Expert Mission
to Assess and Propose Alternative Sanitation Systems to Meet the Demand of the Urban Poor Population in the Republic of Yemen

Draft Mission Report

on behalf of the

The National Water and Sanitation Authority (NWSA)
Republic of Yemen
and

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EXPERT MISSION TO ASSESS AND PROPOSE ALTERNATIVE SANITATION SYSTEMS TO MEET THE DAMAND OF THE URBAN POOR POPULATION IN THE REPUBLIC OF YEMEN

DRAFT FINAL REPORT

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1 INTRODUCTION

The challenge to meet the water related Millennium Development Goals (MDGs; World Summit Johannesburg 2002) requires an open view of donors, planners, decision makers and users on a broad range of options to follow. It is at the same time necessary to allow a critical view on measures taken so far, which were obviously not sufficient or suitable to allow all parts of the population to have sustainable access to safe drinking water and appropriate sanitation services. This study investigates “Alternative Wastewater Systems (AWS)” for improvements in the sanitation sector and thus contributes to the implementation of the MDGs especially for Yemeni provincial towns.

The Draft Country Water Assistance Strategy (Norman 2004) shows comprehensive figures on measures and investments required to achieve the goal to “*Reduce the proportion of people without access to safe water supply and sanitation by half from 2000 to 2015*”. Only for the urban population it would be required to invest approx. 1.6 billion USD until the year 2015 to achieve the MDG, which would mean 75% water supply coverage and 63% sanitation coverage.

Since 1975, Yemen’s population has grown by two and a half times reaching its current level of 18.7 million. In compliance with the latest 1994 Census, the total resident population of the Yemen estimated at 14,561,330 persons. The average growth rate is around 3.7%, which still stands as one of the highest in the world. About 48% of the Yemeni population is below 15 years of age.

Based on the 1994 population census, Yemen is still predominantly rural. In 1994 only 23% of the population (approx. 3.3 million capita) lived in urban areas, while the projection for 1998 was already 31% or 5.4 million people (World Bank 2000). The urban population is growing faster (10% to 15% urban growth rate) than the total population. Still, the country is characterized by the prevalence of small population concentrations dispersed across the whole country. Total population concentrations in the country amounted to 106,322 neighbourhoods, localities and villages.

The high population growth and the fast urbanization require immediate action to be taken in the water sector in order to avoid a further deterioration of the situation and to meet the MDGs. Statistics of the “World development Indicators Database” (World Bank, April 2002) state that 45% of the total Yemeni population had access to improved sanitation facilities, while the average in the Middle East & Northern Africa was 83%. This figure shows the shortcomings in this sector in Yemen.

Some 10% of the urban population is served with a centralized sewerage system. Over 90 percent depend on individual on-site solutions or have no facilities at all. On-site facilities are cess-pits or septic tanks, some of which are emptied by trucks owned by the municipality or private companies.

According to the Yemen Poverty Reduction Strategy Paper (2002) 41.8% of the population in Yemen are incapable of obtaining all their food and non food requirements and 17.6% of the Yemeni population even live below the food poverty criteria. Another large number of the population is living close to the poverty line and are vulnerable to being dragged in to below the poverty line. The gross national income in the Yemen was 460 UDS in the year 2001 compared to figures of over 20,000 USD in developed industrialised countries. This illustrates that Yemen is one of the least developed and poorest countries worldwide. Given these conditions it is surprising that the Yemen receives comparably low development aid of only 15 USD per capita compared to an average of 80 USD per capita for the 49 least developed countries.

Conventional, centralised wastewater systems, which are the standard in most wastewater projects proposed or already implemented with support of international donors in Yemen, do in many cases not meet the technical and economical conditions. The water consumption is generally low due to habits, low income and scarcity of water resources. Therefore conventional sewers tend to block. Revenue from water sales is not sufficient to operate and maintain the systems properly. Therefore systems deteriorate fast and no capital for re-investments and extensions can be accumulated.

AWS are to an increasing degree considered a feasible solution not only in developing countries, but also in the developed countries, where the negative effect of conventional wastewater systems on the ecosystem and the costs of conventional systems are a concern.

Many of the urban centres in Yemen are already partly served by conventional sewerage, or conventional sewerage is planned (see section 4.2). The study therefore also focuses on the applicability of AWS in towns where already a conventional system exists and show in how far AWS can be used to serve fringe areas, which have not been connected to the conventional system.

Few centralized sewage treatment plants (STP) exist in Yemen. According to Abdul Malik (2003) 9 STP are functional (6 Waste Stabilisation Ponds: Taiz, Al Hoddeidah, Aden, Dhamar, Mukalla, Rada'a; 2 Activated Sludge: Sana'a, Ibb; 1 Trickling filter: Hadjah).

The reuse of treated wastewater is the focus of a KfW-financed study presently underway and shall therefore not be focused on in this mission. Also the EcoSan approach is part of a separate study for several towns in the south of Yemen and shall therefore not be in the main focus of this mission..

1.1 OBJECTIVE OF THE STUDY

This study has been launched by KfW in order to investigate the appropriateness of the present design standards and the applicability of alternative water systems (AWS). Alternatives to conventional, centralized sanitation systems are proposed and assessed for medium sized towns and rural centres.

Options consider technical, socio- economic, administrative, legal, institutional, and business aspects.

Objectives of the study were, based (i) on an analysis of the existing information, (ii) on the results of its field visits and discussions with the involved groups and institutions and (iii) on the expert's knowledge and experience, the objectives of the mission were to

- elaborate in a general manner possible scenarios for AWS under the given circumstances, thus giving a broad orientation for opportunities and challenges and narrowing the scope of work;

- indicate the options to be studied in detail, outline the details of the selected AWS-concepts, which may combine a) technical specifications and standards, b) costs and socio-economic analysis, c) administrative, legal and institutional implications, d) options for involving private sector enterprises in the water supply and sanitation services,
- assess the suitability of different concepts under given hydro-geological and environmental framework conditions,
- refer to assessment processes and strategies needed for the selection of urban water concepts that not only fit the natural conditions but at the same time provide high quality water services to the users and that have high acceptability by the users. To reach this , an essential prerequisite is to describe the actually existing information gaps, as well as the risks and bottlenecks for successful implementation of the identified preferred concepts,
- assess the adequacy of currently applied construction standards,
- assess the feasibility of upgrading existing decentralized systems/implementation of new decentralized systems.

With letter dated 17th September 2003 KfW ordered an Expert Mission to investigate alternative wastewater systems for the Yemen. This mission took place from the 14th February to the 10th March 2004.

1.2 COMPOSITION OF THE TEAM

The expert mission has been carried out by a multidisciplinary team of three experts from Germany and two local experts. Dr. Kummer is a sanitary engineer with long experience in the Yemen and other Arabian Countries. Dr. Hiessl is a hydrologist and water resources engineer with special experience in systems analysis of urban infrastructure systems. Prof. Dr. Dr. Rudolph, a civil engineer with special experience in water supply and sanitation and an economist, was responsible for the economic assessment of AWS and for sanitary engineering aspects. Dr. Fadhl Al-Nozaily, from the Water & Environment Centre of Sana'a University is an internationally experienced expert in sanitary engineering and well acquainted with the Yemeni conditions and regulations. Mrs. Fatima Mashoor, a sociologist from the Yemen Center for Social Studies & Labour Research was responsible for sociological aspects and the interviewing.

The expert mission closely cooperated with NWSA and the National Water Resources Authority (NWRA), as well as with the relevant provincial and local authorities concerned. Mr. Ahmed Kaid Sarhan, the NWSA Coordinator for projects supported by KfW together with Mr. Ibrahim Al Haimi of NWSA and the Mr. Saleh Al Ashtal of NWRA, both hydro-geologists, accompanied the expert team during the mission as representatives of their respective organisations. They served as translators, provided technical and organizational support and

Throughout the mission, the experts continuously maintained contact with KfW`s local experts and the GTZ Office Sana'a.

1.3 APPROACH OF THE STUDY

The mission to Yemen was prepared in Germany and an Inception Report has been submitted showing the timing and the goals of the mission. The full range of AWS options has been outlined in the Inception Report and no options have been excluded beforehand.

Three case study towns (Damt, Abs, Khamir) have been proposed by NWSA and have been visited by the experts. This case study approach gave the experts in-sight to the actual conditions encountered in Yemen provincial towns. The site visits included a detailed tour of the town, inspection of existing water related infrastructure and meetings with local representatives active in the water sector. In two towns all experts had the chance to visit private houses, to talk with the house owners / occupants and to inspect the sanitary house installations. The Sociologist visited a number of houses in each towns for interviews with selected locals.

Interviews with representatives of water related institutions and donor organizations in Sana'a (for organisations / persons met see annex) gave the experts the opportunity to receive a broad spectrum of the different views of the water sector in Yemen.

Based on the empirical findings from the case studies the experts provisionally developed 4 technical scenarios for alternative sanitation systems. They also condensed their findings about the major problems associated with the suitability and appropriateness of various urban water systems concepts in Yemeni in the form of 12 theses characterising main topics encountered during the mission.

In two workshops held in the Ministry of Water & Environment at the end of the mission the scenarios were presented and the theses discussed. The first workshop with stakeholders was held entirely in Arabic language. The discussion on conventional centralised water systems and more decentralised AWS showed different opinions within the group of participants, with the group favouring conventional systems being bigger than the opposing group. During the second workshop the ratio was the other way round.

After the mission the scenarios for alternative sanitation systems have been elaborated in more detail. The scenarios have then been assessed using a set of criteria developed for this study.

Recommendations for further steps in direction of the implementation of alternative sanitation systems have been included in the summary.

The expert team has proposed AWS, which they deem to be feasible for implementation to contribute to achieve the MDGs, and has on the other hand highlighted existing problems and/or information deficits which are to be treated by future support activities.

The expert team was explicitly asked to give a realistic and outspoken assessment of potentials and problems notwithstanding their nature. The risks for the successful implementation of AWS can only be dealt with when they are clearly known to the parties involved. It was an important task of the expert team to sensitise the Yemeni authorities of the problems they are facing in achieving the MDGs and the opportunities and limitations which are existing.

Throughout their field visit, the expert team has clarified that any opinions and statements voiced by the team or otherwise submitted to interview partners and institutions are personal ones and do not necessarily reflect the opinion of KfW.

Major emphasis has been given to sanitation with regard to the depth of analysis and concept elaboration. However, since water supply cannot be separated from sanitation, consideration has been given to Alternative Water Supply Systems in line with the Alternative Sanitation System.

The main focus of the development of AWS has been on 3 provincial towns, representative for 3 main climatic / hydro-geologic areas, which shall then serve as exemplary cases for all provincial towns in the respective areas. The respective towns have been proposed by NWSA.

This report summarises the findings of visits to case study towns and of meetings with various stakeholders as well as presents proposals for alternative water systems and recommendations for further steps in direction of implementation of such systems

As in many other developing and transformation regions, the information sources were found to be quite poor, especially regarding reliable data and up-to-date maps (for available maps see Appendix A8). For the three case study towns, the information basis was definitely not sufficient to carry out a technical pre-design and pre-cost-calculation without prior survey (e.g. satellite photos would have been helpful to complete existing maps etc.). Furthermore, the rapid growth of the population and housing areas would have made any forecast difficult, except those areas, where town planning is clearly defined and enforced.

Comparing conventional and alternative wastewater systems, the approach could, therefore, not be based on preliminary technical considerations and economic calculations. Instead, the experts had to work with rough estimations and evaluate their impressions from the onsite visits, verified by opinions and information from local experts as far as possible.

2 SITUATION OF WATER SUPPLY AND SANITATION IN YEMEN

The present conditions in the water sector in Yemen have been described in the Terms of Reference for this mission in a comprehensive manner. The following has been mainly quoted from the ToR.

(start quote) The wastewater and sanitation sector is the most important of currently four focal areas of German Financial Co-operation with the Republic of Yemen (both in terms of the financial volume involved and in terms of the number of ongoing cooperation projects). Within the sector, it has been agreed upon to focus on water supply and sanitation in medium-sized provincial towns (20,000-40,000 inhabitants). Cooperation between KfW and the Yemeni National Water and Sanitation Authority (NWSA), who has been responsible for the implementation of all investment projects in the water sector supported so far (Aden, Ibb, Hajjah, Yarim and Amran, Tihama towns) is well established for many years. In the course of the ongoing reform process in the Yemeni water sector, responsibility for the implementation and operation of water supply and wastewater schemes has been or will be delegated to the respective local branches of NWSA. In the cities of Aden, Ibb, Hoddeidah and Mukallah, these local branches have already been transformed into autonomous entities under the title of local corporations, a process, which in the medium terms is envisaged to be applied to all major water supply and sewerage systems.

So far, only conventional sewage disposal systems have been implemented or are currently being prepared for implementation. Operation of the Sewage Treatment Plant (STP) Ibb started in the year 1991, that of the STP Hajjah in 1999. The STP Ibb was originally conceived and constructed as an extended aeration plant allowing for simultaneous sludge stabilisation, but will be transformed into an activated sludge treatment plant with separate aerobic sludge stabilisation. In Aden, Yarim and Amran the wastewater treatment facilities have been constructed as non-aerated lagoon systems (stabilisation ponds).

However, as water scarcity in Yemen is severe in many regions of the country and the incidence of poverty is high, the need to develop and implement AWS in Yemen is imminent.

Yemen is one of the most water-stressed countries in the world. Available renewable water resources amount to approximately 2.5 billion cubic meters – about 150 cubic meters per capita annually, which is far below the "water poverty line" of 500 cubic meters. It is mainly the water consumption of the agricultural sector (about 90% of total annual water withdrawals), which is responsible for the excessive mining of renewable and fossil groundwater resources. However, as the urban population is growing at a fast pace, domestic water consumption is also becoming an increasingly critical factor with regard to the use of Yemen's groundwater resources.

At the same time, poverty is increasingly widespread among the Yemeni population. A recently conducted socio-economic survey, conducted for the provincial towns of Al Shaher, Ja'ar, Zinjibar and Jiblah concluded that between 55% (Al Shaher) and 83% (Jiblah) of the towns` population dispose of an income, which is below the absolute poverty line and between 21% (Al Shaher) and 58% (Jiblah) even have to be categorized as living below the food poverty line. Under such socio-economic framework conditions, conventional water supply and sewerage systems are far too costly to be operated at a tariff level, which allows for ensuring full financial sustainability of the systems.

The experience of German-Yemeni cooperation in the water sector shows that a tariff level is achievable, which is generally sufficient to cover operation and maintenance costs of the water supply and sewage systems, when calculated on a static basis (see Annex 2). However, the agreed objective of both the Yemeni Government and KfW to achieve full cost coverage could thus far not be met. However, in view of the limited ability to pay of large parts of the Yemeni population, the potential for further increases of domestic water and sewage tariffs is limited.

Considering the scarcity of fresh water resources in Yemen, an important contribution to the conservation of groundwater resources and the improvement of the chronically negative water balance could be achieved by the re-utilisation of treated wastewater, either for agricultural irrigation, for groundwater recharge and – to a limited extent –for industrial purposes. The potential of wastewater reuse and appropriate technical, organizational and economic concepts and pre-designs are investigated in a feasibility study, which is under preparation.

The Ecological Sanitation (EcoSan) approach could be one alternative to the existing systems from the ecological as well as from the economical point of view. In the framework of the ongoing project preparation (feasibility study) for the "Provincial Towns Program II" for the "Water Supply and Sanitation in the towns Al Shehr - Ja'ar - Jiblah and Zinjibar in Yemen" the potential for the introduction of the EcoSan approach is identified and concepts are elaborated on feasibility level by an expert team. The objective is to assess the potential for the implementation of EcoSan demonstration projects with the objective to assess the proper functioning and operational reliability as well as aspects of economic benefits and user acceptance of these concepts.

The aforesaid approaches shall therefore not be in the main focus of the expert mission (end quote)

A large number of publications have been found on the water resources in Yemen such as by the World Bank (2000), Abdul-Malik (2003), Mohieldeen (1999) and others. The public sector reform and especially the decentralisation process of the water related administration is subject of the World Bank (2000), Abdul-Malik (2002), Sahooli (1999) and others.

No comprehensive report on the preset conditions in water supply and sanitation services in Yemen has been found during the literature review, which would state the level of services and existing facilities in the major urban centres. Therefore the consultant compiled all data available to him in order to win an overview of the present conditions. Table 2-1 shows a list of major towns in Yemen. These 61 towns represent more than 90% of Yemen's urban population as per the census 1994. Information on water and sanitation projects retrieved from various sources has been included in this table. According to this information in 33 towns water and sanitation projects (centralized, conventional systems) have been completed, are under construction or in the planning phase. This leaves 28 towns where – to the present knowledge of the team – no major sanitation projects have been launched, with 20 of these town having less than 20,000 population.

In order to evaluate and assess the various options to rebuild and/or technologically modernize existing urban water systems a set of criteria has been developed (see chapter 7). For the application of this set of criteria on the specific options developed for the towns data on the socio-economic as well as on the infrastructure situation for these towns have been compiled. Since it was not possible within the present project to conduct extensive surveys to collect these data the project team has used available data.

Table 2-1: Population in Yemeni towns and water supply and sanitation projects (to the knowledge of the Consultant)

	Town	Govern.	Popul. 1975	Popul. 1986	Census 1994	estimated 2005 *)	>100,000	40,000 - 100,000	20,000 - 40,000	5,000 - 20,000	Water supply and sanitation projects			
											Donor	water network	sewerage	WWTP
1	Abs	HAJ	...	...	18,320	16,400				16,400				
2	Addis Al Shargiah					30,700			30,700					
3	Aden	ADA	240,400	...	398,294	712,000	712,000				KfW	existing	existing	ponds
4	Al-Bayda'	BAY	6,500	10,700	19,294	28,100			28,100		IDA	planned	planned	planned
5	Al-Dahi	HUD	...	...	10,496	15,300				15,300				
6	Al Dalea (Dhalla?)				??	12,900				12,900	IDA	planned	planned	planned
7	Al Ghal Bawazir					57,500		57,500						
8	Al-Ghaydah	MAR	...	...	7,785	11,300				11,300	IDA	planned	planned	planned
9	Al Gahidah [Al Qaida]	TAI			??	45,500		45,500			IDA	planned	planned	planned
10	Al Hami					12,000				12,000				
11	Al Hawta (Hauwta)				??	36,000			36,000		IDA	planned	planned	planned
12	Al-Hudaydah [Hodeida]	HUD	88,700	150,756	298,452	565,000	565,000				OPEC fund	existing	existng	ponds
13	Al Jawf				??	9,800				9,800	IDA	planned	planned	planned
14	Al-Mahabishah	HAJ	...	...	12,918	18,800				18,800				
15	Al-Mahwit	MAH	2,600	...	9,060	13,200				13,200	IDA (SFD)	planned	planned	planned
16	Al Mansuriyah				??	14,500				14,500	KfW	existing		
17	Al-Marawi'ah (Maruwia)	HUD	6,800	...	30,504	27,400			27,400					
18	Al-Mukalla	HAD	45,000	...	122,359	219,000	219,000				IDA	existing	existing	ponds
19	Al-Mukha	TAI	...	...	10,355	15,100				15,100	KfW	existing		
20	Al Rahidah					13,600				13,600				
21	Amran	SAN	5,400	...	28,212	41,100		41,100			KfW	existing	existing	ponds
22	Ash-Shihr [Al Shaher]	HAD	...	...	48,577	62,800		62,800			KfW	Study	Study	Study
23	Ataq (As-Sa'id)	SHA	...	...	13,995	16,900				16,900	IDA	planned	planned	planned
24	Az-Zaydiyah (Al Zaydia)	HUD	5,300	...	13,912	20,300			20,300					
25	Bajil	HUD	7,300	...	40,561	59,100		59,100			KfW	existing	constr.	constr.
26	Bayhan al-Qisab	SHA	...	...	12,685	18,500				18,500				
27	Bayt al-Faqih	HUD	13,300	...	28,773	41,900		41,900			KfW	existing	constr.	constr.
28	Damt				??	11,000				11,000	IDA	planned	planned	planned
29	Dhamar	DHA	21,000	46,471	82,920	157,000	157,000				KfW, IDA	existing	existing	ponds
30	Dhi As-Sufal	IBB	...	...	31,963	*46,665*		46,665						
31	Dimnat Khadir	TAI	...	...	15,651	*22,850*			22,850					
32	Fuwa					18,800				18,800				
33	Garahi					14,000				14,000				
34	Hajjah	HAJ	6,300	15,623	24,645	35,900			35,900		KfW	existing	existing	trickling filt.
35	Harad	HAJ	...	...	15,710	22,900			22,900					
36	Harib					10,800				10,800				
37	Hays	TAI		...	10,678	15,600				15,600				
38	Ibb	IBB	20,600	49,471	103,312	196,000	196,000				KfW	existing	existing	activ. sludge
39	Jaar	ABY	...	...		36,100			36,100		KfW	Study	Study	Study
40	Jiblah	IBB			??	18,300				18,300	KfW	Study	Study	Study
41	Khamr	AMR	...	...	10,903	15,900				15,900	IDA	planned	planned	planned
42	Khokha					12,900				12,900				
43	Lauwdar					11,800				11,800				
44	Lahij (Tuban)	LAH	...	...	19,006	*27,748*			27,748					
45	Ma'aber					14,200				14,200				
46	Manakha				??	11,200				11,200	IDA	planned	planned	planned
47	Ma'rib (Mareb)	MAR	3,000	...	6,996	7,980				7,980	IDA	planned	planned	planned
48	Mudiyah	ABY	...	...	11,071	*16,163*				16,163				
49	Qutayh					17,100				17,100				
50	Rada	BAY	6,900	...	39,227	64,300		64,300			Netherlands	existing	existing	ponds
51	Rayda					12,900				12,900				
52	Sadah	SAD	4,600	24,149	27,621	40,000		40,000			KfW	planned	planned	planned
53	Sana'a	SAN	134,600	427,505	954,448	2,021,000	2,021,000				various	existing	existing	existing
54	Shibam					8,810				8,810				
55	Taiz	TAI	86,900	172,439	317,571	601,000	601,000				IDA	existing	existing	ponds
56	Thila	AMR	...	...	11,564	*16,883*				16,883				
57	Tohieta					16,900				16,900				
58	Turbah					11,700				11,700				
59	Yarim	IBB	8,000	...	27,802	40,500		40,500			KfW	existing	existing	ponds
60	Zabid	HUD	7,600	...	44,239	32,700			32,700		KfW	existing	constr.	constr.
61	Zinjibar	ABY	...	...		29,000			29,000		KfW	Study	Study	Study
	Sum capita				**2,879,879**	**5,771,300**	**4,471,000**	**499,365**	**349,698**	**451,236**				
	No. of towns					**61**	**7**	**10**	**12**	**32**				

*) as per: Urban Water Supply and Sanitation Thematic Group: Country Water Resources Assistance Strategy, Draft, February 2004; italic numbers added with 3.5% annual growth rate

3 THE NEED FOR ALTERNATIVE WATER SUPPLY AND SANITATION SYSTEMS FOR YEMEN

During the mission a number of institutions and individuals have been contacted and discussions on the mission subject have been held. The list of contacts is attached in Appendix A2. The opinions of the interview partners covered the full range from “continue like done so far” to “completely new approach to sanitation is required”. This chapter summarises opinions received without referring to the individual sources.

A main reason for the preference given to conventional, centralised sanitation systems is the poor design and operation of most of the existing on-site facilities. Overflowing and collapsing cess pits give bad examples of alternative solutions and can be found anywhere throughout the country. This situation results from poor design and construction standards and bad or no maintenance at all. Therefore the perception of the users and house owners is that on-site solutions are a problem.

The “Urban Water Supply and Sanitation Thematic Group” with in the Technical Secretariat in the Ministry of Water estimated that 150 million USD investments per year are required in order to reach the MDGs (72% WS and 54% Sanitation coverage) until 2009. This figure shows clearly the necessity to develop suitable options for the water sector in order to make these big investments a success with positive long-term results.

Big cities have centralised sewerage systems. Small cities want the same. Alternative solutions have an image problem.

Previous wastewater projects neglected the technical problems. Now the systems face operational problems, as well as technical problems such as corrosion.

In Hoddeidah the sewerage system has corrosion problems in the asbestos cement pipes due to infiltrating sea water. There is also a problem with sedimentation of sand and other solid material because the houses have no flush toilets. Septic sewers smell. Solid waste is disposed in the sewers.

In Dhamar most of the wastewater does not reach the WWTP because farmers demolish the pipes or block the manholes in order to take raw wastewater for irrigation.

In Hajjah the water tariff covers 50% of O&M costs. Spare parts for the WWTP are partly not available in Yemen and need therefore long time to come and are expensive. Technical solutions should concentrate on locally available materials, technology and knowledge. O&M personnel is hardly available for highly advanced technology. Any technology should therefore be adopted to available human resources.

The University appreciates the decentralisation idea. Now there are malfunctioning WWTP, which cause environmental problems. Since some decades the successfully operating traditional Yemeni WW handling technology has been replaced with systems designed for water–rich countries, because of urbanisation and higher water use.

At present, there is no ongoing research on alternative water / wastewater systems in Yemen, but ideas should come from Yemen not only to build on the traditional Yemeni sanitation technology but also to build ownership of such ideas and to provide a basis for a long-term oriented water-industry.

The water sector is in transition and responsibilities and ownership are in many cases not clear. Local Champions are needed for a successful project, together with community development, generation of income through involvement of local enterprises, and local ownership for sustainability. It is important that implemented water projects are not alien.

In Sana'a a private market for filtered drinking water using membranes for filtration developed. The price is 50 YR for 20 litres. There is competition between the suppliers, but there is no quality monitoring. This situation is unsatisfactory and risky for the users.

New IDA projects all include environmental mitigation plans, training and capacity building and the inclusion of Yemeni firms in the project execution.

Projects with small volume and not following Government procurement regulations can be implemented within less than 1 year period from the study until start of operation. Such projects have e.g. been implemented under the Rural Water Supply and Sanitation Project financed by the IDA.

An example for small bore sewer system is under implementation funded by the Social Fund for Development in Al Mahweet. Project costs are 1,000,000 USD for 12,000 capita. The septic tanks are partly on private and partly on public land and serve each a cluster of houses. Locations have been fixed by the Local Council. The NWSA branch supervises the connection of houses to inspection chambers. The connection rate is presently around 25%. For a connection a contract between NWSA and the house owner is signed. The tariff has not yet been set.

Nowadays contracts are split into small contracts in order to encourage local companies. Local companies should be involved and competition between local companies should be encouraged in order to increase quality.

With rural water schemes the tariff should cover the O&M costs, while the tariff should not exceed 7.5% of the monthly income. Experience shows that 80% of the rural systems break down and are not run any more due to O&M problem caused by low tariffs. Sophisticated sanitation is hardly available in rural areas.

There are 301 districts in Yemen, each having a local council. There are in total approx. 60,000 rural settlements and 60 centres.

In Abyan area people used to move and changed the location of their habitation according to the availability of water. Now the "Rural water supply and sanitation project" provides water and people settle. Four pilot studies for sanitation are planned, and the technical solution has not yet been defined. Networks for water supply have been calculated for 40 l/c/d water consumption. Contractors construct these projects with 75% IDA financing, 20% Government financing and 5% local financing. Water Associations run the projects. Project values range from 30,000 to 250,000 USD with 100,000 to 150,000 USD being a typical average. These projects do not follow the Government procurement regulations but decisions are taken by a Steering Committee chaired by the Ministry of Water. They can typically be finalised within less than a year's period.

Missing town planning and the missing enforcement of existing town planning is a major obstacle for the implementation of all kinds of urban infrastructure. Missing enforcement of regulated settlement development is for instance a major obstacle to the development of main roads, because people settle directly at the roads and do not leave space for widening of roads or utilities beside the roads. Now road planners overcame this obstacle by foreseeing space for widening of roads in the middle between the lanes.

4 SPECTRUM OF ALTERNATIVE WATER SUPPLY AND SANITATION SYSTEMS TAKEN INTO CONSIDERATION

In recent years AWS have gained increasing interest amongst planners, researchers and decision makers. As a consequence literature on this subject is nowadays available in abundance. The team has tried to select the most recent and relevant publications on technical as well as organisational, sociological and economical aspects of AWS.

Attached to this report are two reference lists, one of literature on Alternative Water/Wastewater Systems and one on the Water/Wastewater Sector in Yemen. Some of the literature shall be highlighted in this chapter.

A comprehensive compendium and discussion of AWS options is included in Rudolph (June 2001). Black (1998) provides a critical retrospective of 20 years international water and sanitation cooperation of the World Bank. Boydell (2000) and Bruijne (2000) pledge for AWS in urban and peri urban areas as do Mara (1996 and 1999) and Neder (1998) and many others.

Rosenzweig/Perez (2002) provide a comprehensive methodology for the identification of sustainable sanitation options (including AWS) with participation of beneficiaries and stakeholders. Hiessl et al. (2003) provide a case study on the application of the scenario approach to develop alternatives for urban water infrastructure systems - especially in terms of technological modernization of existing systems – with a strong involvement of local decision makers. Also Mukherjee (2003), Ockelford/Reed (2002) and the DFID (1998) provide detailed methodologies for participatory planning. Bricke (2000) provides a comprehensive manual for the training of managers and planners in view of their participation in the planning phases.

Design manuals/guidelines for alternative systems identified relevant to this study include the publications by Bakalian (1994) for simplified sewerage, by Otis/Mara (1985) for small bore sewer systems, by Mara et al. (1998) for waste stabilisation ponds, by the US EPA for various applications and by Alam/Parkinson (2002) for tertiary sewerage systems.

Examples for successfully implemented AWS are presented by Bruijne (2000) for Palestine, by Colling (2000) and Foster (2002) for Bolivia, by Kessides (1997) for Brazil and Sub-Saharan Africa, by Mara (1996) for Brazil and Pakistan, by Mooijman (1998) on Honduras. Neder/Nazareth (1998) present a comprehensive document on the condominial sewers in Brazil. Alam/Parkinson (2002) present a detailed report on simplified tertiary sewers in Failalabad in Pakistan. UN-Habitat (2003) provides information on the Orangi project in Pakistan. Rudolph/Schäfer (2001) have evaluated a large number of AWS projects in the developed countries.

Although the water supply is not the main focus of this study, the present and in future foreseen level of water supply determines the water consumption and the wastewater production, and is therefore to be investigated in parallel. In principle the following options for water supply exist.

Table 4-1: Water Supply Options (Source: Rudolph, 2001b, modified and amended)

Type	**Description**	**Supply l/c/d**	**No. of households supplied**
Decentralised water supply			
Communal open wells	A bucket attached to the end of a rope is used to draw water from a well	10-50	
Tube wells / boreholes	Pumps are attached to the top of a pipe which is sunk into an aquifer. water is obtained through a public stand post or water kiosk	10-50	
Private water vendors (bottles, buckets, jerry cans)	Bottled water is sold by water vendors	10-50	1
Private water vendors (tank wagon)	A tank wagon delivers water to the house. It is stored in a yard or roof top tank	30-250	1
Public tanker trucks	A tank wagon delivers water to the house. It is stored in a yard or roof top tank	30-250	1
Rainwater harvesting	Collection of rainwater from roofs and other clean surfaces (limited suitability for drinking purposes)		1
Atmospheric water vapour	Water collected through "Air wells". In special devices the dew point is reached and water condenses.		
Centralised, piped water supply			
Communal standpipes	A public piped water supply system supplies water to taps in the street, to be shared by many homes	10-50	25
Water Kiosk (variant to communal standpipe)	A public piped water supply system supplies water kiosks were it is sold	10-50	100
Yard taps	A public piped water supply system supplies water to taps in the yard of each house	30-100	1-5
House connections	Service pipes are laid to supply water directly to the houses (conventional system)	50-250	1

Technical options for sanitation include on-site solutions, semi-centralised and centralised solutions. In principle the options listed in table 4-3 for sanitation have been described in the literature and investigated for application in this study. They have been compiled by Rudolph (2001b) in the context of a BMBF study on AWS and show a short description, advantages and disadvantages and examples. Other criteria such as costs, skills have been added following DFID (1998).

The listed sanitation options can also be combined with various types of in-house handling of the streams. The table 4-2 shows options for in-house handling of streams:

Table 4-2: In-House Handling of Wastewater Streams

	Type of Toilet					
	Witout water			**With much or little water**		
Type of waste/wastewater	VIP latrines or variations	Composting toilet	Urine separating, dehydration toilet	Flush or pour flush toilet	Urine separating, full flush or pour flush toilet	Urine separating, full flush toilet, flush with recycled greywater
Urine	to pit	composting	storage	to sewer or pit	storage	storage
Faecals	tp pit	composting	composting	to sewer or pit	to sewer or pit	to sewer or pit
Toilet flush water	n/a	n/a	n/a	to sewer or pit	to sewer or pit	to sewer or pit
Kitchen water (dishwashing etc.)	to pit	to sewer or pit	to sewer or pit	to sewer or pit	to sewer or pit	to sewer or pit
Body hygene water (bathroom)	to pit	to sewer or pit	to sewer or pit	to sewer or pit	to sewer or pit	recycling
Clothes washing water	to pit	to sewer or pit	to sewer or pit	to sewer or pit	to sewer or pit	recycling
Separate urine transport and treatment required	no	no	yes	no	yes	yes
Separate handling of faecal sludge required	no	yes	yes	no	no	no

Urine separating has been practiced in Yemen for hundreds of years. Also dehydration of faeces s has been common practice.

Most of the sanitation options are well known. The two not so well-established options of 1) small bore (or settled) sewerage and 2) condominial (or simplified) sewerage have been successfully implemented in in South America and in the USA. They are described in more detail in chapter 6 of this report.

Table 4-3: Options for Sanitation (Rudolph, 2001b, modified and amended)

	Type	Other names	Description	Average flush water volume (litres)	Skills needed for O&M	Relative construction costs (per person)	Relative O&M costs (per person)	Advantages	Disadvantages	Examples
1	**On-Site**									
1.1	Bucket sanitation systems.	-	A bucket is placed under a seat in a privy.	nil	cleaning only	1	1		Problem with flies and stench. Bucket soons fills when many people use the system.	
1.2	Ordinary pit latrines	Cess pit	A pit with a seat, in a shelter.	nil	cleaning only	1	1	Basic enough for people to construct themselves.	Often badly built. Problem with flies and stench.	Dar-Es-Salaam, Tanzania.
1.3	VIP latrines.	VIP toilettes, VIP pits	Reinforced pit with concrete cover and seat. Air vent with screen and anti-mosquito baffle.	nil	cleaning only	2	1	Easy to construct. Cheap. Hygienic	No good if ground is rocky or groundwater table is near surface.	Zimbabwe.
1.4	Aqua-privy with on-site disposal.		Waste enters a digester to be processed by bacteria. Liquid effluent soaks away.	**1**	periodic tank emptying	15-25	2-3	Cheap. Easy to install.	Water tank needs frequent filling. Digester requires periodic emptying. Effluent can contaminate the surrounding ground.	India.
1.5	Septic tank with on-site disposal.		As aqua-privy with on- site disposal, except that this is a full flush system on-site disposal.	**10-20**	periodic tank emptying	15-25	2-3	Can be installed where there are no sewers.	Expensive to install. Reserved for large sites. Cost of emptying sludge disposal.	
2	**Centralised**									
2.1	Aqua-privy with solids-free sewerage.	Settled sewerage, small diameter gravity sewers, small bore sewers, septic tank effluent drainage, sewered interceptor tanks	Waste enters a digester to be processed by bacteria. Liquid to sewer pipe.	**1**	periodic tank emptying, plus maintenance of sewers and operation of treatment plant	5-70 (depending on aqua privies already existing)	10	Small volume of water needed for flush. No soak-away required.	Digester needs periodic emptying.	USA, Australia, Brazil.
2.2	Septic tank (interceptor tank) with solids free sewerage	ditto	ditto	**10-20**	ditto	ditto	10	ditto	ditto	USA
2.3	Intermediate flush toilet (with conventional sewerage).	Pour flush toilette	Similar to a full flush system but uses less water. All waste goes to a sewer.	**3-6**	maintenance of sewers and operation of treatment plant	20-70	10	Full flush system is convenient. Use little water.	Needs to be designed and installed correctly.	Developed cities.
2.4	Full flush toilet (with conventional sewerage).		Full flush system with on-site sewer to transfer waste to main sewer.	**10-20**	ditto	20-70	10	Most convenient system.	Most expensive system to construct. Uses the most water.	Developed cities.

2.5	Full or intermediate flush toilet (with simplified sewerage).	Shallow sewerage, condominial sewerage			ditto	10-50	10			Brazil

Options for Wastewater Treatment

Any sewage collected in sewerage systems needs to be treated before discharge in order to reduce pollution of receiving waters, or to provide the quality required for further use of treated wastewater. The most common treatment plants in Yemen are waste stabilisation ponds. Also the activated sludge process and trickling filters are already in use in Yemen. During this study the advantages and disadvantages of the various treatment options given the conditions in the different regions of the Yemen will be assessed and recommendations given on the most advantageous options. For instance do the waste stabilisation ponds have the advantage of low operation and maintenance requirements and low investment costs, but disadvantages are high space requirements. High evaporation reduces the quantity of treated wastewater available for further use. Technical plants need less space, but required skilled and willing personnel for operation and have high operation costs. In principle the table 4-4 shows the available options.

Table 4-4: Options for Wastewater Treatment (DFID, 1998, amended)

Treatment process	Description	Key features
*Land treatment (soil aquifer treatment - SAT)	Sewage is applied in controlled conditions to the soil	Soil matrix has quite a high capacity for treatment of normal domestic sewage, as long as capacity is not exceeded. Some pollutants, such as phosphorus, are not very well removed. Can be used as a method of recharge of aquifers
*Reed beds (or constructed wetlands)	Sewage flows through an area of reeds	Treatment is by action of soil matrix and particularly the soil/root interface of the plants. Requires significant land area, but no oxygenation requirement.
*Waste stabilization ponds (WSP) (lagoons or oxidation ponds)	Large surface area ponds	Treatment is essentially by action of sunlight, encouraging algal growth which provides the oxygen requirement for bacteria to oxidize the organic waste. Requires significant land area, but one of the few processes which is effective at treating pathogenic material. Natural process with no power/oxygen requirement. Often used to provide water of sufficient quality for irrigation, and very suited to hot, sunny climates.
Aerated lagoons	Like WSPs but with mechanical aeration	Not very common - oxygen requirement mostly from aeration and hence more complicated and higher O&M cost.
Oxidation ditch	Oval-shaped channel with aeration provided	Has more power requirement than WSPs, but has much reduced land requirement, and not as difficult to control as processes such as ASP (see below)
Rotating biological contactor (or biodisk)	Series of thin vertical plates which provide surface area for bacteria to grow.	Plates are exposed to air and then the sewage by rotating with about 30% immersion in sewage. Treatment is by conventional aerobic process. Used in small-scale applications in Europe.
Trickling (or percolating) filters	Sewage passes down through a loose aggregate bed - bacteria on aggregate treat sewage	An aerobic process in which bacteria take oxygen from the atmosphere (no external mechanical aeration). Has moving parts, which often break down in developing-country locations.
Activated sludge process (ASP)	Oxygen is mechanically supplied to bacteria which feed on organic material and provide treatment	Sophisticated process with many mechanical and electrical parts, which also needs careful operator control. Produces large quantities of sludge for disposal, but provides high degree of treatment (when working well).
*Upflow Anaerobic Sludge Blanket (UASB)	Anaerobic process using blanket of bacteria to absorb polluting load	Suited to hot climates. Produces little sludge, and no oxygen requirement (no power requirement) - but does not produce as high a quality effluent as processes such as ASP.

Notes: Other anaerobic processes exist, but UASB is presently the most common

* indicates processes more suitable for developing countries

5 CONDITIONS IN CASE STUDY TOWNS

The three selected towns cover three areas of Yemen. Damt is in the southern mountains, Abs in the northern Tihama and Khamir in the Northern mountains of Yemen. Figure 5-1 shows the location of the case study towns.

Figure 5-1: Location of the case study towns

5.1 DAMT

A map of Damt is included in Appendix A8 and a photo report in Appendix A4.

5.1.1 DESCRIPTION OF TOWN

5.1.1.1 Geography and History

Damt town is considered as tourist city, with many tourists coming for medical treatment. It is situated at 1900 masl, located at the main road to Aden (Sana'a- Al-Dalea- Aden), 190 km south of the capital city Sana'a, 65 km north of Al-Dalea Governorate. The climate is cool in summer and cold in winter. The development of Damt is related to its short history. Basically three areas can be distinguished as follows:

- the old town, situated at the Western bank of the Wadi
- the commercial area which can be divided into an old and a new commercial area, situated uphill from the old town.
- the high class area is situated at the upper and most Western part of Damt town which is enclosed by volcanic mountains.

The town of Damt is situated around a volcano. This volcano as well as the confined aquifer with sulphide hot water is a consequence by the highly specific (hydro-) geologic situation in Damt.

As Damt's early developments go back to the agricultural activities at the Eastern wadi banks, the oldest part of the town is found at the opposite wadi banks where the ground is unsuitable for agriculture due to the volcanic aquifer. Today this area is the most densely populated one and is still occupied by farmers who appear to be the group with the least economic resources.

Around the farmer's living area a small market and service area developed. Today this area which is sloping to the west is found between the old town and the Yarim – Aden road. Local groceries, workshops, tailors and the suq-area have been established along the unpaved entrance roads to the old town.

The asphalting of the road Yarim-Aden about fifteen years ago led to economic growth and an enlargement of the market area. Along and close to the main road restaurants, modern hotels, brick factories, pump workshops and chicken farms developed, and governmental institutions shifted from Old Damt to Damt. The new commercial area is mainly characterised by wide but not asphalted streets and block buildings.

There are major tourist activities in Damt. Tourists come to Damt for medical treatment using the hot spring sulphate water. Also the climate is favourable.

5.1.1.2 Demography

The number of population in the district is about 55,000 including a number of small villages and ozlas (villages).

The population in Damt City is about 18,000 persons. There are approximately 1400 families. The family size in the area is 12-14 members with a family consisting of the grand parents, parents and cildren and grand children, all living in one house. The overall number of houses in the town of Damt amounts to about 1700 houses.

The houses visited during the site visit all had one floor and 2-3 rooms.

The target group interviewed were mainly housewives, illiterate but understood the aim of the mission. They were between 20-30 years old. Only very few inhabitants do have a higher education. .

5.1.1.3 Environment

The town is growing fast and migration is taking place from other areas in Yemen into Damt. The town is not yet administratively well organised. It looks very dirty.

Solid waste is only collected at the main places and main roads (i.e partially) once per week. Serious littering of the entire town and the wadi can be observed. Solid waste in the drains and wadi causes obstruction of flow resulting in bad smelling stagnant pools inside the town. Solid waste consists of plastics, tins, cloths, slaughter waste and is disposed of everywhere in the town. A number of provisional dump sites exist, where the waste is abandoned or burned.

Most of the roads are not paved, which leads to dusty conditions through traffic in the town.

The continuous flow of the artesian wells and hot springs encourages the women to wash clothes outside their houses beside theses wells. As no provisions for washing are existing at these sites, littering and accumulation of solid waste at these places occurs and wet conditions lead to fouling, bad smell and mosquito breeding.

From the northern part of the city wastewater is discharged into a channel flowing towards the wadi. This wastewater is mixed with the hot springs water flowing directly from the wells or from the houses into the channel. Hot water mixed with the wastewater flow the channel stinks, looks ugly and is expected to cause health risks. This wastewater is stagnates in the wadi, infiltrates there and pollutes the shallow groundwater pumped from shallow wells mainly for agricultural use.

The western part of the city is situated on rocky soil, which makes it expensive to connect to the channel or to construct on-site sanitation, such as cess-pits. Some households therefore discharge wastewater into the streets, while some of population goes out for excreta disposal.

5.1.1.4 Economy

In Damt the average family income ist estimated to be about 10.000 to 25.000 YR. Beside tourism farming is the main conomic activity in Damt. Farming in this district is seasonal, with rainfall being the main water source. The rainfall is seasonal but some crops are grown the whole year depending on the wells.

The nearest agricultural fields of Damt are located at the banks of the outside corner of the wadi passing the old town. From the aerial map of 1989, it is already clearly shown that the borders of this agricultural area are bound by its physical constraint of fertile soil and that no further extension is to be expected. Small-scale agriculture provides mainly the income for the inhabitants of Damt living in the old part of the town, located along the wadi.

The food crops are irrigated by shallow wells (about 3 to 10 m deep) which have been dug at the banks of the wadi. Since most agricultural wells are drilled to the shallow aquifer the water quantity and quality of irrigation water pumped from these wells depend strongly on the water quality in the wadi and the rainfall history of that year. Also, farmers construct small and temporary dams to increase the storage and enhance infiltration of water from the wadi.

At the southern side of this agricultural area, some small natural hot springs exist indicating the presence of the volcanic aquifer. As long as sufficient sweet water is available in the wadi and/ or stored in the area, the crops are not damaged by the volcanic water.

North and South West of Damt small-scale agricultural fields are following the banks of the wadi where suitable soil and fresh water aquifers are available. Food crops and grains dominate the cultivation but farming of qat is present as well.

At about 2 to 10 km east of Damt in the direction of Juban, qat is farmed in the valley. The qat is irrigated from the same aquifer, which supplies Damt and its surrounding villages with drinking water. The private agricultural wells (about 20) and the two SURWAS wells abstract water from approximately 200 m depth. The qat farming seems to make good business, which becomes obvious at the village Haql al Farid where a number of beautiful villas have been built and are being constructed. The village in its whole gives a wealthier impression than other villages nearby.

Villages and households within the water project without sufficient resources for the growing of qat depend on small-scale seasonal agriculture of food crops and extensive stock breeding (sheep, goats and cows).

Some poultry farms are located some kilometres out of town mainly along the main road Yarim-Aden and Damt-Juban.

In general, the area has good soil for growing a variety of crops (fruit and vegetable). Qat planting plays also a major role and a lot of water is used for growing of qat. The main crops in the district are corn, fruit like guava and mango, vegetables such as potatoes, tomatoes, coffee and qat.

Most of the women are illiterate; they suffer from a difficult economic situation, and cannot contribute to the family's income. In and around the villages a woman only can work in her family's farm. Women produce local food such as Ghee and Milk, and take care of Qat plants. Also women and girls produce handcrafts such as plates of corn stems products from the palm trees, and in sewing clothes and embroidering. The local products need to compete with imported products and do generally not generate enough income to enhance significantly the families living standards. Only a small number of women get employment opportunities in fields such as teaching, nursing and midwifery. It is noticeable that no specialised associations exist concentrating on women empowerment.

Men in the villages work on their properties as farmers, they grow crops and Qat. They travel to the town centre once a week in order to market their products. In the town, working opportunities include work in stores, groceries, or in the small Qat shops. Some established small block factories and some established gas and oil stations, mechanic garages ,and craft works like (Al-Qamrea- made of gypsum with differently coloured glass) the typical Yemeni windows exist. Few people invest in the hot spring water, rent small baths (Sauna) and sell bathing products.

Damt is considered as a tourist city with its medical hot springs sulphate water. Tourists are approaching Damt mainly for bathing.

5.1.1.5 Administration

A number of governmental and private institutions exist in Damt as listed below.

Governmental institution	Private Institution
Court branch	Local council
Security administration	Al Moatamar Party branch
District administration	Al Islah Party branch
Political security	Communist Party branch
Construction, housing and urban planning	Economic corporation
Telecommunication office	Water committee
Electricity office	Teachers union
Tax office	Drivers union
Duty office	Local sport club
Supplementary and trading office	
Health office	
Culture office	
Tourism office	
Education office	
Agriculture and water resources office	
Finance office	
Post office	
Traffic administration	
Information office	
Governmental Real estate	
Office branch of Ministry of Endowment	

5.1.1.6 Education

The education indicators show that the illiteracy rate is high among male and female, with various factors leading to this situation:

1. Education services cannot cope with the population figures. There are only five schools for about 2480 students (1430 boys and 1050 girls. These numbers show the great gap between the girls and boys school enrolment.
2. Families rather keep girls indoors or get them work on the families farm instead of sending them to school. Girls are responsible for the household while parents are busy at the farm, they help feeding the livestock, produce butter ,milk sheep and cows, etc.
3. Families do hardly allow co education of boys and girls. Lack of female teachers leads to the fact that girls join school together with boys only until they reach grade 6.

4. Families living away from urban centres refrain from sending their children to the schools, which are mainly located at the centres.

5.1.1.7 Health

The health services do not meet the requirements. There are 8 health centres and units for cases such as malaria, typhoid, kidney sickness and vaccination services, family health and planning. These centres are not well equipped and the cadre is not sufficiently qualified. Therefore more serious cases are not treated in these centres. On the other hand the population is normally not in a position to pay for treatment in costly private clinics or hospitals.

Many health problems are caused by a lack of safe drinking and irrigation water, poor sanitary conditions and poor education and awareness of hygiene.

The health indicators for the year 2003 show 5040 Malaria, 4320 Diarrhoea, 5020 Parasites, 2320 Schistosomiasis cases.

5.1.2 CONDITIONS OF WATER SUPPLY AND SANITATION

5.1.2.1 Water resources and water usage

There are a number of water resources in Damt, which are used for various purposes as follows:

1. Fresh water and drinking water:

   The Damt water supply project serves 13 villages and the town of Damt. Two wells are situated about 10 km to the Eastern side of Damt. The water is pumped to a nearby reservoir situated half way up the western slope flanking the wadi. The circular tank, which was ready in 1994, is in good shape except for some places at the bottom where very small leakages occur.

   These two wells, each with approx. 580 m³/day capacity are the main drinking water source of the town. Presently only one well is working. A centralised water supply network exists to which approx. 1400 households are connected. The water tariff is 100 YR/m³ for the public water supply. However, the water supply system suffers from operational problems, which lead to interrupted supply. Losses in the system are in the range of 30%. Therefore a large portion of the population relies on the supply through water tankers, the costs for water from tankers being 600 YR/ m³.

   During town visit and interviews it was observed that fresh water is expensive and therefore people tend to reduce their usage of water to a minimum. Especially women in the old town go out and try to make use of the other sources as upstream wadi water and volcano water for washing of clothes and dishes. Water in the houses (tanker or water supply project) is mostly used for drinking, cooking and body washing.

   Poorer parts of the population (also some of the interviewed households) need to bring water for drinking and domestic use from long distance in plastic bottles of 10 -20 litre. This is the duty of the women and even small girls of 10-14 years age are involved in such suffering and hard work. The water is carried from tanks near the mosques and from tanks made of cement offered by charity organisations and private persons.

2. Hot springs

   Hot springs in the vicinity of the city around the big (high) hot spring (volcano or Haradah), especially along the Wadi Bana.

   There are several hot springs (Hammams) around the Big Haradah, namely Hamman Al-Dordosh, and Hammam Al-Hasasiah.

   Also there are 7 volcanic openings (Haradahs), three of which are active. The big Haradah rises 150m high above the surrounding, and has a 50 m wide opening at the top. The second Haradah is called the small Haradah. The third Haradah is called Al-Tahah and is located at the west bank of the Wadi Bana.

   Water quality is brackish with a TDS (total dissolved solids) exceeding 1600mg/l. This water is not suitability for drinking or irrigation without prior treatment.

3. Artesian wells

   During recent years, local people drilled 4 such artesian wells (named Hamoud Atef, Al-Dhulaimi, Al-Asady and Al-Awdy) in order to utilize the water for medical treatment. This water is considered healthy due the physical properties (temp 37-49 C) and chemical properties of the water (sulphate). These wells have been dug without supervision or permission by authorities and no hydro-geological investigations have been conducted. Wells have been drilled through the impervious layer covering the aquifer and are 120 to 175 m deep. Water flows continuously at rate of 173 l/sec and with 0.3 to 0.9 bar pressure. The total hotwater discharge of springs plus artesian wells is estimated to 350 l/s.

   Hot water from the artesian wells is presently not properly utilised, but it is discharged mainly unused directly to the wadi. A rough estimate is that 7 million cubic meter per year are being discharged from the 4 wells and the hot springs in Damt.

   It mixes with untreated wastewater and causes environmental problems such as wet areas with mosquito breeding.

   Within the farmers' area and local commerce area, the hot water of the volcano aquifer was explored and bathhouses established near and around the volcano. Some individual households connected themselves to the volcano by hose pipes and are receiving volcano water inside the houses.

4. Shallow hand-dug groundwater wells.

   These wells are located in the wadi and are fed from water infiltrating in the wadi. The water from these wells is mainly used for irrigation purposes.

5.1.2.2 Wastewater disposal

A wastewater project with a centralised, conventional sewerage system is planned. The costs for this system are estimated to 1.7 Million Dollar.

Presently, no centralised sewerage system exists in Damt and no pubic sanitation service is provided. All sanitation facilities are private. Approx. half of the households discharge their wastewater directly through private pipes to the wadi and the other half to cesspits in the streets.

There is a channel leading from the biggest artesian well through the town to the wadi. This channel serves as a main wastewater disposal facility to which a large part of the town's households is connected.

In the town of Damt the following methods are used for disposal of domestic wastewater:

- The households in old town and in the vicinity of the open channel discharge their wastewater to the wadi and channel. Many of these pipes are improperly constructed or broken, leading to discharge to the streets.
- Part of houses in the upper new part of town discharge to a cess-pit. They are very few in number because cesspits would only be constructed under three preconditions:
    - The house is located far from the open drains or wadi (there is no way to connect to the wadi).
    - The family has enough financial resources (a cesspit of 3*4*5 m depth costs YER 300,000 due to the necessity of using dynamite)
    - The house is located far enough from the volcano (otherwise you may coincidentally bore a hot spring)
- Some households without connection to the wadi or a cess pit discharge their wastewater directly to the streets.

The old part of Damt at the wadi banks, inhabited mostly by farmers is characterised by low drinking water consumption and basic housing of this group compared to the other groups in Damt. Due to three reasons this area suffers most from sanitation problems:

- Lack of financial resources leads to bad of maintenance of latrines and drainage facilities.
- The high population figure and housing density cause a stronger impact of health risks caused by sanitation problems.
- The low position of the area makes it the receiving area of almost all the waste water of the upper town.

Water from the hot springs and artesian wells water is running continuously for 24 hrs daily to open drains. The main open drain discharges into the wadi just upstream of the old town.

Some wastewater samples have been taken in Damt and analysed in the Central Health Laboratory in Aden. The results are as follows:

Location	COD	SO4	PO4	NH4	pH
-	mg/l	mg/l	mg/l	mg/l	-
Artesian well water		342			
Open channel downstream of artesian well after clothes washing place	108	300	34	0.06	7.2
Wastewater pipe to channel	272	220	35	14	6.6
Open channel inside town	228	270	30	13	8.1
Retention pond in wadi	588	248	32	15	8.3
Effluent of retention pond	528	248	32	15	8.4

5.1.2.3 Artesian and spring water

It may be technically possible to reduce the run off of artesian well and spring water (needs to be investigated) by closing of wells (springs). A reduced flow from the two main volcanic springs can reduce the discharge of the open drains significantly. This will have positive impact on the sweet water resources in the agricultural fields East of Damt as the ratio of rain water/ volcano water in the wadi will rise compared to the present situation. A positive impact can then be expected on agricultural fields located downstream, which depend on the shallow wells at the wadi banks. Agriculture at the wadi banks in and downstream of Damt therefore has a strong interest to keep the sulphide volcano water separated from sweet groundwater.

Another positive impact of reducing the permanent flow of volcano water may be the safeguarding of a controlled exploitation of the volcanic aquifer, which has large economic potentials.

Three negative impacts of reducing the flow of volcanic springs can be mentioned. Firstly, the presently existing open drains may under those circumstances not carry sufficient water to ensure a fast removal of household wastewater and faeces out of town which may result in the accumulation of sludge in the open drains. Due to the existence of the open drains and the impossibility for on-site sanitation, households historically connected their latrines to the open drains and wadi.

Secondly, reducing the flow of volcanic springs may result in an increased use of fresh water by households, because presently many households go to the volcanic springs for clothes and dish washing. There is a risk that the problem will shift from a controllable point source to a disperse source.

The third negative impact mentioned may be that most volcanic springs are running continuously to ensure a certain level of hygiene in bath houses. Reducing the quantity of volcano water may result in a stagnation of tourism development.

5.1.2.4 Organization of the water sector

A water project granted by the Dutch government has been constructed since 1996. It serves the city and 7 villages. Presently it is operated by the AUTONOMUS management and supervised by the Local Council. It is intended to hand over the operation to NWSA after establishment of a NWSA branch.

5.1.3 DAMT, PRE-SELECTION OF AWS OPTIONS

Regarding the pre-selection of sanitation systems, the site conditions found were as follows:

1. As explained in above the current situation without proper sanitation system causes severe problems with contamination of natural water resources (groundwater, surface waters) and especially malaria (anopheles "nursing fields" along the rivulet and Wadi).

   *One essential task of a proper sanitation system is to **prevent** such severe **malaria** problems.*

2. As the chemical analysis and the site survey have shown (see chapter 5-1), the rivulet crossing the town and ending in the Wadi has a strong self-purification power, which (anyhow) is not strong enough to prevent anaerobic conditions and visible pollution along the whole rivulet, even in the city centre.

   *A new sanitation system should assure **sufficient reduction of pollution** loading and littering of the **rivulet** and river banks at minimum to a level, which avoids odours and visible water pollution.*

3. The geo-hydrological conditions of Damt are very specific. The volcanic underground contains caves, and wastewater discharge to the underground can directly flow into the groundwater without reliable filter effect.

   *The sanitation system should, maybe with exceptions on specific locations, prevent that untreated wastewater is dismissed to the **underground soil**.*

4. Down the valley, there is a strong demand for agricultural irrigation (surface water intake, see photos in appendix A4).

   *The favoured sanitation system must deliver **irrigational waters** of sufficient quality for agricultural purpose, to be collected from the Wadi-site.*

5. Part of the existing water supply system of Damt are the so-called "Hamam Waters", from artesian wells, hot springs etc. Many houses connected to such wells, operate a 24 hours/day, 365 days/year continuous toilet flushing.

   Anyhow, it is intended to close some artesian springs and some wells, and to disconnect the outflowing waters from the water supply system.

   *A major precondition of essential importance is, whether the **Hamam Waters** will be disconnected from the water supply system or not. The sanitation system of choice should take account of this fact.*

6. Damt is a new town with house installations. It seems unlikely that major changes with the existing house installations and the way of wastewater collection in one single pipe could be realised against the resistance of house owners and inhabitants.

*The sanitation systems to be discussed further must base on this **existing house installation** (no separation of black waters/grey waters/yellow waters etc.), and avoid the (probably high) costs to change the sanitation equipment of houses (toilets, bath, kitchen) and the in-house piping for wastewater collection.*

7. Many houses, especially in the new zones, larger houses, and most public houses, are equipped with cess pits, often just finished in construction, with investment costs between 300,000 and 400,000 YR.

   *The sanitation system of choice should take into account and - if possible - make use of the existing wastewater **cess pits**.*

8. Except for two main roads, all roads in Damt City are unpaved. Sewers and man-sewers already built were broken in some places, manholes in the middle of the road were distorted, broken sometimes.

   *The sanitation system, especially the sewerage, must withstand the ongoing **road construction process**, until the roads are finished and equipped with asphalt layer.*

9. It will be an ambitious (and unavoidable) task to raise awareness of the Damt population to keep the water ways clean, to refrain from disposing of garbage and solid waste into the rivulet and wells.

   *The sanitation system of choice should not overstretch the understanding and operational skills of the consumers, but (instead) be **very simple** and easy to operate and control.*

10. The City of Damt is planning to develop its tourist attractions (namely the volcano, the artesian well, the thermal bath caves etc.).

    *The sanitation system of choice should allow tourist activities, without creating nuisance by **odours, flies, noise** etc.*

11. In some locations, housing areas, the **soil conditions** are not favourable to install underground facilities: Sometimes very hard rocks would have to be cut or broken, sometimes the groundwater level is very high (so that technical means to stabilise tanks underground would have to be realised).

    The facilities necessary for the favoured sanitation system should not raise additionally, unacceptable high costs in case that rocks or high groundwater levels are existing onsite.

12. Due to the volcanic geo-hydrological circumstances, soil and ground waters in some locations of Damt are highly aggressive.

    *Materials used as underground equipment of sanitation systems should withstand **corrosion**.*

13. Damt is a growing town, above the national average (Yemen pollution growth in average is around 3.5 % p.a.). Some experts estimated that, including immigration from rural areas, the population growth of Damt reaches 10 % p.a. The site survey

revealed that new house estates are under preparation, which might add one third of additional population to Damt.

*The sanitation system of choice must be able to grow "with the town" and allow **flexible extension** following the development, not basing on design criteria of a finally predicted capacity.*

14. The existing water supply system of Damt is not covering all districts, and not with water of equal quality and pressure. Even more, the water supply utility has defined different zones which are supplied with water in a rotating system (zone 1: every Monday, zone 2: every Tuesday etc.).

    *The introduction of a sanitation system, consisting of a **combination of different** site-specific **solutions**, with differences in service comfort and (maybe) service charge, would not introduce a totally new experience for the citizens of Damt.*

15. A very important issue is the institutional framework and the culture of mutual co-operation between public respectively municipal institutions and private households, enterprises: As found during interviews and site-survey, there is quite a low credibility for public service for the reliability and quality of public service onsite of the private. Households and enterprises have their experiences with short cuts of water supply and chaotic utilisation of well-sites (with women and children washing clothes etc., polluting the water directly at the spring). On the other side, the municipal water utility is enforced, by its experiences, and not to rely on honest customers.

    *As far as grants are not available, all refinancing must be realised out of a low "cash-flow". Any system with high requirement of pre-financing will be much more difficult to realise. A sanitation system should be preferred, which can be **built stepwise**, as the income of the water utility and the volume of wastewater customers served grows.*

16. As the income per capita in Damt is lower than in other cities which have been researched so far, the level of affordability for sewerage charges seems to be significantly lower than 1,000 YR per month.

    *The total costs for the sanitation system (CAPEX + OPEX) must be lower than the total of grants, soft loans, tax contributions and **sewerage charges** significantly below 1,000 YR/month.*

These site conditions found can be understood as criteria for the pre-selection of AWS-options out of the spectrum of alternative sanitation systems as discussed in chapter 4. The options listed in the following pre-selection table are mainly the same as the ones that have already been described with table 4-3. Some modifications have been introduced (the options are not classified in central or de-central, but in separate/combined collection wastewater streams; the wording has been slightly modified according to terms used in IWA working groups etc.).

Table 5-2: Viability of AWS-Options for Damt (Fulfilment of Pre-Conditions)

	Site-specific Pre-Condition / AWS-Option	Pre-condition 1 *Malaria Prevention*	Pre-condition 2 *Canal Protection*	Pre-condition 3 *Ground-water Protection*	Pre-condition 4 *Irrigational Waste-water Reuse*	Pre-condition 5 *Hamam Waters*	Pre-condition 6 *House Installation existing*	Pre-condition 7 *Existing Cess Pits*	Pre-condition 8 *Road Pavements*	Pre-condition 9 *Operational Simplicity*	Pre-condition 10 *Low Atmos-phere Emissions*	Pre-condition 11 *Local Soil Conditions*	Pre-condition 12 *Under-ground Corrosion*	Pre-condition 13 *Flexible Extension*	Pre-condition 14 *Combi-Solutions*	Pre-condition 15 *Stepwise Invest-ments*	Pre-condition 16 *Affordable Sewerage Charge*
1	**Separate Collection of Faeces and Wastewaters**																
1.1	Ordinary pit latrine, grey water dis-charged on-site	?	?	⚡	?	√	⚡	√	√	√	?	?	√	√	√	√	√
1.2	Bucket Sanitation, grey water discharged on-site	?	?	(√)	?	√	⚡	√	√	√	?	(√)	√	√	√	√	√
1.3	Cess pit, grey water discharged on-site	?	?	?	?	√	⚡	√	√	√	(√)	?	√	√	√	√	(√)

Explanation: The symbol indicates, whether the AWS-option under discussion fulfils the pre-condition

? = questionable √ = fulfilled, OK (√) = can be fulfilled with exceptions ⚡ = No, impossible, this leads to exclusion of AWS-option

Site-specific Pre-Condition / AWS-Option		Pre-condition 1 *Malaria Prevention*	Pre-condition 2 *Canal Protection*	Pre-condition 3 *Ground-water Protection*	Pre-condition 4 *Irrigational Waste-water Reuse*	Pre-condition 5 *Hamam Waters*	Pre-condition 6 *House Installation existing*	Pre-condition 7 *Existing Cess Pits*	Pre-condition 8 *Road Pavements*	Pre-condition 9 *Operational Simplicity*	Pre-condition 10 *Low Atmos-phere Emissions*	Pre-condition 11 *Local Soil Conditions*	Pre-condition 12 *Under-ground Corrosion*	Pre-condition 13 *Flexible Extension*	Pre-condition 14 *Combi-Solutions*	Pre-condition 15 *Stepwise Invest-ments*	Pre-condition 16 *Affordable Sewerage Charge*
1.4	Septic tank, grey water discharged on-site	?	?	(√)	?	√	⚡	√	√	√	?	?	√	√	√	√	√
1.5	Septic-tank, grey water discharged to controlled trench resp. percolation	√	(√)	√	?	√	⚡	√	√	√	√	(√)	√	√	√	√	√
1.6	ECOSAN (separate collection, on-site treatment and utilisation of black, yellow and grey waters)	√	√	√	√	?	⚡	?	√	⚡	(√)	(√)	√	√	(√)	√	?

Explanation: The symbol indicates, whether the AWS-option under discussion fulfils the pre-condition

? = questionable   √ = fulfilled, OK   (√) = can be fulfilled with exceptions   ⚡ = No, impossible, this leads to exclusion of AWS-option

Site-specific Pre-Condition / AWS-Option		Pre-condition 1 *Malaria Prevention*	Pre-condition 2 *Canal Protection*	Pre-condition 3 *Ground-water Protection*	Pre-condition 4 *Irrigational Waste-water Reuse*	Pre-condition 5 *Hamam Waters*	Pre-condition 6 *House Installation existing*	Pre-condition 7 *Existing Cess Pits*	Pre-condition 8 *Road Pavements*	Pre-condition 9 *Operational Simplicity*	Pre-condition 10 *Low Atmos-phere Emissions*	Pre-condition 11 *Local Soil Conditions*	Pre-condition 12 *Under-ground Corrosion*	Pre-condition 13 *Flexible Extension*	Pre-condition 14 *Combi-Solutions*	Pre-condition 15 *Stepwise Invest-ments*	Pre-condition 16 *Affordable Sewerage Charge*
2	**Combined Collection of Faeces and Wastewaters**																
2.1	Storage tank, regularly emptied by sewage trucks	√	√	√	(√)	√	(√)	?	√	(√)	√	√	√	√	√	?	⚡
2.2	Septic tank (interceptor tank) with on-site discharge of pre-treated sewerage	?	(√)	(√)	?	√	√	√	(√)	√	(√)	?	√	√	√	√	√
2.3	Septic tank (interceptor tank) connected to small bore sewerage for solids-free wastewater	√	√	√	√	√	√	(√)	(√)	√	√	√	√	√	√	√	?

Explanation: The symbol indicates, whether the AWS-option under discussion fulfils the pre-condition

? = questionable √ = fulfilled, OK (√) = can be fulfilled with exceptions ⚡ = No, impossible, this leads to exclusion of AWS-option

Site-specific Pre-Condition / AWS-Option		Pre-condition 1 *Malaria Prevention*	Pre-condition 2 *Canal Protection*	Pre-condition 3 *Ground-water Protection*	Pre-condition 4 *Irrigational Waste-water Reuse*	Pre-condition 5 *Hamam Waters*	Pre-condition 6 *House Installation existing*	Pre-condition 7 *Existing Cess Pits*	Pre-condition 8 *Road Pavements*	Pre-condition 9 *Operational Simplicity*	Pre-condition 10 *Low Atmos-phere Emissions*	Pre-condition 11 *Local Soil Conditions*	Pre-condition 12 *Under-ground Corrosion*	Pre-condition 13 *Flexible Extension*	Pre-condition 14 *Combi-Solutions*	Pre-condition 15 *Stepwise Invest-ments*	Pre-condition 16 *Affordable Sewerage Charge*
2.4	Small STP with on-site discharge of purified wastewater	(√)	√	√	?	√	√	?	√	⚡	√	√	√	√	√	√	?
2.5	Full or intermediate flush toilet with simplified sewerage	√	√	√	√	√	√	?	?	√	√	√	√	?	√	?	?
2.6	Full flush toilet with conventional sewerage	√	√	√	√	√	√	√	√	?	√	√	√	?	?	?	⚡

<u>Note:</u> The technical conditions were found to be quite different within the selected town. The pre-selection is focused on the dominating conditions and the prevailing AWS-options. This does definitely not mean that other AWS-options, even those which have been totally excluded, would not be reasonable for selected houses or especially clusters of selected houses ir the town - even though these would be exceptions compared with the favoured AWS-option.

Explanation: The symbol indicates, whether the AWS-option under discussion fulfils the pre-condition

? = questionable   √ = fulfilled, OK   (√) = can be fulfilled with exceptions   ⚡ = No, impossible, this leads to exclusion of AWS-option

5.2 ABS

5.2.1 DESCRIPTION OF TOWN

5.2.1.1 Geography and History

Abs is located in the Tihama near to Harad, one of the gates to Saudia Arabia. It is surrounded by 9 villages. Abs is a centre of the region and provides the neighbouring areas with services such as educational, health, and economic services.

Trading activities have a long tradition in Abs due to the location at one of the main roads between Yemen and Saudi Arabia and its vicinity to the border. Abs is a resting place for merchants on their business trips to Saudi Arabia.

The climate is very hot and humid with summer temperatures reaching 40°C. The houses in the Old City of Abs are built in the traditional way from straw and clay and the thick walls protect the inhabitants from the hot weather. Sandy soils in the Abs plain tend to cover plantations in windy conditions and farmers plant trees around the farms to stop the sand.

Water is very scarce in Abs. Water supply for irrigation purposes depends largely on rainfall and groundwater. There are about 800 agricultural wells, 400 of them for irrigation of the Mango plantations in the Aljar area.

5.2.1.2 Demography

Abs has approximately 30,000 inhabitants and a very high population growth rate. The fertility rate is high, early marriage is common, there is no family planning and illiteracy is widespread. The mortality rate is high because of the insufficient curative and preventive health services. The life expectation is between 55 to 60 Years.

5.2.1.3 Environment

The city is relatively clean because the office of the Ministry of Public Works in Abs manages the solid waste collection under the umbrella of the Local Council. Still, some garbage is burned in the yards of the houses or in public places.

No centralised sewerage system exists in Abs, but wastewater is disposed off decentralised. Health problems arise from the habit to dispose grey water to the streets.

In winter pollution problems increase and insects breed widely. This causes water borne diseases such as malaria.

5.2.1.4 Economy

Poverty is a serious problem in Abs among the population. The families largely depend on the men, who are mostly generating the family income, which is estimated between 20.000 and 25.000 YR.

Agriculture is the main source of income in Abs. The main crops are sesame, wheat, corn, maize, fruit and vegetable. Mango plays a major economic role and is also exported to Saudi Arabia. Palm trees are planted around the cultivated lands to protect them from the winds and sand. Qat is also grown, and creates income to farmers.

Most farms have wells (in average 2 wells) to cover the needs for irrigation water and domestic use. The farmers also sell water to the truck owners, who sell this water to the households in the town.

There is almost no industry in Abs. Some activities are based on the agricultural sector and include packing and canning fruits and vegetables. These activities are small private enterprises set up in order to top up the family income.

Trading employs a number of people due to the location of Abs at the road to Saudi Arabia.

There are some Government Offices in Abs giving work and income to a number of people. Also there is employment in the field of teaching and nursing.

Besides their work in the farms, women top up the family income with handicrafts, pottery, sewing, and embroidery. However, these activities generate only very limited income.

Abs has no major tourist attractions and does not have the infrastructure like hotels and restaurant to accommodate tourists. Furthermore the electricity and water supply are not sufficient and the high temperature and humidity especially in summer is not pleasant for tourists.

5.2.1.5 Administration

The local council has a cooperative relationship with many other governmental departments, such as security department, criminal investigation department, education department, transportation department, housing department, commercial department, taxation department, electricity department, population and public health department, primary court department, and the social care fund department.

5.2.1.6 Education

No accurate numbers of the schools and of the students in the area can be obtained, because of the lack of the statistic data. A first impression is that educational service does not cover the area sufficiently and the rate of illiteracy is high. Only few primary and secondary schools exist in Abs. These schools are not well equipped and have poor facilities while some schools need to be rehabilitated or rebuilt because they are in a very bad condition.

Many children living in the countryside do not go to school for the following reasons:

1. Their families cannot bear the cost of the transportation to reach the schools.
2. The families do not send their children to school because they need them in farms.
3. The families are mostly poor cannot bear the costs for bags, uniforms, copies, pens, etc.
4. Lack of awareness.

5.2.1.7 Health

Generally, the health situation appears to be bad. The majority of the inhabitants are classified as poor, they mostly suffer from several diseases mainly malnutrition, which cause less resistance against the environmental diseases such as Malaria, Diarrhoea, Typhoid and Cholera. The health service provided in the area does not cover the basic needs. Hospitals only receive the very simple cases; they have sections for first aid, family planning, immunization. The houses are very small compared to family size, thus favouring the transmission of diseases within the families. Also there is a lack of awareness towards personal hygiene.

5.2.2 CONDITIONS OF WATER SUPPLY AND SANITATION

5.2.2.1 Water resources and water usage

There is a piped water supply system under construction in Abs but it has not been finalised. It has been constructed in steps and by different contractors and some problems with the main junctions, valves, etc, have not been solved. At present no construction activities are ongoing.

Top priority of the population of Abs is therefore the finalisation of this piped water supply system, because until now they rely on expensive tanker truck supply. The impression of the mission was that the population feels no serious sanitation problem.

The water source for the water project under construction consists of 3 deep wells (200 m deep) at Al-Garr, a place approx. 20 km West of Abs. The production of each well will be around 30-40 m^3/hr or total production 1100 m^3/day. A pressure main leading from the well field to Abs has been constructed and connected to concrete reservoir (tank) on a hill to the east of Abs. A number of 2030 house connections have been installed. The remaining and not yet completed part of the project is the distribution network. This project is financed by NWSA and executed by a local contractor.

In the area of the well field there are Mango farms (6000 ha) pumping water from the same aquifer and using drip irrigation.

There are also three desalination plants supplying some drinking water at Al Robo, Safer, and Abs.

The water for house holds is presently brought by tankers a rate of 200 YR/m^3 from shallow open hand-dug wells located east of Abs at. These wells are normally recharged by rainfall. 10 shallow wells (depth of 10-12m) exist East of Abs, with an estimated total water production of 500 m^3/day. This is the only source of potable water for Abs. The estimated water consumption in Abs is 20 l/c/d in Winter with 40 l/c/d in summer.

It has been concluded that there is not groundwater available inside the city. Trial holes up to 300 m depth showed no groundwater.

5.2.2.2 Wastewater disposal

No centralised sewerage system exists or is planned. Households mostly dispose the grey water to the streets. Black water is mostly disposed into a small cesspit of one meter depth and 2x2 m (width x length), which is located in the vicinity of the houses or in the streets. Since the soil is sandy, the walls of pits are constructed with stones and concrete. When the cesspit is full it is either evacuated with a vacuum truck or a new pit is excavated. As water consumption in Abs is generally low due to high water costs and water scarcity the existing cesspits can mostly cope with the water quantities without overflowing. Also the practice to dispose grey water to the streets extends the lifetime of cesspits.

Some households have no latrine and people go outside for urination and defecation or use the facilities of Mosques.

People take good care of cleanliness inside their houses. Also public areas in Abs are relatively clean.

5.2.2.3 Organization of the water sector

The water supply project under implementation is currently managed by NWSA and there is an intention of opening a NWSA branch once the supply system is operational. It is also supervised by the Local Council. A project manager for the water sector has been appointed by NWSA but since the project is not yet complete and operated he is not yet active.

There is no public sanitation project and sanitation is under the control of the Public Works Office.

5.2.3 ABS, PRE-SELECTION OF AWS OPTIONS

Regarding the pre-selection of sanitation systems, the site conditions found were as follows:

1. The current situation without proper sanitation system causes severe hygienic problems, especially the open discharge of faeces and grey water flows.

   The essential task of a proper sanitation system is to ***prevent*** *such severe* ***hygienic*** *problems.*

4. Down the valley, there is a strong demand for agricultural irrigation.

   The favoured sanitation system must deliver ***irrigational waters*** *of sufficient quality for agricultural purpose, to be collected from the Wadi-site.*

6. Abs is a new town with house installations. It seems unlikely that major changes with the existing house installations and the way of wastewater collection in one

single pipe could be realised against the resistance of house owners and inhabitants.

*The sanitation systems to be discussed further must base on this **existing house installation** (no separation of black waters/grey waters/yellow waters etc.), and avoid the (probably high) costs to change the sanitation equipment of houses (toilets, bath, kitchen) and the in-house piping for wastewater collection.*

7. Many houses, especially in the new zones, larger houses, and most public houses, are equipped with cess pits, often just finished in construction, with investment costs between 300,000 and 400,000 YR.

   *The sanitation system of choice should take into account and - if possible - make use of the existing wastewater **cess pits**.*

8. Except for two main roads, all roads in Abs City are unpaved. Sewers and man-sewers already built were broken in some places, manholes in the middle of the road were distorted, broken sometimes.

   *The sanitation system, especially the sewerage, must withstand the ongoing **road construction process**, until the roads are finished and equipped with asphalt layer.*

9. It will be an ambitious (and unavoidable) task to raise awareness of the Abs population to keep the water ways clean, to refrain from disposing of garbage and solid waste into the rivulet and wells.

   *The sanitation system of choice should not overstretch the understanding and operational skills of the consumers, but (instead) be **very simple** and easy to operate and control.*

11. In some locations, housing areas, the **soil conditions** are not favourable to install underground facilities: Sometimes very hard rocks would have to be cut or broken, sometimes the groundwater level is very high (so that technical means to stabilise tanks underground would have to be realised).

    The facilities necessary for the favoured sanitation system should not raise additionally, unacceptable high costs in case that rocks or high groundwater levels are existing onsite.

13. Abs is a growing town, above the national average (Yemen pollution growth in average is around 3.5 % p.a.). Some experts estimated that, including immigration from rural areas, the pollution growth of Abs reaches 10 % p.a. The site survey revealed that new house estates are under preparation, which might add one third of additional population to Abs.

    *The sanitation system of choice must be able to grow "with the town" and allow **flexible extension** following the development, not basing on design criteria of a finally predicted capacity.*

14. A centralised, piped water supply system is under construction in Abs. Presently people rely on tanker supply.

*The introduction of a sanitation system, consisting of a **combination of different** site-specific **solutions**, with differences in service comfort and (maybe) service charge, would not introduce a totally new experience for the citizens of Abs.*

15. A very important issue is the institutional framework and the culture of mutual co-operation between public respectively municipal institutions and private households, enterprises: As found during interviews and site-survey, there is quite a low credibility for public service for the reliability and quality of public service onsite of the private. Households and enterprises have their experiences with short cuts of water supply and chaotic utilisation of well-sites (with women and children washing clothes etc., polluting the water directly at the spring). On the other side, the municipal water utility is enforced, by its experiences, and not to rely on honest customers.

    *As far as grants are not available, all refinancing must be realised out of a low "cash-flow". Any system with high requirement of pre-financing will be much more difficult to realise. A sanitation system should be preferred, which can be **built stepwise**, as the income of the water utility and the volume of wastewater customers served grows.*

16. As the income per capita in Abs is lower than in other cities which have been researched so far, the level of affordability for sewerage charges seems to be significantly lower than 1,000 YR per month.

    *The total costs for the sanitation system (CAPEX + OPEX) must be lower than the total of grants, soft loans, tax contributions and **sewerage charges** significantly below 1,000 YR/month.*

Table 5-3: Viability of AWS-Options for Abs (Fulfilment of Pre-Conditions)

	Site-specific Pre-Condition / AWS-Option	Pre-condition 1 *Malaria Prevention*	Pre-condition 4 *Irrigational Waste-water Reuse*	Pre-condition 6 *House Installation existing*	Pre-condition 7 *Existing Cess Pits*	Pre-condition 8 *Road Pavements*	Pre-condition 9 *Operational Simplicity*	Pre-condition 11 *Local Soil Conditions*	Pre-condition 13 *Flexible Extension*	Pre-condition 14 *Combi-Solutions*	Pre-condition 15 *Stepwise Invest-ments*	Pre-condition 16 *Affordable Sewerage Charge*
1	**Separate Collection of Faeces and Wastewaters**											
1.1	Ordinary pit latrine, grey water dis-charged on-site	?	?	(√)	√	√	√	?	√	√	√	√
1.2	Bucket Sanitation, grey water discharged on-site	?	?	(√)	√	√	√	(√)	√	√	√	√
1.3	Cess pit, grey water discharged on-site	?	?	(√)	√	√	√	?	√	√	√	(√)

Explanation: The symbol indicates, whether the AWS-option under discussion fulfils the pre-condition

? = questionable √ = fulfilled, OK (√) = can be fulfilled with exceptions ⚡ = No, impossible, this leads to exclusion of AWS-option

Site-specific Pre-Condition / AWS-Option		Pre-condition 1 *Malaria Prevention*	Pre-condition 4 *Irrigational Waste-water Reuse*	Pre-condition 6 *House Installation existing*	Pre-condition 7 *Existing Cess Pits*	Pre-condition 8 *Road Pavements*	Pre-condition 9 *Operational Simplicity*	Pre-condition 11 *Local Soil Conditions*	Pre-condition 13 *Flexible Extension*	Pre-condition 14 *Combi-Solutions*	Pre-condition 15 *Stepwise Invest-ments*	Pre-condition 16 *Affordable Sewerage Charge*
1.4	Septic tank, grey water discharged on-site	?	?	(√)	√	√	√	?	√	√	√	√
1.5	Septic-tank, grey water discharged to controlled trench resp. percolation	√	?	(√)	√	√	√	(√)	√	√	√	√
1.6	ECOSAN (separate collection, on-site treatment and utilisation of black, yellow and grey waters)	√	√	(√)	?	√	⚡	(√)	√	(√)	√	?

Explanation: The symbol indicates, whether the AWS-option under discussion fulfils the pre-condition

? = questionable   √ = fulfilled, OK   (√) = can be fulfilled with exceptions   ⚡ = No, impossible, this leads to exclusion of AWS-option

	Site-specific Pre-Condition / AWS-Option	Pre-condition 1 *Malaria Prevention*	Pre-condition 4 *Irrigational Waste-water Reuse*	Pre-condition 6 *House Installation existing*	Pre-condition 7 *Existing Cess Pits*	Pre-condition 8 *Road Pavements*	Pre-condition 9 *Operational Simplicity*	Pre-condition 11 *Local Soil Conditions*	Pre-condition 13 *Flexible Extension*	Pre-condition 14 *Combi-Solutions*	Pre-condition 15 *Stepwise Invest-ments*	Pre-condition 16 *Affordable Sewerage Charge*
2	**Combined Collection of Faeces and Wastewaters**											
2.1	Storage tank, regularly emptied by sewage trucks	√	(√)	(√)	?	√	(√)	√	√	√	?	⚡
2.2	Septic tank (interceptor tank) with on-site discharge of pre-treated sewerage	?	?	√	√	(√)	√	?	√	√	√	√
2.3	Septic tank (interceptor tank) connected to small bore sewerage for solids-free wastewater	√	√	√	(√)	(√)	√	√	√	√	√	?

Explanation: The symbol indicates, whether the AWS-option under discussion fulfils the pre-condition

? = questionable √ = fulfilled, OK (√) = can be fulfilled with exceptions ⚡ = No, impossible, this leads to exclusion of AWS-option

Site-specific Pre-Condition / AWS-Option		Pre-condition 1 *Malaria Prevention*	Pre-condition 4 *Irrigational Waste-water Reuse*	Pre-condition 6 *House Installation existing*	Pre-condition 7 *Existing Cess Pits*	Pre-condition 8 *Road Pavements*	Pre-condition 9 *Operational Simplicity*	Pre-condition 11 *Local Soil Conditions*	Pre-condition 13 *Flexible Extension*	Pre-condition 14 *Combi-Solutions*	Pre-condition 15 *Stepwise Invest-ments*	Pre-condition 16 *Affordable Sewerage Charge*
2.4	Small STP with on-site discharge of purified wastewater	(√)	?	√	?	√	⚡	√	√	√	√	?
2.5	Full or intermediate flush toilet with simplified sewerage	√	√	√	?	?	√	√	?	√	?	?
2.6	Full flush toilet with conventional sewerage	√	√	√	√	√	?	√	?	?	?	⚡

<u>Note:</u> The technical conditions were found to be quite different within the selected town. The pre-selection is focused on the dominating conditions and the prevailing AWS-options. This does definitely not mean that other AWS-options, even those which have been totally excluded, would not be reasonable for selected houses or especially clusters of selected houses in the town - even though these would be exceptions compared with the favoured AWS-option.

Explanation: The symbol indicates, whether the AWS-option under discussion fulfils the pre-condition

? = questionable √ = fulfilled, OK (√) = can be fulfilled with exceptions ⚡ = No, impossible, this leads to exclusion of AWS-option

5.3 KHAMIR

5.3.1 DESCRIPTION OF TOWN

5.3.1.1 Geography and History

Khamer affiliates Amran Governorate. It is a very dry area with little agricultural area that can be used for cultivation.

The majority of the inhabitants are farmers working in their farms and living on their land. Qat plant is the main crop. The houses are constructed of stones, mostly of black and white stones built with traditional designs. Houses are sometimes built on rocky hills and on the mountains.

5.3.1.2 Demography

The population in Khamir city is about 15,000 and the indicators show a high population growth rate. Reasons are as in Abs. The rate of the mortality is also high because of the insufficient health services. The life expectation is 60 to 70 years. Land owners, and qat dealers are able to pay the cost of improved health services.

The family size in Khamir is about 15-20 members it is mostly an expanded family consisting of the grand parents, parents, children, and grand children all living in one house. Houses have mostly two to three floors and 6-8 medium to large rooms.

Interviewed inhabitants were mainly housewives between 20-30 years age. Few of the population have a higher education. Most people areilliterate. However, they were very respondent to the aim of the study because they take discussed water issues very serious because they touch their daily life.

5.3.1.3 Environment

Serious environmental problems in Khamir are mainly caused by a lack of solid waste collection and improper sanitation.

Because there is no proper sanitation, people discharge the wastewater houses to the street by pipes. The solid waste is collected in plastic bags and thrown to the street, also near to wells and water tanks. This behaviour causes spread of diseases like typhoid, malaria, diarrhoea etc.

Also the misbehaviour of the small shops, factories, and garage owners towards the solid waste disposal aggravates the situation.

The people in general live in unhealthy houses, which do not have enough space, light, and ventilation. The streets are very narrow and dirty because of the wastewater and solid waste disposal practices. There is also some lack awareness concerning environmental problems.

5.3.1.4 Economy

Agricultural activities are the main source of income in Khamir. However, only part of the land can be used for agriculture because most of the land is dry not fertile and water for irrigation is scarce. However people mainly depend on agriculture in spite of the lack water and fertile soil and it is still the most important source income.

The main crops in the area are maize, wheat, corn, vegetable and fruits such as grapes. All above mentioned crops are of minor importance compared to qat, which is much more profitable and is the cash crop for approx. 80% of the farmers.

The farmers depend on rainfall to irrigate their plantations. During the dry season, the farmers stop planting vegetable and fruits and concentrate on qat, which provides good income throughout the year. Qat irrigation consumes a large portion of the available irrigation water.

There are no industrial activities in Khamir.

Some income is generated through work in stores, groceries and Government employment opportunities in teaching field, nursing and governmental offices.

Women play a minor role in generating family income; most of them are housewives and work unpaid on the farms. Only a small number are employed with the Government in the field of teaching, nursing and midwifery.

Generally the monthly family income reaches 30000 - 60000 YR (US$ 180 - $ 300) and even sometimes more for those who have qat plantations.

Although Khamir city is an ancient town, it is not considered as a tourist place. Due water scarcity, the lack of sanitation and solid waste collection it is very dirty and does not attract tourism. Khamir does not have infrastructure for tourism like hotels, public transport and clean restaurants.

5.3.1.5 Administration

The administration of water project in the area is affiliated to NWSA.

The local council has a cooperative relationship with many other governmental departments, such as for security, education, health, agriculture, electricity, civil affairs, transportation, media, criminal investigation, culture, social care fund and administration.

5.3.1.6 Education

Educational institutions in Khamir are primary schools to college. There are 1570 pupils going to primary schools and 2,600 (also from villages close by) to secondary schools

The number of male students is higher than the number of female students. Main reasons for this fact include:

- The tradition of the community doesn’t encourage girls to reach the secondary level.
- Many families rather keep their daughters indoor preparing them for their future role as housewives and mothers.

- No separate schools for girls exist. The schools also lack separate toilets for girls, which drives them to finish school when they reach 5th grade.
- There is a lack of female teachers.

5.3.1.7 Health

Reliable statistical figures on the number of population benefiting from the public health service in the area are not available. The majority of the inhabitants depend on the government health services in particular those who suffer of the environmental diseases. Only part of the population is in a position to bear the cost of treatment in private clinics or hospitals.

Al-Salam hospital in Khamir recorded the following numbers of cases in the year 2003, most of which are caused by a malfunctioning water supply and a lack of sanitation:

431 typhoid cases, 2081 kidney diseases, 1240 intestinal parasites, 2706 diarrhoea cases, 1131 malaria cases, 410 bilharzias cases. The hospital received some cases of dermal sickness caused by the use of salty water. Inhabitants suffer from kidney failure/ stones, brown teeth, and urination problems in Khamir due to highly saline water.

The public hospital has two main sections, the preventive section and the curative section. The preventive section conducts vaccinations, conducts spray campaigns to prevent flies and mosquitoes spread, and initiates awareness campaigns for men and women also for students at schools and health education. Curative services included the treatment of environmental diseases, the provision of free medicine and x ray services. The hospital staff consists of 46 physicians and assistants, 7 technicians, 1 laboratory specialist and 10 workers.

Though the public health service is offered free to the population, still many seek help in private hospitals and centres to find better service especially in serious cases.

5.3.2 CONDITIONS OF WATER SUPPLY AND SANITATION

5.3.2.1 Water resources and water usage

There is a public water supply network available, to which approx. 1200 houses are connected (about 1200* 15 persons). The public wells fell mostly dry and the remaining well provides salty water. This water and also the water used in the Mosques is <u>not suitable for drinking</u>. The water production fell from originally 900 m³/ d to now 300 m³/ d. The water tariff ranges from 80 YR/ m³ to 120 YR/ m³.

Most households now rely on water supply from private wells by tankers, which costs around 800 YR/ m³. Households store the water in concrete or metal tanks in their properties. Bottled drinking water costs 30 YR per 5 litres bottle.

Poor people transport water for drinking and domestic use in plastic bottles of 10-20 litre. Even girls from 10-14 years are involved in such suffering and hard work. The water they collect from the concrete tanks offered by Charity givers and situated near the mosques.

There is a high water demand for the irrigation at, which competes with the human direct use of water. As qat is the main cash crop for 80% of the population the irrigation of qat has a strong lobby.

People suffer seriously from water shortage. Currently the governmental water project has stopped to supply the houses since four months. This makes the situation more complicated and worse.

The daily consumed water consumption for domestic use is around 50 liter.

Poorer people, who cannot afford tanks and tanker water collect water from the mosques and their neighbours in bottles of 10 litres.

5.3.2.2 Wastewater disposal practices

In the old town the traditional dry system still exists – but is today no longer operated (no separation). Instead the faeces are discharge to piles behind the houses, where they dry up, cause smell, attract flies, and lead to an unhealthy environment. Some „cesspits" exist in the rocky underground. The pits are expensive to dig (400.000 YR). Pit emptying costs in the range of 7.000 YR. Cesspits are sometimes emptied by vacuum trucks, but often overflow to the roads when full.

In the new part of the town some 800 „cesspits" (operation problems like in old town) exist. Grey water is often directly discharged to the streets in order to save cess pit capacity. Some people still go to the mosques for defecation. It is also common to leave the house and defecate in the surrounding. It has been observed for some houses that the faeces are thrown from the windows to the backside of the houses.

Wastewater from the hospitals and health centres is also disposed directly to the streets.

5.3.2.3 Organisation of the water sector

Due to the non completion of the water project in Khamir, administration faces serious difficulties, particularly because water supply was stopped completely since four months. The population is disappointed and lost trust in the administration.

At a meeting, Sheik Mabkut expressed his will to solve this problem. The Government should also be approached for help in this important issue. However, he lost hope that such support will be granted.

Solid waste is also thrown directly from the houses and all other organization to the streets.

5.3.3 KHAMIR, PRE-SELECTION OF AWS OPTIONS

Regarding the pre-selection of sanitation systems, the site conditions found were as follows:

1. The current situation without proper sanitation system causes severe hygienic problems, especially the discharge of faeces and grey water flows.

The essential task of a proper sanitation system is to ***prevent*** *such severe* ***hygienic*** *problems.*

4. Throughout the region, there is a strong demand for agricultural irrigation.

   The favoured sanitation system must deliver ***irrigational waters*** *of sufficient quality for agricultural purpose..*

6. Khamir is an old town with historic houses, often without installations except the "traditional Yemen EcoSan". Unlike Damt, the traditional separation of faeces and other wastewaters could be used as basis for separated wastewater collection.

   The sanitation systems to be discussed further can base on this ***existing house installation*** *(separation of black waters/grey waters/yellow waters etc.), without having to change the sanitation equipment of houses (toilets, bath, kitchen) and the in-house piping for wastewater collection.*

7. Many houses, especially in larger houses, and most public houses, are equipped with black water cess pits, seldom evacuates, with investment costs reported between 200,000 and 300,000 YR.

   The sanitation system of choice should take into account and - if possible - make use of the existing black water ***cess pits****.*

8. Many roads in Khamir City are unpaved. Sewers and man-sewers already built were broken in some places, manholes in the middle of the road were distorted, broken sometimes.

   The sanitation system, especially the sewerage, must withstand the ongoing ***road construction process****, until the roads are finished and equipped with asphalt layer.*

9. It will be an ambitious (and unavoidable) task to raise awareness of the Khamir population to keep the walking streets clean from wastewater.

   The sanitation system of choice should not overstretch the understanding and operational skills of the consumers, but (instead) be ***very simple*** *and easy to operate and control.*

13. Khamir is a growing town, above the national average (Yemen pollution growth in average is around 3.7 % p.a.). Some experts estimated that, including immigration from rural areas, the pollution growth of Khamir reaches 5 % p.a.

    The sanitation system of choice must be able to grow "with the town" and allow ***flexible extension*** *following the development, not basing on design criteria of a finally predicted capacity.*

14. The existing water supply system was out of operation, due to lack of sufficient quantity of water from the wells. Instead, a tanker based distribution system is working, with trucks carrying 3 to 8 m³ to be pumped into the house-owners water storage tanks.

*The introduction of a sanitation system designed for a continuous wastewater flow to **flush sewers would not work** in Khamir..*

15. A very important issue is the institutional framework and the culture of mutual co-operation between public respectively municipal institutions and private households, enterprises: As found during interviews and site-survey, there is quite a low credibility for public service for the reliability and quality of public service onsite of the private. Households and enterprises have their experiences with short cuts of water supply and chaotic utilisation of well-sites (with women and children washing clothes etc., polluting the water directly at the spring). On the other side, the municipal water utility is enforced, by its experiences, and not to rely on honest customers.

    *As far as grants are not available, all refinancing must be realised out of a low "cash-flow". Any system with high requirement of pre-financing will be much more difficult to realise. A sanitation system should be preferred, which can be **built stepwise**, as the income of the water utility and the volume of wastewater customers served grows.*

16. As the income per capita in Khamir (a Kat growing region) is a bit higher than in other cities which have been researched for water-tariff-affordability studies so far, the level of affordability for sewerage charges seems to be higher than 1,000 YR per month.

    *The total costs for the sanitation system (CAPEX + OPEX) must be lower than the total of grants, softloans, tax contributions and **sewerage charges, which might be** a bit higher thab 1,000 YR/month.*

As described in chapter 4, there are different approaches and methods to structurise alternatives for urban sanitation, ending up with different tables and figures containing an overview of such alternatives.

The figures and tables below show that various alternatives for sanitation do not fulfil the pre-conditions named in the chapter above and must be excluded from further discussion.

Table 5-4: Viability of AWS-Options for Khamir (Fulfilment of Pre-Conditions)

Site-specific Pre-Condition / AWS-Option		Pre-condition 1 *Malaria Prevention*	Pre-condition 4 *Irrigational Waste-water Reuse*	Pre-condition 6 *House Installation existing*	Pre-condition 7 *Existing Cess Pits*	Pre-condition 8 *Road Pavements*	Pre-condition 9 *Operational Simplicity*	Pre-condition 13 *Flexible Extension*	Pre-condition 14 *Combi-Solutions*	Pre-condition 15 *Stepwise Invest-ments*	Pre-condition 16 *Affordable Sewerage Charge*
1	**Separate Collection of Faeces and Wastewaters**										
1.1	Ordinary pit latrine, grey water dis-charged on-site	?	?	(√)	√	√	√	√	√	√	√
1.2	Bucket Sanitation, grey water discharged on-site	?	?	(√)	√	√	√	√	√	√	√
1.3	Cess pit, grey water discharged on-site	?	?	(√)	√	√	√	√	√	√	(√)

Explanation: The symbol indicates, whether the AWS-option under discussion fulfils the pre-condition

? = questionable √ = fulfilled, OK (√) = can be fulfilled with exceptions ⚡ = No, impossible, this leads to exclusion of AWS-option

Site-specific Pre-Condition / AWS-Option		Pre-condition 1 *Malaria Prevention*	Pre-condition 4 *Irrigational Waste-water Reuse*	Pre-condition 6 *House Installation existing*	Pre-condition 7 *Existing Cess Pits*	Pre-condition 8 *Road Pavements*	Pre-condition 9 *Operational Simplicity*	Pre-condition 13 *Flexible Extension*	Pre-condition 14 *Combi-Solutions*	Pre-condition 15 *Stepwise Invest-ments*	Pre-condition 16 *Affordable Sewerage Charge*
1.4	Septic tank, grey water discharged on-site	?	?	(√)	√	√	√	√	√	√	√
1.5	Septic-tank, grey water discharged to controlled trench resp. percolation	√	?	(√)	√	√	√	√	√	√	√
1.6	ECOSAN (separate collection, on-site treatment and utilisation of black, yellow and grey waters)	√	√	(√)	?	√	⚡	√	(√)	√	?

Explanation: The symbol indicates, whether the AWS-option under discussion fulfils the pre-condition

? = questionable √ = fulfilled, OK (√) = can be fulfilled with exceptions ⚡ = No, impossible, this leads to exclusion of AWS-option

	Site-specific Pre-Condition / **AWS-Option**	**Pre-condition 1** ***Malaria Prevention***	**Pre-condition 4** ***Irrigational Waste-water Reuse***	**Pre-condition 6** ***House Installation existing***	**Pre-condition 7** ***Existing Cess Pits***	**Pre-condition 8** ***Road Pavements***	**Pre-condition 9** ***Operational Simplicity***	**Pre-condition 13** ***Flexible Extension***	**Pre-condition 14** ***Combi-Solutions***	**Pre-condition 15** ***Stepwise Invest-ments***	**Pre-condition 16** ***Affordable Sewerage Charge***
2	**Combined Collection of Faeces and Wastewaters**										
2.1	Storage tank, regularly emptied by sewage trucks	√	(√)	(√)	?	√	(√)	√	√	?	⚡
2.2	Septic tank (interceptor tank) with on-site discharge of pre-treated sewerage	?	?	√	√	(√)	√	√	√	√	√
2.3	Septic tank (interceptor tank) connected to small bore sewerage for solids-free wastewater	√	√	√	(√)	(√)	√	√	√	√	?

Explanation: The symbol indicates, whether the AWS-option under discussion fulfils the pre-condition

? = questionable √ = fulfilled, OK (√) = can be fulfilled with exceptions ⚡ = No, impossible, this leads to exclusion of AWS-option

Site-specific Pre-Condition / AWS-Option		Pre-condition 1 *Malaria Prevention*	Pre-condition 4 *Irrigational Waste-water Reuse*	Pre-condition 6 *House Installation existing*	Pre-condition 7 *Existing Cess Pits*	Pre-condition 8 *Road Pavements*	Pre-condition 9 *Operational Simplicity*	Pre-condition 13 *Flexible Extension*	Pre-condition 14 *Combi-Solutions*	Pre-condition 15 *Stepwise Invest-ments*	Pre-condition 16 *Affordable Sewerage Charge*
2.4	Small STP with on-site discharge of purified wastewater	(√)	?	√	?	√	⚡	√	√	√	?
2.5	Full or intermediate flush toilet with simplified sewerage	√	√	√	?	?	√	?	√	?	?
2.5	Full flush toilet with conventional sew erage	√	√	√	√	√	?	?	?	?	⚡

Note: The technical conditions were found to be quite different within the selected town. The pre-selection is focused on the dominating conditions and the prevailing AWS-options. This does definitely not mean that other AWS-options, even those which have been totally excluded, would not be reasonable for selected houses or especially clusters of selected houses in the town - even though these would be exceptions compared with the favoured AWS-option.

Explanation: The symbol indicates, whether the AWS-option under discussion fulfils the pre-condition

? = questionable   √ = fulfilled, OK   (√) = can be fulfilled with exceptions   ⚡ = No, impossible, this leads to exclusion of AWS-option

5.4 SUMMARY OF CONDITIONS IN THE CASE STUDY TOWNS

The towns can be characterised as follows:

- Damt, Abs and Khamir: fast growing
- Serious wastewater problems:
  - o Damt: heavy littering and severe pollution of the town canal, overflow of cesspits
  - o Abs: extreme water scarcity, discharge of grey water to the streets
  - o Khamir: water scarcity for domestic use, overflow of cesspits, lack of sanitation in the old city
- Necessary slope for gravity wastewater collection is existing in Damt, Abs, Khamir

The table 5-5 gives an overview about some data characterising the three case study towns.

Table 5-5: Data on case study towns

Technical Data			
	Damt	**Abs**	**Khamir**
Population	18.000	30.000	15.000
Growth rate – rough estimate [%]	5-10	4	6
Surface gradient	high	slight	high
Elevation [m asl]	2000	200	2300
Precipitation [mm / a]	300 – 400	100 – 200	200 – 300
pot. Evapotranspiration [mm / a]	1500 – 2500	1800 – 2700	1500 – 2500
Est. water consumption [l / c / d]	25 (+ hot water)	30	25
Sanitation facilities [toilets / house]	1	1	2-3
solid waste collection	some collection in center	city area covered	city area mostly covered
Socio-Economic Data			
	Damt	**Abs**	**Khamir**
No. of persons / households	12-14	12-14	15-20
Average family income [YR / month]	10.000 – 20.000	20.000 – 25.000	30.000 – 60.000
Price of potable water by tanker [YR / 3 m³]	1300	1500	2000
Expenditure for water [YR / month / house]	900 – 1200	1000 – 5000	3500 – 5000
Percentage of income spent for water [%]	7	13	10
Time spent for water supply	Little	Little	High
Water access for the poor	easy	existing	Difficult
Level of cleanliness	Low	Medium	Medium
no of diarrhea reported / a	4320	common	2706
no of malaria reported / a	5040	common	1131
no of parasites reported / a	5200	common	1240
no of bilharzia reported / a	2300	common	410
Potable water / non-potable water cons. [l/household/d]	20 – 30 (bottles) / 120	20 (bottles) / 60	30 – 40 (tankers) / 170
common water born diseases	malaria, typhoid, diarrhea, hepatitis, kidney stones, various parasites (bilhazia,...), maltean fever,	malaria, typhoid, diarrhea, hepatitis, kidney stones, various parasites (bilhazia,...), maltean fever, cholera, skin diseases	typhoid, diarrhea, hepatitis, kidney stones, various parasites (bilhazia,...), maltean fever,
no of typhoid reported / a	5000	–	2000

5.5 FINDINGS FROM VISITS TO TOWNS WITH IMPLEMENTED CONVENTIONAL WASTEWATER SYSTEMS

During their trip to Yemen the experts also travelled through Amran, Dhamar, Hajjah, Hoddeidah, and Yarim and had short stopovers. All these towns have implemented sewerage systems and wastewater treatment plants. The findings were as follows:

Amran:

The sewerage system and wastewater treatment plant have been completed but the connection of houses to the system is still ongoing. Therefore the WWTP (pond system) receives presently only very little flow. Three manholes have been opened, one in the transmission line to the WWTP in front of the NWSA building, one in front of the main gate to the old town and one start manhole in the old town. The ventilation openings in the covers were closed. The covers showed corrosion although they are new. In the manhole in front of the old town gate, which has a 90° bend, faeces settled. Unfortunately, Amran was the only town were the experts had the chance to open manhole covers.

The WWTP has a proper appearance and no major deficiencies could be identified during the short stay. The anaerobic ponds were full, of black colour and gas bubbles can be observed. At the time of the outflow of the anaerobic ponds went to one facultative pond, which was not full and had no effluent. Some of the maturation ponds had some water fill but none were full. Some maturation ponds were still dry. The experts advised the personnel to fill all ponds partly in order to avoid that the clay sealing layer dries up and breaks. The colour of the facultative ponds and maturation ponds was red to pink. The cause for this colour could not be determined.

Dhamar:

The WWTP received no inflow at the time of the visit. The operation staff said that already since some time there is no inflow, because farmers block the manholes and use raw wastewater for the irrigation of their crops.

Hajjah:

Heavy rainfall in Hajjah made a detailed visit of the WWTP difficult. The inflow to the WWTP was high, but not excessive despite the heavy rainfall as could be observed at the Parshall flume. The experts had the impression that the operation of the WWTP could be improved. As an example the recycle pumps at the trickling filters were running at full capacity despite the high inflow. The final clarifiers to the trickling filters are turbulent due to wrong design and construction. This situation could be altered easily through the introduction of additional chambers before the final clarifiers. These could even be constructed by the WWTP personnel.

Hoddeidah:

The WWTP (pond system) can only be reached via a dirty and bumpy road leading through the solid waste disposal site. The experts had the impression that hardly anybody looks after this plant and it is a refuge for dogs and birds. No mechanical equipment is existing and the inflow leads directly into the first pond. In the pond sediments reach the surface, islands in the ponds appear, and birds breed on them. Still the effluent looks not too bad and irrigates a large green area downstream.

Yarim:

The WWTP and the sewerage system have been completed but house connections are still under construction. Therefore the WWTP receives only little flow. The anaerobic ponds appear to work well with gas bubbles appearing on the surface. The facultative pond had inflow but was not full and had therefore no effluent at the time of the visit. Most maturation ponds are still dry.

6 PRE-SELECTION OF VIABLE SANITATION SYSTEMS FOR THE CASE STUDY TOWNS

6.1 DESCRIPTION OF PRE-SELECTED SANITATION SYSTEMS

As it has already been explained with the pre-selection-tables 5-2, 5-3, 5-4, the conditions are quite different even within selected Yemeni towns. It seems likely, that in many towns a combination of different AWS-options will be feasible, e.g. decentralised systems in the outer areas, whereas the densely populated town centre could be served by centralised or semi-centralised sewer network. Therefore, none of the AWS-options described in chapter 4 can be excluded from the very beginning.

Basing on the evaluation of the site-conditions in the three pilot towns, and on the impressions which the expert teams gained during the field mission and survey of existing information, there are mainly four options which should be discussed more in detail. These four options are the ones which did not have to be excluded during the pre-selection process for any of the three towns, plus the conventional system as traditionally established reference respectively option five.

6.1.1 AWS-OPTIONS FOR FURTHER DISCUSSION

Having to exclude a number of AWS-options, as summarised in the tables in chapter 5, there are four AWS-options remaining for further discussion: The AWS-options listed under the numbers 2.1, 2.2, 2,3 and 2,5 in the tables. These options shall be described more in detail as follows:

Option 1: **Storage tanks + tankers**: individual or cluster storage systems (retention tanks) for wastewater (black water = faeces + urine + wastewater from kitchen), grey water from shower, bath and hand washing, kitchen wastes) with a regular emptying (weekly or more frequently) by vacuum tankers and transport for further treatment to a centralised treatment plant.

Option 2: **Septic tanks + infiltration**: (Semi-) decentralised collection and treatment of wastewater in septic tanks (“cluster solution”) with outlets / overflows to infiltration or discharge to local Wadi depending on local situation. Joint collection of all wastewater. Regular desludging of the septic tanks (annually or bi-annually) through vacuum tankers and centralised treatment (e.g. anaerobic or facultative lagoons/ponds) of the sludges for agricultural use.

Modification (a): Construction and operation of a long, inclined trickling filter system along the small Wadi for treatment of the septic tank overflows (case study Damt).

Modification (b): Cess pits having reached their end of live are emptied and will be replaced by septic tanks (allows for continuous transition to a town-wide septic tank system).

Option 3: **Small bore system** to collect the overflow of septic tanks for centralised or semi-decentralised treatment (e.g. artificial mini wetlands). Could be a later state of development starting with Alternative 2.

Option 4: **Simplified (semi-) centralised sewerage system** (separate system, wastewater only - no rainfall runoff); according to adapted design standards: shallow, small diameter sewers with a treatment process (either one or more treatment plants).

As a reference the conventional, centralised sewerage system will be subjected to the selection criteria

Option 5: **Conventional centralised sewerage system** (separate system, wastewater only, no rainfall runoff) according to present conventional design standards

Whereas the options 1 and 2 are well known from standard literature and traditional application in rural areas, the options 3 and 4 are not yet established so well, and shall therefore be described in more detail as follows:

Unlike the conventional sewerage, which is designed for the full wastewater flow (= unsettled raw sewage plus storm water) including settleable particles, the small-bore (= small diameter pipe) system is designed for settled sewage only. It is also called “solid-free sewerage” or “settled sewerage” system. The raw sewage from one or more (= "cluster") households is discharged into a single-compartment septic tank (= interceptor tank). The settled effluent from the septic tank is then discharged into shallow, small-bore gravity sewers. Sewers do therefore not need to be constructed with self cleansing velocity and can even have adverse gradient. Peaks are smaller due to buffering in the tanks. Costs can be substantially reduced compared to conventional sewerage. Such system is particularly cost saving, when interceptor tanks already exist but infiltration of untreated sewage into the soil shall be stopped, or when the infiltration capacity is exceeded due to increased water consumption.

Design principles:

- Not designed for self-cleansing velocities
- Flow in the sewers can change along the flow from normal gravity open-channel flow to full bore pressure flow and back.
- Shallow excavation depth, because pipes are normally laid away from vehicular traffic
- Small diameter (DN 100 minimum)
- Use of simple inspection boxes instead of large manholes
- Especially suitable for areas which have already septic tanks (or other facilities which can be modified for septic tanks) but where (1) the soil cannot accept the wastewater infiltration or (2) groundwater pollution is a problem.
- Settled sewerage was developed in Zambia, now used in Australia, USA, Colombia, Nigeria.
- From the user’s perspective, use differs little from conventional sewerage.

Advantages:

- Works well without blockages at very low water consumptions
- Small diameters of pipes (low cost)
- Equalised flow through septic/interceptor tanks
- Shallow pipes (low cost)
- Use of existing facilities as interceptor tanks
- Stepwise development possible
- Low maintenance requirements of the sewer pipes

Disadvantages:

- Many operation and maintenance points at the interceptor tanks
- Space requirement for the interceptor tanks
- Possible nuisance caused by interceptor tanks and emptying of interceptor tanks
- Requirement of a well organised emptying cycle of interceptor tanks.

The small bore system is target of various interesting research projects, and it seems realistic to count on further technological progress.[1)]

[1)] Such as a *self-desludging interceptor tank*, as under pilot-testing by CSIR, 2004. A washtub outlet is connected to the tank separately from the normal wastewater pipe from the toilets. When the washtub is emptied, the water that drains into the interceptor tank activates a siphon, which flushes accumulated sludge into the outfall pipeline with the effluent. Because digested sludge is a fine, particulate material with a specific gravity only fractionally higher than water, it is easily suspended and transported by the effluent.

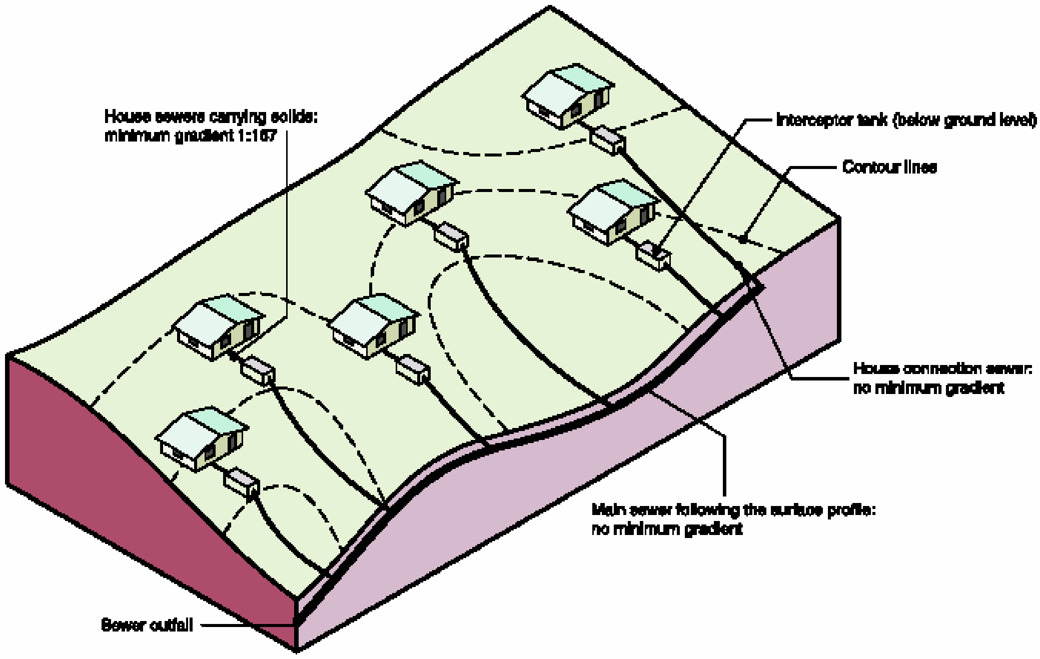


Figure 6-1: Solids-Free Sewerage System (DFID, 1998)

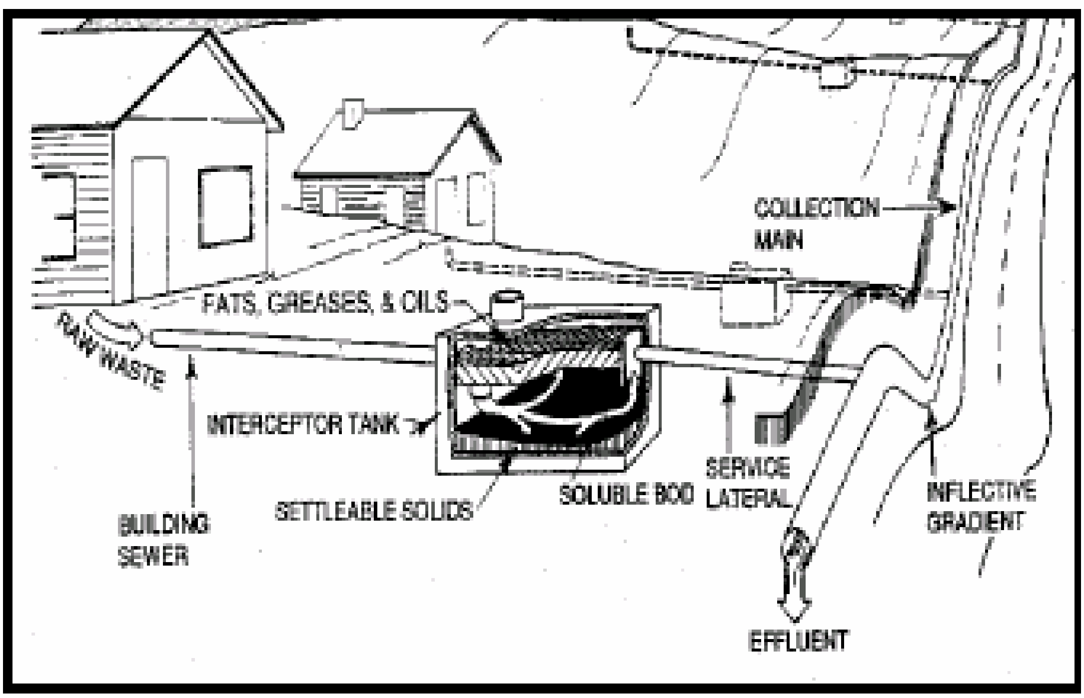


Figure 6-2: Solids-Free Sewage System Interceptor Tank (EPA, 2000)

Figure 6-3 shows an example An example for small bore sewer system presently under implementation funded by the Social Fund for Development in Al Mahweet. Project costs are 1,000,000 USD for 12,000 capita. The septic tanks are partly on private and partly on public land and serve each a cluster of houses. Locations have been fixed by the Local Council. The NWSA branch supervises the connection of houses to inspection chambers. The connection rate is presently around 25%. For a connection a contract between NWSA and the house owner is signed. The tariff has not yet been set.

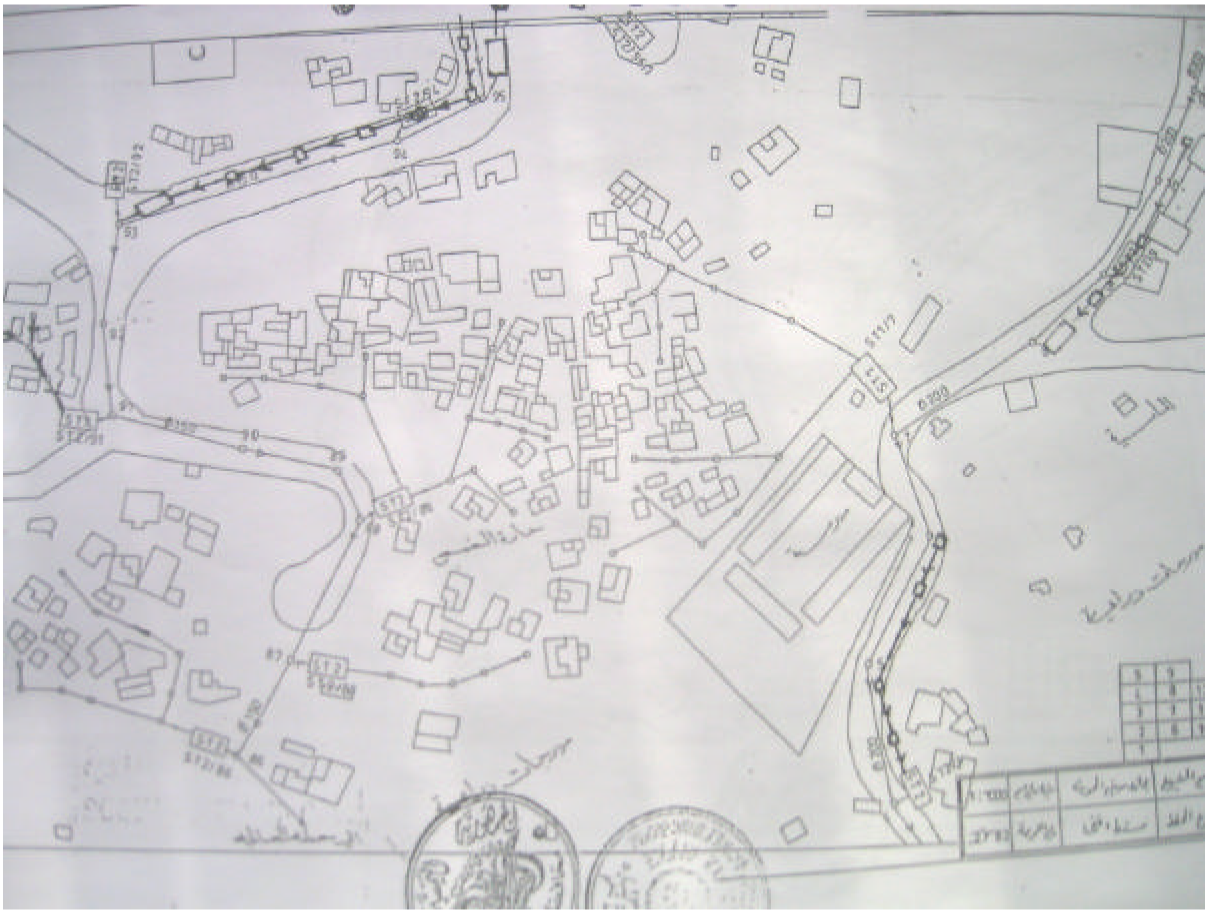


Figure 6-3: Small bore sewer system in Al Mahweet

6.1.2 SIMPLIFIED (SEMI-) CENTRALISED SEWERAGE

This is a system, in which the sewerage receives unsettled raw sewage (most appropriate in high-density, low-income housing areas which have an on-plot water-supply and no space for on-site sanitation or interceptor tanks of settled sewerage).

The design factors determining the costs of sewerage systems are:

- Average diameter
- Average depth

- Average slope relative to ground topography
- Number and depth of manholes
- Population density
- Set-up costs
- Excavation in rock.

The means to achieve lower costs for sewerage (simplified sewerage) are:

- Decentralisation (splitting into two or more separate smaller systems)
- Locate sewers away from traffic loads to minimise excavation (known as condominial sewerage when laid inside the blocks)
- Chose carefully the design period (50, 20, 10 years ?)
- Chose carefully the design flow (return coefficient may be as low as 0.4)
- Reduce minimum diameter for street sewers to DN 150 or even DN 100 (no additional maintenance problems experienced in Nebraska and Brazil)
- Hydraulic design based on minimum tractive tension, rather than minimum self cleansing velocity (e.g. DN 100 at 1:200 slope may be possible)
- Reduce minimum sewer depth (coverage) to 0.65 m under sidewalks and to 1.00 m below residential streets
- Reduce number of manholes (experience shows that 90% of manholes are never opened)
- Reduce diameter of manholes to 0.6-0.9 m
- Construct manholes from pre-cast concrete pipes or concrete rings with pre-cast slabs and bottoms
- Replace manholes at changes of direction or slope by underground boxes or chambers.

Advantages:

- Low costs due to different (partly lower) construction standards
- Same quality of service to the consumer as conventional sewerage
- People identify themselves with the system because some design and construction is their own
- The need to develop own standards for the conditions in Yemen thus promoting local knowledge

Disadvantages:

- International acknowledged construction standards are partly not adhered to (e.g. DIN) therefore Implementing Agencies, Donors and Consultants do not feel safe
- A certain water consumption is required in order to avoid blockages
- Condominial sewers are sometimes not easy to access for O&M
- Experience is limited to some countries
- Specific designs for the Yemen need to be developed
- Lower construction standards and partly construction through unskilled labour may lead to reduced lifetime.

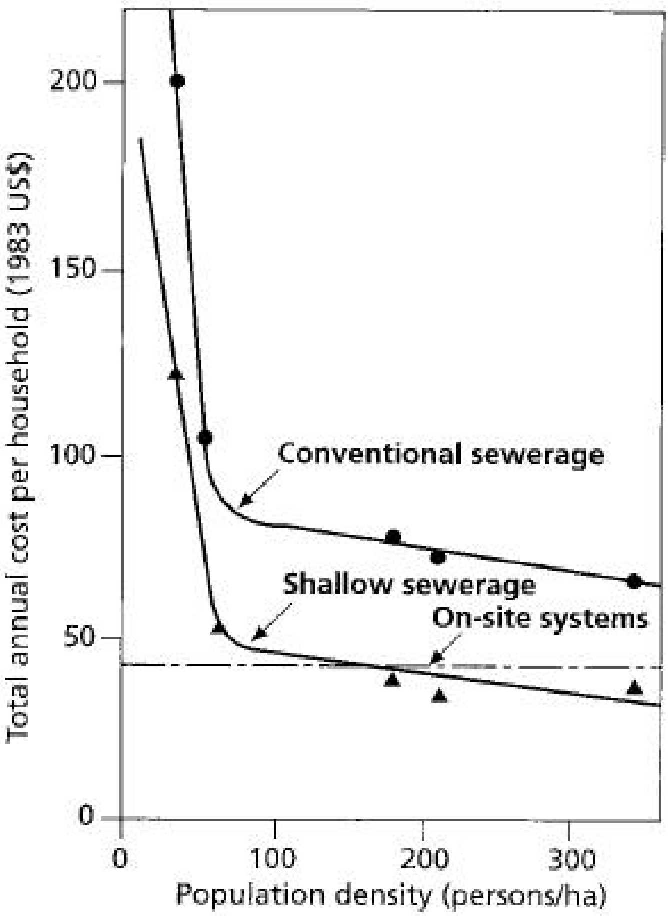


Figure 6-4: Annual costs for sewerage per household (Mara 1996)

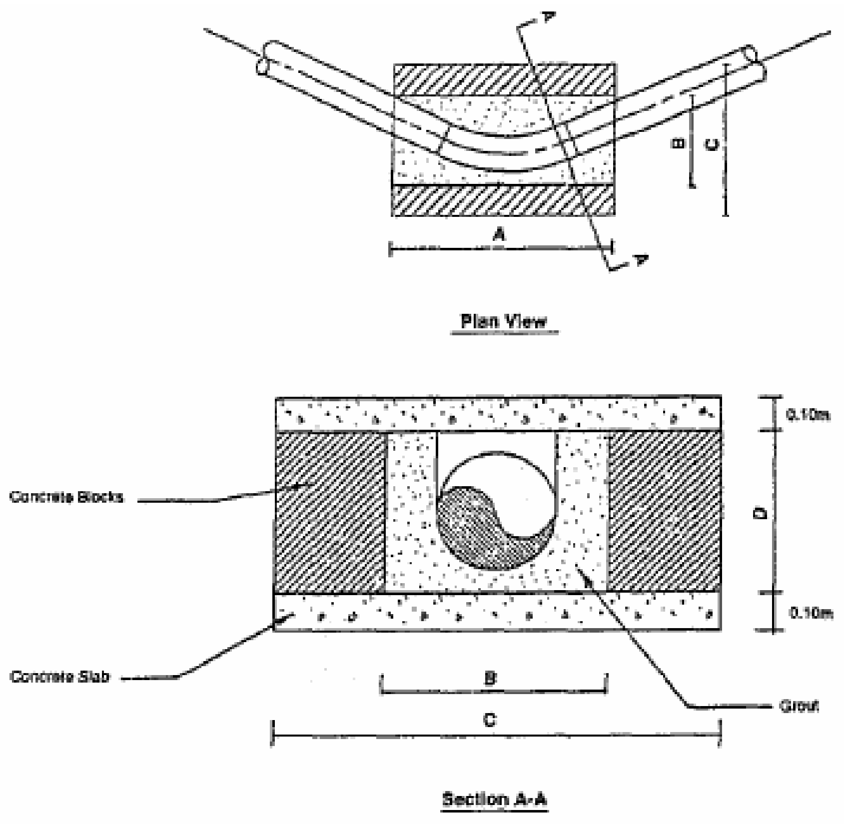


Figure 6-5: Buried box for change in direction (Bakalian 1994)

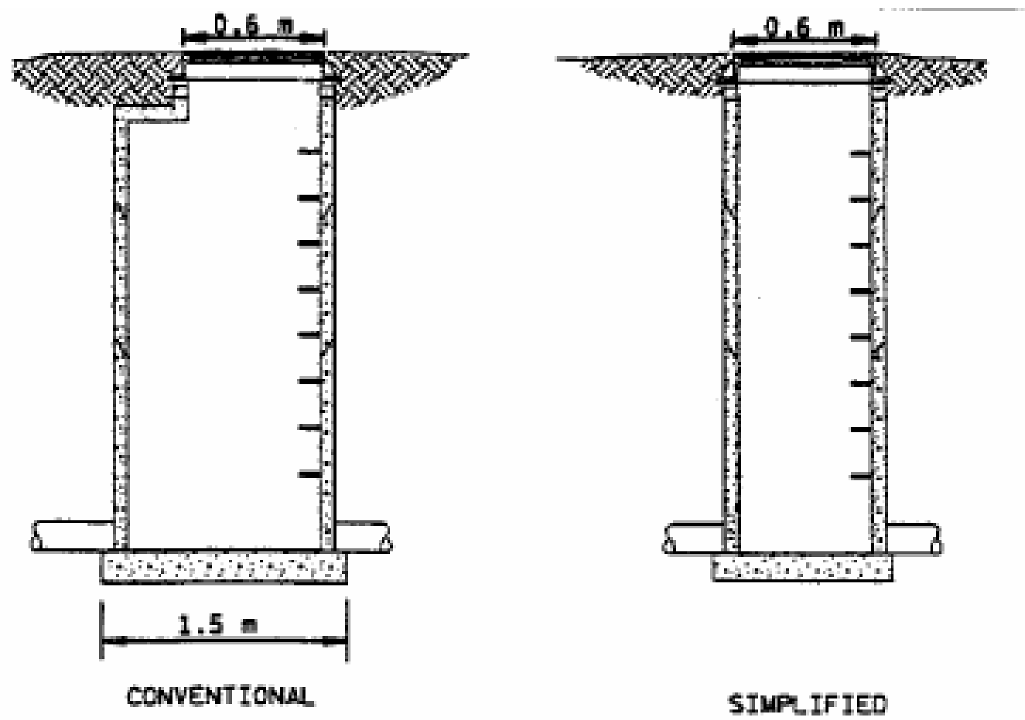


Figure 6-6: Comparison of conventional and simplified manhole (Bakalian 1994)

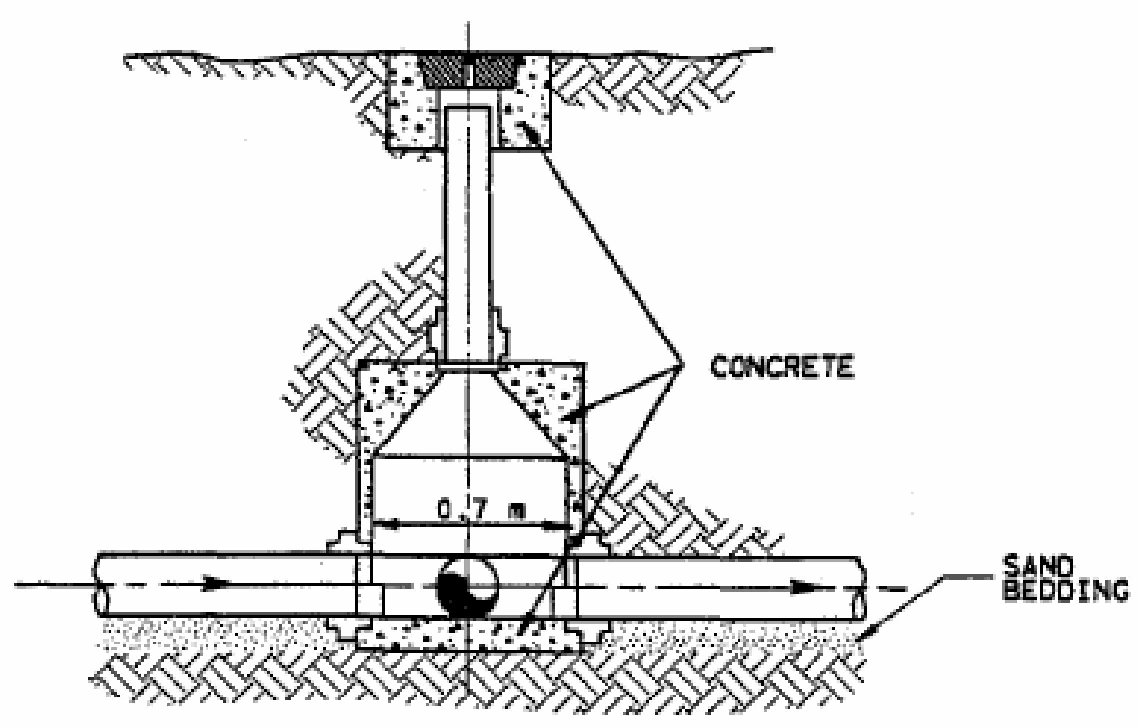


Figure 6-7: Junction inspection cleanout (Bakalina 1994)

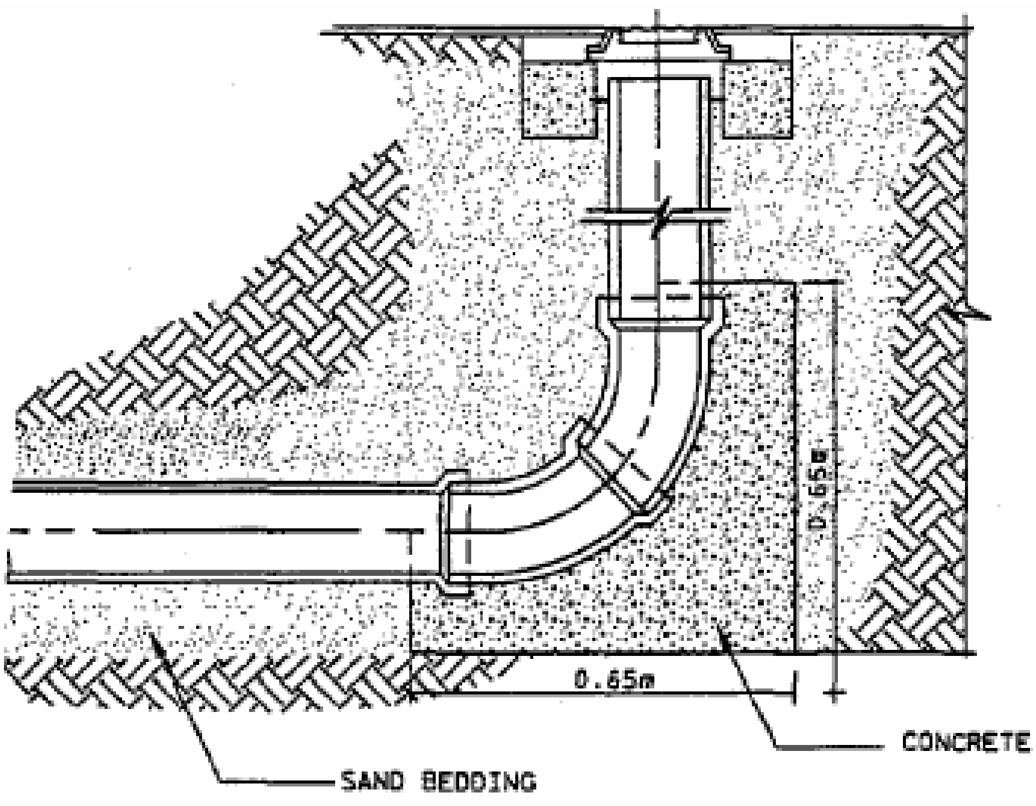


Figure 6-8: Terminal cleanout (Bakalian 1994)

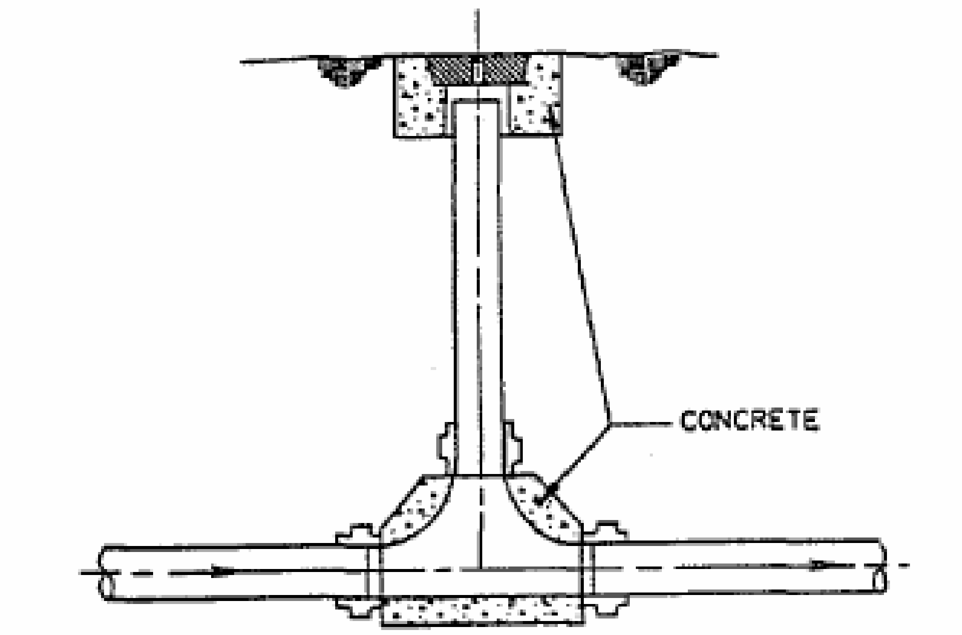


Figure 6-9: Inspection cleanout (Bakalian 1994)

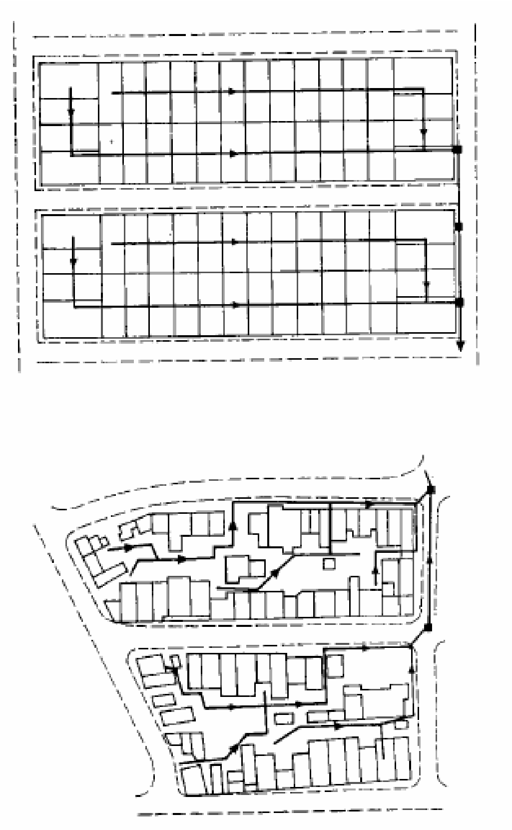


Figure 6-10: Simplified sewerage in planned and unplanned areas (Mara 1996)

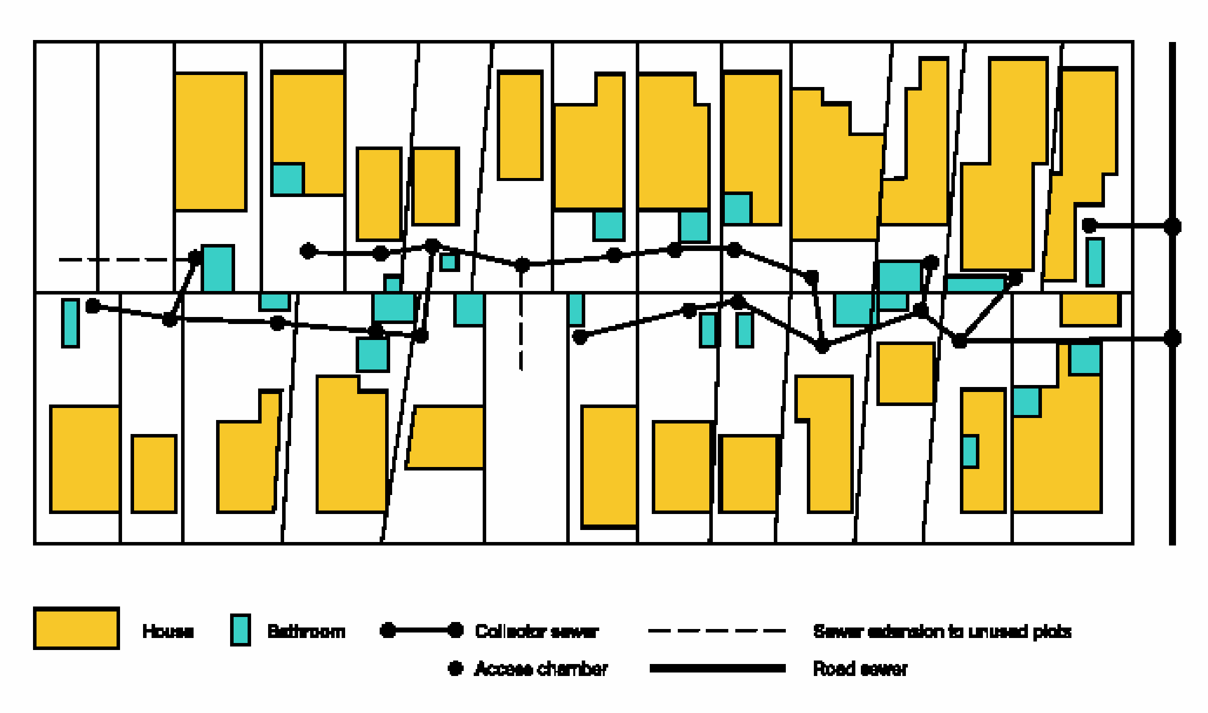


Figure 6-11: Condominial sewer layout in Petrolina, Brazil (DFID, 1998)

6.1.3 ADDITIONAL COMMENTS ON EXCLUDED OPTIONS

During the workshops held with donors, experts and stakeholders from the wastewater sector of Yemen, it was found that controversies are existing regarding the

- conventional system
  which has been widely used for the cities in Yemen so far (mostly gravity sewers serving wastewater ponds) and are still under construction and preparation for project finance by KfW and other donors,

- EcoSan system
  as it has become popular among NGOs and professionals (since the IWA International Water Association has established a working group on "Sustainable Sanitation"). Lots of articles have been submitted since the last five years (collected and further promoted by the GTZ EcoSan programme).

Therefore, it seems necessary to add some specific remarks, why the experts had to exclude these two options under site conditions as found in the three pilot towns:

Conventional System

Among experts, it is widely accepted that full gravity sewerage and centralised wastewater treatment plants are ***affordable*** only under certain conditions, like minimum income per capita, maximum specific investment costs per capita (depending on technical site conditions, like population density) etc. As discussed before, none of these basic economic conditions was fulfilled for the three towns Damt, Abs and Khamir.

Furthermore, the experts experienced severe ***technical problems*** with conventional systems installed in other towns, resulting from the fact, that the water consumption is much lower than the minimum water consumption and "flushing power" for which gravity sewers can be designed.

Of course, there do exist possible technical counter measures to cope with such problems (additional flushing of sewers, prevention against corrosion or utilisation of plastic instead of concrete etc. etc.). Anyhow, such measures would further raise the costs necessary for conventional systems.

A study on the investment needs (Noman 2004) presumed that the investment per sanitation connection would not be much higher than 900 USD in towns with flat terrain and high population density, respectively 2250 USD for mountainous terrain. Anyhow, the experts collected information and data which led to much higher specific investment cost units per connection: A re-calculation of a donor-financed project was reported to disclose total-investment-cost figures of more than 9,000 € per connection.

EcoSan Systems

In literature (and later on in Khamir, where some old historic houses were still operating sanitation like 100 years before), one can find kind of a traditional "Yemen EcoSan system". Therefore, one could have expected that the site conditions in rural towns of Yemen are very favourite to apply modern EcoSan sanitation.

Anyhow, it was found on-site that most of the houses had already changed to **combined** PVC pipe **installations**, not separating faeces, urine and grey waters, and that it would be very costly and probably not accepted by house owners to change such house installations ex post.

Furthermore, it seemed unlikely that the majority of house owners is still willing to spend the necessary **attention and maintenance** needed for traditional Yemen systems (Keep the locality very clean! Do not dilute faeces with water! Cover faeces with ash! - which means, Do not use gas in the kitchen, but wood for heating ... etc. ...).

Further, specific reasons not to pursue separation of various wastewater streams are:

- Faeces always come with water (due to the wet anal hygiene customary in Arabic countries) and need treatment (due to the organic load as well as due to the hygienic problems associated with faeces).

- Reuse of urine is socially not acceptable.

- Wastewater from kitchen contains organic load (incl. fat) and detergents and therefore needs treatment; additionally re-use of treated wastewater for irrigation is not accepted for irrigation of crops.

- Grey water from personal hygiene and from laundry contain tensides/surfactants (not easily decomposed biologically) and therefore needs treatment.

Anyhow, it should be understood very clearly that the conventional system as well as the EcoSan system may be a viable and very reasonable option under conditions which are unlike the ones in the three pilot towns visited and evaluated by the experts.

In no way, the experts would intend to criticise the conventional system e.g. in the densely populated centre of cities, or the EcoSan sanitation in selected locations, as realised under the umbrella of NGOs very successfully.

6.2 NON-TECHNICAL ASPECTS (OWNERSHIP, INSTITUTIONAL AND ORGANISATIONAL ASPECTS)

Having focused on the *technical concept* of sanitation, especially the construction of sanitation system, there are other, non-technical aspects alternative concepts and to decentralisation. Decentralisation could also be considered in terms of ownership of the technical subsystems of the urban water infrastructure as well as in terms of who is responsible for the operation and maintenance of the technical infrastructure. For example, decentralised technical units could be owned resp. maintained and operated by the private households. This is the usual case so far. However, instead of decentralising the technical components as well as the ownership and responsibility for O&M, new options result in (semi-) centralising the ownership resp. O&M to a (public or private) utility or at least a few companies, while at the same time applying a decentralisation concept in terms of the technical system. This (semi-) centralisation with respect to ownership resp. responsibility for O&M supports professional operation and assures a service while at the same time supports building new qualifications and local income. The following table indicates that many different combinations are possible with the four AWS-options:

Figure 6-12: Degree of Centralisation

		Degree of Centralisation		
Perspectives	Technical concept	On-site treatment	Few small treatment plants	Centralised treatment
	Ownership	Homeowner	Contractors	Local Corporation, utility
	Operation	Homeowner	Contractor	Local Corporation, utility

Decentralisation, in context to AWS, is defined in this report as the transfer of responsibility to lower levels of government. Typically three types of decentralisation exist in the WS&S sector:

- Devolution – transferring responsibility and authority to local governments
- Deconcentration – placing resources and staff at lower levels within the same administrative structure (autonomous, regional offices of the national water company)

- Delegation – assigning responsibility to a third party, such as an autonomous regional water entity or a private sector company.

Elder case studies deliver a testament to lessons learned in the past 20 years in the water and sanitation (WS&S) sector about the central elements of sustainable projects. Although these lessons will not be discussed in detail here, they include certain key elements [Fragano, 2001]:

- The importance of cost recovery
- The need for meaningful community involvement
- The impact of the selection of technology on sustainability
- The need to focus on operations and maintenance
- The key role of institutions.

The following table indicates that many different combinations are possible with the four AWS-options.

Table 6-13: Operation and Ownership options for Selected Technical Options

AWS-Option		Technical Concept	Decentralization / Centralization					
			Ownership		Operation and maintenance			
			House Owners	Local Corp., Utility	Facility	House Owners	Contractors	Local Corp., Utility
Storage tanks + tankers	1a	One tank for each house	X	X	Storage Tanks	X	X	X
					Vacuum Trucks		X	X
	1b	Tanks for clusters of houses		X	Storage Tanks		X	X
					Vacuum Trucks		X	X
Septic tanks + infiltration	2a	One septic tank for each house	X	X	Septic Tanks	X	X	X
					Vacuum Trucks		X	X
	2b	Septic tanks for clusters of houses		X	Septic Tanks		X	X
					Vacuum Trucks		X	X
Small bore system	3a	Septic tank for each house	X	X	Septic Tanks	X	X	X
					Vacuum Trucks		X	X
	3b	Septic tank for clusters of houses		X	Septic Tanks		X	X
					Vacuum Trucks		X	X
	3c	Several small bore systems to several STP		X	Sewerage System and STP		X	X
	3d	One small bore system for entire town to one STP		X	Sewerage System and STP			X
Simplified sewerage system	4a	Several separated sewer systems to several STP		X	Sewerage System and STP		X	X
	4b	One sewer system to one STP		X	Sewerage System and STP			X

The resistance to the application of non-conventional wastewater management systems often stems from:

- The wastewater management agencies preference to conventional systems for which they have well established design standards and operating procedures;
- The security and safety of selecting familiar solutions;
- The general perception of planners, engineers, and the public that non-conventional systems offer sub-quality service;
- The lack of knowledge of non-conventional options and technologies [Bakir, 2000].

Generally spoken, a prejudice often found by potential customers and stakeholders is that the conventional system would work at the same level of sanitation comfort and reliability as in Western industrialised cities, and that the cost and maintenance-load is born by public institutions. On the other hand, there had been failures with decentralised systems, resulting in e.g. odour nuisance and unexpected additional operational tasks for the water consumers. In this context, it seems very important to *professionalise the operation* of any sanitation systems, utilising the logistic capacities and local expertise existing.

This could mean that the municipal utility or private enterprises organise the regular excavation of interceptor of pits, septic tank etc. instead of leaving this to individual organisation or uncontrolled septic tank overflow.

This could also mean that a municipal or private task force is made responsible for regular and reliable de-littering of wells and canals, or even for the maintenance of small-bore pipes etc.

With the four options favoured by the experts for the three pilot towns, it seems possible to organise economic incentives and the direct link between success of a sanitation system and a direct link between the influence of the water customer to make the system work and the customer's benefit from a working system.

6.3 LESSONS LEARNT

At the end of the mission two workshops were held at the Ministry of Water & Environment. The goal of the workshops was to present and discuss the findings to / with local decision makers in the field of sanitation as well as to donor organisations. The first workshop with stakeholders was held entirely in Arabic language. The discussion on conventional centralised water systems and more decentralised AWS showed different opinions within the group of participants, with the group favouring conventional systems being bigger than the opposing group. During the second workshop with representatives of donor organizations the ratio was the other way round.

The following 12 theses have been developed during the mission. The theses were formulated to summarise the empirical findings of the experts during their site visits and to act as starters for the discussions in the workshops at the end of the mission.

The contributions of the participants to the discussion and their reactions to the theses have been recorded by the moderator and the local experts who acted as note takers as close as possible to the original wording. The summary to each theses also provides some comments of the experts to the participant’s contributions.

Thesis 1:

Conventional systems have been developed for water consumption higher than 100 l/c/d. Taking into account the **scarcity of water resources** in Yemen, reaching this level of consumption is not reasonable from an economic as well as from an availability point of view.

Reactions:

- there are reports of conventional systems working with 50-60 l/c/d water consumption
- wastewater could also include plastic or other solid materials

- show us one implemented sewerage system in Yemen that does not work properly or even blocks
- the Rada'a project is one of the successful projects because of the surface gradient
- the Sana'a sewerage system is working with lower flow
- technologies were imported from western countries, without taking into consideration the local conditions
- at locations with high surface gradient less water flow is required - the problems are resulting from misuse of network and not from the system itself
- the figure 100l/c/d is to exclude conventional system as one of the options
- there are cities, which have high rate of water consumption e.g. hot coastal cities like Aden and Hoddeidah -water consumption 100l/c/d is not affordable for poor users
- the government should subsidy tariffs for water consumption to reach better hygiene standards for poor users

Summary of the discussion: The discussion of this thesis was intense. The promoters of conventional systems (mainly in NWSA) felt themselves attacked. They see a danger that projects presently under preparation may be put under question by this discussion. Those participants who vehemently defended the conventional centralised sanitation system as being suitable also under Yemeni conditions, however, complained that problems experienced with these systems would be caused only by bad designs, wrong construction materials and misuse.

Thesis 2:

During their short mission, the experts could not find a satisfactory and systematic re-calculation and evaluation of existing sanitation systems in Yemen. Such evaluations would provide valuable data to decide about most appropriate sanitation systems case wise. For proper selection and design of sanitation systems **information from projects implemented** are necessary and more valuable than textbook knowledge.

Reactions:

- this thesis is correct, there are no comprehensive reports or studies to refer to;
- there is no centralised data base - information about cost calculation and cost recovery is not available, projects don't follow that;
- reports are available, but the mission did not have enough time to look for it;
- there are no projects in the towns visited by the mission, and therefore there was no information available;
- there are different institutions implementing sanitation projects and have information readily available;
- information and reliable data are precondition to identify suitable alternatives;
- project calculations include investment cost and operation costs.

Summary of the discussion: Only few participants understood well the meaning of this thesis. Hardly anybody was really interested in the economic recalculation of running projects. However, the experts did receive no hints on any of such existing economical post- analysis of running projects in the discussion. Also other sources confirmed that there are no post-evaluations of water projects with respect to life cycle costs are available.

Thesis 3:

Conventional systems need systematic and **enforced town planning, made (preferably paved) roads and reliable design assumptions** for the network. None of the case study towns fulfils all preconditions. Therefore, conventional systems are not applicable, at least not without significant modifications for the three towns visited.

Reactions:

- this thesis is true ;
- this is no preconditions for implementing as sewerage system, because many projects were implemented in many locations under these circumstances;
- the three cases study towns are exceptional cases, which should not be generalised;
- this thesis is true if we could enforce Law and regulations. Every town has its specific problems and conditions;
- if we took this thesis as precondition, we would never implement any project.

Summary of the discussion: Participants stated that town planning is existing and plans are available in the Ministry of Planning. However, in none of the case study towns up-to-date town planning maps were available. Without such maps town planning cannot be enforced on site. Also only small parts of the case study towns appeared to follow a designed structure.

Thesis 4:

The Yemeni towns are fast growing settlements. The sanitation system must be flexible for **easy extension and upgrading**. Quite often, sanitation systems with fixed network structures cannot provide the required flexibility (at least not without high surplus costs).

Reactions:

- this thesis is true, because the cost of the network is much higher than the cost of treatment stations;
- this is no problem because conventional networks are designed for such growth - any new settlement would be also easily connected to the network;
- there are statistical data for population growth and settlement, which are a basis for the network design;
- the network is designed for 25 years, main costs for extension und upgrading are costs for new connections;
- conventional systems serve for certain period, after that solutions would be found accordingly;
- all good designed systems are flexible and suitable for extension.

Summary of the discussion: Some of the participants followed the idea of the experts that adding single decentralised units is easier to manage and requires less logistical effort than extending networks. Promoters of conventional systems did not but argued that this is only a question of proper design and organization.

Thesis 5:

Traditionally, on-site sanitation facilities are in the ownership and responsibility of the house owner. House owners - after some bad experience - consider this to be a burden they would like to get rid off. **Professional organization of O&M of the on-site facilities** can provide an equal level of comfort and reliability as house owners expect from conventional systems. decentralised solutions in other than the usual institutional setting offer more options than explored so far.

Reactions:

- in Sana'a we had bad experiences with private organizations, which were commissioned to collect solid waste;
- traditional sanitation systems were successful. The problems started and grew with the new life conditions;
- the community may not accept the centralised organisation alternatives;
- decentralised system should have well institutionalised systems for O&M;
- traditional systems were based on the architecture of the houses. Nowadays the house architecture and the sanitation facilities changed;
- change the word “decentralised systems” in this thesis to “alternative systems”;
- take into consideration the situation of the in-house sanitation facilities;
- Jordan has good experiences with regard to re-use of grey water;
- sanitation system should be designed as far as possible to use grey water for house gardens;
- O& M in decentralised systems needs reliable contractors;
- is this designed to come up that the "decentralised system is the best solution"?.

Summary of the discussion: In principle the participants agreed to the thesis, but many complained that the theses focus too much on the comparison centralised/decentralised and would promote too much the decentralised solutions.

Thesis 6:

In decentralised wastewater systems the effects of misuse or improper maintenance become immediately obvious to the users. In conventional centralised wastewater systems misuse and improper maintenance causes problems mostly to the disadvantage of others, not of the user himself. Therefore, decentralised systems are more suitable to **motivate users for proper utilisation**.

Reactions:

- conventional system are more suitable for large cities, decentralised systems are suitable for secondary cities;
- land problem especially for new treatment stations as well as for extension of stations is one of the biggest problems (In Shabwa a project has been stopped for that reason);
- connecting a filter device, to avoid entering of big solid waste particles into the network could help in solving this problem;

- why I have to pay for the damaging and environmental pollution, if I am not the one who causes the problem?
- community / contractors should be trained in O&M;
- if the smell comes up the house owner will maintain his network immediately;
- the costs for O&M in decentralised system should be calculated.

Summary of the discussion: Generally the reaction was that such problems of misuse can be overcome with appropriate design. Also it was stated that any large particles would already block the pipes inside the houses an not enter the sewers.

Thesis 7:

Decentralised systems are often characterised by low percentage of fixed cost and higher percentage of variable cost than conventional systems. Therefore, decentralised systems contain lower **financial risk in case of failure**. (E.g.: less wastewater than expected: conventional sewer needs additional flushing, costs increase, whereas costs for a decentralised system decrease).

Reactions:

- the design of a sanitation system should take into consideration the environmental impact. People and animals could be affected. The cost of environment loses and environment protection should be also calculated;
- the purpose of this study is to analyse the technologies, which we are using and find out suitable technologies;
- the maintenance cost of decentralised network is difficult to predict. We couldn't have full control of that sanitation network.

Summary of the discussion: Only few participants understood this theses. Therefore there were no reactions directly related to this thesis. Basic economic working knowledge relevant to the assessment of the operation of water infrastructure systems seemed to be missing.

Thesis 8:

Implementation of small scale solutions for wastewater services in rural towns of Yemen require technical equipment and skills which are usually available in the region. Therefore, many small scale facilities can be implemented by local companies and thus, are likely to generate **local income**.

Reactions:

- this thesis is not correct. Implementation of conventional sanitation system is done by local contractors;
- in some small towns, contactors have neither equipment, nor know-how;
- selection of a propitiate alternatives systems decentralised or centralised should be done according to the conditions of location.

Summary of the discussion: Participants saw no advantage of alternative solutions to the conventional solutions with respect to the generation of local income. Already do the contractors hire local staff. The focus of the contributions were on the construction phase.

The aspect of local income generation with the operation of the system was not taken up by the discussants.

Thesis 9:

Wastewater collection and transport is the major issue in terms of costs (esp. investment), operational needs, and flexibility for extensions when deciding about sanitation systems. These aspects must be regarded prior to the selection of an appropriate wastewater treatment technology.

Reactions:

No comments.

Summary of the discussion: -

Thesis 10:

The assumption about the **useful technical lifetime** of a system is essential for its economic assessment. If one component of a sanitation system fails (e.g. pump) the long technical life time of other components (e.g. concrete or PE-pipe) is worthless. The useful technical lifetime of sewerage is often overestimated and this results in a too optimistic cost calculation.

Reactions:

- Q: Second part is not clear A: The operational life time of a complex system depends on the life time of its components;
- feasibility studies by the consultant may not, take into consideration the economical and social conditions of the community;
- estimation of water consumption per person is not correct.

Summary of the discussion: This was not really of interest to most participants.

Thesis 11:

Any sanitation system must fit into the existing **in-house installations**. Any change of in-house installations necessary for proper functioning of the selected sanitation system would be costly and difficult to enforce (e.g. separation toilets and separate grey water pipes are needed for EcoSan). Only with newly developed areas and houses, a free choice of sanitation system is possible.

Reactions:

full agreement.

Summary of the discussion: -

Thesis 12:

The urgency to respond to water scarcity in Yemen with use of innovative and sustainable solutions for water supply and sanitation is one of the highest worldwide. This can be taken as a chance for Yemeni research institutions and industry to develop suitable technologies to cope with water scarcity. The creation of such suitable technologies could be a basis for **commercial development in Yemen**, may be even for export.

<u>Reactions</u>: full agreement, projects in this context are needed.

Summary of the discussion: -

After the presentations a lively discussion started. Some of the contributions / statements by participants are reported here as transcriptions without any commenting to provide a glance on the perspectives and concerns of the participants:

- The main problem for the decentralised system is maintenance.
- There is no specialist who will collect the sludge from septic tank.
- There is a typical decentralised system in School in Sana'a.
- We should have pilot plant before decision on alternative.
- Solutions should be site specific.
- Data base for proper selection of the alternatives based on number of population is missing.
- We should consider the technical issues before thinking about the source of financial support for sanitation.
- Socio-economic, cultural, financial (poverty alleviation strategy) and environmental issues should be considered .
- Analyse existing project specially public participation in O&M.
- Conducting EIA will provide the base of success of the project.
- Acceptability of different alternatives by local beneficiaries is a problem.
- Think about cost in case of such long term projects.
- The purpose of suggesting alternatives not only means to compare possible technical solutions but also alternatives to non-technical aspects.
- Density of population, water consumption are important criteria to choose a proper system. Cost comparison will then come later.
- So far, there is no good example for proper design and construction of alternative systems which can be used as a case study.
- We can not impose technical system which does not work and rejected by people.
- Non of the sites visited provided enough data to base a proper system selection on.
- People like to have big things but then they fail in payment and operation.
- Separate systems are the best. Khamir can be improved by minimum of smell.
- Interruption of treatment in septic tank by collection is not advised.

- You can not generalize using alternatives at all places. Consideration for optimisation of all factors (social, technical, economical) is important.
- So far, there are no good examples for alternative systems. So that we can not say whether these solutions far feasible and affordable.
- Human factors should also be included and investigated such as: Training, Payment, why it is not working.
- The house installations should be considered when choosing sanitation concepts.
- If centralised systems as well as decentralised ones are operated well, cost can be the factor to choose the best in any country.
- Operational risk evaluation for centralised and decentralised should be carried out.
- Operational aspects, both in the public and in the private sphere, are important and should be considered for the selection of a sanitation concept.
- Cost assessments should include investment cost, planning cost, O&M cost, life cycle cost, as well as other aspects such as affordability and income effects.
- There is a need for pilot projects to prove viability of a solution concept and its acceptability.
- Design parameters should not copied form other countries.
- Change in attitude is also needed. Some people in Yemen still think that the pipes should be bigger to include some solid waste.
- Low cost systems are rejected by people because they do not want to be bothered with sanitation technology, they just want to have good service. They say: do things proper or leave us alone. So far, centralised technology such as pond system did not provide us with proper service at low cost.
- We should prepare the people so that they can contribute and feel that its their problem.
- In Damt the canal is causing Malaria. It should be continuously cleaned.
- Convince people to clean site. Sensitive things are important to start with.
- Complicated systems can implemented in Yemen, too. It is only a matter of incentives.
- The high acceptability of households for the centralised systems is rooted in perception that because the sanitation problem is gone with no cost.
- Since in Abs there is not enough water, sanitation is not felt to be a problem.
- Subsidizing the cost at some place and not at others is a problem. Treat people equally nationwide.
- To reduce the cost any approach should be demand driven and not donor driven. Use pilot systems. Use low cost technology. Use less standards. Avoid international contractors and standards. SFD projects are done by local people with low cost.
- Insufficient O&M of conventional systems will lead to corrosion but you can also change and replace the corroded material. An advantage of alternative systems like small bore systems, is that they have a longer live time.

- Septic tank evacuation will be handicapped by electro-mechanical problems, trucks and pumps need maintenance.
- In conventional systems scarce water is needed for flushing .
- In Shabwah people ascertained that the land required for the treatment plant will be made available. But later they fail to make it. So the project stopped.
- The customer does not feel the real cost.
- Every conventional system in Yemen is working and people are paying. In Hajjah: Design consumption is 60 while the actual is 30 and still working (high slope).
- Raise income rather than lowering the cost. This will strengthen the local economy.
- More flexible standards are needed for our conditions such as: social, climate-related, technical, hygienic standards.
- Pilot project should be demand driven and care should be taken to get social coherence. Listen to people and stick to their ideas. Payment is the important factor for the people.

Conclusions from the workshops:

Some participants complained that the theses and the discussion focused so much on the comparison of conventional centralised systems and alternative (mostly more decentralised) systems. They accused us that we are there to criticize and denigrate all the systems implemented in many Yemeni towns. In so far, the theses were correct to trigger a controversy discussion.

Some of the theses dealing with costs and risks (especially thesis 7 and 10) were too theoretical in order to reach the technically oriented participants of this workshop.

In the Arabic workshop the discussion was hotter than in the English workshop. The international experts had little input in the discussion, but the local experts and the participants amongst each other were discussing taking different positions.

7 ASSESSMENT OF ALTERNATIVE URBAN WATER / WASTEWATER SYSTEMS

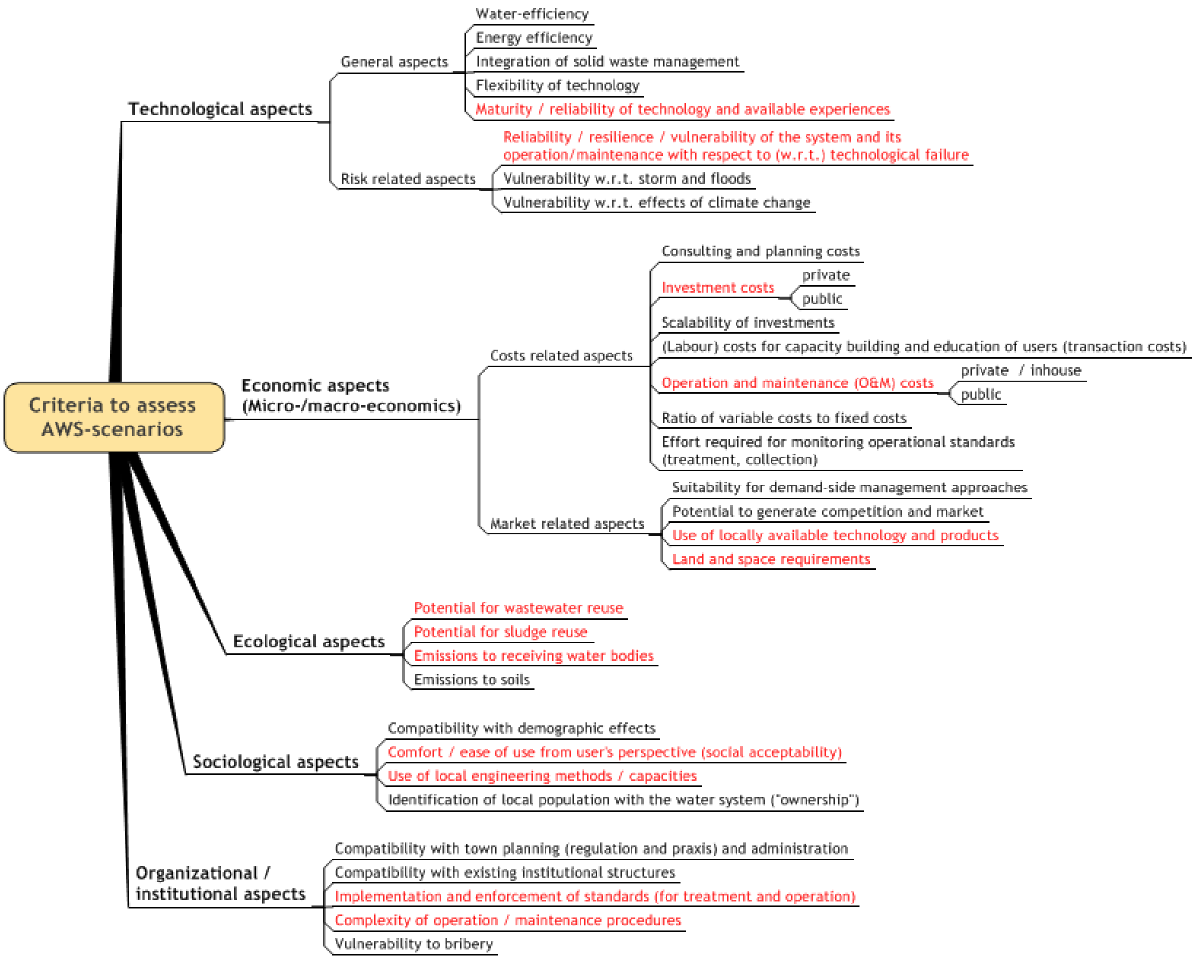
In the preparatory phase of the mission, the experts have put together a preliminary list of criteria to assess the suitability of alternative wastewater system ("**AWS**") concepts for their applicability in Yemeni provincial towns (Chapter 6 of the Inception Report: Kummer et al., 2004). During and after the mission, the preliminary list was reworked according to the empirical findings from the site visits and from the discussion with local experts. It was found to be important not to limit the perspective to the sanitation part of AWS but to also include aspects related to the water supply part, because any option to conserve water directly effects the generation of wastewater, the composition of wastewater and therefore, the treatment options applicable. Additionally, depending on the kind of treatment of the wastewater, options to reuse the treated water might become available. Any reclamation of treated wastewater immediately effects the water supply side of the urban water system.

There are quite a number of aspects and characteristics of AWS which are important but can not be expressed in a quantitative way (either because the aspects are inherently qualitative, or because there is no quantitative indicator available, or because there are no data available / can not be provided at reasonable costs). These aspects need to be assessed qualitatively using experience and professional common sense. Since the final goal of the assessment is not to measure the absolute performance of a given AWS-concept with respect to a given criterion but to provide a ranking of the given set of alternatives of AWS in a given planning context, a relative comparison of the alternative AWS is sufficient. Therefore, the criteria are applied for pair wise comparisons in the following way: "Is this AWS-concept better than that concept with respect to the aspect XX ?"

In any given planning context the assessment of potentially applicable AWS-concepts has to consider a multitude of aspects according to which the available alternatives can be assessed (e.g. economic aspects, ecological aspects).

The set of criteria developed for the assessment of alternative AWS in this project is shown in Figure 7-1. The criteria are subsequently described and discussed. Any of the aspect described depends on the technological concept of a given AWS and therefore, provides a criterion to be considered and traded-off against other aspects when selecting a specific AWS-concept for a given planning context.

Figure 7.1: The set criteria used to assess the generic urban water system concepts for the Yemeni provincial towns. (The red criteria are those required from the ToR.)



7.1 CRITERIA TO ASSESS ALTERNATIVE AWS-CONCEPTS

To assess the AWS-concepts a system of criteria was developed specifically for this project. The criteria cover technological, economic, ecological, sociological and organizational/institutional aspects.

7.1.1 CRITERIA FOR TECHNOLOGICAL ASPECTS

The criteria to assess technological aspects of alternative AWS-concepts are grouped in two subsets: The first subset deals with general technological aspects and the second subset deals with risk-related technological aspects.

7.1.1.1 General technological aspects

- **Water-efficiency of AWS**: In Yemen water resources are scarce and there is a clear trend of further increasing scarcity e.g. due to population growth. Under such circumstances it is especially important that an AWS provides water services to the users (i.e. water supply and sanitation services) as efficiently as possible. This means that water losses are minimized and that the benefits per unit water are maximized. Water-efficiency is be defined as the ratio of the quantity of water supplied into the urban water supply system to the quantity of water delivered and charged to the users.
- **Energy-efficiency of the AWS**: The provision of AWS-services always requires (electrical) energy, mainly for the operation of the pumps (to pump raw water, to treat water, to supply water to the users, to collect sewerage and to treat wastewater). Since the generation and reliable provision of electrical energy is costly an AWS requiring less energy for the provision of a given level of service is more preferable than an AWS requiring more electrical energy to provide that service.
- **Integration of solid waste management in AWS-concept**: There is a potential synergy to organic solid wastes together waste water if anaerobic treatment processes are applied and the organic material is digested to yield biogas. Beside the technical synergies there are also economic, institutional and ecological synergies that can be realized through a systematic integration of both sectors. Especially organizational / institutional synergies are even easier to realize if there is no organizational tradition of separate service-organizations and an integrated utility organization can be formed from scratch. For a given organizational history the costs of integration of solid waste management with urban water services largely depends on technical concept of the AWS-concept.
- **Flexibility**: In general, the flexibility of an AWS increases the more decentralized the system concept is. Flexibility can be described with various perspectives, e.g. w.r.t. (1) future integration of new technologies; (2) extension of capacity; and (3) extension of service area. There is a rapid technological progress going on (e.g. membrane technology) that should be able to be integrated in the AWS. At the same time there is a rapid growth of population in Yemeni provincial towns which requires a high flexibility of the AWS-concept in terms of capacity and extension of service area.
- **Maturity / reliability of technology and available experiences**: As with technologies in other sectors of the economy it is also valid in the utility sector that various technologies are in various stages of maturation. This means that some AWS-related technologies are more field-tested and time-tested than others. Especially in situations where there is a lack of institutional and organizational experience to set up and operate complex utility services it is important that the technological concepts applied match the technical and organizational capabilities of those responsible for their operation. Therefore, AWS-concepts based on mature technology tend not only to be cheaper but also more robust and thus may provide a sound starting point for institutional development than UWIS-concepts based on advanced and innovative technologies.

7.1.1.2 Risk related technological aspects

- **Reliability / resilience / vulnerability of the system with respect to (w.r.t.) technical failure**: The provision of water infrastructure services is important not only for private households but also for industrial and business water users. Any interruption or failure of the provision of water services not only has economic implications on the part of the water users but at the same time may cause operational problems in the AWS itself (e.g. in the water supply network due to stagnation or entry of air into the pressure pipe system). Depending on the technical concept an AWS can be more or less prone or susceptible to failure. For any given definition of failure (e.g. interruption of water supply) there are three major aspects associated: (1) Reliability: a measure of the frequency of the occurrence of failure in the system. (2) Resilience: a measures of the average length of failure situations. (3) Vulnerability: a measures of the average intensity of failure (e.g. the average number of households affected once a failure occurs).

- **Vulnerability of AWS w.r.t. storm and floods**: Excessive rainstorms or floods may damage an existing AWS or settlement areas by either causing physical damages to structures directly or indirectly by causing water damages to other assets. This may be the case, e.g. if the roads are not paved and heavy rainfall erodes the road which might leave the sewer pipes uncovered.
- **Vulnerability of AWS w.r.t. effects of climate change**: An AWS (or any of its components for water supply or sanitation) is designed according to specifications (e.g. regarding population to be served, capacities, service area, water demand, wastewater production, rainfall runoff) fixed at the planning of the system. If these assumptions prove wrong or the if the real situation diverges substantially from the design assumptions during the technical life time of the system (30 to 80 years) the system design no longer fits the actual loads. This might cause increased risk of failure or lead to reduced level in the provision of the services. Since climate change might cause e.g. changes in local rainfall regime, important design assumption for urban water systems can be expected to change. Since the vulnerability of any given AWS is influenced by its overall technical concept and the vulnerability of its most vulnerable components it is in the general interest to decide for a AWS-concept that minimizes negative effects of climate change. This strongly correlates with need to have highly flexible system concepts to adapt to changing conditions.

7.1.2 CRITERIA FOR ECONOMIC ASPECTS

Two sets of economic aspects to assess AWS-concepts are used: (1) cost-related aspects and (2) market related aspects.

7.1.2.1 Cost related aspects

- **Consulting and planning costs**: The more centralized the technical concept of an AWS is the more complex is the planning of the system, starting from conceptualisation and design to the approval planning and the construction process since these kind of AWS-concepts are highly tailored to the specific situation. On the other hand in the case of planning a decentralized system at least the final steps of the approval planning allow that more off-the-shelf solutions can be used for the decentralized parts of the system (e.g. the treatment units). Recurring to more standardized solutions reduces the cost of planning. Therefore, the overall cost for consulting and planning can be expected to vary depending on the degree of centralization / decentralization of the AWS.
- **Investment costs**: In the case of the Yemeni provincial towns the in-house part of the AWS is usually existing well before the public part is implemented. At the same time it is essential for the proper functioning of the overall AWS that the in-house and the public part of the systems are compatible. For the selection of an AWS-concept it is important to consider that any AWS-concept causes costs on the part of the (public) utility but also on the part of the users, who have to hook-up and provide the appropriate in-house installations. Since the investments are paid for by different economic actors (i.e. the public / municipality on the on hand and the private households / businesses on the other) both types of investments need to be considered in the selection of an appropriated AWS-concept for a given planning context.
- **Scalability of investments**: Building or extending an AWS must recognize the fact, that the investment is not a continuous but stepwise function due to the indivisibility of

individual subsystems. AWS-concepts which avoid large indivisible subsystems are easier to scale than those which heavily depend on large subsystems. The better an AWS-concepts is to scale, the easier it is to finance the provision of water services. Highly scalable AWS-concepts also allow to effectively use limited funds to implement functioning water treatment units and thus support stepwise provision of functioning water services. A further advantage of highly scalable AWS-concepts is that such projects usually can be divided in a number of smaller and largely independent projects which can be implemented in a shorter period of time elapsing from the start of planning to the start of operation of the AWS.

- **Costs for capacity building and education of users (transaction costs)**: In order to assure that the investments in an AWS generate value the system must be used and operated properly. Depending on the AWS-concept the customers (private households, businesses, etc.) must be instructed / educated. Without that investment any AWS-projects runs a high risk that it will not be operational for the technical lifetime assumed in the planning-phase but instead will be abandoned early due to malfunction and / or refusal of the intended end-users. The cost for capacity building will depend on the technology per se and its susceptibility to failure under the given conditions. The latter, at least to some degree, also depends on how advanced or how mature a technology is.
- **Operation and maintenance (O&M) costs**: The operation and maintenance of both, the public and the in-house subsystems of the AWS continuously cause cost if the overall AWS is to function properly. Depending on the AWS-concept the degree of centralization / decentralization of (1) the technical units, (2) the ownership of the units and (3) the delegation of the responsibility for proper operation to one or more operators the distribution of costs can vary substantially. Therefore, as with the investment costs the O&M costs of any specific AWS-concept can be further differentiated according to who owns respectively operates the system or subsystems (e.g. private households, private investors, municipality, operators). Additionally, depending on the degree of centralization / decentralization there are various economies of scale or learning curve effects that might reduce these costs. Finally, depending on the degree of centralization / decentralization the costs generated at the level of the regulatory body for regulatory control and monitoring of the operational standards differ.
- **Ratio of variable costs to fixed costs**: This criterion describes the ability of an AWS to effectively apply demand side management and thus the ability to manage the system through changes in user behaviour. The higher the ratio the more effective are DSM-measures; the lower the ratio the less effective are DSM and – at the same time - the higher the risk for the operators of the system to fall victim to the sunk cost effect. A high ratio also increases the flexibility of the utility/operator of an AWS to adapt to changing market conditions. This is especially important under rapidly changing conditions as in Yemeni provincial towns.
- **Effort required for monitoring operational standards (treatment, collection)**: Any AWS needs to be operated against given standards (for water treatment and quality of water supplied, for wastewater collected, treated and reused / discharged, and for sludge produced and reused / disposed). Without such standards neither the quality of the services nor an environmental sound management can be assured. The overall effort will to a certain extent depend on the type of the AWS-concept.

7.1.2.2 Market related aspects

- **Suitability for demand-side-management approaches**: Not every AWS-concepts has the same potential for effective application of demand-side management instruments and not every AWS-concept depends on supply-side management options to the same extend to deal with supply-demand gaps. Especially under conditions of water scarcity and rapid growth of population (both is typical for Yemeni provincial towns) it is important that an AWS-concept does not only not preclude demand side measures but instead encourages continuous efforts to reduce demands by improving the water use efficiencies and thus supports conservation of valuable water resources.

- **Potential to generate competition and market**: Depending on the degree of centralization / decentralization of the AWS-concept, the planning, implementation and operation and maintenance of the system can be assigned to various actors who in turn require specific level of (technical, organizational, fiscal etc.) skills and qualifications. The more centralized an AWS-concept is, the higher the required skills are and the fewer actors are involved. This reduces competition. On the other hand a more decentralized approach usually requires less skills and at the same time supports competition with respect the provision of the required services (planning, construction, operation & maintenance). In order for an AWS to have lasting success under the conditions typical Yemeni provincial towns it is important that local craftspeople, construction companies and manufacturers can contribute substantially to the implementation and operation of the AWS. This generates local income and "ownership" of the locals for "their AWS". A strong involvement of the local businesses also supports the generation of qualifications and skills of the local workforce. This, together with the competitive local market, will minimize the costs for the operation of the AWS.
- **Use of locally available technology and products (dependency on foreign technology imports)**: Since the final goal of any development aid is to make the donees / beneficiaries independent of any foreign aid. The provision of such essential infrastructure services like urban water services is a important instrument to strengthen the local economy and thus contribute to develop independence. In order to use this instrument it is essential that the fraction of locally available technology and products used to build and operate the AWS is as large as possible. Locally available technology is a limiting factor under Yemeni conditions. The ability to make use of locally available technologies depends on the AWS-concept. Not only the potential to use locally available technologies and products is influenced by the selection of a specific AWS-concept but also the future degree of dependence of the donee on foreign technology imports. Additionally, a strong integration of locally available technology and products will provide incentives for the local economy and also stimulate innovation on the part of local businesses.
- **Land (space) requirements**: The degree of centralization / decentralization of the technological concept of an AWS determines the total amount of space required to build the technical components for water distribution / collection and treatment. It also determines the number of lots of land necessary to implement the subsystems and the location of these lots (within / outside the residential area). Depending on the local situation it might be easier to acquire a number of smaller lots throughout the residential area to build decentralized treatment units. In other situations it might be easier to set aside a larger peace of land outside the residential area as a site for on big centralized treatment plant. Also the interference of the land built with subsystems of the AWS with natural ecosystems has to be taken into consideration.

7.1.3 CRITERIA FOR ECOLOGICAL ASPECTS

- **Potential for wastewater reuse:** Under situations of water scarcity, it is especially important to use water as efficient as possible. On the one hand this means to conserve water in terms of water quantity. On the other hand it means that for a specific application the water should fit that application's requirements regarding water quality. From an economic point of view as well as from a technical point of view it does not make any sense to use high-quality water for uses that only require lower quality water or vice versa. For example using water treated to potable water standards for flushing toilets is a waste of treatment effort. So if after treatment (which from an economic point of view is adding value to the raw wastewater) of wastewater the wastewater is just discharged is a waste of effort if there are uses that require only non-potable water quality and for which treated wastewater as a water supply is sufficient or can be made suitable with little extra treatment or additional effort (e.g. for transportation from point of treatment to point of use or for disinfection) and thus the use of high quality (e.g. potable) water can be substituted. Depending on the technical concept of the AWS this potential for reuse of treated wastewater differs. Especially under the extreme water scarcity in Yemen AWS-concepts that allow for water reuse are preferable.

- **Potential for sludge reuse:** Municipal wastewater contains a substantial amount of nutrients (e.g. phosphorous and nitrogen). Conventional biological wastewater treatment does not remove the nutrients but leaves most of them in the sludge. This is the reason why the sludge is – at least in principle – is ideally suited to be used in agriculture as fertilizer. However, due to the fact that municipal wastewater usually is a mixture of wastewaters from various sources (residential, industrial, runoff from the streets) and therefore also contains a wide spectrum of pollutants like heavy metals, organic solvents, pharmaceutical substances and their metabolites. The sludge from the treatment of such complex wastewater usually is contaminated and therefore not suitable for agricultural application but must be disposed of in an environmentally safe way (e.g. incineration; landfill). Principally, the less wastewater streams from various sources are mixed within an AWS the higher the potential to end of with a reusable sludge.
- **Emissions to receiving water bodies**: The degree of mixing of various wastewater streams (e.g. from residential users, from industrial users) and the treatment technology to be applied in a given AWS varies with the AWS-concept. This in turn results in different degrees of pollution remaining in the wastewater after treatment. Therefore, the potential emissions to receiving water bodies depend on the AWS-concept. Another aspect is, that depending on the AWS-concept part of the wastewater can potentially be reused after treatment while the other part will be discharged to some receiving water body (river, groundwater). Some of the "pollutants" like the nutrients phosphorous and nitrogen remaining in the wastewater after treatment might provide positive effects if the wastewater in used for irrigation while the same substances might heavily contribute to eutrophication if the wastewater is discharged to a river. While in the case of reuse of treated wastewater for irrigation nutrients can be considered as resources other pollutants remaining (like heavy metals, antibiotics, or microorganisms) might pose a substantial threat to the receiving water bodies, soils and also pose health risk for people exposed to the wastewater.
- **Emissions to soils**: Depending on the AWS-concept various streams of wastewater from residential and industrial sources are mixed and treated jointly. The sludge resulting from the treatment of that wastewater will show different types and degrees of pollution (e.g. heavy metals, organic pollutants) depending on the type of wastewater. Therefore, the AWS-concept (including the approach to the disposal of wastewater treatment sludge) should be selected to minimize the emission to soils under the specific conditions.

7.1.4 CRITERIA FOR SOCIOLOGICAL ASPECTS

- **Compatibility with demographic situation / population growth**: In Yemen there is an average annual population growth of about 4 % while some of the provincial towns have a population growth rate of up to 10 %. A growth rate of 4% annually means that there is a doubling of population in less than 20 years, while at a growth rate of 10 % the population doubles about every 7 years! This growth rate also means that the demand for water services, both water supply and wastewater, also grows very fast. As a consequence, the volume of water to be supplied and volume of sewer collected and treated is rapidly increasing under these conditions. It is further to be expected that the population growth brings with it a fast urban sprawl and thus a rapid increase of the service areas to be served by the urban water infrastructure. Therefore, any AWS-concept to be successful und these conditions needs to be very flexible and allow for easy extension.

- **Comfort and ease of use from user's perspective (social acceptability)**: For a AWS-concept to be successful it is essential that it not only provides a good quality service to the user but that it is also easy and comfortable to use. Any system that is complicated to use (relative to the skills of the users) is prone to either be not used at all or to be misused. The latter results in an increased effort for O&M to keep it functioning. Generally, depending on the AWS-concept a gap is to be expected between the required and the existing skills of the users of the AWS. To close this gap efforts for capacity building (see criteria on investments in capacity building) are necessary. The easier a system is to use for a user the less effort has to be put into capacity building.
- **Use of local engineering methods and capacities:** The situation of water scarcity in Yemen – also intensifying – is not new but a fact related to the geographic situation of the country. Due to that, there is a century-long technological tradition in Yemen and Yemeni towns to deal with water scarcity and to handle wastewater in densely populated areas. The traditional approach, however, lost acceptance with the appearance of the European flush water toilet and gravity sewers using water as the major transport medium for excreta. Since the "modern" European system was developed to be applied under conditions of ample natural supply of water it does not fit the conditions in Yemen from principal considerations. Therefore, any AWS-concept that builds on traditional Yemeni technology and enhances this approach with modern technology instead of replacing it will in the long run provide a more sustainable solution.
- **Identification of local population with the water system ("ownership")**: In order to increase the chance of success for an AWS it is essential that the population served accepts the system as "their" systems, i.e. that they develop some kind of "ownership". This is necessary to generate the willingness to pay for O&M of the system . Important factors (beside economic factors) influencing this acceptance are the compatibility of an AWS-concept with the traditional and religious customs and heritage of the population. Another factor certainly is the "image" a specific AWS-technology has from the users' point of view. While the acceptance of any AWS might be influenced with investments in marketing and capacity building effort, to keep the costs low, AWS-concepts should have a high identification potential with the to-be users.

7.1.5 CRITERIA FOR ORGANIZATIONAL AND INSTITUTIONAL ASPECTS

- **Compatibility with town planning (regulation and praxis) and administration**: A functioning and stringent town planning (including administration and approval of building applications) in Yemeni provincial towns is essentially non-existent today. The urban sprawl is rather uncontrolled by administration. The typical sequence in the development of new urban residential areas commences with some landowners start building houses on their lots. Some houses will be finished in a relative short period of time. On other building sites construction is discontinued since for the time being the mayor function of erected part of the building is to claim the ownership of the land than to provide living space to the owner. Once a certain number of houses are completed and occupied the residents start putting pressure on the administration to develop infrastructures for that area. With this modus operandi centralized AWS-concepts (which per se need a more long-term planning horizons) are much more difficult to plan and implement that more decentralized approaches which can be adjusted to the actual state of development of a given development area. With this in mind, the consideration of the actual town planning praxis in the specific situation should be considered in the selection of an AWS-concept.

- **Compatibility with existing institutional structures**: The operation and management of any infrastructure system requires institutional and organizational capabilities, e.g. to hook-up and bill of the customers, to maintain the technical components, to qualify personnel, to implement and monitor standards. The organizational structures required will depend on the AWS-concept. For example, to operate a centralized AWS-concept a centralized organization (e.g. a public or private utility) is necessary. In such a situation a decentralized approach with a number of independent organizations responsible for various parts of the overall system will not be feasible. On the other hand a technically decentralized AWS-concept principally offers more options to organize the O&M of the various subsystems. Both, decentralized organizational structures as well as a centralized organization might be suitable for that kind of AWS. Since in Yemeni provincial towns the institutional arrangements for the provision of infrastructure services (water supply, wastewater, solid waste, energy etc) are under development the organizational and institutional requirements have to be aligned with the respective requirements of the AWS-concept. In addition, if multiple organizational bodies are involved in the operation of an AWS any unclear assignment of responsibilities or overlapping responsibilities and unclear organizational interfaces present a major risk for failure of the AWS and therefore should be avoided.
- **Implementation and enforcement of standards (for treatment and operation)**: To operate an infrastructure system (economically and ecologically) effectively and efficiently and to provide a consistent and equal high quality service to all customers certain standards and regulation need to be in place and enforced. Without this the systems can not be governed in a socially acceptable way. The required effort as well as the required skills differ from one AWS-concept to another.
- **Complexity of operation / maintenance procedures**: As any technological system an AWS needs to be operated and systematically maintained in order to provide the intended function. This requires qualified personnel and organizational skills with the operating utility. However, it is equally essential that the users of the AWS are knowledgeable in order to avoid abuse and malpractice. The less complex and easier it is to maintain the overall AWS-concept and its major components the more successful the implementation.
- **Vulnerability to bribery**: Some bribery associated with planning and construction of AWS is probably inescapably under Yemeni conditions. Estimates are that about 10 % of the investment costs of AWS-projects are bribes. Therefore, the question is how to reduce the appeal of bribery and thus how to reduce costs. Of course the attempt to a bribe or the corruptibility of decision makers increase with the sum of the investment. On the other hand bribery is eased if there are only a small number of people drectly involved. Therefore, breaking down large AWS-projects in a large number of smaller and independent projects with a large number of people involved in their planning and implementation reduces the leverage of bribing. Depending on the AWS-concept of an infrastructure project (e.g. whether it is possible to split the project in a large number of smaller and independent projects) bribe prevention is more or less effective.

7.2 ASSESSMENT OF THE AWS-CONCEPTS WITH THE ANALYTIC HIERARCHY PROCESS

The set of criteria developed in the previous section is now applied to evaluate and assess the options for alternative urban water systems (-> Chapter 4) specifically for the selected towns. In general, the assessment of the alternative AWS is a multi-criteria assessment. To provide an overall ranking of the alternatives in a given decision situation where each alternative can be assessed according to a multitude of decision criteria requires a multi-criteria assessment method. In the present study the Analytic Hierarchy Process (AHP) (Saaty, 1980) is applied to assess the alternative AWS-concepts under the specific conditions of Yemeni provincial towns. The AHP is a theoretically we grounded and widely applied multi-criteria decision making methodology. The AHP also supports the structuring of the set of criteria, the assessment of weights of the criteria, and the sensitivity analysis of the ranking. Additionally, the AHP provides support in to conduct all of these steps of a multi-criteria decision making in a group decision making context. This is especially important in the present context where the project team expects to have to recur in some of the necessary assessment to qualitative estimations due to a lack of data. In such a situation it will be of utmost importance that all the members of the team including the local experts and representatives of the Yemen Water Administration with their experience and thorough knowledge of the indigenous situation can effectively and efficiently contribute to the assessment of the alternatives.

7.3 RESULTS

The matrix shown in Table 7-2 summarizes the preliminary and qualitative assessment by the experts of the various alternative wastewater systems AWS-1 to AWS-5 using the the criteria system developed in section 7.1.

The more “A”s an alternative system has the more it is preferred under the respective criterion. The alternative systems are only be compared to a given criterion. So far, the assessment does not aggregate the overall rank of the AWS since the weighting system for the criteria is not yet derived.

<u>A detailed and final assessment and discussion of the evaluation results could not be finalised due to the limited time available until submission of this draft report. Such discussion will be provided with the revision of this report</u>

Table 7-2: Summary of the preliminary assessment of the alternative water systems according to the criteria system described in section 7.1

		Criterion	AWS-1	AWS-2	AWS-3	AWS-4	AWS-5
CRITERIA FOR TECHNOLOGICAL ASPECTS	General technological aspects	Water-efficiency of UWS	AAA	AAA	AAA	A	A
		Energy-efficiency of the UWS	A	AAAA	AA	AA	AA
		Integration of solid waste management in UWS-concept	AA	AA	AA	AA	AA
		Flexibility	AAA	AAAA	A	A	A
		Maturity / reliability of technology and available experiences	AAA	AAA	A	A	AAA
	Risk related technological aspects	Reliability / resilience / vulnerability of the system with respect to (w.r.t.) technical failure	AAAA	AA	AA	A	A
		Vulnerability of UWS w.r.t. storm and floods	A	AA	AAAA	A	A
		Vulnerability of UWS w.r.t. effects of climate change	AA	AA	AAAA	A	A
CRITERIA FOR ECONOMIC ASPECTS	Cost related aspects	Consulting and planning costs	AA	AAA	AA	A	A
		Investment costs (privates households)	AAA	AAA	AAA	A	A
		Investment costs (public part of the system)	A	AA	AAA	AAA	A
		Scalability of investments	AA	AAAAA	A	A	A
		Costs for capacity building and education of users (transaction costs)	AAA	AAA	AAA	A	A
		Operation and maintenance (O&M) costs (in-house part)	AAA	AAA	AAA	A	A
		Operation and maintenance (O&M) costs (public part)	A	AAAA	A	AA	AAA
		Ratio of variable costs to fixed costs	AA	AAAAA	AA	A	A
		Effort required for monitoring operational standards (treatment, collection)	AAA	A	AA	AA	AA
	Market related aspects	Suitability for demand-side-management approaches	AAA	AAA	AAA	A	A
		Potential to generate competition and market	AAA	AAA	A	A	A
		Use of locally available technology and products (dependency on foreign technology imports)	AA	AAA	AA	AA	A
		Land (space) requirements	A	A	A	A	A
CRITERIA FOR ECOLOGICAL ASPECT		Potential for wastewater reuse	AAA	A	AAAA	A	A
		Potential for sludge reuse	A	AAAA	AAA	A	A
		Emissions to receiving water bodies	AA	A	AA	AA	AA
		Emissions to soils	AA	A	AA	A	AAA
CRITERIA FOR SOCIOLOGICAL ASPECTS		Compatibility with demographic situation / population growth	AA	AAAAA	AA	A	A
		Comfort and ease of use from user's perspective (social acceptability)	A	A	AA	AAA	AAA
		Use of local engineering methods and capacities	A	A	AAA	AAA	AAA
		Identification of local population with the water system ("ownership")	AAAA	AA	A	A	A
CRITERIA FOR ORGANIZATIONAL AND INSTITUTIONAL ASPECTS		Compatibility with town planning (regulation and praxis) and administration	AAAA	AAAA	A	A	A
		Compatibility with existing institutional structures	AAA	AAAA	A	A	A
		Implementation and enforcement of standards (for treatment and operation)	AAAA	A	A	AA	AA
		Complexity of operation / maintenance procedures	A	A	A	AAA	AAAA
		Vulnerability to bribery	AAAA	AAA	AA	A	A

8 RECOMMENDATIONS FOR FURTHER STEPS TOWARDS SUSTAINABLE WATER SUPPLY AND SANITATION SYSTEMS IN YEMEN

8.1 GENERAL CONCLUSIONS FROM THE CASE STUDIES

The development of drinking water resources is a major concern for all three case study towns. The wells available have not enough capacity to serve the population and in the case of Khamir produce salty water. Groundwater aquifers are available in all three towns but there is a strong competition between agricultural use and satisfying the needs of the urban population. The farmers have a strong position in this competition, because they own most of the land under which water can be found. Wells to cover the urban population’s needs can therefore not always been drilled in the most favourable locations. Increasing agricultural use of groundwater leads to an over-exploitation of groundwater resources. The supply situation can therefore not be expected to improve to such degree that the water consumption will significantly rise above 40 l/c/d. This figure is the average consumption figure in some Tihama towns as evaluated by GTZ. From the various figures received during the visits to the three case study towns presently the water consumption is in the range of 25 to 30 l/c/d.

Standards for water supply in Yemeni towns have been set through various nationally and internationally financed projects. The standard concept is a conventional centralised piped water supply scheme with house connections. It is very doubtful that any other water supply option, which does not aim at the piped supply of the houses (e.g. public stand posts) will be accepted by the population even if it would support a higher degree of conservation and more efficient uses of the scarce resource water. In all three case study towns therefore a piped water supply network is the most preferred solution. In Damt and Khamir such networks exist and are more or less operational. In Abs a network is under construction.

Any wastewater disposal scheme needs to consider the above mentioned water supply situation. In addition to potable water supply the hot water source (springs and artesian wells) needs to be considered as a specific characteristic in Damt. In general, the cultural and religious traditions requiring the use of water for anal cleansing and washing after defecation, are another ancillary condition that needs to be considered in the planning of any urban water system in Yemen. This heritage might explain the prevalence of water-based sanitation in Yemen.

Presently sanitation in the case study towns is handled by the water users and is not regulated. Handling of wastewater is not only a nuisance but also an economic burden for the private households, which they want to get rid of. This is one of the major causes responsible for the frequent malpractice of the operation of private wastewater disposal practices.

From the options for AWS pre-selected in chapter 6 and assessed with respect to their sustainability in chapter 7, for the three case study towns a number of preliminary recommendations can be made. Before presenting the recommendations, the authors, however, would like to stress, that due to the limited information received during the visits to the towns and the very outdated maps, the rapid growth of population in the cases study towns as well as the rapid urban sprawl of the towns these recommendations can only be considered as general comments and generic lessons learnt. As already stated in chapter 1.3 neither the available information and maps nor the time available for this mission allowed for a more detailed recommendation or even preliminary design of sanitation measures for the case study towns.

Recommendations for Damt

In Damt people make use of the fact that a continuous water flow from artesian wells and hot springs exists discharging to a channel in the town supplying the wadi. A large part of the town's wastewater is also directly discharged to this channel through private pipes. The dilution of the residential wastewater by the hot water and transport capacity of the hot water allows for such practice. Still pollution, nuisance, and health dangers caused by this practice are severe.

In those parts of the town without direct access to the channel and wadi either cess pits have been dug or no systematic wastewater disposal has been implemented at all. Since the ground is rocky, cesspits are expensive and there is little infiltration. In order to prolong the period of use of the cess pits for faeces the grey water is often directly discharged to the streets. People who do not even have access to cess pits use the sanitation facilities of mosques.

Under the special pre-conditions in Damt the following measures are proposed to improve the sanitation conditions:

1. Clean-up of the "channel" and the wadi
2. If possible under the hydro-geologic conditions closure and controlled use of the hot spring water is essential. On one hand this would allow to conserve this valuable water resource and on the other hand it would reduce wet areas in the town and wadi which are major breeding grounds for Anopheles flies and thus severely contribute to the severe malaria problem in Damt.
3. Construction and operation of public facilities for cloth washing with proper management of wastewater would contribute not only to reduce environmental pollution of the hot spring water but also would contribute to public health.
4. In the town centre as well as in residential areas now connected to the "channel" a collector pipe system should be constructed along the channel. The private wastewater pipes should be connected to this interceptor pipe. The wastewater collected by the interceptor pipe should be treated in a yet to be built wastewater treatment plant (pond system) for which the location in the wadi is still to be determined.
5. In the outskirts of Damt without direct connection to the channel and wadi storage tanks or septic tanks should be constructed and a vacuum truck based service for a regular emptying of the tanks should be implemented. The wastewater collected from the tanks should be treated in the treatment plant.
6. Once the construction phase has finished in a neighbourhood and the population growth in that area has stabilized a shallow small bore sewer system collecting the solid-free overflow of the septic tanks may be considered to be the next step of development and replace the tanker-based system. The operation of the small-bore sewer system also would provide a next step in capacity building and the development of skills of the institution responsible for the operation of the overall wastewater system

Recommendations for Abs:

Presently the population in Abs fully relies on the water supply through tankers or even people carry water in buckets and canisters to their homes. The population therefore uses very little water and feels no wastewater disposal problem. A source for drinking water is available and attracted excessive mango farming in the area.

Small covered pits have been dug for the disposal of faeces and urine. Grey water is discharged to the unpaved roads. For larger houses along the asphalted main road larger pits have been constructed to which all wastewater is discharged. Generally, the hygienic conditions in Abs seemed much better than those in the two other case study towns. The soil in Abs is highly permeable and no usable groundwater source is available within the town's limits. The infiltration of wastewater in the ground may therefore offer a feasible solution but would require a thorough study of the hydro-geologic conditions.

The following measures are being proposed for Abs:

1. As long as the water supply issue is not solved and the water consumption is not increasing sanitation improvements are of low priority.
2. Septic tanks and infiltration pits are proposed for all of Abs once there is higher water usage. A staggered implementation of such facilities is recommended.
3. In the future the collection of the septic tank overflow in a small bore sewer system is possible and should be implemented in a later phase once the water consumption exceeds the infiltration capacity of the soil or if the hydro-geologic situation requires protection of groundwater and soils.

Recommendations for Khamir

Great effort has been made by NWSA to explore suitable drinking water sources for Khamir but until now no reliable source supplying sweet drinking water is available. The existing water supply network supplied salty water for a short period of operation and has now been taken out of operation because people refused to pay for salty water. Today, Khamir is supplied with potable water by tankers which carry the water from wells 20 km outside Khamir. People in Khamir do suffer from water shortage.

Although there is little water used in the households a severe sanitation problem exists especially in the old town of Khamir. The photo report in the appendix A6 drastically shows the shortcomings. Cesspits – if available - tend to overflow because the infiltration capacity of the soil is low and no regular emptying of cesspits has been organised. Many households have no wastewater disposal facilities at all. Grey water is discharged to the streets. The former dry toilets are still in use but the faeces are neither covered with ash nor are they dried any more in the traditional way. Instead, the faeces and urine together with the anal hygiene water and flush water in many cases are just dumped in the back of the houses. These dump sites attract flies and pose a high risk for public health. Immediate action is required in order to provide a healthy environment.

The following measures are being proposed for Khamir:

1. An awareness campaign should be launched aiming to sensitise the population for the health risks and environmental problems caused by their present behaviour. There should be a program implemented cleaning up the local dump sites for faeces and urine.
2. For the old town of Khamir, where the traditional toilet is still in use - but not properly in use – an upgrade of the existing facilities leading to less smell and more comfortable use is an option to be investigated in detail.
3. In the case the traditional dry system is not to be reinstalled construction of cess pits to collect black water from the toilets are to be constructed as minimum solutions for houses in the old town.
4. A better solution for the old town which would require more effort and investments would implement septic tanks and infiltration pits. This systems could be enhanced later on with

a small bore sewer system and a wastewater treatment plant. This solution would allow to discharge all wastewater to the septic tank and avoid grey water discharge to the streets.

5. For the new town, where no separation of wastewater streams can be realised because of the existing in-house installations septic tanks and infiltration pits, later supplemented with a small bore sewer system is proposed for immediate implementation.

General recommendations for all three towns:

Recommendations have been made in chapter 7.3, where the results of the evaluation have been presented. Some of the most important general recommendations are summarised here:

1. Any successful implementation of an urban water and sanitation service requires an institutional backing and the existence of proper administration. This also includes institutions responsible for proper town planning including the enforcement of the plans but also institutions taking care of solid waste collection and disposal, as well as for enforcement of building standards. Parallel to addressing sanitation improvements strong emphasis should be put in the development of such an institutional infrastructure and capacity building of the institutions involved in the provision of the utility services.
2. The present problems in the sanitation sector are not determined by a lack of appropriate technical solutions available for sanitation. It is only that such solutions are not implemented or, once implemented, not operated properly. Therefore, in each feasibility study for a project a broader spectrum of sanitation options should be investigated and compared and the necessary institutional arrangements should be designed and developed in parallel with the technical concept.
3. The present organisational and technical skills of the Yemeni urban population and administration are more favourable for decentralised than for centralised technical solutions for sanitation. Technical improvements of existing decentralised facilities together with a more centralised (town-wide) operation and maintenance of such facilities is recommended.
4. In Yemen, being a water scarce country, any technical solution conserving water and providing a more efficient use of water is highly preferable.
5. Universities, as the major educational institutions providing technical and operational competencies and skills for Yemeni people, should systematically be included in the effort to build up local knowledge on alternative wastewater systems as well as in the development of technological solutions optimised for Yemeni conditions.
6. Participatory planning is essential for a successful implementation and sustainable operation of any sanitation system. Chapter 8.3 provides some principles.

8.2 APPLICABILITY OF CONCLUSIONS IN OTHER REGIONS OF YEMEN

The three towns visited during the mission showed very different conditions, however, with some typical factors being similar in all three towns as laid down above. Water scarcity, weak or missing town planning including its enforcement, low environmental awareness of the population, and low management and technical skills of the officials involved in the water sector on town level can be expected to be similar all over Yemen.

The house construction standards vary significantly between the towns and between the different quarters of each town. Even more types of construction standards can be expected throughout the Yemen thus influencing the sanitation requirements. The same applies for topography, soil conditions, groundwater conditions and others.

Although the spectrum of local conditions is surely much broader than observed in the three case study towns, the three towns already provided a reasonable spectrum of conditions, which were used to develop the criteria for the evaluation of sanitation options.

This set of criteria presented in chapter 7 is comprehensive and is expected to cover also conditions in other parts of Yemen.

8.3 PARTICIPATORY PLANNING

From all statements of experts in the water sector in Yemen it became clear that the participation of local population in the design and decision process for a municipal water system is essential in order to achieve acceptance, willingness to pay and proper usage.

Working steps

The following working steps have been developed by both the international and the local experts o this mission during meetings in Sana'a and reflect their mutual understanding of participatory planning tailored for Yemen.

1. Composition of the project team: international experts, national experts, selected persons from project town as regular members of the project team (and champions for the solution to be developed)

2. Short mission of international and national experts to the town for investigation of existing conditions, and establishment of first contacts with local administration
(similar to the present study, but more elaborate: 2 weeks)

3. Development of scenarios for municipal water systems
(similar to the present study, but more elaborate: 2 weeks)

4. Verification of the scenarios with local administration (2 days)

5. Presentation and discussion of the scenarios by national experts (in Arabic) in two workshops (one for men, one for women) to local stakeholder representatives (1 week preparation, 1 day for parallel workshops)

6. Consolidation / modification of (selected) scenarios through the (national and international) experts (1 week)

7. Presentation and discussion of the consolidated scenarios by national experts (in Arabic) in two workshops (one for women, one for men) to the local stakeholder representatives and administration; decision / selection of a preferred scenario (1 week preparation, 1 day for parallel workshops)

8. Detailed feasibility study and environmental impact assessment for a water system based on the preferred scenario (depending on size of town and selected system)

Factors constraining participation

There are factors which may hamper or be opposed to the involvement of the target group in the planning process.

- Illiteracy.
- A substantial fraction of population may not be in a position to participate because of extreme poverty.
- Lack of infrastructures & community resources.
- Over-reliance on government for solutions of problems.
- Mayor focus of Yemen (urban) population on the individual and family interests and relative non-interest in communal / tribal and even societal perspectives.
- Historical centrifugal tendencies in Yemeni society.
- Lack of understanding of the system context of the problems.
- Low “ownership” and responsibility resulting in bad maintenance of systems.
- Weakness of administrative and regulative guidance for the implementation of water systems (e.g. building codes, standards and their sustaining enforcement).
- Large variety of existing individual water-related facilities at the family resp. individual household level is a major obstacle for a new solution (sunk costs, familiarity with the specific technology).
- Divergence between willingness of population to pay before implementation and after.
- Imbalance between the decision-related / political role of women in Yemen society and their involvement in the operation / use of water systems (“gender gap”). Difficulty to reach women and involve them in participatory planning.
- Lack of knowledge sharing among the water related projects (incl. learning from mistakes).
- Individual interests spur “individual solutions” instead of recognizing that the problem needs a very strong systems and society point of view in order to arrive at a sustainable solution. Low awareness and responsibility for the social implications of individual behaviour.
- Acuteness of existing water related problems is increasing while at same time the decision making processes tend to slow down due to the involvement of lobbying groups in the decision process (the smaller the resources available for allocation the harder the fight for shares).

9 EXECUTIVE SUMMARY

When discussing the wastewater issue with stakeholders the experts heard a few statements many times. 1. There are no good examples of on-site sanitation facilities in Yemen, but people see overflowing or collapsing cess pits or polluted streets and see the costs and effort for the house owners to construct and operate such facilities. From a conventional system they expect to get rid of all this hassle and pollution. 2. The people manifest their willingness to pay for improved services in the planning phase. Once the project is implemented they start to negotiate the payments and complain about the costs. 3. Yemen people are not third class people and do not want any system inferior than usual in western countries.

From the discussions in Sana'a and in the case study towns the experts got the impression that the development of appropriate technical solutions is the minor problem of promoting alternative solutions for wastewater disposal. The development of a strong institutional framework, which would operate and/or even own alternative / decentralised facilities would solve many problems. It is necessary to convince the users and operators that alternative solutions can provide the same level and comfort of service to the users if designed, constructed and operated properly. Also it is necessary to show that such systems are successfully operating in developed countries and are not a low cost solution for the poor.

The experts saw one example of a functioning on-site facility with a constructed wetland in a school in Sana'a (see picture in Appendix A7). More such examples especially combined with educational and awareness raising measures amongst the youth can be a step to start promoting alternative systems.

There are at least four requisites necessary for proper functioning of technical urban infrastructure systems like the water/wastewater system: (1) The regulatory framework and its enforcement are in place and enforced. (2) Organizational skills for the operation and management of the infrastructure systems are available and fit with the technological concept of the infrastructure. (3) Traffic regulations and town planning are enforced and solid waste disposal is solved. (4) Strong local leaders are promoting the planning, implementation and operation of the infrastructure as well as the other sectors.

<u>Approach</u>

Three case study towns (Damt, Abs, Khamir) have been proposed by NWSA and have been visited by the experts. This case study approach gave the experts in-sight to the actual conditions encountered in Yemen provincial towns.

Interviews with representatives of water related institutions and donor organizations in Sana'a gave the experts the opportunity to receive a broad spectrum of the different views of the water sector in Yemen.

From the conditions in the case study towns the experts provisionally developed 4 technical scenarios for alternative sanitation systems and set up 12 theses characterising main topics encountered during the mission.

In two workshops held in the Ministry of Water & Environment at the end of the mission the technical scenarios were presented and the 12 theses discussed. The first workshop with stakeholders was held entirely in Arabic language. The discussion on conventional centralised water systems and more decentralised AWS showed different opinions within the group of participants, with the group favouring conventional systems being bigger than the opposing group. During the second workshop with representatives of donor organizations the ratio was the other way round.

After the mission the scenarios for alternative sanitation systems have been elaborated in more detail. The scenarios have then been assessed using a set of criteria developed for this study.

Summary of conditions in the case study towns

The three towns Damt, Abs and Khamir can be characterised as follows:

- Damt, Abs and Khamir: fast growing
- Serious wastewater problems:
  - Damt: heavy littering and severe pollution of the town canal, overflow of cesspits, all streets with the exception of main street are unpaved and in very bad condition.
  - Abs: extreme water scarcity, discharge of grey water to the streets
  - Khamir: water scarcity for domestic use, overflow of cesspits, lack of sanitation in the old city causes unbearable environmental conditions
  - Necessary slope for gravity wastewater collection is existing in Damt, Abs, Khamir

The following table gives an overview about key data on the three towns:

Technical Data			
	Damt	**Abs**	**Khamir**
Population	18.000	30.000	15.000
Growth rate – rough estimate [%]	5-10	4	6
Surface gradient	high	slight	high
Elevation [m asl]	2000	200	2300
Precipitation [mm / a]	300 – 400	100 – 200	200 – 300
pot. Evapotranspiration [mm / a]	1500 – 2500	1800 – 2700	1500 – 2500
Est. water consumption [l / c / d]	25 (+ hot water)	30	25
Sanitation facilities [toilets / house]	1	1	2-3
solid waste collection	some collection in center	city area covered	city area mostly covered
Socio-Economic Data			
	Damt	**Abs**	**Khamir**
No. of persons / households	12-14	12-14	15-20
Average family income [YR / month]	10.000 – 20.000	20.000 – 25.000	30.000 – 60.000
Price of potable water by tanker [YR / 3 m³]	1300	1500	2000
Expenditure for water [YR / month / house]	900 – 1200	1000 – 5000	3500 – 5000
Percentage of income spent for water [%]	7	13	10
Time spent for water supply	Little	Little	High
Water access for the poor	easy	existing	Difficult
Level of cleanliness	Low	Medium	Medium
no of diarrhea reported / a	4320	common	2706
no of malaria reported / a	5040	common	1131
no of parasites reported / a	5200	common	1240
no of bilharzia reported / a	2300	common	410
Potable water / non-potable water cons. [l/household/d]	20 – 30 (bottles) / 120	20 (bottles) / 60	30 – 40 (tankers) / 170
common water born diseases	malaria, typhoid, diarrhea, hepatitis, kidney stones, various parasites (bilhazia,...), maltean fever,	malaria, typhoid, diarrhea, hepatitis, kidney stones, various parasites (bilhazia,...), maltean fever, cholera, skin diseases	typhoid, diarrhea, hepatitis, kidney stones, various parasites (bilhazia,...), maltean fever,
no of typhoid reported / a	5000	–	2000

Alternative technical sanitation options considered in more detail for the three towns

In the chapter 4 of the report a wide selection of possible technical sanitation options has been presented and discussed. It seems likely, that in many towns a combination of different AWS-options will be feasible, e.g. decentralised systems in the outer areas, whereas the densely populated town centre could be served by centralised or semi-centralised sewer network. Therefore, none of the AWS-options described in chapter 4 can be excluded from the very beginning.

Basing on the evaluation of the site-conditions in the three pilot towns, and on the impressions which the expert teams gained during the field mission and survey of existing information, there are mainly four options which should be discussed more in detail. These four options are the ones which did not have to be excluded during the pre-selection process for any of the three towns, plus the conventional system as traditionally established reference respectively option five.

Option 1: **Storage tanks + tankers**: individual or - where possible - cluster storage systems (retention tanks) for wastewater (black water = faeces + urine + wastewater from kitchen), grey water from shower, bath and hand washing, kitchen wastes) with a regular emptying (weekly or more frequently) by vacuum tankers and transport for further treatment to a centralised treatment plant.

Option 2: **Septic tanks + infiltration**: (Semi-) decentralised collection and treatment of wastewater in septic tanks (“cluster solution”) with outlets / overflows to infiltration or discharge to local Wadi depending on local situation. Joint collection of all wastewater. Regular desludging of the septic tanks (annually or bi-annually) through vacuum tankers and centralised treatment (e.g. anaerobic or facultative lagoons/ponds) of the sludges for agricultural use.

Modification (a): Construction and operation of a long, inclined trickling filter system along the small Wadi for treatment of the septic tank overflows (case study Damt).

Modification (b): Cess pits having reached their end of live are emptied and will be replaced by septic tanks (allows for continuous transition to a town-wide septic tank system).

Option 3: **Small bore system** to collect the overflow of septic tanks for centralised or semi-decentralised treatment (e.g. artificial mini wetlands). This option could be a later state of development starting with Alternative 2.

Option 4: **Simplified (semi-) centralised sewerage system** (separate system, wastewater only - no rainfall runoff); according to adapted design standards: shallow, small diameter sewers with a treatment process (either one or more treatment plants).

Comments on excluded technical options

It seems necessary to add some specific remarks, why the experts had to exclude two options under site conditions as found in the three pilot towns:

Among experts, it is widely accepted that **conventional gravity sewerage** and centralised wastewater treatment plants are ***affordable*** only under certain conditions, like minimum income per capita, maximum specific investment costs per capita. None of these basic economic conditions was fulfilled for the three towns Damt, Abs and Khamir. Furthermore, from discussions the experts noticed severe ***technical problems*** with conventional systems installed in other Yemeni towns, resulting from the fact, that the water consumption is much lower than the minimum water consumption and "flushing power" for which gravity sewers can be designed. Of course, there do exist possible technical counter measures to cope with such problems Anyhow, such measures would further raise the costs necessary for conventional systems.

In literature (and later on in Khamir, where some old historic houses were still operating traditional Yemeni sanitation like 100 years before), one can find kind of a traditional "Yemen EcoSan system". Therefore, one could have expected that the site conditions in provincial towns of Yemen are very favourite to apply modern **EcoSan** sanitation. Anyhow, it was found on-site that most of the houses had already changed to **combined** PVC pipe **installations**, <u>not</u> separating faeces, urine and grey waters, and that it would be very costly and probably not accepted by house owners to change such house installations ex post into dual piping for separation of wastewater streams. Furthermore, it seemed unlikely that they spend the necessary **attention and maintenance** needed for traditional Yemen systems.

Anyhow, it should be understood very clearly that the conventional system as well as the EcoSan system may be a viable and very reasonable option under conditions which are unlike the ones in the three pilot towns visited and evaluated by the experts.

In no way, the experts would intend to criticise the conventional system e.g. in the densely populated centre of cities, or the EcoSan sanitation in selected locations, as realised under the umbrella of NGOs very successfully.

<u>Non-technical aspects (ownership, institutional and organisational aspects</u>

Having focused on the *technical concept* of sanitation, especially the construction of sanitation system, there are other, non-technical aspects to decentralisation. Decentralisation could also be considered in terms of ownership of the technical subsystems of the urban water infrastructure as well as in terms of who is responsible for the operation and maintenance of the technical infrastructure.

Major obstacles to the application of non-conventional wastewater management systems result from the fact that

- the wastewater management agencies have a strong preference to conventional systems because of the well established design standards and operating procedures;
- any decision for a familiar solution maximises security and safety and minimises risks and the need to develop new skills and qualifications;
- due to lack of knowledge on the state of technological development most planners, engineers and of the public have the prejudice that non-conventional systems offer sub-quality service and have low efficiency.

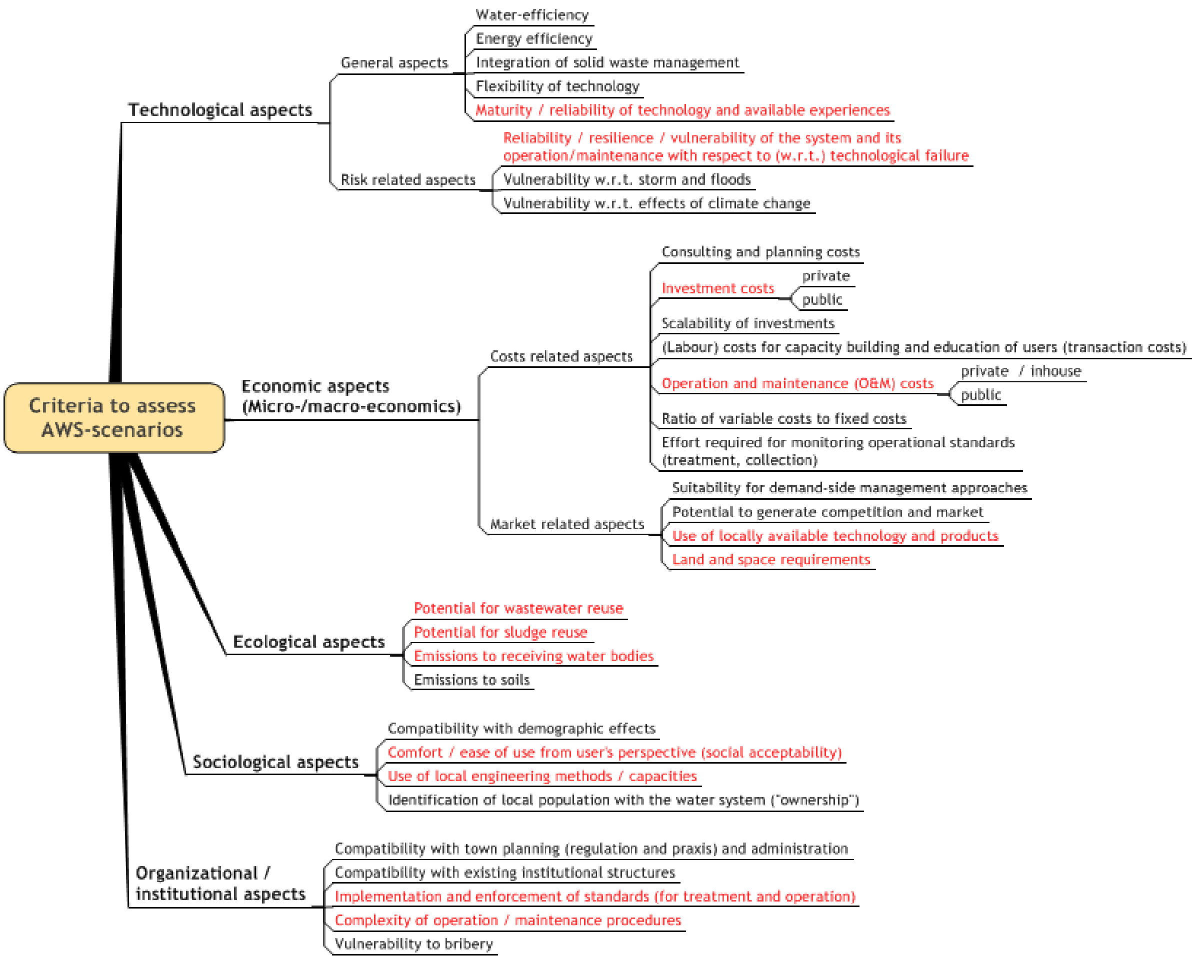
Generally spoken, a prejudice often found by potential customers and stakeholders is that the conventional system would work at the same level of sanitation comfort and reliability as in Western industrialised cities, and that the cost and maintenance-load is born by public institutions. On the other hand, there had been failures with decentralised systems (which were owned and operated by private households), resulting in e.g. odour nuisance and unexpected additional operational tasks for the water consumers. In this context, it seems very important to *professionalise the operation* of any sanitation systems, utilising the logistic capacities and local expertise existing.

The following table indicates that many different combinations are possible with the four AWS-options:

AWS-Option		Technical Concept	Decentralization / Centralization					
			Ownership		Operation and maintenance			
			House Owners	Local Corp., Utility	Facility	House Owners	Contractors	Local Corp., Utility
Storage tanks + tankers	1a	One tank for each house	x	x	Storage Tanks Vacuum Trucks	x	x x	x x
	1b	Tanks for clusters of houses		x	Storage Tanks Vacuum Trucks		x x	x x
Septic tanks + infiltration	2a	One septic tank for each house	x	x	Septic Tanks Vacuum Trucks	x	x x	x x
	2b	Septic tanks for clusters of houses		x	Septic Tanks Vacuum Trucks		x x	x x
Small bore system	3a	Septic tank for each house	x	x	Septic Tanks Vacuum Trucks	x	x x	x x
	3b	Septic tank for clusters of houses		x	Septic Tanks Vacuum Trucks		x x	x x
	3c	Several small bore systems to several STP		x	Sewerage System and STP		x	x
	3d	One small bore system for entire town to one STP		x	Sewerage System and STP			x
Simplified sewerage system	4a	Several separated sewer systems to several STP		x	Sewerage System and STP		x	x
	4b	One sewer system to one STP		x	Sewerage System and STP			x

Criteria for the evaluation / assessment of sanitation options

To assess the alternative urban water system ("**AWS**") a system of criteria was developed specifically for this project. The criteria cover technological, economic, ecological, sociological and organizational/institutional aspects. The following figure provides an overview on the criteria that will be used to assess the various options of alternative urban water systems:



Assessment of the AWS-Concepts with the Analytic Hierarchy Process

The set of criteria ahs been applied to evaluate and assess the 4 options for alternative urban water systems and the reference option 5 (conventional sewerage) specifically for the selected towns. In general, the assessment of the alternative AWS is a multi-criteria assessment. To provide an overall ranking of the alternatives in a given decision situation where each alternative can be assessed according to a multitude of decision criteria requires a multi-criteria assessment method. In the present study the Analytic Hierarchy Process (AHP) (Saaty, 1980) is applied to assess the alternative AWS-concepts under the specific conditions of Yemeni provincial towns. The AHP is a theoretically we grounded and widely applied multi-criteria decision making methodology. The AHP also supports the structuring of the set of criteria, the assessment of weights of the criteria, and the sensitivity analysis of the ranking. Additionally, the AHP provides support in to conduct all of these steps of a multi-criteria decision making in a group decision making context. This is especially important in the present context where the project team expects to have to recur in some of the necessary assessment to qualitative estimations due to a lack of data. In such a situation it will be of utmost importance that all the members of the team including the local experts and representatives of the Yemen Water Administration with their experience and thorough knowledge of the indigenous situation can effectively and efficiently contribute to the assessment of the alternatives.

The matrix shown in the following table summarizes the preliminary and qualitative assessment by the experts of the various alternative wastewater systems AWS-1 to AWS-5 using the the criteria system shown above.

The more “A”s an alternative system has the more it is preferred under the respective criterion. The alternative systems are only be compared to a given criterion. So far, the assessment does not aggregate the overall rank of the AWS since the weighting system for the criteria is not yet derived.

		Criterion	AWS-1	AWS-2	AWS-3	AWS-4	AWS-5
CRITERIA FOR TECHNOLOGICAL ASPECTS	General technological aspects	Water-efficiency of UWS	AAA	AAA	AAA	A	A
		Energy-efficiency of the UWS	A	AAAA	AA	AA	AA
		Integration of solid waste management in UWS-concept	AA	AA	AA	AA	AA
		Flexibility	AAA	AAAA	A	A	A
		Maturity / reliability of technology and available experiences	AAA	AAA	A	A	AAA
	Risk related technological aspects	Reliability / resilience / vulnerability of the system with respect to (w.r.t.) technical failure	AAAA	AA	AA	A	A
		Vulnerability of UWS w.r.t. storm and floods	A	AA	AAAA	A	A
		Vulnerability of UWS w.r.t. effects of climate change	AA	AA	AAAA	A	A
CRITERIA FOR ECONOMIC ASPECTS	Cost related aspects	Consulting and planning costs	AA	AAA	AA	A	A
		Investment costs (privates households)	AAA	AAA	AAA	A	A
		Investment costs (public part of the system)	A	AA	AAA	AAA	A
		Scalability of investments	AA	AAAAA	A	A	A
		Costs for capacity building and education of users (transaction costs)	AAA	AAA	AAA	A	A
		Operation and maintenance (O&M) costs (in-house part)	AAA	AAA	AAA	A	A
		Operation and maintenance (O&M) costs (public part)	A	AAAA	A	AA	AAA
		Ratio of variable costs to fixed costs	AA	AAAAA	AA	A	A
		Effort required for monitoring operational standards (treatment, collection)	AAA	A	AA	AA	AA
	Market related aspects	Suitability for demand-side-management approaches	AAA	AAA	AAA	A	A
		Potential to generate competition and market	AAA	AAA	A	A	A
		Use of locally available technology and products (dependency on foreign technology imports)	AA	AAA	AA	AA	A
		Land (space) requirements	A	A	A	A	A
CRITERIA FOR ECOLOGICAL ASPECT		Potential for wastewater reuse	AAA	A	AAAA	A	A
		Potential for sludge reuse	A	AAAA	AAA	A	A
		Emissions to receiving water bodies	AA	A	AA	AA	AA
		Emissions to soils	AA	A	AA	A	AAA
CRITERIA FOR SOCIOLOGICAL ASPECTS		Compatibility with demographic situation / population growth	AA	AAAAA	AA	A	A
		Comfort and ease of use from user's perspective (social acceptability)	A	A	AA	AAA	AAA
		Use of local engineering methods and capacities	A	A	AAA	AAA	AAA
		Identification of local population with the water system ("ownership")	AAAA	AA	A	A	A
CRITERIA FOR ORGANIZATIONAL AND INSTITUTIONAL ASPECTS		Compatibility with town planning (regulation and praxis) and administration	AAAA	AAAA	A	A	A
		Compatibility with existing institutional structures	AAA	AAAA	A	A	A
		Implementation and enforcement of standards (for treatment and operation)	AAAA	A	A	AA	AA
		Complexity of operation / maintenance procedures	A	A	A	AAA	AAAA
		Vulnerability to bribery	AAAA	AAA	AA	A	A

A detailed and final assessment and discussion of the evaluation results could not be finalised due to the limited time available until submission of this draft report. Such discussion will be provided with the revision of this report

Recommendations for the case study towns

From the options for AWS pre-selected and assessed with respect to their sustainability, for the three case study towns a number of preliminary recommendations can be made. Before presenting the recommendations, the authors, however, would like to stress, that due to the limited information received during the visits to the towns and the very outdated maps, the rapid growth of population in the cases study towns as well as the rapid urban sprawl of the towns these recommendations can only be considered as general comments and generic lessons learnt. The available information and maps nor the time available for this mission allowed for a more detailed recommendation or even preliminary design of sanitation measures for the case study towns.

Damt:

In Damt people make use of the fact that a continuous water flow from artesian wells and hot springs exists discharging to a channel in the town supplying the wadi. A large part of the town's wastewater is also directly discharged to this channel through private pipes. The dilution of the residential wastewater by the hot water and transport capacity of the hot water allows for such practice. Still pollution, nuisance, and health dangers caused by this practice are severe.

In those parts of the town without direct access to the channel and wadi either cess pits have been dug or no systematic wastewater disposal has been implemented at all. Since the ground is rocky, cesspits are expensive and there is little infiltration. In order to prolong the period of use of the cess pits for faeces the grey water is often directly discharged to the streets. People who do not even have access to cess pits use the sanitation facilities of mosques.

Under the special pre-conditions in Damt the following measures are proposed to improve the sanitation conditions:

1. Clean-up of the "channel" and the wadi
2. If possible under the hydro-geologic conditions closure and controlled use of the hot spring water is essential. On one hand this would allow to conserve this valuable water resource and on the other hand it would reduce wet areas in the town and wadi which are major breeding grounds for Anopheles flies and thus severely contribute to the severe malaria problem in Damt.
3. Construction and operation of public facilities for cloth washing with proper management of wastewater would contribute not only to reduce environmental pollution of the hot spring water but also would contribute to public health.
4. In the town centre as well as in residential areas now connected to the "channel" a collector pipe system should be constructed along the channel. The private wastewater pipes should be connected to this interceptor pipe. The wastewater collected by the interceptor pipe should be treated in a yet to be built wastewater treatment plant (pond system) for which the location in the wadi is still to be determined.
5. In the outskirts of Damt without direct connection to the channel and wadi storage tanks or septic tanks should be constructed and a vacuum truck based service for a regular emptying of the tanks should be implemented. The wastewater collected from the tanks should be treated in the treatment plant.

6. Once the construction phase has finished in a neighbourhood and the population growth in that area has stabilized a shallow small bore sewer system collecting the solid-free overflow of the septic tanks may be considered to be the next step of development and replace the tanker-based system. The operation of the small-bore sewer system also would provide a next step in capacity building and the development of skills of the institution responsible for the operation of the overall wastewater system

Abs:

Presently the population in Abs fully relies on the water supply through tankers or even carry water in buckets and canisters to their homes. The population therefore uses very little water and feels no wastewater disposal problem. A source for drinking water is available and attracted excessive mango farming in the area.

Small covered pits have been dug for the disposal of faeces and urine. Grey water is discharged to the unpaved roads. For larger houses along the asphalted main road larger pits have been constructed to which all wastewater is discharged. Generally, the hygienic conditions in Abs seemed much better than those in the two other case study towns. The soil in Abs is highly permeable and no usable groundwater source is available within the town's limits. The infiltration of wastewater in the ground may therefore offer a feasible solution but would require a thorough study of the hydro-geologic conditions.

The following measures are being proposed for Abs:

1. As long as the water supply issue is not solved and the water consumption is not increasing sanitation improvements are of low priority.
2. Septic tanks and infiltration pits are proposed for all of Abs once there is higher water usage. A staggered implementation of such facilities is recommended.
3. In the future the collection of the septic tank overflow in a small bore sewer system is possible and should be implemented in a later phase once the water consumption exceeds the infiltration capacity of the soil or if the hydro-geologic situation requires protection of groundwater and soils.

Khamir:

Great effort has been made by NWSA to explore suitable drinking water sources for Khamir but until now no reliable source supplying sweet drinking water is available. The existing water supply network supplied salty water for a short period of operation and has now been taken out of operation because people refused to pay for salty water. Today, Khamir is supplied with potable water by tankers which carry the water from wells 20 km outside Khamir. People in Khamir do suffer from water shortage.

Although there is little water used in the households a severe sanitation problem exists especially in the old town of Khamir. The photo report in the appendix A6 drastically shows the shortcomings. Cesspits – if available - tend to overflow because the infiltration capacity of the soil is low and no regular emptying of cesspits has been organised. Many households have no wastewater disposal facilities at all. Grey water is discharged to the streets. The former dry toilets are still in use but the faeces are neither covered with ash nor are they dried any more in the traditional way. Instead, the faeces and urine together with the anal hygiene water and flush water in many cases are just dumped in the back of the houses. These dump sites attract flies and pose a high risk for public health. Immediate action is required in order to provide a healthy environment.

The following measures are being proposed for Khamir:

1. An awareness campaign should be launched aiming to sensitise the population for the health risks and environmental problems caused by their present behaviour. There should be a program implemented cleaning up the local dump sites for faeces and urine.
2. For the old town of Khamir, where the traditional toilet is still in use - but not properly in use – an upgrade of the existing facilities leading to less smell and more comfortable use is an option to be investigated in detail.
3. In the case the traditional dry system is not to be reinstalled construction of cess pits to collect black water from the toilets are a to be constructed as minimum solutions for houses in the old town.
4. A better solution for the old town which would require more effort and investments would implement septic tanks and infiltration pits. This system could be enhanced later on with a small bore sewer system and a wastewater treatment plant. This solution would allow to discharge all wastewater to the septic tank and avoid grey water discharge to the streets.
5. For the new town, where no separation of wastewater streams can be realised because of the existing in-house installations septic tanks and infiltration pits, later supplemented with a small bore sewer system is proposed for immediate implementation.

General recommendations for all three towns:

Recommendations have been made in chapter 7.3, where the results of the evaluation have been presented. Some of the most important general recommendations are summarised here:

1. Any successful implementation of an urban water and sanitation service requires an institutional backing and the existence of proper administration. This also includes institutions responsible for proper town planning including the enforcement of the plans but also institutions taking care of solid waste collection and disposal, as well as for enforcement of building standards. Parallel to addressing sanitation improvements strong emphasis should be put in the development of such an institutional infrastructure and capacity building of the institutions involved in the provision of the utility services.
2. The present problems in the sanitation sector are not determined by a lack of appropriate technical solutions available for sanitation. It is only that such solutions are not implemented or, once implemented, not operated properly Therefore in each feasibility study for a project a broader spectrum of sanitation options shall be investigated and compared and the necessary institutional arrangements should be designed and developed in parallel with the technical concept.
3. The present organisational and technical skills of the Yemeni urban population and administration are more favourable for decentralised than for centralised technical solutions for sanitation. Technical improvements of existing decentralised facilities together with a more centralised (town-wide) operation and maintenance of such facilities is recommended.
4. Yemen, being a water scarce country, any technical solution conserving water and providing a more efficient use of water is highly preferable.
5. Universities, as the major educational institutions providing technical and operational competencies and skills for Yemeni people, should systematically be included in the effort to build up local knowledge on alternative wastewater systems as well as in the development of technological solutions optimised for Yemeni conditions.
6. Participatory planning is essential for a successful implementation and sustainable operation of any sanitation system. Chapter 8.3 provides some principles.

Applicability of Conclusions in Other Regions of Yemen

The three towns visited during the mission showed very different conditions, however, with some typical factors being similar in all three towns as laid down above. Water scarcity, weak or missing town planning including its enforcement, low environmental awareness of the population, and low management and technical skills of the officials involved in the water sector on town level can be expected to be similar all over Yemen.

The house construction standards vary significantly between the towns and between the different quarters of each town. Even more types of construction standards can be expected throughout the Yemen thus influencing the sanitation requirements. The same applies for topography, soil conditions, groundwater conditions and others.

Although the spectrum of local conditions is surely much broader than observed in the three case study towns, the three towns already provided a reasonable spectrum of conditions, which were used to develop the criteria for the evaluation of sanitation options.

This set of criteria developed for assessment of options is comprehensive and is expected to cover also conditions in other parts of Yemen.

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Appendix

Appendix A1: Mission Schedule

Date	Time	Activity
Sa. 14.02.	22:50	Arrival Kummer, Hiessl in Sana'a
So. 15.02.	 08.30 09:00 11:30 12:30 15:00	Sana'a, meetings with: - NWSA Coordinator for KfW projects: Mr. Ahmed Kaid Sarhan - Local KfW Representatives: Mr. Redecker, Mr. Ali Kassim Manshalin and Local Experts: Mrs. Fatima Mashoor, Dr. Fadhl Ali Al-Nozaily - NWSA Chairman: Mr. Abdulmoamen Mutahar - GTZ: Mr. Wolf, Mr. Shawagfeh - Social Fund For Development: Mr. Almojahed
Mo. 16.02.	 09:00 11:00 22:50	Sana'a, meetings with: - Ministry of Water & Environment, Technical Secretariat: Mr. Anwar Sahooly, Mrs. Susanna Smets - NWRA Chairman: Salem Bashaaib; Deputy Chairman, Abdulla Al-Thary; Saleh Al Ashtal - Arrival Rudolph in Sana'a
Di. 17.02.	 08:00 – 13:00 On the way On the way afternoon	Damt (other name: Hammam Damt): - Driving from Sana'a to Damt - Visit to Dhamar WWTP - Visit to Jarim WWTP - Meeting with the Director of the Local Council and tour of the town, existing water supply facilities
Mi. 18.02.	 morning afternoon afternoon ongoing	Damt: - Office of the local (private) water supply company - Meeting with the former and present Director of the local water supply company - Visit to 4 private houses - Development of concepts for AWS in Damt
Do. 19.02.	 09:00 morning afternoon	Damt: - Meeting in the Director's office, discussion of findings and future actions - Taking wastewater samples. Analysis of wastewater follows in the laboratory of the Central Health Laboratory Aden. - Individual walk through the town, development of AWS concepts for Damt
Fr. 20.02.	 08:00 – 13:00 afternoon	Damt: - Driving from Damt to Sana'a - Discussion of findings, reporting for Damt
Sa. 21.02.	 00:25	Sana'a: Holiday, Muharram (Islamic New Year) - Departure Rudolph to Germany
So. 22.02.	 ongoing	Sana'a - Discussion of findings, reporting for Damt (Hiessl, Kummer, Nozaily, Mrs. Ahmed)
Mo.23.02.	 08:30 – 09:00 09:30 – 11:00 11:00 ongoing	Sana'a, meetings with: - World Bank UWSSP: Mr. Isam M. Makki - University of Sana'a, Department for Civil Engineering: Prof. Dr. Abdulla S. Babaqi - KfW: Mr. Redecker, Mr. Ali Kassim - Discussion of findings, reporting
Di. 24.02.	 09:00 – 11.00 17:00 – 19:00	Sana'a, meetings with: - Ministry of Planning & Int. Coop.: Mr. Hashim Aon-Allah - Dorsch Consult: Mr. Klar
Mi. 25.02.	 07:00 – 12:00 13:00 – 15:00 15:00 – 17:00	Abs: - Driving from Sana'a to Abs via Bajil - Meeting with NWSA Representative: Mr. Ali Al-Sherafi, and the Director of the Local Council - Tour of the town

Date	Time	Activity
Do. 26.02.	 07:00 – 08:00 10:00 – 12:00 12:00 – 15 00 15:00 – 20:00 On the way	Abs: - Visit to Hoddeidah WWTP - Meeting at the Director's office with Local Council Representatives, local representatives active in the water sector - Visit of the town, school, mosques, public buildings and sanitation sites with the Public Works Director - Driving from Abs to Sana'a - Visit to Hajjah WWTP
Fr. 27.02.	 Ongoing	Sana'a - Discussion of findings, reporting for Abs
Sa. 28.02.	 10:00 12:00 ongoing	Sana'a - Ministry of Water & Environment, Deputy Minister: Dr. Mohamed Al-Hamdi - Social Fund for Development, Water Projects Officer: Mr. Jihad Taha Mujahed - Discussion of findings, reporting
So. 29.02.	 11:00 13:00 Ongoing	Sana'a - Dutch Aid, Mr. Mohamed Al-Aroosi - Rural Water Supply and Sanitation Project of World Bank, Project Director: Mr. Abdul-Razzak - Discussion of findings, reporting
Mo. 01.03..	 08:40 09:00 – 11:00 11:00 – 13:00 13:00 – 16:00 16:00 – 18:00	Khamir (other names: Khamer, Khamr): - Arrival Rudolph in Sana'a - Driving from Sana'a to Khamir - Meeting with NWSA Representative: Mr. Ali Al-Ashwal, tour of the town - Meeting with the Municipality - Driving from Khamir to Sana'a
Di. 02.03.	 07:00 – 09:00 09:00 – 11:00 11:00 – 13:00 13:00 – 15:00 16:00 – 18:00 On the way	Khamir: - Driving from Sana'a to Khamir - Meeting with the Major, Local Council Representatives - Meeting with local representatives active in the water sector - Visit to individual private houses - Driving from Khamir to Sana'a - Visit to Amran WWTP
Mi, Do., Fr	 Ongoing	Sana'a: - Data evaluation, preparation of workshop
Sa. 06.03.	 09:00 Ongoing	Sana'a: - Meeting with NWSA and KfW - Preparation of workshop
So. 07.03.	 09:00 – 13:00	Sana'a - Workshop in Sana'a with stakeholders
Mo. 08.03.	 09:00 – 13:00 ongoing	Sana'a: - Workshop in Sana'a with donors - Reporting, discussions of findings
Di. 09.03.	00:25	- Departure Hiessl, Kummer, Rudolph to Germany

Appendix A2: Persons / institutions met and interviewed

Organisation	**Persons**
Ministry of Water & Environment	Dr. Mohamed Lutf Al Eryani, H.E. Minister; Dr. Mohamed J. M. Al-Hamdi, Deputy Minister
Ministry of Planning & International Cooperation	Hashim Aon-Allah, Assistant Deputy Minister
National Water and Sanitation Authority (NWSA)	Abdulmoamen Mutahar, Chairman; Ahmed Kaid Sarhan, German Financial Cooperation Coordinator
National Water Resources Authority (NWRA)	Salem Bashaaib, Chairman; Abdulla Al-Thary, Deputy Chairman; Mrs. Marion Jericho, Engineer Urban and Landscape Planning
Technical Secretariat for Water Supply and Sanitation Sector Reform at the Ministry of Water and Environment	Anwar Sahouly, Chairman; Mrs. Susanna Smets, Junior Expert
Kreditanstalt für Wiederaufbau	Gerhard Redecker, Director KfW-Office Sana'a; Ali A.Kassim Manshalin, Local Expert
Gesellschaft für Technische Zusammenarbeit	Eberhard Wolf, Head of the Advisor Team; Zeyad Shawagfeh, Management Advisor Provincial Towns Project
University of Sana'a, W&E Centre	Prof. Dr. Abdulla S. Babaqi, Director of Water & Environment Center; Dr. Fadhl Al-Nozaily, Assistant Professor Dr. Abdulla Noaman, Assistant Professor
Social Fund For Development	Abdulwahab Almojahed, Head of Water & Environment Unit; Ali Abdulwahi
Social Fund For Development, Sana'a Branch	Jihad Taha Muhjahed, Water Projects Officer
World Bank UWSSP	Mr. Isam M. Makki, Project Director
Royal Netherlands Embassy	Mohamed Al-Aroosi, Program Officer Water
Rural Water Supply & Sanitation Project at the Ministry of Water & Environment	Mohamed A. Abdul-Razzak, Project Director
Dorsch Consult	Werner Klar, Team Leader
Organisation	**Persons**
In Damt:	
Directorate	Ahmed Al-Kohlani, General Director
Local Council	Mosied Qaid Abdallah, General Secretary
Local Council, Services Committee	Abdulkhaliq Al-Gorbani, Head of Committee
Public Works Office	Zaid Al Hanbaqi, Water Project
Security Office	Sadiq
In Abs:	
Local Council	Mohamed Al-Rozom, General Secretary
Public Works Office	Hadi Ahmed Abdu, Director
Local Council, Services Committee	Qadri Ahmed Issa, Head of Committee
Local Council, Services Committee	Hadi Ibrahim Hassan, Member of Committee
Local Council, Social Affairs Committee	Hamdi Mohamed Ahmed, Member of Committee
Agricultural Office	Mohamed Yousuf, Director
NWSA	Ali Al-Sharafi, Project Director
Security Office	Sadiq
In Khamir:	
Directorate	Mabkhoot Al-Mashraqi, General Director
Local Council	Mohamed Al-Rozom, General Secretary
Public Works Office	Samir Al-Gailani, Engineer
NWSA	Ali Al Ashwal, Project Director Water Supply
Local Council	Adnan Lutfallah Shiea, Member
Planning Office	Ameen Al-Gashmi

Appendix A3: Theses discussed in the workshops

Thesis 1:

Conventional systems have been developed for water consumption higher than 100 l/c/d. Taking into account the **scarcity of water resources** in Yemen, reaching this level of consumption is not reasonable from an economic as well as from an availability point of view.

Thesis 2:

During their short mission, the experts could not find a satisfactory and systematic re-calculation and evaluation of existing sanitation systems in Yemen. Such evaluations would provide valuable data to decide about most appropriate sanitation systems casewise. For proper selection and design of sanitation systems **information from projects implemented** are necessary and more valuable than textbook knowledge.

Thesis 3:

Conventional systems need systematic and **enforced town planning, made (preferably paved) roads and reliable design assumptions** for the network. None of the case study towns fulfills all preconditions. Therefore, conventional systems are not applicable, at least not without significant modifications for the three towns visited.

Thesis 4:

The Yemeni towns are fast growing settlements. The sanitation system must be flexible for **easy extension and upgrading**. Quite often, sanitation systems with fixed network structures cannot provide the required flexibility (at least not without high surplus costs).

Thesis 5:

Traditionally, on-site sanitation facilities are in the ownership and responsibility of the house owner. House owners - after some bad experience - consider this to be a burden they would like to get rid off. **Professional organization of O&M of the on-site facilities** can provide an equal level of comfort and reliability as house owners expect from conventional systems. Decentralized solutions in other than the usual institutional setting offer more options than explored so far.

Thesis 6:

In decentralized wastewater systems the effects of misuse or improper maintenance become immediately obvious to the users. In conventional centralized wastewater systems misuse and improper maintenance causes problems mostly to the disadvantage of others, not of the user himself. Therefore, decentralized systems are more suitable to **motivate users for proper utilization**.

Thesis 7:

Decentralized systems are often characterized by low percentage of fixed cost and higher percentage of variable cost than conventional systems. Therefore, decentralized systems contain lower **financial risk in case of failure**. (E.g.: less wastewater than expected: conventional sewer needs additional flushing, costs increase, whereas costs for a decentralized system decrease).

Thesis 8:

Implementation of small scale solutions for wastewater services in rural towns of Yemen require technical equipment and skills which are usually available in the region. Therefore, many small scale facilities can be implemented by local companies and thus, are likely to generate **local income**.

Thesis 9:

Wastewater collection and transport is the major issue in terms of costs (esp. investment), operational needs, and flexibility for extensions when deciding about sanitation systems. These aspects must be regarded prior to the selection of an appropriate wastewater treatment technology.

Thesis 10:

The assumption about the **useful technical lifetime** of a system is essential for its economic assessment. If one component of a sanitation system fails (e.g. pump) the long technical life time of other components (e.g. concrete or PE-pipe) is worthless. The useful technical lifetime of sewerage is often overestimated and this results in a too optimistic cost calculation.

Thesis 11:

Any sanitation system must fit into the existing **in-house installations**. Any change of in-house installations necessary for proper functioning of the selected sanitation system would be costly and difficult to enforce (e.g. separation toilets and separate greywater pipes are needed for ECOSAN). Only with newly developed areas and houses, a free choice of sanitation system is possible.

Thesis 12:

The urgency to respond to water scarcity in Yemen with use of innovative and sustainable solutions for water supply and sanitation is one of the highest worldwide. This can be taken as a chance for Yemeni research institutions and industry to develop suitable technologies to cope with water scarcity. The creation of such suitable technologies could be a basis for **commercial development in Yemen**, may be even for export.