Evaluating the Feasibility Study of Hilla – Kifl Irrigation Project

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Abstract

Now and in the future, many countries expect to face inadequate water resources to fulfil their recent environmental, industrial, domestic and agricultural water needs. The world population is expected to grow about 30% at the year 2025, getting 8 billion persons. The living standards are also anticipated to increase as a result of improving urbanization, communications and globalization. So, competition on water among the domestic, industrial, agricultural and other users will rise in unprecedented levels.

The researcher studied feasibility study and records that were generated during the life of the Hilla – Kifl irrigation project so as to get some perception into the planning and implementation processes. The researcher made field visits concentrating on direct observation of unending and completed project activities. During the field visits, group discussions and interviews with project staff, farmers and resident engineer were held.

The objective of this research is to define the extent to which the feasibility study aims and objectives of Hilla – Kifl irrigation project were met. It was also significant to find best lessons and practices learned so as to improve the design, planning and implementation of future irrigation projects.

Key Words: Hilla – Kifl irrigation project, feasibility study, irrigation project, agricultural development

تقويم دراسة الجدوى لمشروع ري حله - كفل

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الخلاصة

العديد من البلدان تتوقع ان تواجه نقصا في الموارد المائية اللازمة للوفاء بأحتياجاتها البيئية والصناعية والمحلية والزراعية في الوقت الحالي وفي المستقبل. من المتوقع ان يحدث نمو في سكان العالم بنسبة ٣٠% ليصل في سنة ٢٠٢٥ ال ٨ بليون شخص. مستوى المعيشة من المتوقع ان يتحسن كنتيجة لتطور العمران والاتصالات والعولمة. وهذا يؤدي الى ازدياد المنافسة على المياه في المجالات المدنية والصناعية والزراعية وبمستويات لم يسبق لها مثيل.

قام الباحث بتقويم دراسة الجدوى والوثائق المتعلقة بمراحل مشروع ري حله – كفل للخروج بتصور موضوعي ودقيق عن عمليات التخطيط والتنفيذ. كما قام الباحث باجراء زيارات ميدانية ركزت على المشاهدات المباشرة للفعاليات المكتملة او التي يجري العمل فيها. وخلال الزيارات الحقلية، تم اجراء مجموعة من المقابلات والمناقشات مع ملاك المشروع والمزارعين والمهندس المقيم للمشروع.

يهدف البحث الى ايجاد المدى الذي تم فيه تحقيق اهداف دراسة الجدوى الخاصة بمشروع ري حلة – كفل. مع تحديد الممارسات والدروس المستخلصة لتحسين التصميم والتخطيط والتنفيذ لمشاريع الري المستقبلية.

1. Introduction

Current Iraqi economy depends broadly on oil production as well as agricultural production which still signifies the second source of economy resources and gives the economy of Iraq a feature over some oil countries. Agricultural sector forms an important part of the economy of Iraqi due to water availability; the main yields are fruit, seeds, vegetables and dates. Agricultural areas are found nearby Euphrates and Tigris rivers.

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Irrigation continues to be significant in the production of food all over the world. The systems of irrigation are in poor status and are poorly managed all over the world. In most irrigation systems, operational efficiency, distributional equity, reliability, adequacy of supply and timeliness of water delivery are lacking and significantly less than designed.

The feasibility study of project either improves a job situation by investigating the variety of potential issues and likely choices, or composes a base for its improvement. Feasibility study is commonly an action executed in the beginning phase of the project. It should handle concerns which could affect the achievement of a possible job and evaluate the benefits and difficulties of each decision so they can be graded. Feasibility study comprises a cost / benefit analysis.

2. Research Justification

The causes behind perform this research work are:

1. Iraq is facing fast increasing needs versus inadequate water resources. Therefore, Iraq pursues to do more with a smaller amount of water.
2. Irrigation projects have acquired significance, because of need for water and the wars of future will be on water.
3. Hilla – Kifl irrigation project has considerable significance because it consists of drainage, irrigation, and road networks.
4. To find weakness points so as to cope them in the future works.

3. Research Objective

The objective of the research is to evaluate through the feasibility study Hilla – Kifl irrigation project.

4. Feasibility Study Concept

Feasibility study provides proof that an initial idea might work. This study and the concept stage are frequently considered to be pre-project actions. Actually, it is reasonably common for the feasibility study to be processed as a project in its own right. Feasibility study can take many views; it just needs to offer proof that a new concept could work (www.project-management-basics.com).

In its simplest view, a feasibility study signifies a definition of an opportunity or problem to be studied, an analysis of the present mode of operation, a definition of needs, an assessment of alternatives, and an decided upon course of action. So, the activities for making a feasibility study are universal in nature and can be applied to any project type, be it for software and systems development, creating an acquisition, or any extra project (Bryce, 2009).

The feasibility study must offer a perfect basis to permit the early analysis and design events of project to start in a concentrated way (Inter Agency Policy and Project Unit, 2008).

5. Feasibility Study Definition

Feasibility study evaluates of investment plans. It is a comprehensive study of all phases of investment in projects to aid both the development in the country as a whole and the investor (Alsoalhy, 2006).

Feasibility study is to identify if the economic and technical decisions are feasible and it provides appropriate solutions or recommendation to cancel or proceed in the project (الموسوي،٢٠٠٤). Feasibility study is divided as follow (عبد الكريم وكدواوي, 1999):

1. Economic feasibility study: it demonstrations the effect of the project on the total national

economy.

2. Technical feasibility study: it is the comprehensive study of technological alternatives to select the better one that agrees with the society situations and the targets of industrialization and evolution.
3. Financial feasibility study: it studies the project cash flow.

6. Feasibility Study Components

The feasibility study of any project involves (Alsoalhy, 2006):

1. Environmental feasibility study.
2. Marketing feasibility study.
3. Social feasibility study.
4. Technical feasibility study.
5. Economic feasibility study.
6. Financial feasibility study.
7. Methods of payment of loans.
8. Sensitivity analysis of the project.
9. Write a feasibility study.

7. Irrigation System

The irrigation system involves a (main) pumping station or (main) intake structure, a transport system, a field application system, a distribution system, and a system of drainage. The (major) pumping station, or (major) intake structure, guides water from the supply source, for instance river or reservoir, into the system of irrigation. The transport system guarantees transportation of water from the major pumping station or major intake structure up to the field ditches. The system of distribution guarantees the transportation of water over field ditches to the watered areas. The system of field implementation guarantees the transportation of water within the areas. The system of drainage eliminates the surplus water from the fields (Brouwer *et al.*, 1985; Asawa, 2005).

Performance evaluation of drainage and irrigation is the methodical observation, registration and interpretation of the management of a drainage and irrigation system, with the objective of guaranteeing that the input of resources, operational plans, intended outputs and necessary actions proceed as planned (Bos *et al.*, 2005).

8. Hilla – Kifl Irrigation Project

The Hilla – Kifl project region is located between 32°13' to 32°43' northern latitude and 44°13' to 44°26' eastern longitude and belongs to the Babylon Governorate. The borders of the region are shaped by the Kifl channel, flowing matching to the Euphrates river, on the west, the Shatt Al-Hilla from the north to the east and by the way from Hilla on the east to Kifl on the south. The project region includes 175400 feddans and covers about 20 km from west to east and 50 km from north to south, at its broadest; Figure 1 shows the project region. The Romanian company (Arshef) reclaimed 124400 feddans of the Hilla – Kifl project region from 1985 until 1990 which represent the northern, middle and 25% of southern parts, the work was stopped in 1990, two Iraqi companies started to accomplish the remaining area of the southern part in 2006.

9. Feasibility Study for Hilla – Kifl Irrigation Project

The feasibility study for Hilla – Kifl irrigation project was done under contract No. 16 signed in Baghdad on 15th July 1978 between the State Organization for Soil and Land Reclamation of the

Ministry of Water Resources of the Republic of Iraq and Swiss Consultants, consortium for consulting engineering services (Swiss Consultants, 1980).

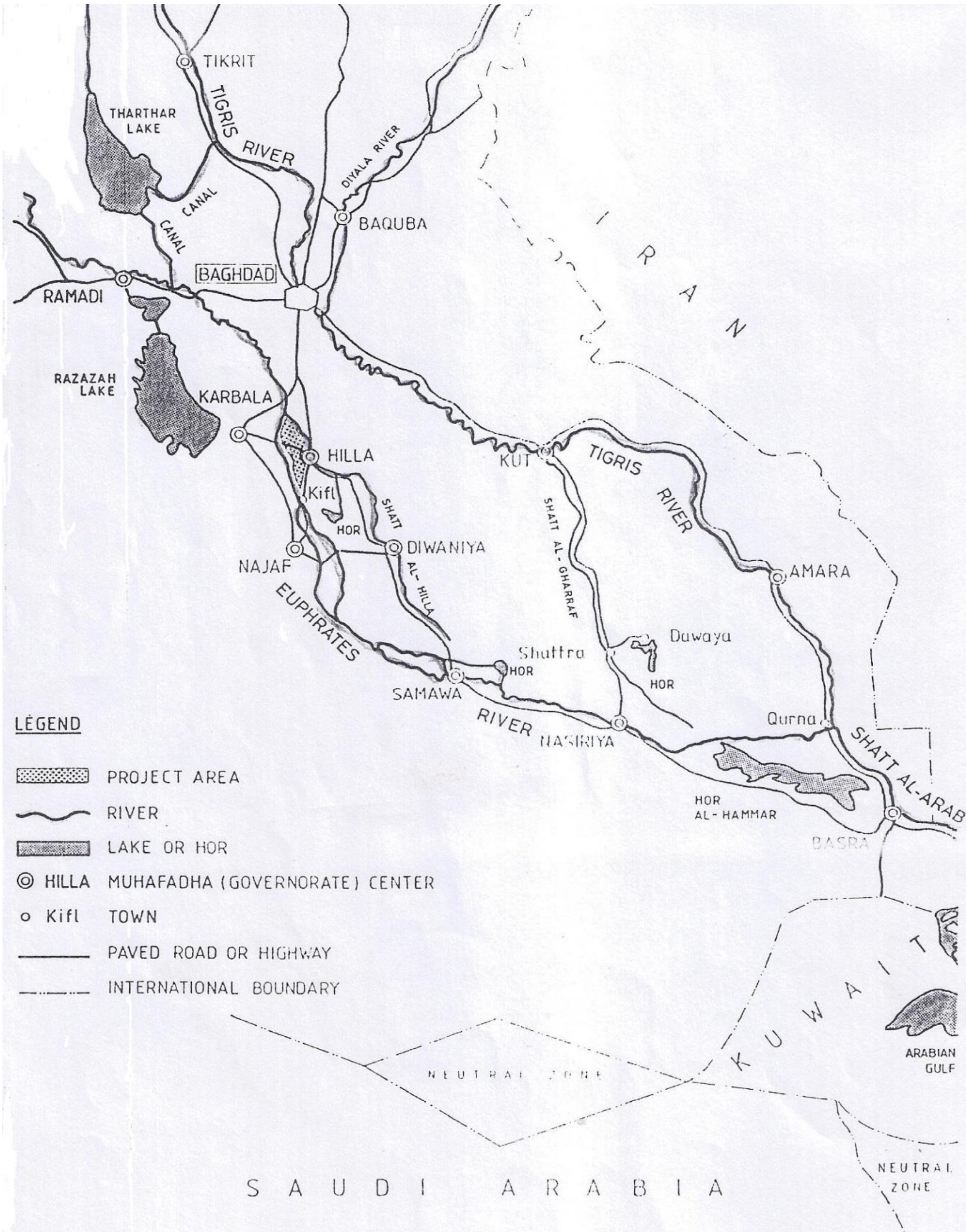

Figure 1. Hilla – Kifl irrigation project region (Swiss Consultants, 1980)

10. Irrigation and Drainage Facilities of Hilla – Kifl Irrigation Project

Water of irrigation is supplied to the project region by the Hilla and the Kifl canals, which transfer the water by gravity from the Euphrates, upstream of Hindiya barrage. The whole project region is previously covered by branch drains and a system of collector, which debouch into a main drain, transferring the drainage water to the south of the region so as to be drained to the eastern Euphrates drain project.

10.1. Irrigation Network

The project is supplied water from a main channel with length of 6.91 km divided to Kifl channel (50.25 km) and Hilla channel (51 km) with a branch channel 1 (17.74 km) running by pumping, branch channels with length of 112 km are branched from the main channels, and these channels are divided to a distributary channels (179 km) which supply water course channels (2507 km) built on the both side of them are field outlet to supply water to the earthen field channels.

10.2. Drainage Network

Hilla – Kifl irrigation project owns 27 branch drains with total length of 243 km, which gather drainage water from collector drains (1150 km length), and are linked to a main drain with length of 55.9 km and discharge 12.15 m^3/s, which debouch by gravity into the eastern Euphrates drain project.

11. Hilla – Kifl Irrigation Project Importance

The importance of Hilla – Kifl project lies in:

1. Improving quality of soil to increase farmer incomes and agricultural production to reduce poverty.
2. Rehabilitation and resettlement.
3. Developing the transport network for promoting the area.

12. Irrigation, Drainage and Road Networks in 1978

The researcher introduces a simple explanation of the irrigation, drainage and road networks before the implementation of Hilla – Kifl irrigation project:

12.1. Kifl channel

Kifl channel forms the western part of the project region. It begins just upstream of the Hindiyah barrage and it continues up to the Kifl city and beyond. Within the project region the channel is about 60 km length. Kifl channel receives its water by gravity intake from the Euphrates. The design water level upstream of the intake is +31.8 m, and 30.8 m downstream with a flow of 20 m^3/s. the level of +30.8 m is in conformity with the level of the channel embankments. Kifl channel is not worked at a continuous supply. Depending on the water request, the intake structure is opened for a couple of days after which it is closed again. Water levels in the channel differ strongly as a result of this mode of operation. Another consequence is that farmers taking water from Kifl channel frequently do so by methods of small pumping station, when the level of water is low. Only part of the gravity intakes has gates in the north, on the way to the south the number of gates increases. The deficiency of gates in the north almost certainly causes water to enter the region uncontrolled, which adds to the drainage problems in the center of the region. Between the city of Kifl and its intake structure the channel has three check structures wholly constructed as undershot gates, the check structures and the inlet structure are in a reasonable situation.

12.2. Shatt Al-Hilla

Shatt Al-Hilla is a tributary of the Euphrates River; it has been given a flow regulating structure with a full capacity of 200 m^3/s at its bifurcation from the Euphrates River. As with Kifl channel, Shatt Al-Hilla receives water only part of the time and not constantly. Because of the fluctuating of water levels both pumping stations and gravity inlets are used along the river.

12.3. Drainage Network

Drainage network divides into a main, branch and collector drains. The drainage network density decreases from south to north. It does not implement as required. Levels of water in the drains are less than 2 m below the surface. There are possibly several causes for this: connections between main drains, branch drains and collector drains do not implement optimally and weed growth in drains. The drainage network receives also drainage water from outside the boundaries of project. At the extreme southern point of the main drain a drainage pumping station has been constructed with 3 pumps of $2m^3/s$ each, a second pumping station was constructed with 2 pumps of $3m^3/s$ each; the total installed future pumping capacity $12m^3/s$.

12.4. Road Network

The road network in the project region consists of Hilla – Tahmaziya – Umkafsha road, Hilla – Twarig – Kerbela main road and Baghdad – Hilla – Najef main road. Earth routes have been implemented along Kifl channel, varying in width between (5-10) m. Kifl channel is crossed by several bridges, bridges for motorized transportation and foot bridges. West of the shatt Al-Hilla there is an existent route, which however is narrower than the routes along the Kifl channel. Along most of the drains, earth routes have been implemented of varying width.

13. Recommendations of the Feasibility Study

The feasibility study suggested many solutions and recommendations to be considered and implemented and these are:

13.1. Irrigation Network

The whole area of the project is 175400 feddans and the net area is 152000 feddans, the annual water demand, at headwork and the maximum release are 710.8 M m^3 and $33.5m^3/s$, respectively for the concrete lining channels. The existing agricultural density is (107-110) % and it will be (120-130) % after the full accomplishment of the project as anticipated.

13.1.1. Kifl Channel

The alignment of Kifl main channel can be maintained and requires only remodeling. The region receiving water from the channel is about 69004 feddans in total, which excludes the region to be irrigated between the region south of Kifl city and Kifl channel and the Euphrates. In the modern design the levels of water will have to be raised and with that the banks of the channel. The size of the channel was found to be appropriate for the new waster needs at a flow of 19.2 m^3/s, excepting the first 4.9 km, where the Hilla and Kifl main channels run together. With the water levels raised, the cross section of the channel becomes too big through the first years of operation, but it will reach system situations once it has silted up to the wanted capacity.

13.1.2. Hilla Main Channel

Most of the eastern section of the project region is irrigated from Hilla main channel. It takes water from Kifl main channel about 4.9 km downstream of the main intake structure of the project. At the place where both channels part, a division structure has been designed, where water can be measured in both ways. The region north and east of Hilla main channel is too high to be irrigated by gravity from Kifl main channel. It includes about 21587 feddans in total for which a separate channel with pumping means has been designed (Branch channel 1). Along Hilla main channel 27 distributary channels branch, which supply a region of about 84809 feddans in total at a flow of $15m^3/s$.

13.1.3. The Branch Channel 1

The Branch channel 1 has been designed to irrigate the high area in the north east of the project region. It takes its water from a pumping station. The channel irrigates about 21587 feddans in total at a flow of $3.5m^3/s$. if pumping on the Branch channel 1 is to be avoided, while still preserving irrigation on the 21587 feddans, the level of water upstream of the Hindiyah barrage has to be raised by 1.11m.

13.1.4. Channel Lining

The network of irrigation was designed as compacted earth channels. As an alternate, concrete lined channels were studied. One of the main feature of lining, is high acceptable flow velocities, cannot be made utilize of with the flat topography slopes prevalent in the project region. Thus, the advantage of concrete lining is limited to decreasing seepage losses through the channel embankments, and guaranteeing the stability of the channel side slopes. A cost assessment between concrete lined channels and compacted earth channels, including costs for maintenance. Indicated that the higher investments for implementation of concrete lined channels could not recompense for the costs of leakage water saved by lining. The whole investment in earthwork on all irrigation channels is about 6.3 million Iraqi diners. The costs of maintenance can be considered 5% of the year investment costs, which is 317000 Iraqi dinar/year. In case of lining, the extra investment is 12.8 million Iraqi dinars, which gives a whole of 19.1 million Iraqi dinars if the costs of maintenance are considered 2% of the whole investment, the maintenance costs are 383000 Iraqi dinar/year, which is more than the costs of maintenance on earth channels. From an economic viewpoint, concrete lining becomes therefore not to be justified and compacted earth channels are thus recommended. The estimated whole investment of unreinforced concrete lining is summarized in Appendix-A.

13.2. Drainage Network

The drainage network design has been strongly affected by the drains previously existing. Considering the specified design water levels for the two current drainage pumping stations at Kifl which debouch the drainage water into Al-Shameya drain, the two stations can be maintained in the new design. The full mounted capacity of these two pumping plants is $12m^3/s$, while after total development of the Hilla – Kifl project, the drainage release will reach about 13.5 m^3/s (hereof $2m^3/s$ from outside the project region). An added pumping plant will thus be essential, permitting also to have adequate stand-by capacity for all three pumping plants, the extreme water level upstream and downstream of the drainage pumping station is 20.55m and 22.6m respectively. The main drain obtains its water from branch drains, at the minimum level the water course units are drained by collector drains, which collect their water from field drains.

13.3. Road Network

Along irrigation channels and drains, routes have been considered on both sides. These routes serve maintenance objectives. In the situation of irrigation channels the routes give access to the turnout structures for inspection and operation. The routes along the drains stop surface water from inflowing directly into the drains, which would cause corrosion on the side slopes. They also work as spoil banks for the excavated soil from the drains. All routes have been designed with a width of 4m on each side of the channel embankment, excepting distributary channels with one way irrigation. In this situation the side without the water course turnouts has been designed with a width of 2m and the side with water course turnouts a width of 4m. Routes that have main function for transportation within the region will be implemented as gravel; they are divided into major access route with 6m width and 70 km length, and secondary access route with width of 4m and length of 185 km.

13.4. Construction Program

Construction of the drainage and irrigation network was scheduled to be accomplished in 10 year, 9 development units of about 2600 to 5700 feddans in total irrigated region. The full initial investment values at macroeconomic values will amount to 107702200 Iraqi dinar and the reinvestment values during the life of project of 50 years will be 21533000 Iraqi dinar. In the view of the size of the project region, the intricate network and the subdivision of the project region into three distinctive sections, the southern and the northern sections covering each one 40% of the project region, the central section covering 20% by two routes crossing it with their allocated reservation corridors, the network is to be implemented under three separate contracts of civil engineering, while one single contract for the electro mechanical elements of the two pumping stations is suggested. An international contractor is suggested due to the high requirement for skilled technical staff, management, machinery and equipment.

14. Evaluation and Discussion of the Implementation of the Study Recommendations

The main advantage which affects the design of the layout of the project of Hilla – Kifl is the topography of the region. There are no large unsuitable zones, deep rifts or mountains which might then dictate situations to the design. This section discusses and evaluates the differences between the actual situation and the feasibility study recommendations of the Hilla – Kifl irrigation project, causes behind that and the researcher's opinion, which depend on four main coordinates:

14.1. The Irrigation Network

Concerning the implementation of an irrigation system, an essential choice is whether to line the channels or not. The choice relies on the economics of lining; the additional costs should be considered against the features. A technical decision was depended at the beginning of 1980 by the Ministry of Water Resources to depend lining to all irrigation channels. The compacted earth channels, recommended on economic and technical feasibility considerations, will thus be methodically changed by the alternate of concrete lined channels. Despite cost increase the researcher finds this choice appropriate due to the, reduction in water level of Tigris and Euphrates rivers, lack of water resources and saving in water. The amount of the water saved can be used for extra area to be irrigated, decreased size of drainage and irrigation channels and structures, decreased maintenance and operation costs, concrete lining channels are more durable and make less damage to routes, agricultural land and dikes due to seepage. In spite of channels lining, the annual water demand and the maximum flow are 707Mm^3 and 36.2m^3/s respectively which are more than the recommendations of feasibility study (631.8Mm^3, 33.5m^3/s), this is because of inefficiency and weakness of irrigation, maintenance and operation systems and many sections of Hilla and Kifl main channels are still as compacted earth. The layout follows closely the geography and the existing irrigation network. The region will be irrigated by two main channels the existing Kifl main channel to the west (18.5m^3/s) and the Hilla main channel to the east (14.2m^3/s), in addition to the branch channel 1 (3.5m^3/s). Larger sections of the Kifl main channel (42.25km) and little of the Hilla main channel (9km) are yet without lining because the lining of two channels is implemented in sections to keep the yields under irrigation from loss, weakness of technical abilities and limitation of financial resources. The most significant changes in the Kifl main channel and Hilla main channel are in the field of working, in the new condition they are worked on continuous supply. In the suggested design, water courses only take off from distributary channels and not from the branch and main channels. Consequently, along the Kifl main channel a number of distributary channels parallel to the main channel have been implemented. The Hilla main channel follows the high areas in the east, where it reaches the Hilla city; it has to run along the future expansion of the city. Concerning the Branch channel 1, the researcher realizes that a rise in the Euphrates water level is unrealistic, but as well in view of a comparative cost estimation it looks that such a solution cannot be accurately justified, there for a pumping station was implemented, which pumps water from the Kifl main channel to the branch channel 1 and is located just downstream of the railway bridge over the Kifl main channel. From the pumping station the channel goes straight to the Shatt Al-Hilla banks, which it follows almost wholly up to the Hilla city, Figure 2 shows the irrigation and drainage network of Hilla – Kifl irrigation project.

14.2. The Drainage Network

The researcher believes that the main reason behind saline increase is the delay in drainage network execution which leads to loss of many agricultural lands. The main drain and most of its branches were completely maintained and their location in the field was found to be appropriate. The collector drains network could not be wholly maintained because of their location occasionally came into conflict with the necessities of the irrigation network. The main drain begins in the north of the region and runs all the way down to the south. There is no opportunity to empty drainage water at another position other than in the south due to the necessity that no saline drainage water pollutes the Euphrates water. North of the route Hilla – Twariagh the main drain takes water from a number of branch drains that run parallel to the main drain over suitable distances. The branch drains in that region join the main drain before it crosses the route between Um Kafsha and Hilla. Below the route Hilla – Um Kafsha, the main drain creates a wide curvature to the west around the ruins of Borsipa. After that it runs straight south to the station of drainage pumping. No further development was conducted for the two pumping stations and in 1998 the two pumping stations were stopped for the reason
that the drainage water of the project drains to the eastern Euphrates drain project by gravity, which appears a good choice from the researcher's point of view for utilization in another project to decrease the cost.

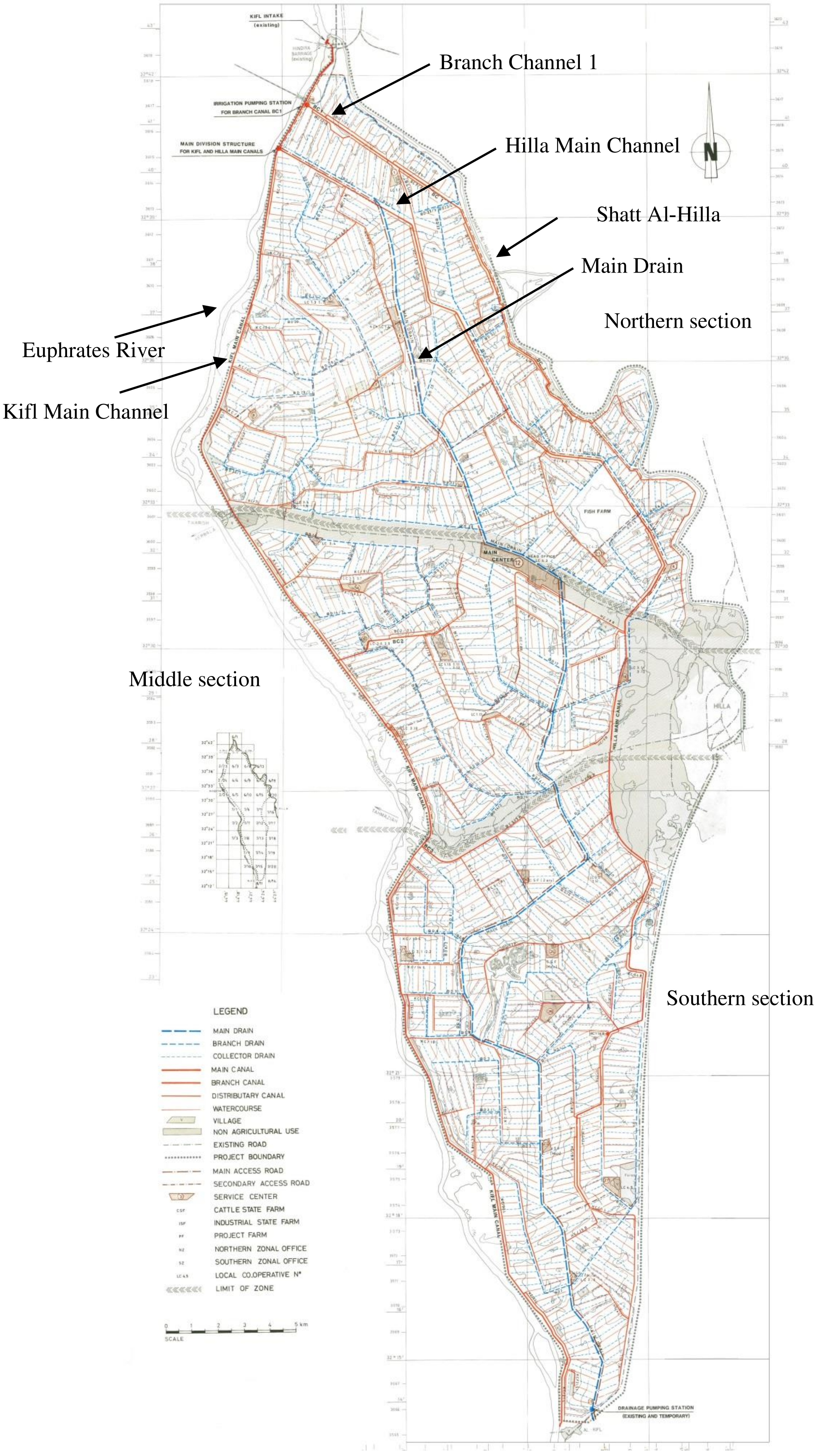

Figure 2. Irrigation and drainage network (Swiss Consultants, 1980)

14.3. Route Network

Maintenance on the current earth routes was made, nine bridges for vehicles and a wide network of transport routes (main route with 6m in width and 51 km in length, secondary routes with whole length of 237km and 4m in width) were implemented, the researcher finds this development has a positive effect on the promoting of the area due to ease and ensures, an optimal cost decrease, the transport of goods and people, helps the new agricultural production to discover its way to the consumption centers easily and prevents the project region from being isolated by increasing exchanges with the other parts of the country.

14.4. Hilla – Kifl Irrigation Project Implementation

The Iraqi government announced a tender to implement the Hilla – Kifl irrigation project as a total (northern, middle and southern sections). Many international companies competed to gain the contract. A Romanian company (Arshef) gained the contract at the middle of 1980s, due to the second gulf war the work stopped; from 1985 until 1990 the company achieved the northern, middle and 25% of the southern sections and reclaimed 124400 feddans which represent 70% of the entire project. Long negotiation between Iraqi Government and the Romanian company led to pay 60% of the contract value to the company. Due to the exceptional siege circumstances and government interest in security and political nature projects the work stopped until 2006. Two Iraqi companies won the contract with total price of 7040631000 Iraqi dinar and asked for duration 720 days to implement the remaining of the southern section, 15000 feddans were reclaimed from 48000 feddans, the section of the project finished by two companies constitutes 98%, this means the companies implemented the part in 125% of the scheduled execution duration. These are due to the weakness of technical and financial abilities of the two Iraqi companies. Many public services of the Hilla – Kifl irrigation project were canceled (A1 masjid, schools, electric network and station, club, systematic homes, dispensary, and pure water and sewage network and treatment stations). Announcing tender for the three sections at the same time is not a good decision from the researcher's point of view, it's a much better that the tender for the northern section should have been announced first and on completion the tender for middle section should have been announced to benefit from price competition and evaluate the contractor's efficiency and experience, this could have been done with the southern section. Canceling of many public services in the project on the pretext of reducing cost or being executed by other ministries, affects negatively the total value of the project and the benefits obtained from it.

15. Conclusions

From the aforementioned discussion and evaluation of the implementation of the Hilla – Kifl irrigation project and feasibility study recommendations, the following conclusions have been illustrated:

1. The efficiency, financial and technical abilities of the Romanian company managed to achieve 70% and reclaim 124400 feddans of the Hilla – Kifl irrigation project in five years.
2. Second Gulf war and exceptional siege circumstances were the reason behind the work hold up from 1990 until 2006.
3. Two Iraqi companies started in 2006 to reclaim 15000 feddans from the southern part, and accomplished 98% of the work.
4. The implementation percentage of the irrigation network is 70% because 42.25km of Kifl main channel and 9km of Hilla main channel are still as compacted earth.
5. Concerning the drainage network, 90% of the work was executed.

6. Despite channels lining the maximum release value and annual water requirement are more than the feasibility study recommendations due to the inefficiency of operation and maintenance systems.
7. The wide routes network participates in the development of the Hilla – Kifl irrigation project and facilitates the transport of people and goods.

16. Recommendations

From the abovementioned discussion, evaluation and the illustrated conclusions, the following recommendations are specified:

1. Using specialist international companies to achieve the irrigation projects, which need high technical and financial abilities.
2. Giving an important interest to the execution of the irrigation projects because of the water resources shortage.
3. Providing the financial and technical resources to accomplish lining of the Hilla and Kifl main channels.
4. Using efficiency and modern operation and maintenance systems to reduce the waste in water.

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Appendix-A

- Cost transferred to American Dollars with neglect of the inflation from 1978 until now.

Table 1. Comparison between compacted earth and concrete lined main channels (Swiss Consultants, 1980)

No.	Channel Characteristics of Typical Section	Units	Comp. earth	Conc. lined
1	Q	m^3/s	11	11
2	Slope	cm/km	5	5
3	Side Slope	-	2:1	1.5:1
4	Manning's No.	$s/m^{1/3}$	0.025	0.015
5	Concrete Lining Thickness	m	0.0	0.1
6	Water Depth	m	2.70	2.70
7	Bottom Width	m	5	2.70
8	Max. Velocity	m/s	0.39	0.60
9	Seepage Loss.	m^3/m^2/day	0.04	0.01
10	Seepage Loss.	m^3/m'channel/yr.	250	45
11	Maintenance Cost As Percent of Constr. Cost	%	5	2
12	Extra Pumping Cost of Seepage	$\$/m^3$/year	0.000165	0.000165
13	Interest Rate 6% Depreciation over 40 years, Annuity		0.0665	0.0665
	Construction Costs Per m' Channel			
14	Earthwork	$/m'	121.721	78.3156
15	Concrete Lining	$/m'	0	131.967
16	Constr. Cost Per m' Channel	$/m'channel	121.721	210.2826
	Yearly Costs Per m' Channel			
17	Annuity over Construction Cost	$/yr.	8.0883	13.9854
18	Maintenance Costs	$/yr.	6.0852	4.2042
19	Pumping Cost of Seepage	$/yr.	0.0132	0.0033
20	Yearly Costs	$/m'channel/yr.	14.187	18.1929
21	Difference in Yearly Cost	$/m'channel/yr.	0.0	4.0062
22	Amount of Water Saved	m^3/m'channel/yr.	0	205
23	Cost of Water Saved	$\$/m^3$	-	0.0198

Table 2. Comparison between compacted earth and concrete lined distributary channels (Swiss Consultants, 1980)

No.	Channel Characteristics of Typical Section	Units	Comp. earth	Conc. lined
1	Q	m^3/s	0.554	0.554
2	Slope	cm/km	20	20
3	Side Slope	-	1.5:1	1.5:1
4	Manning's No.	$s/m^{1/3}$	0.025	0.015
5	Concrete Lining Thickness	m	0.0	0.075
6	Water Depth	m	2.70	0.68
7	Bottom Width	m	1.2	0.68
8	Max. Velocity	m/s	0.30	0.48
9	Seepage Loss.	m^3/m^2/day	0.06	0.01
10	Seepage Loss.	m^3/m'channel/yr.	70	17
11	Maintenance Cost As Percent of Constr. Cost	%	5	2
12	Extra Pumping Cost of Seepage	$\$/m^3$/year	0.000165	0.000165
13	Interest Rate 6% Depreciation over 40 years, Annuity		0.0665	0.0665

	Construction Costs Per m' Channel			
14	Earthwork	\$/m'	24.644	19.437
15	Concrete Lining	\$/m'	0	39.039
16	Constr. Cost Per m' Channel	\$/m'channel	24.644	58.476
	Yearly Costs Per m' Channel			
17	Annuity over Construction Cost	\$/yr.	1.617	3.887
18	Maintenance Costs	\$/yr.	1.231	1.168
19	Pumping Cost of Seepage	\$/yr.	0.0132	0.0033
20	Yearly Costs	\$/m'channel/yr.	2.861	5.058
21	Difference in Yearly Cost	\$/m'channel/yr.	0.0	2.178
22	Amount of Water Saved	m^3/m'channel/yr.	0	53
23	Cost of Water Saved	\$/m^3	-	0.0396

Table 3. Comparison between compacted earth and concrete lined water course channels (Swiss Consultants, 1980)

No.	Channel Characteristics of Typical Section	Units	Comp. earth	Conc. lined
1	Q	m^3/s	0.1	0.1
2	Slope	cm/km	20	20
3	Side Slope	-	1.5:1	1:1
4	Manning's No.	s/$m^{1/3}$	0.025	0.015
5	Concrete Lining Thickness	m	0.0	0.05
6	Water Depth	m	0.45	0.36
7	Bottom Width	m	0.5	0.36
8	Max. Velocity	m/s	0.19	0.31
9	Seepage Loss.	m^3/m^2/day	0.06	0.01
10	Seepage Loss.	m^3/m'channel/yr.	46	12
11	Maintenance Cost As Percent of Constr. Cost	%	5	2
12	Extra Pumping Cost of Seepage	\$/m^3/year	0.000165	0.000165
13	Interest Rate 6% Depreciation over 40 years, Annuity		0.0665	0.0665
	Construction Costs Per m' Channel			
14	Earthwork	\$/m'	14.814	14.104
15	Concrete Lining	\$/m'	0	22.176
16	Constr. Cost Per m' Channel	\$/m'channel	14.814	36.280
	Yearly Costs Per m' Channel			
17	Annuity over Construction Cost	\$/yr.	0.983	2.412
18	Maintenance Costs	\$/yr.	0.739	0.726
19	Pumping Cost of Seepage	\$/yr.	0.0066	0.0
20	Yearly Costs	\$/m'channel/yr.	1.729	3.138
21	Difference in Yearly Cost	\$/m'channel/yr.	0.0	1.409
22	Amount of Water Saved	m^3/m'channel/yr.	0	34
23	Cost of Water Saved	\$/m^3	-	0.0429

Table 4. Reduction of channels cross section by lining (Swiss Consultants, 1980)

Channel Category	**Cross Section**		**Reduction of C.S. by Lining**	
	Com. earth	Conc. lined		
	A (m^2)	A (m^2)	ΔA (m^2)	ΔA%
Main Channel	30.011	22.881	7.229	24%
Distributary Channel	2.303	1.768	0.535	23%
Water Course	0.844	0.576	0.268	32%