SLUICING TIME	15 Hours

DISCHARGE	12.0 m3/s
TIME BETWEEN SLUICINGS	15 days
MEAN SEDIMENT CONCENTRATION PASSING km 1.7	102 ppm
APPROXIMATE SLUICING TIME	24 hours

More detailed simulations can be carried out if it is decided to proceed with construction. However from the data tabulated above it seems that routine flushing every two weeks will be necessary, the sluicing time depending on how much sediment has accumulated. As formal irrigation is not carried out at night sediment flushing at night will minimise the time that irrigation supplies will be disrupted.

The sediment concentrations passing the settling reach can be compared with those listed in section 5.4. The sediment concentrations passed to the canal are lower than transporting capacity even at the minimum discharge of 6 m3/s. As the sediments passed to the canal will also be very fine, (D50=.09mm) no problems of sediment deposition in the main canal during the dry season are expected.

A small quantity of gravel and cobbles will continue to be diverted to the canal, and will settle, as now, in the first one hundred metres of the canal. Routine clearance of these sediment deposits will still be needed if water levels at the canal head are not to be raised unacceptably.

6.0 OPERATION

At this stage only the broad principles of the operation of the sediment handling facilities is discussed. Detailed operational rules would need to be prepared if a decision is made to proceed with construction.

During the wet season the vortex tube would be operated with as high a flushing discharge as possible, subject to the constraints imposed by the discharge capacity of the canal head reach and the escape channel. At the new canal design discharge the water extraction ratio would be 20%, and the sediment trapping efficiency 61%. Larger trap efficiencies will be obtained if the tubes are run at higher water extraction ratios when the canal discharge is at less than design discharge.

In the dry season two options are possible. In the first the vortex tube would be operated in the same way as in the wet season, in this case the main constraint being the availability of additional water to operate the vortex tube. However the recommended method of operation in the dry season is to maintain the canal full supply level at the cross regulator at km 1.7, which will encourage sediment deposition when the flows are low. The low level escape would be operated about every two weeks to flush sediment deposits from the head reach.

7 CONTROL OF FINE SEDIMENTS

A vortex tube extractor will not control sediments smaller than fine sand. However fine sediments settle in the field channels and are adversely effecting soils , so it is necessary to consider the how they could be controlled. The settling velocity of the clay fractions is so small that they will be carried through the canal system to the fields. However a useful trap efficiency for sediments larger than about 10 microns can be obtained with small settling basins. These could be located at the heads of laterals, and would have to be periodically desilted. Thus desilting carried out down the length of a lateral would be replaced by desilting from small basins.

We have carried out trial calculations for a settling basin in channel conveying 0.3 m3/s, using the Camp settling basin design method to obtain an approximate estimate of what could be achieved. The results of a calculation for a settling basin 3.0 metres wide and 75 metres long are listed below.

SEDIMENT SIZE (MICRONS)	TRAP EFFICIENCY %
63	98
50	96
40	93
30	76
20	44
10	12
5	3

A long narrow basin was assumed as it is necessary to provide storage for the deposited sediment, and it is assumed that a narrow basin would be more practicable than a wide basin. The dimensions and length of the basin can be adjusted to suit the requirements of sediment storage, the size of sediment to be controlled, and the required trap efficiency.

If NIA wish to pursue this option further then more detailed computations could be carried out. Before this can be done the settling velocities of the silt sized sediment fractions will have to be measured in the field.

8 PREDICTED PERFORMANCE OF SEDIMENT CONTROL FACILITIES

The table below gives an estimate of the performance of the sediment control facilities described above.

	Sediment settling (Tonnes * 1000, per annum) (Sand Sizes)
Present Conditions	112
After IOSP(1) (No Sediment control	280
After IOSP (With Sediment Control)	84(2)

Note 1, based on a mean canal discharge of 15 m3/s.

Note 2, most of this would be trapped in small settling basins in laterals

For the silt and clay sizes we do not have enough information on the settling velocities to make more then a very approximate estimate of the proportion of sediments currently settling in laterals and smaller channels. However on the basis of the size range of fine sediments transported in the Magat river system a trap efficiency of about 40 % of the silt and clay fractions might be achieved. A large proportion of the fine silt and clay fractions are transported to the fields at present, and this would continue with the new sediment handling arrangements.

9 RIVER BED LEVELS

Bed levels in the Agno river are known to be rising, JICA, 1989, reporting a rise of about one metre in eight years in the reach downstream from the intake site. The installation as designed could function with a further rise in river bed levels of about one metre before operation of the vortex tubes would be seriously effected, however future rises in river bed levels are a cause for concern.

It is suggested that NIA should locate all the available surveys of the reach downstream from the intake, including if possible, the surveys carried out at the time the system was constructed. These can be compared with cross sections measured during this years dry season, and a decision made as to the likely rise in bed levels in future years.

10 FUTURE ACTION

Using the information contained in this note NIA, Region 1, are to estimate the cost of constructing the sediment control facilities as described. If it is then decided to proceed with the construction HR would be pleased to offer further assistance with the sediment control aspects of the detailed design.

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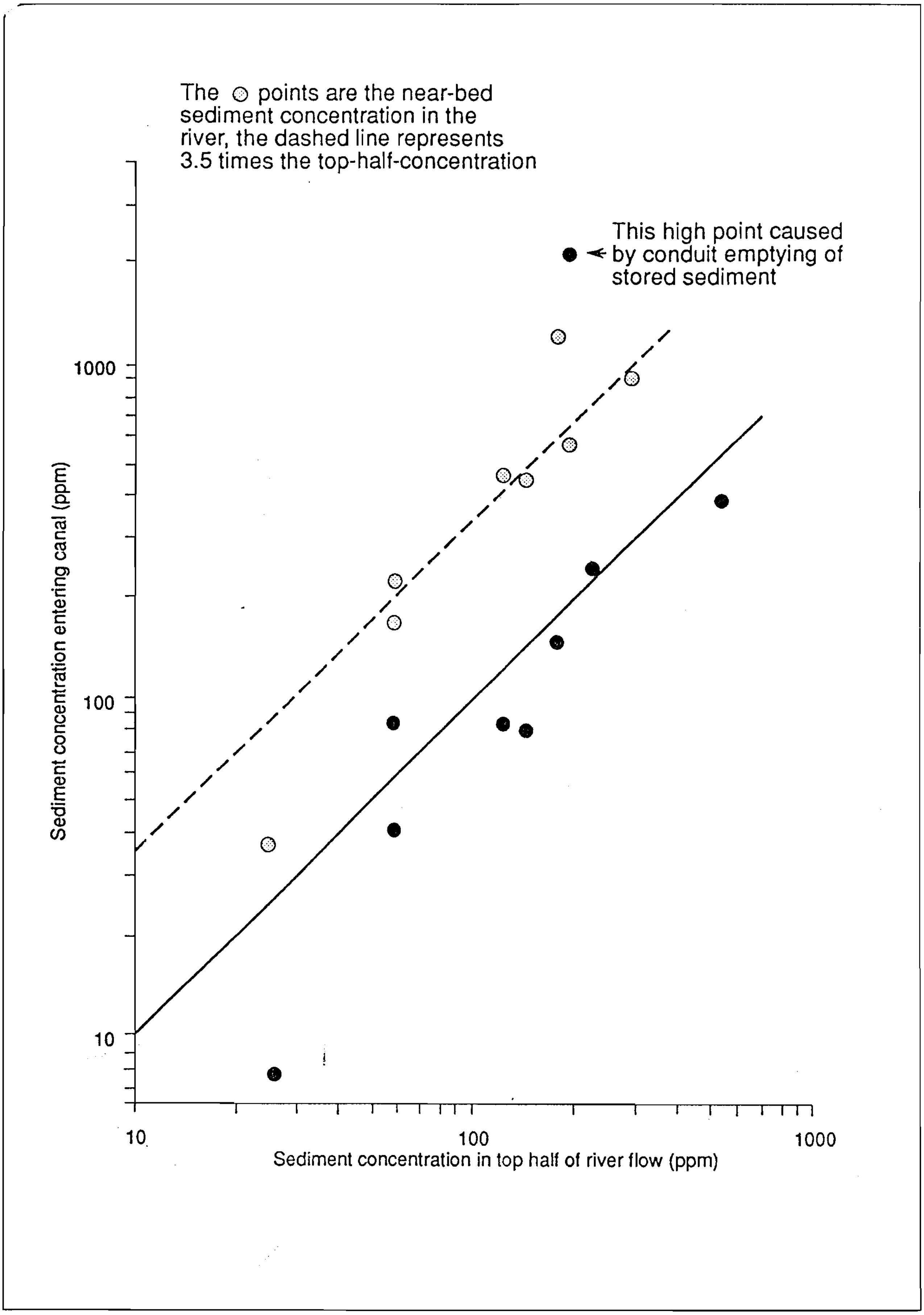


Fig 1 Comparing sediment concentration entering canal to concentration in top half of river flow

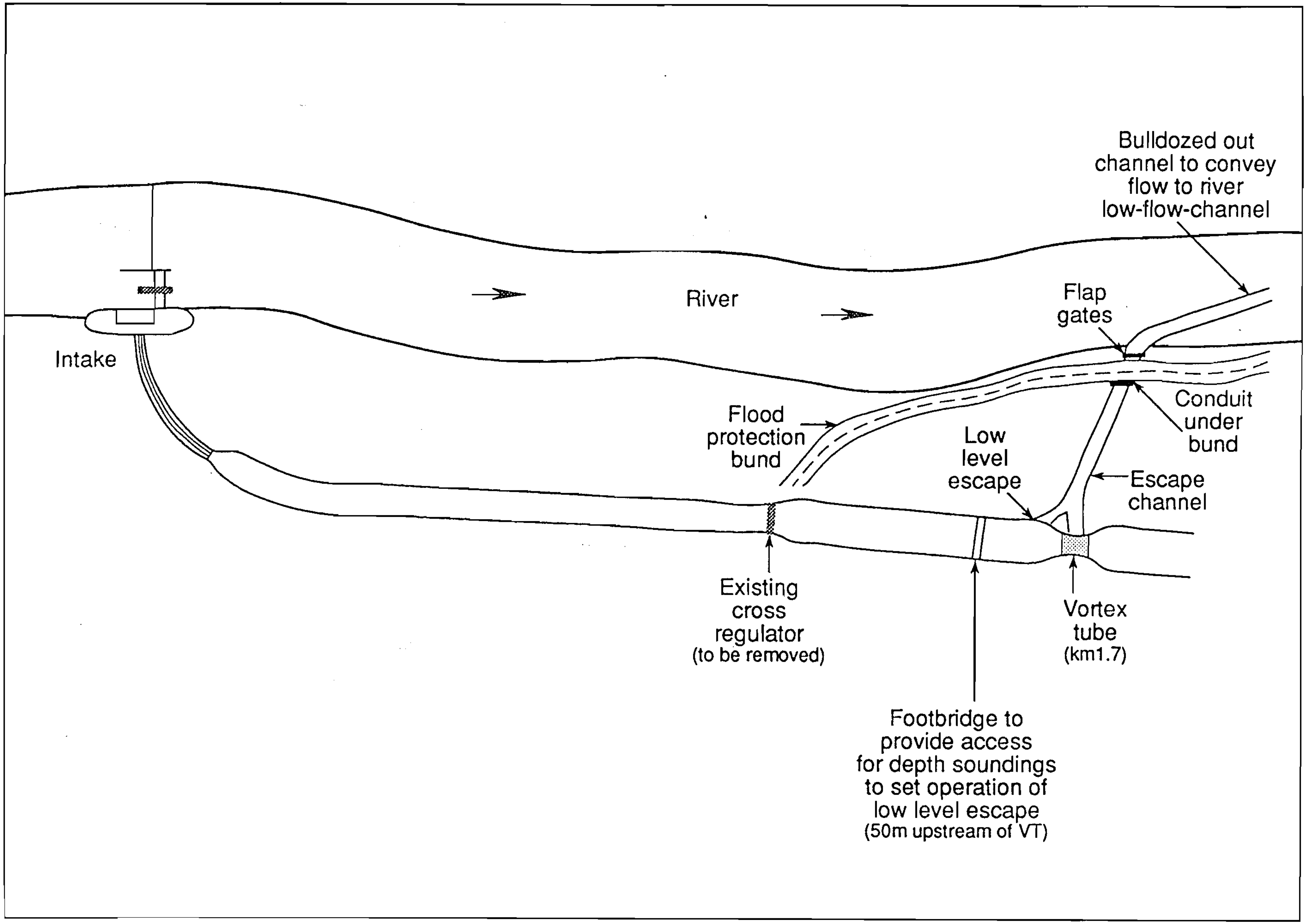
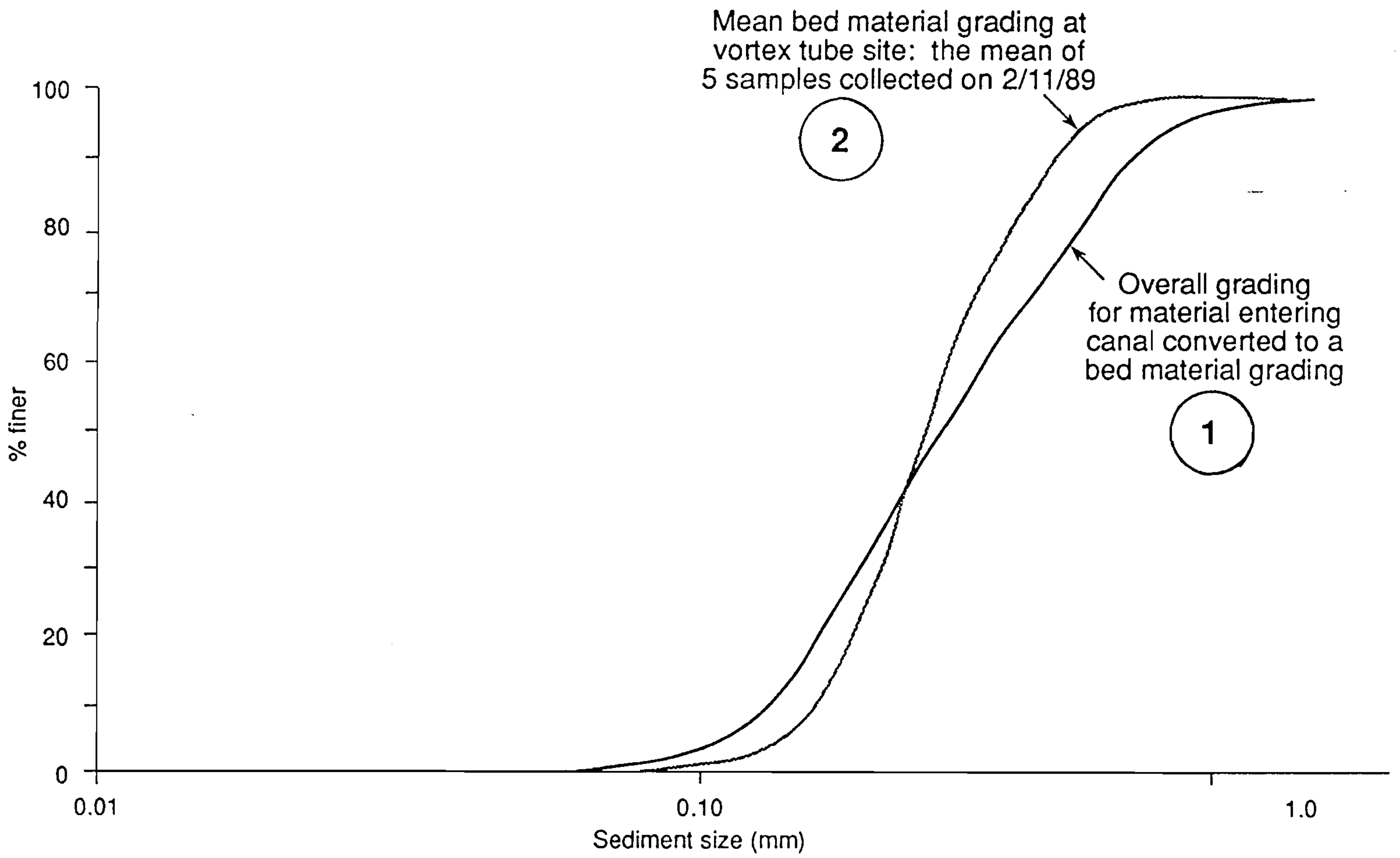


Fig 2 Layout sketch

Fig 3 Agno Canal bed grading for vortex tube design



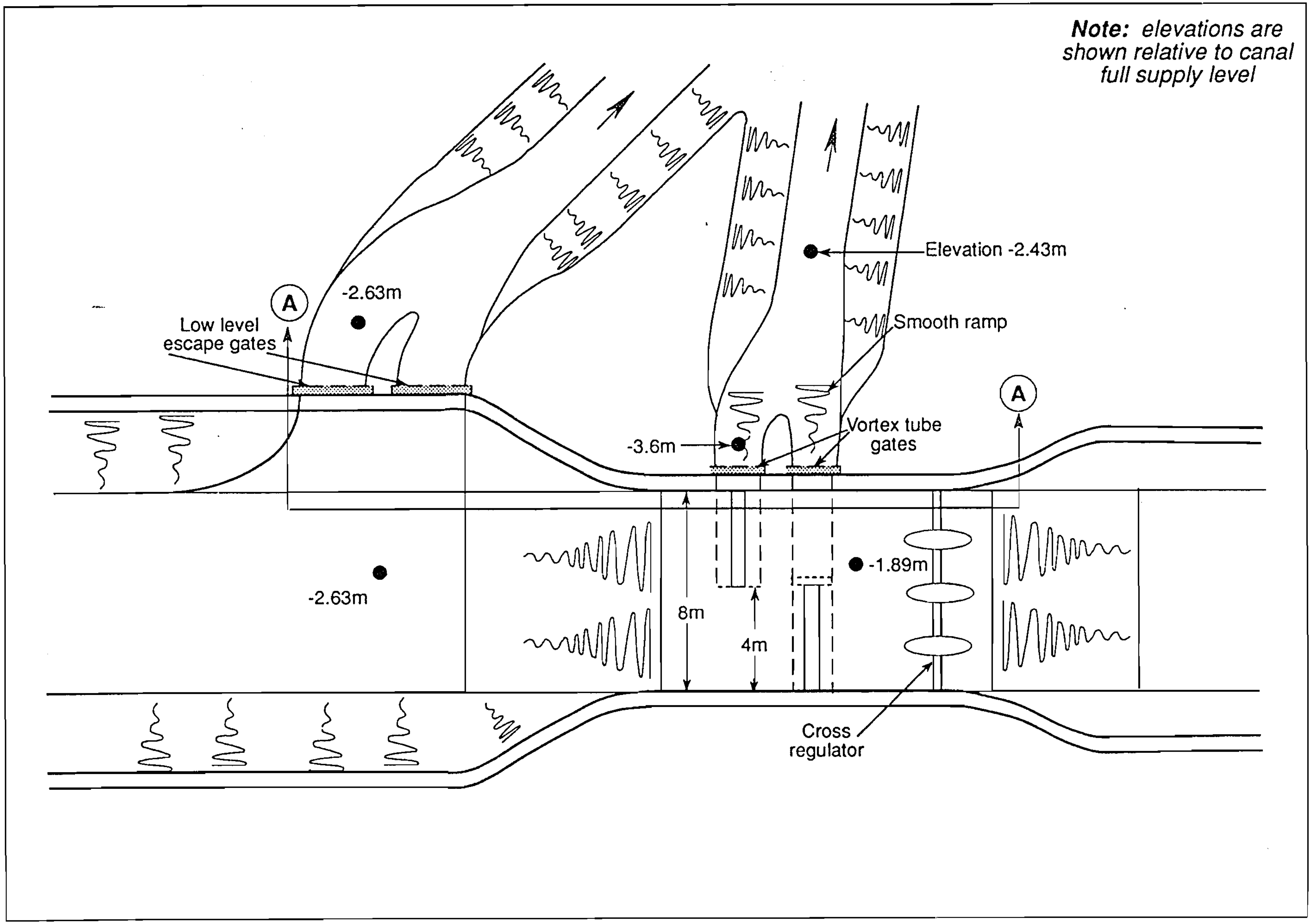


Fig 4 Plan view of combined vortex tube sediment extractor and low level escape

Fig 5 Section through combined vortex tube sediment extractor and low level escape (section A-A)