IMPROVEMENT OF IRRIGATION AND DRAINAGE MANAGEMENT THROUGH PARTICIPATORY IRRIGATION MANAGEMENT AT ALL STAGES IN BAND-AMIR AREA IN FARS PROVINCE

AMELIORATION DE LA GESTION D'IRRIGATION ET DE DRAINAGE PAR LA GESTION PARTICIPATOIRE DE L'IRRIGATION A BAND-AMIR DANS LA PROVINCE DE FARS

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ABSTRACT

Optimizing irrigation and drainage networks management is possible when there is a full cooperation among all the stake holders. Governmental involvement in deciding key issues without considering the local communities' viewpoints often results in the latter's alienation in matters of water management. In order to decrease social problems and challenges in executing and operating irrigation and drainage networks and improving their performance, it is necessary for all principal agents to take into account the opinions of water users and ensure their participation in design, execution, operation and maintenance of networks.

Second phase studies of irrigation and drainage networks of Band-Amir in Fars province, was accomplished by Mahab Ghodss Consulting Engineering Company in 1384[4], and in order to facilitate execution of the contract, documents and construction drawings were prepared in four different developmental zones. These were put out to tenders by Fars Regional Water Board Shareholders Company. After selecting the relevant contractor, construction process began in 1382.[4]

Along with the project construction development, there gradually emerged some social problems which were due to differing viewpoints of network water users with the project design. It was decided that the consultant undertake social studies, ensure people's

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participation in establishment of water users associations, and modify layout of the network that is acceptable to all.

The main purpose of above mentioned studies is to improve managing irrigation and drainage, implementing developmental methods for participation of water users in design, execution, operation and maintenance of irrigation and drainage networks at the Band-Amir area.

Key words: *Improvement of irrigation management, Participatory stakeholders' development, Irrigation and drainage network, Social problems, Band-Amir.*

RESUME

L'optimisation de la gestion des réseaux d'irrigation et de drainage est possible quand il existe la coopération totale entre les parties prenantes. La décision prise par le gouvernement sur les questions clés sans tenir compte des points de vue des communautés locales donne lieu souvent à l'aliénation de ce dernier en matière de gestion d'eau. Afin de diminuer les problèmes sociaux et les défis qui se posent dans l'exécution et l'exploitation des réseaux d'irrigation et de drainage et d'améliorer leurs performances, il est nécessaire que tous les principaux agents prennent en compte l'avis des usagers d'eau et assurent leur participation dans la conception, l'exécution, l'exploitation et la maintenance des réseaux.

La deuxième phase des études de réseaux d'irrigation et de drainage de Band-Amir dans la province de Fars a été soutenue par « Mahab Ghodss Consulting Engineering Company » en 1384[4]. Pour faciliter l'exécution du contrat, les documents et les dessins de construction ont été préparées pour quatre différentes zones de développement. Ils ont été soumis à une offre par « Fars Regional Water Board Shareholders Company ». Après la sélection de l'entrepreneur pertinent, un processus de construction a commencé pour 1382.

Avec le développement de projets, il a progressivement émergé des problèmes sociaux dus à différents points de vue des usagers d'eau du réseau sur la conception du projet. Il a été décidé que le consultant entreprendrait les études sociales pour assurer la participation du peuple dans l'établissement des Associations d'usagers de l'eau, et modifier la disposition du réseau qui serait acceptable à tous.

L'étude vise à améliorer la gestion d'irrigation et de drainage, mettre en œuvre les méthodes de développement de la participation des usagers d'eau dans la conception, l'exécution, l'exploitation et la maintenance des réseaux d'irrigation et de drainage de Band-Amir.

Mots clés: *Amélioration de la gestion de l'irrigation, développement participatoire des parties prenantes, réseau d'irrigation et de drainage, problèmes sociaux, Bande- Amir.*

1. INTRODUCTION

The concept of water users' participation is that they have participation in decision making, responsibilities and authority. The 5 basic principles for effective and stable management of Irrigation and drainage network are:

- Infrastructures which correspond to water rights and local management capacities.
- Enough financial and human resources for an effective management
- Clear and transparent management responsibilities
- Appreciation
- Protective inspections

Lack of balance between above factors results in malfunction of operation of networks.

Active and effective participation of farmers in ownership and management of irrigation and drainage network requires their awareness of the short and long term benefits of this participation. Optimum development in agriculture and requires creative collaboration between al main stakeholders including development organizations, Energy and Jihade-Agricalture ministries, consulting engineers, development experts and institutions and local communities.

In many developing countries such a desired collaboration often does not exist due to governmental involvement at all stages of development without having a proper grasp of the on-field and social problems. Thus, the goals of development are seldom met. One reasons for this failure is, that, governmental organization do not posses the capacity, readiness and required motivation for accepting view, recommendation and requirements of people and local communities and take a top-down approach and believe that local water users are not able to decide what is good for them. In other words, for a sustainable development, the development should be achieved by people and for people.

Iran has a long history of establishment of operational disciplines in terms of agricultural water users' participation in management of water resources. Utilizing surface and ground water resources was common among ancient Iranians and remains of them can still be seen. The situation, however, gradually changed and the government took over the responsibility of water resources planning exploitation and use. As a result, problems such as distancing of the water users from water management, fund and stuff crunch of the government to deliver to goods as planned, mismanagement of water, quality degradation due to discharging effluents in to the rivers, inability to tackle drought problems, etc., occurred. Then, on the basis of executive regulation, the responsibility of transfer of ownership and management of Dams and Irrigation and drainage networks has been put upon ministry of Energy. In this regulation special provisions have been made to transfer the management and ownership of water facilities to beneficiary water users and establishment of W.U.A. (water users Associations).

In the second development program with the approval of legal provision to attract and ensure farmers' participation in construction of irrigation networks and article note No.19 of this law related to optimum consumption of agricultural water resulted in acceptance of "Regulations for optimum consumption of agricultural water" in the government and therefore the basis for establishment of W.U.A has been laid. The establishment of W.U.A. has two objectives namely, participation:

- In execution and operation of irrigation and drainage networks.
- In O&M of the networks already implemented by the government.

In the first instance, W.U are much motivated because of having the privilege of supplied and conveyed water and receiving governmental support in construction of irrigation networks.

By transfer of ownership and management of irrigation and drainage network through W.U. participation in implementation and operation of these networks; financial and personnel needs, technical and managerial responsibilities of the government would reduce. Although at first, the management transfer would increase irrigation costs for the farmers but it seems that after a while by enhancement of system efficiency, conditions would improve.

It should be admitted that transfer of ownership and management of irrigation and drainage network in itself would not guarantee the success of these networks and if legal protection and technical and financial support along with continuous assessment is not available after the transfer, and W.U be left on themselves, one should expect the undesirable outcomes.

The history of studies in Bande-Amir area as a part of Korbal plains dates back to the year 1350; Various consultants depending on project needs have worked and studied at different stages. The history of studies in project area and objectives and results are summarized below:

- First studies date back to the year 1970 AD by Justin-Courtney Consultant Engineer Co, for 300,000 ha of irrigable lands of Bande-Amir between Doroodzan Dam and Bakhtegan lake. In the project report, prepared after detailed investigation on the historical background of the area, location, topography, geology, soil resources, climatology, Hydrology, water resources, present conditions of agriculture, livestock raising, irrigation and land ownership and land capabilities; new plans for water demand, proposed cropping pattern, market potential, water management, cost estimates and other agricultural and livestock raising issues in the area were prepared.
- In the year 1357, agriculture and livestock raising development studies in Korbal plains were done by Taleghani-Daftari Consultants and the backgrounds for optimum soil and water resources use, and current-problems of the area were investigated and finally different types of irrigation and drainage plans were presented. One objective for these studies had been to present regulation and design for the continuation of left and right canals of Doroodzan. Also, considering suitable return water capacities from drains to Kor River and capacity of Ramjerd irrigation network (upstream) Water flow needed for Korbal plain irrigation at Polkhan was determined and implemented in operation program of Doroodzan Dam and Sivand and Maein River control.
- In the year 1370, First phase studies of irrigation and drainage sub network of Korbal area were done by DezAb Consulting Engineers over an area of 50,000 ha. Results of above studies in 5-volume report includes subjects such as Hydrology, Irrigation, Agriculture Live stock raising, Present conditions, Plans for agricultural and live stoke raising, Development of tertiary and quarternary irrigation and drainage networks.
- Concerning soil resources and land classification studies, latest investigation by Vissan Consulting Engineers were done and presented as authentic soil resource studies of Korbal Lands for an area of 65,000 ha. The related drawings and reports prepared in the year 1372. These studies include soil and land classification for irrigation and classification of irrigable areas.
- Second phase studies contract of sub network of irrigation and drainage of Bande-Amir were awarded to MGCE and their report was submitted to the clients in the year 1384.

- Due to long passage of time, the first irrigation and drainage studies of Korbal plain (studied by Dezab Consulting Engineers) and lack of sufficiency toward project demands, MGCE was obliged to prepare two case study reports under titles No.1 “Summary Report and Results of completed studies and provision of main lines of revision studies” and No.2 “Proposal for drainage investigations and needed scope of works” and submitted to the client in 1379. Revision studies of Bande-Amir sub network were awarded to this Consulting Engineering Compan in 1380. These studies mainly include updating climatic information, presenting crop pattern and water demand, preparing regulations and design criteria of irrigation and drainage network, economical assessment of the project. The reort was submitted in 1382.
- First people’s participating studies in Bande-Amir area were done by Poorab Fars consultant who in the year 1388 completed studies of right bank of Kor River under the title” Development studies of irrigation and drainage network based on participatory techniques and empowerment of local people of Bande-Amir irrigable lands”. The purpose of these studies was to attract villagers participation in development of modern secondary and tertiary irrigation and drainage networks of areas of Bande-Amir, Kialak, Meidan, Kohak 1 & 2 and Atabak villages.
- To implement second phase studies of irrigations and drainage sub network of Bande-Amir, construction of Development unit No.4 of Bande-Amir was put to bid by Fars Regional Water Authority Company and project commenced in the year 1387, by Raahsar Company under the title “Supervision of construction of secondary and tertiary irrigation and drainage networks of Bande-Amir development unit No.4”. Also to implement another part of irrigation and drainage network a contract under the title “Supervision of left over construction of Bande-Amir tertiary canals was put to bid and by selecting the contractor (Pars Maroon Company), project implementation commenced from the year 1388.
- Ultimately, in order to modify the left over layout maps of the project (Development units No.1~No.3 of Bande-Amir) on the basis of social studies , a new project titled “Social studies and people participation, W.U.A establishment and land acquisition and modifying layout maps of Bande-Amir irrigation and drainage network” was awarded to MGCE Co. in 1389.

The command area of Bande-Amir irrigation and drainage sub network is situated on both banks of Kor River in between traditional Bande-Amir (barrage) of Amir and FeizAbad. Northern part of these lands are bounded by primary left canal, situated at the end of Doroodzan plain. From north-eastern and east is limited to the main Doroodzan Drain. From south and south eastern to the main Left Drain and west and south-western to the main Right Drain.

Main mountains in the command area are Rahmat mountain in North-eastern, SiahKoh (Kohderaz) in north-western, Chahe Barf in the west, Shoor, Poorbaba, Talezar, Kamargory, Anjir, Barshmishiri and Chahe Ahangari in south-west.

Altitude varies form 1858m amslat Bande-Amir to 1568 amsl on the eastern part. Figures No.1 and No.2 show the locations of study area and development units of Bande-Amir sub-network.

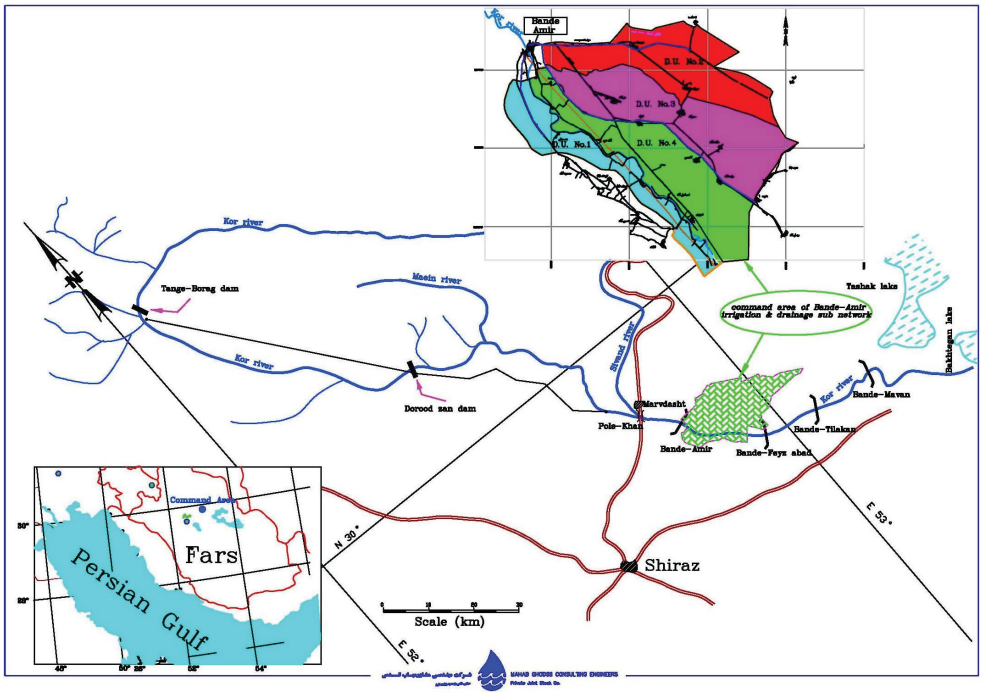

Fig. 1. Location and command area of Bande-Amir irrigation and drainage sub-network

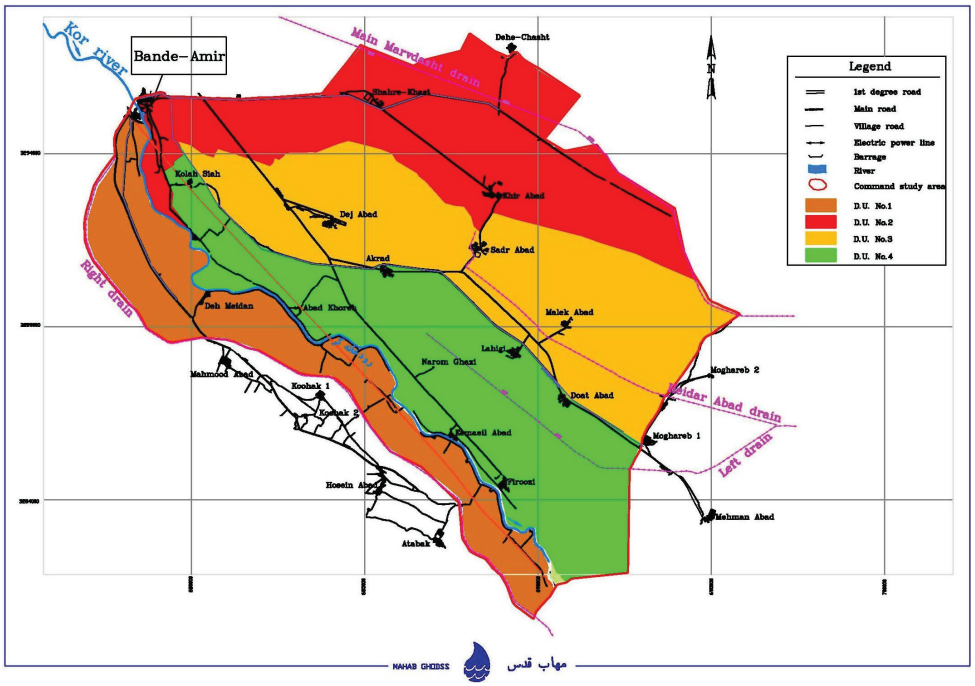

Fig. 2. Command study and development units of Bande-Amir irrigation and drainage sub-network

2. INVESTIGATION METHODS

Social and technical investigation methods (participatory studies) in Bande-Amir irrigation and drainage sub network could be outlined as bellow:

A- preliminary studies by social team on existing drawings.

B- Preparing layout drawings of the project for every village to be presented in the preliminary meeting with network W.U.

C- Preparing cadastr maps for every village to get familiarity with ownership status of the network W.U.

D- Primary site inspections by social and technical teams and collecting villagers demands and opinions which follow these stages:

- primary meeting with local project agents (including W.U representatives, client and supervisor engineer) in order to get familiarity with problems associated with network construction
- Primary meeting with W.U representative of every village to get familiarity with social problems and main W.U demands
- Providing a list of W.U of every village and inviting them to take part in meeting of problem presentation.
- Meeting of problem presentation with W.U of every village and providing minutes of meeting signed and approved by all involved in the project and stake holders (including Client, Consultant and W.U)

E- Synthesizing villagers demands by social study team and submitting them to the technical team

F- Considering technical demands of villagers by technical team and providing proper responses for every one of them.

G- Change in the layout drawing by technical team and remitting them to social studies team

H- Preliminary studies of social study team on new layout drawing

I- Providing new layout drawings for every village for presentation in the final meeting with W.U.

J- Re-inspection of project area by social and technical teams which follow these stages:

- Preliminary meeting with the client in order to explain on responses given to W.U demands and technical reasons for rejecting some of them.
- Re invitation for all W.U of every village to participate in the final meeting .
- Final meeting with all W.U of every village and drafting final minutes of meeting together with provision of new drawings by all involved in the project and stakeholders (client, consultant and W.U)

K- Synthesizing views of villagers by social studies team and submitting them to technical team.

L- Achieving final investigations by technical team and change in design of revised layout of network, if necessary

M- Provision of new drawings and submitting them to the client

It should be noted that during all stages concerning W.U demands (preliminary and final) and prior to remitting new drawings, the consultant should through sessions of technical and steering committees of the project, while applying complementary studies to overcome important technical and social challenges, by confident of authenticity of new design works through applying experienced expert's views

3. DISCUSSION

In order to investigate the outcomes of social and technical studies with the pupose of modifying layout of Bande-Amir irrigation and drainage subnetwork, at first, the social demands of W.U in every executive unit of Bande-Amir network were taken into consideration and then, the results of technical investigations and consultant's responses which were the outcome of several specialized sessions, presented and ultimately the most important experiences gained through this social study will be analyzed.

But before dealing with these issues, it should be said that existing problems are not of the same nature and could be classified in different categories and regarding the kind of problems, specialized encounter and the way of responding to them would differ. The main categorized problems are as follow:

Legal Problems:

These problems exist as the result of ownership broader than W.U or the client's authorities like lands owned by Pious Foundation (Waqf) or Natural Resouces Organization .These problems exist in Gardean village (Natural Resources) and Kalahsiah(Waqf)Undoubtedly, solving these problems are out of consultant's ability and requires collaboration between W.U and main owners. At this stage the client and consultant have directed W.U toward a constructive collaboration to make possible the construction and operation of network at that village.

Cultural Problems:

Main cultural problems are due to lack of confidence and confidence building between W.U in relation to administrative system of operation in just distribution of water, approximately in all villages, W.U are not satisfied with the functionality of operation administration offices and mention instances of unsuccessful experiences in their traditional networks or even not so successful experiences in modern ones.In this respect, social-technical teamwork of the consultant while holding common meetings with experts of operation administrators of province, conveyed concerns of farmers to them and reciprocally these experts insured that operational system of modern networks are obligated to just distribution of water and would utilize all supervision and legal authorities available (like applying regular inspections, isolation of main distributory stations between neighboring villages and treating unlawful operations with penalties).The outcome of those discussions are reflected in the meeting held with W.U and confidence building has been done as possible

Social Problems:

Social problems are classified in two categories:

First, existing social problems with a long history between same villages which at times had effects on layout provision (from technical and economical view points)

Second, is the existing social problems between W.U at one village which are classified in 3 groups namely (Farmer, owner and new settler) While each of these requires his independent sub network.

To solve these problems with collaborators and holding a number of meetings with W.U and considering impossibility of short time resolution of these grass root problems and very bad outcomes of non implementing social problems in design work, social demands of villagers were accepted by social-technical team work and the client. Establishment of independent secondary canals for every village and division of tertiary canals among different internal groups in every village are but few examples.

Now to get better familiarity with findings of social-technical studies achieved, which have greatly affected features of network and helped conformity with W.U demands (with the purpose of furnishing proper development of social participation of them in network implementation) We will investigate those problems in every executive unit and express the results of social, technical and economical studies and then would present the responses. It is to be mentioned that development until No.4 of Bande-Amir is divided in 3 construction units according to the drawings.

A-Construction unit No.1

This construction unit comprises parts of Akrad village, Dolat Abad, village and part of Lahigi village and by putting to bid and selection of the contractor, the remained network of this village is under construction. Demands of W.U in this unit are as follow:

1. Water supply of every village lands by secondary and tertiary independent canals
2. Reducing the distance between tertiary canals to 300 m to avoid irrigations problems.
3. Reducing the distance between tertiary drains to 300 m to achieve sufficient sub surface drainage of lands.
4. Design on the basis of land consolidation in Akrad and DolatAbad villages
5. Design on the basis of preserving borders between internal groups (owner, farmer, new settler) in Lahiji village
6. Emphasis on just water distribution in the common division box between Lahiji and Dolatabad villages
7. Necessity of locating tertiary canals alignments and traditional sub channels of Lahiji village

Results of treating the above issues and responds of the consultant are as follow:

1. Independent tertiary canals are allocated for every village and concerning secondary canals, as technical and hydraulic issues permit, this independence is maintained

otherwise in coordination with W.U, Necessary action regarding optimum design have been implemented

2. Considering reducing the distance between tertiary canals, this problems is related to confusion over proper length of quarternary channels, because at first, W.U considered on-farm channels as furrows and therefore a length of 600-700m not sufficient.After analyzing sattelite images and local visitations by social-technical team, it became clear that the length of sub channels of W.U which now play the role of quarternary channels is much more than the designed one(upto 2 km in some instances) and this confusion is over now.
3. Considering reduction of the distance between tertiary drains to 300m for sufficiency of subsurface drainage, considering lack of subsurface drainage studies, impossibility of constructing subsurface drainage system in near future and the existing traditional drains at a distance of 300m, The consultant decided to preserve these drains as the request of W.U and when necessary dredge and modify sections and deliver them to W.U.
4. Design of sub network has been revised on the basis of Land consolidation in Akrad and Dolatabad villages
5. The borders between internal groups in Lahiji village have been considered in the new layout after surveying work and determining internal borders.
6. Regarding just distribution of water, designed structures are capable of measuring and proportionally division of water flow and the operation administration office has undertaken the just distribution of water.
7. In Lahiji village, the alignment of tertiary canals is situated on traditional sub channels with possibility of offtake from both sides via on-farm channels.

B-Construction unit No.2

This construction unit comprises Firoozy, Esmail Abad, Nerom Ghazi and Gardan villages, W.U requirement in this unit are as follow:

1. Construction of secondary independent canals for every village
2. Preserving existing drain in Firoozy village and reducing the distance between drains to 300m
3. Independence of tertiary canals of EsmailAbad and Firoozi village
4. Preserving borders between internal groups within Esmail Abad,Firoozi and Gardan villages.
5. Dredging Jihad Drain (LMD1) for proper discharge of sub drains into this drain
6. Non passage of EsmailAbad drains through Firoozi village
7. Preserving constructed sub canals and situation of leveled lands in Nerom Ghazi village

Results of treating the above issues and responds of the consultant are as follow:

1. For every village, an independent secondary canal has been determined by offtaking from conveyance canal of unit No.2 (Sc10)
2. Existing channels within Firoozi village are preserved and when lacking such drain, some subdrains have been designed in a distance of 300m.

3. Independent tertiary canals have been designed for EsmailAbad and Firoozi villages
4. Internal borders between different groups within every villages (farmer, owner,new selter) have determined after surveying work and considered in the new design of layout for EsmailAbad and Firoozi Villages.
5. Dredging of Jihad Drain(LMP1) will be implemented after completion of surveying work and preparing longitudinal profile, sections and determining the invert elevation of discharge.
6. Except for main drain of EsmailAbad village (which already existed in Firoozi lands)other drains of EsmailAbad on the south of Firoozi village are discharged into Firoozi channel and will not pass through the village lands
7. With respect to internal network design within Nerom Ghazi village, the existing direction of flow and sub canals constructed by W.U will be considered in design work.

It should be noted that within this construction unit, due to social problems with neighboring villages, determination of the alignment of secondary canal (or pipeline) for Nerom Ghazi which lacks a natural channel (not like other villages, has confronted problems. Now experts of this consultant in collaboration with the client are working to solve this problem. Regarding Garden village, due to some legal problems in some lands of this village and lack of representatives accepted by all internal groups and hesitation over implementation of modern network in this village by some inhabitants have created real challenges. Attempts continue now to resolve these problems. In Case the legal issues (related to natural Resources Lands) remain unsolved and the villagers do not agree with construction of a new network, other options have been studied, so that other villagers, do not loose their networks, like investigating alternative alignments for water conveyance and passing through Garden village lands(river right of way and alignment of existing channel)

C-Construction unit No.3

This construction unit comprises Kalasiah, Abdolkarim; Abadkhoreh villages, demands of W.U of these villages are:

1. Taking into consideration the issue of over charge of flow upstream of Bande-Amir and the necessity to stop it.
2. Independent secondary canals for each village
3. Independent tertiary canals for each village
4. Division of the lands owned by the farmers and land owners in Abadkhoreh and Abdolkarimi villages.
5. Necessity for design of tertiary drains at a distance of 300-350m for sufficiency of subsurface drainage of lands.
6. Lack of need for drainage of lands located at river banks in Abdolkarimi and Abadkhoreh villages.
7. Independence of supplying canals of unit No.3 (SC9) from kalasiah network and aligning it on the axis of existing channels in these lands

The results of investigation of above issues and the response of the consultant:

1. To achieve the requirement of W.U related to over charge from Kor River at upstream of Bande-Amir, which both the client and consultant are serious about it.
2. Provisions are made for independent secondary canals for Abadkhoreh and Abdolkarimi villages.
3. Tertiary canals within internal network of Abdolkarimi, and Abadkhoreh villages have been designed.
4. Ownership limits of various groups within lands of Abadkhoreh and Abdolkarimi villages have been determined after surveying work and considering in design of the network
5. Tertiary drains within Abdolkarimi and Abadkhoreh villages have been designed in a distance of 300-350 m
6. No drains have been considered in lands near river banks of Abdolkarimi village and design of Abadkhoreh village drains has been achieved in a distance of 400m from the river.
7. Regarding Kolahsiah village due to legal problems(all lands belong to the pious Foundation(Oghaf)) in this village there isn't any possibility to contract and built network for w.u of this village. Meanwhile w.u have guaranteed not to interfere in construction of water supply cannal at downstream lands (on the condition that this would be on the same alignment of existing channels as possible)

4. CONCLUSIONS AND RECOMMENDATIONS

The most important experiments resulted from studies achieved by social-technical team work at Bande-Amir network are summarized in the following order:

- weakness in present works (Desinged or at operation) with respect to social and technical issues and need for their revision
- Non upto date maps of ownerships (cadastre) and related problems in time of revision of sub networks and during achievement of social studies.
- Lack of coordination of sub network with w.u demands as main administrators of the networks
- Lack of confidence in w.u regarding operation system and necessity for holding common meetings between them to dispel their worries
- The positive role and place of client's people participion office with respect to the establishment of wide participation of w.u in construction of networks and minimizing land acquisition problems prior to the commencement of social studies of the consultant.
- Positive role and place of social-technical workteam of consultant from viewpoint of w.u regarding confidence building by this teamwork and providing solutions for the concerns of w.u.
- Need for utilizing Audio-video facilities during meeting with w.u to aid in mutual understanding and clear presentation of layout maps and drawings
- Need for presence of social-technical team works during project implementation and prior to construction stages to dispel social problems or confrontations by w.u during network construction.

REFERENCES

Bos, M.G, 1989. Discharge measurement structures, International Institute for Land Reclamation and Improvement/ILRI

P.O.BOX 45, 6700 AA Wageningen, The Netherlands.

Buhadji, H. 2004. Discharge coefficient of lateral diversion from trapezoidal chan- nel. J.irrigation and drainage engineering ., ASCE, 117(4), 461-475.

Chen, Q., Dai, G., & Liu, H. 2002. Volume of fluid model for turbulence numerical simulation of stepped spillway overflow. J. Hydraul. Eng., Vol. 128, No. 7, pp. 683-688.

Dargahi., B . 2004. Experimental study and 3D numerical simulations for a free over flow spillway. J. Hydraul. Eng., Vol. 132, No. 9, pp. 899-907.

Murthy, k.k. and Giridhar, D.P. 1989. Inverted v-notch practical proportional weir. J.irrigation and drainage engineering, vol. 115,No. 6,December.

Murthy, k.k and Giridhar, D.P. 1991. Geometrically simple linear weirs using circular quadrants" bell mouth weirs. J. Hydr. Res., 29(4), 497-508.

Shesha prakash M.N. and Shivapur A.V., 2004. Generalized head-Dischrge equation for flow over sharp-crested inclined inverted v-notch weir. J. irrigation and drainage engineering, Vol.130, No. 4, August.

Savage, B.M., & Johnson, C. 2001. Flow over ogee spillway: Physical and numerical model case study, J. Hydraul. Eng., Vol. 127, No. 8, pp. 640-649.

Xiangju, C., Yongcan, C. & Lin, L. , 2006. Numerical simulation of air-water two-phase flow over stepped spillwas. Thechnological Sciences China, Vol. 49, No. 6, pp.674-684.