

Overview Of Non-Modernized Spate Irrigation Systems In Yemen

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Abbreviations:

GOY	Government of Yemen
ha.	Hectare
HWC	High Water Council
IC	Irrigation Councils
IIP	Irrigation Improvement Project
LWCP	Land and Water Conservation Project
MAI	Ministry of Agriculture and Irrigation
mm	Millimeter
NWRA	National Water Resource Authority
O&M	Operation and Maintenance
ROY	Republic of Yemen
WEC	Water and Environmental Center
WUA	Water Users Association
WUC	Water Users Council
WUG	Water User Groups

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1. Introduction

The Republic of Yemen (ROY) is an arid and semi arid country where most of the land consists of barren mountains and deserts, which are dissected by wadis. These wadis provide are vital for irrigation, domestic water supplies and for industrial use and other purposes depending mainly on groundwater stored in the delta alluvium of these wadis. The agricultural areas in Yemen are either along the banks of the wadis and their deltas or in the terraces and plateaus of some of the mountainous regions.

The total area of Yemen is approximately 555,000 Km² (about 55 millions ha) of which only about 2.5% (i.e. 1.7 million ha) is potentially cultivable. However the average annual total cultivated areas is not more than 1,143,300 ha. Officially the cultivated area distributed according to source of irrigation is as follows - table (1).

Table (1): Cultivated Areas According to Source of Irrigation

Source of Irrigation	Area (in ha)	% of Total Area
1- Spate Irrigation	125,700	11%
2- Base Flow of Spring	45,700	4%
3- Well Irrigation	457,400	40%
4- Rain fed	514,500	45%
Total	1,143,300	100%

Agricultural Statistics Year book 2000 (May 2001)

Yemen has three main hydrological regions:

- The Eastern Red Sea catchments or Tibama catchments draining to the Red Sea.
- The Eastern Rub Al-Khali catchments draining to the desert.
- The Southern Gulf of Aden catchments draining to the Gulf of Aden.

This report discusses the non-modernized spate irrigation systems in Yemen. There was a surge of spate development projects in Yemen in the 1980's. A large number of spate systems were 'modernized' – particularly in the Tihama Plains and around Aden. The

modernization consisted of the construction of permanent diversion weirs, the excavation and sometimes lining of canals and land leveling. Bearing in mind the catastrophic floods of September 1981, March 1982 and the two floods in last decade of 2nd millennium, the approach to wadi development and improvements in spate control should be reviewed. There is a need to reassess and reapprciate the the traditional methods of diversion of spates. This paper aims to make a contribution to this.

With the benefit of hindsight the modernization of spate systems in Yemen has had a number of drawbacks:

- The main one is that under the principle of priority to upstream lands, the larger upstream control led to a large use of the moderate spate flows in the upstream sections – in spite of efforts to formulate and formalize such earlier practices. In the traditional systems a degree of equity was ‘built in’. This inherent equity arose because upstream users can divert minor floods, while larger floods will destroy upstream structures and flow on to downstream diversion structures.
- The larger ability to control spate water flows resulted in an accelerated sedimentation of the command areas – both of flood channels and of land. In some modernized spate system this has been made worse because of a lack of operational sediment exclusion mechanism and the distribution of small distributary channels that reduce velocity and increase canal sedimentation.

The functioning of the traditional irrigation should be studied in more detail in from a technical, agricultural and socio-economic angle, particularly with regard to traditional water rights and equity in water supply, the probability and variability of spate irrigations in the different wadi reaches, the priorities set by the farmers and their wishes in improving their irrigation system, and the economic aspects of the prevalent cropping pattern, including yield and farm inputs and potential for improvement. The large investments gone into the several modernized systems has meant that all attention and intellectual resources has gone into them and that relatively little is known of the other spate systems in the country. This report intends to partly overcome this. It first gives an overview of the wadi systems in Yemen. It then discusses two types of traditional systems – one that uses non-permanent structures for diversion and one that uses traditional structures. It next discusses the organization around these systems – the water

rights and the operation and maintenance. It concludes with a short overview of the predominant crops in the spate systems in the country.

2. Wadis in Yemen

There are two annual flood periods in Yedmen, the first in March-May (*Seif*), and the second in July-September (*Kharij*). The seasonal rainfall, which produces spate flows of short duration are the main source of agricultural water, since there is very little direct rainfall. The catchment areas, rainfall and mean annual flows in the main wadis in Yemen are shown in table 2. During the dry season, from November to March, there is usually no flow at all in the smaller wadis, while the base flow of the larger wadis is generally below 2 m³/s. The wadis start rising in April, and the main flood season is between July and September.

Table 2. Catchment area, Rainfall and Mean Annual Flow in the main wadis in Yemen

Zone	Wadi	Catchment Area, km ²	Mean Annual Rainfall, mm	Mean Annual Flow, Mm ³
Western escarpment	Wadi Mawr	8000	480	210
	Wadi Surdud	2700	650	121
	Wadi Siham	4900	500	130
	Wadi Rima	2700	570	103
	Wadi Zadid	4700	560	164
	Wadi Rasyan	2000	500	54
	Wadi Mawza	1600	400	38
Southern escarpment	Wadi Bana	7200	359	160
	Wadi Tuban	5060	244	125
	Wadi Hassan	3300	300	30
Central escarpment	Wadi AlJawf	14000	140	35
	Wadi Adanh	12600	-	-
	Wadi Ahwar	7250	100	40
	Wadi Mayfa'a	6000	200	30
	Wadi Beihan	3600	150	54
	Wadi Hajer	9324	80	288

Eastern escarpment	Wadi Hadhramout	113900	63	230
	Wadi Maselah	*	200	27

* Unavailable

Source: Seyifm Abdul Aziz and Yusef Ahmed Faraa, (1999) Organization of Water User Association Groups in Yemen,

3. Spate Irrigation

Traditional irrigation structures are those structures, which depend on local materials for their construction. They are built by farmers themselves who rely on experience gained through everyday observation, or knowledge descended from their forefathers. The traditional structures have proved their effectiveness and resistance to low and medium floods for a long time.

The history of irrigation in Yemen is very ancient. Archeological evidence shows that irrigation was practiced in Yemen in 3000 BC and that the cultural and economic prosperity of the area is directly linked with the development of irrigation.

The lexicon of irrigation in Yemen is characterized by two general features: semantic fluidity and regional variation. Definitions are often not strict and meanings frequently are vague. One word can apply to differing phenomena and, conversely, a single thing can be described by a variety of words. Regional variation is a logical corollary to semantic fluidity: words vary in meaning from place to place. But within each locale irrigation terms are both semantically and chronologically stable. For example, in Yemen, water-courses are indicated with many synonyms: *gail*, *nabr*, '*ain al-ma*', Other example, the turn or sequence of irrigation has many synonyms: *rada'ah*, *ador*, *daula*, *martaba*, the same things are applicable for traditional structures and technology used, (further studies is needed in this area).

The name of the diversion structures of the traditional spate irrigation system differ from area to area. The terms used depend on the size, order length, type of building material, shapes, way of built and position in the wadi. Examples of names are: *Oqmas*, *Obars*, *Atm* (in the coastal area), *Saqiya* (in Hadhramout and Shabwa) and *Rozzum* (in the some parts

of the highlands). This overview will concentrate on the two most common types of traditional diversion structures in Yemen.

The main differences between type I and type II are (i) the way of building, which type II needs more skills than type I, (ii) the material used and its availability. Type 2 uses permanent structures while type I depends on temporary diversion structures. Accordingly the names of these structures differ.

4. Traditional Spate Irrigation System - Type I (Non Permanent Diversion Structures)

This type of traditional spate irrigation system is based on the '*Oqmas*', '*Obars*' and '*Atm*' diversion structures, built by the local farmers. These structures are dominant in many wadis in the coastal area of Tihama and in some wadis of the coastal area of Aden Gulf (Abyen and Tuban delta). They are even used side by side modernized structures.

4.1 '*Oqma*'

Oqma is an earthen bank constructed across the canal of the wadi to divert part or the entire flow of the spate to their fields. Large spates will cause failure of the *Oqmas* and reduce or prevent irrigation of the fields. Though *Oqma* are relatively cheap to build, the cost of seasonal maintenance and repair of the bunds is high.

If a large spate comes down, the '*Oqma*' is either broken deliberately or allowed to break under the strain. When this happens a large part of the embankment is washed away, often before the total acreage has been irrigated. The flow cannot be again diverted to the fields until the '*Oqma*' has been rebuilt. The rebuilding of the '*Oqma*' depends on the subsequent behavior of the Wadi flow, and sometimes the '*Oqma*' cannot be rebuilt before the next spate.

4.2 '*Atm*'

Another local system of irrigation is by small earthen banks, the form of temporary bunds or spurs called locally '*Atm*' projecting into the Wadis, which deflect a portion of the spate water over the adjacent fields.

4.3 '*Ubar*'

The water is diverted from the *wadi* by a large canal (*ubar*). The head of this canal (*ras al-ubar*) is constructed at a point where little or no damage can be done to it by the spate. In places where the current is strong, the head of the canal runs approximately parallel to the wadi.

The banks of the canals (*al-aswam*, sing. *sawm*) are low near the river-course, but, as the canal draws away from the *wadi*, the banks grow higher to reach the same level as the plots of land it passes. Often the bunds of the fields (*asmam*) form one bank of the main canal, while the other bank (*al-ubar*) remains facing the *wadi*. At larger distance from the wadi and in sub-main canals the bunds of the fields are from of two *sawams*. To protect the banks against the impact of strong currents strong floods, or against collapse because of water pressure in the canal itself, the banks are buttressed. These buttresses (*kilab*, sing. *kalb*, or *masarif* sing. *masraf*) are rectangular in shape and are constructed out of mud and stone debris. A further method of securing the banks of a canal and protecting them from water pressure is the practice of breaking the bank of the canal facing the *wadi* at a certain point. The bank below the break is then pushed inwards. The resulting escape is called *ma' dhal* or *mansam*, and is left open to release the amount of water thought necessary to reduce the pressure. At times it is blocked with tree branches and mud, and this permits it to function as an automatic safety valve which opens as soon as the water pressure increases beyond the required level. Underneath this emergency escape buttresses (*masraf*) may be constructed out of mud and stone debris to avoid that the escape becomes too big and all water disappears this way.

The main canals (*al-ubar*) are connected with sub-canals called (*sharg*). To divert water from a main canal to a sub-canal, *Oqma* are also built across the main canal. Its location is at a little distance from the point where the head of the sub-canal *ras al-sharg* cuts the bank of the main canal. If however the total diversion of flow is not required, a different kind of an earthen bank is constructed. This is known as *mash' abah*, and consists of

implanted trunks of palm trees, branches and mud. The effect of such earthen bank is that, while the bulk of water is diverted to the sub-canal, a part is left to flow down the main canal. To perfect the process of diverting water into a sub-canal, the bank of the main canal opposite the head of the sub-canal is shaped in the form of a crescent extending to the *Oqma* (barrage).

5. Traditional Spate Irrigation System - Type II (Permanent Diversion Structures)

This type of traditional spate irrigation system is based on the ‘*saqiya*’ plural ‘*Sawaaqi*’; permanent diversion structures. They are built by farmers in Hadramawt and Shabwa Governorate.

5.1 Spate canal ‘*Saqiya*’

Saqiya is the common word for irrigation canal throughout the Islamic world, *Saqiya* consist of two main parts,

- 1. Canal entrance and**
- 2. Canal body.**

5.1.1 Canal entrance

The canal entrance consist of:

1. *Al-Qaid* or *Al-Dameer* and
2. Head of the canal (*ras al- Saqiya*).

5.1.1.1 *Al-Qaid* or *Al-Dameer*

This is a structure built to divert water from the main wadi to agricultural lands in quantities proportional to the irrigated area and the size of the flood in the wadi.

The structure branches off from the main spate canal feeding the land and forms an acute angle with the flow direction and it stretches to the center of the wadi.

The height of *Al Qaid* varies. It is zero in the center of the wadi but reaches the

the height of the spate canal close to the command area (1-1.5 m) (figure 1 and 2).

The foundation is usually deep. The depth depends on the depth of the bed rock. If the bed rock is not too deep farmer prefer to build all the way to the bed rock. If the bedrock is too deep, the depth of the good foundation will be based decided on the basis of local experience and knowledge. The foundation is usually made of interlocking stones and rises gradually to form a triangular prism, so that the drag force on the structure is minimal. The *Qaid* structure is commonly used in Shabwa Governorate especially in Wadi Nahr - Beihan.



Figure 1 *Qaid* in Shabwah Wadi Beihan



Figure 2 *Qaid* in Shabwah Wadi Beihan (form wadi direction)



Figure 3 *Dameer* in Hadramawt Wadi Da'uan

A distinction between *Qaid* and *Dameer* is found in some areas. Any structure built to divert water from the main wadi to agricultural lands can be interchangeably called *Qaid* or *Dameer* for instance in Wadi Nahr - Beihan (Shabwa Governorate). Yet in Wadi Daua'an (Hadramawt) they consider this structure consist of two integrated parts, the

one part called *Dameer* and the other called *Qaid* with the latter being part of the *Dameer*. The *Dameer* is any structure built to divert water from the main wadi to agricultural lands. The *Qaid* is that part which connect the two sides at canal entrance. One finds only few centimeters of this structure above ground level. The name *Qaid* is also used for any other structure, that connect two sides or two heads in *Saqiya* walls.

In Wadi Daua'an *Dameer* structure built in two ways:

- 1- If wadi canal is wide, *Dameer* stretch only to the center of the wadi, the height of *al-Dameer* varies gradually from 10 cm in the center of the wadi to 1-1.5 m where it joints the canal head (*ras al- Saqiya*). The *dameer* structure is built by digging a trench with varying depth from area to area. The total depth depends on the possibility of reaching a suitable hard foundation. In this case farmers build two parallel walls of stone, the gap between these walls filled with sand and small stones, the top of the structure close by suitable stones. *Dameer* are also built deep into the wadi bed.

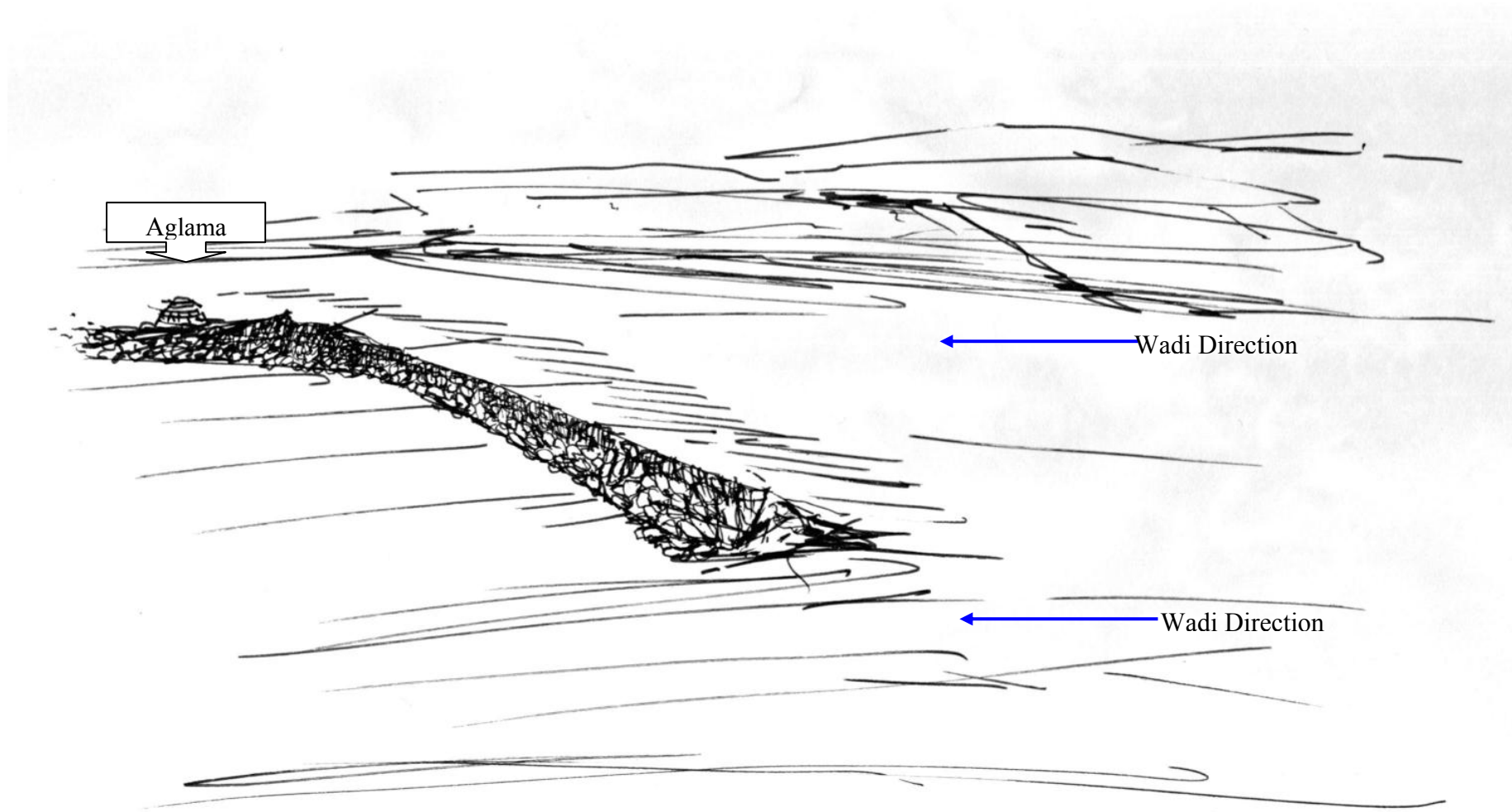


Figure 4 *Qaid or Al-Dameer* part of the wadi

2. If the wadi canal is narrow (about 50 – 60 m), the *Dameer* will be constructed across the canal of the entire wadi, inclined against the wadi canal direction. Due to the big pressure faced by part of the structure, farmers build foundations between 3-4 m in width, the total depth depending on reaching to suitable hard rock. Subsequently two parallel walls of stone are constructed, the gap between these walls filled with sand and small stones. The upstream wall is inclined to the wadi canal direction and the downstream having a ‘stairs’ shape. The top of the structure is finished with stones. The final height is typically 30 cm or more above the upstream wadi level with a varying height at downstream, that depends on the slope of the wadi bed. By this part of the structure water is diverted from the main wadi to the *Saqiya*. Excess water passes over this weir. To avoid scour downstream of the structure, farmers built this wall in a ‘stairs’ shape to slowdown water velocity (figure 6). Additional protection is made by covering the downstream part with a layer of stones.



Figure 5 *Dameer* in Hadramawt Wadi Da’uan

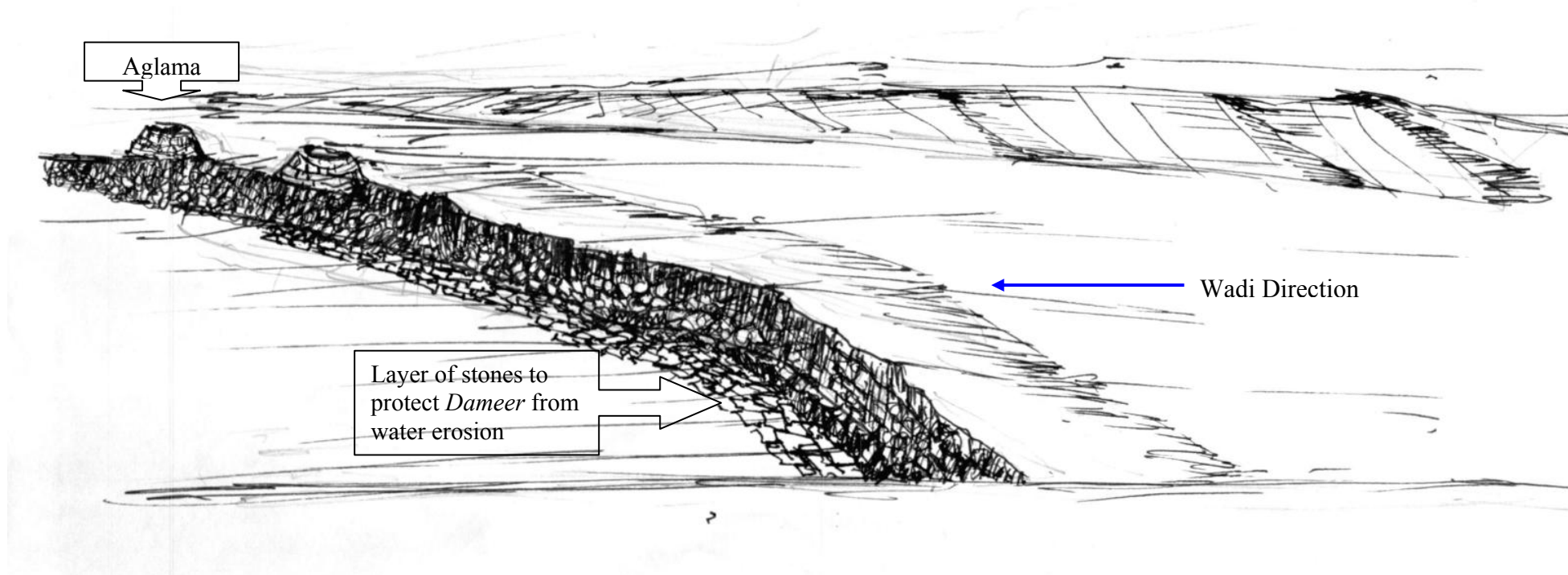


Figure 6 *Qaid or Al-Dameer* full of the wadi



Figure 7 *Qaid* with stairs

5.1.1.2 Head of the canal (*ras al- Saqiya*).

Aglama

The intake of the flood canals – that connects the *Qaid* and *Saqiya* – usually consists of a conical structure called *Aglama*. The *Aglama* usually has a circular base of 3 to 4 m in diameter and a sharp conical point. The height is in most cases between 2 and 3 m and the inclination ranges between 35° to 40°. The outside surface of the structure contains no holes or cavities, as it is completely filled with small stones and cobbles.

The *Aglama* are usually constructed alongside the Wadi, perpendicular to the flood current. In this way they protect a long stretch of agricultural land. When these structures are constructed in a bend, their foundation will be made deeper than usual. The function of the *Aglama* is similar to that of the gabion groynes, which control the direction and velocity of the flood in the wadi and in the canals. The *Aglamais* are constructed after first examining the wadi bank and selecting proper construction places; and secondly, by digging a circular foundation of two meters deep and lining it with large stones, and filling in the gaps with smaller stones. The whole structure is built up in this way. *Aglamais* can

successfully substitute gabions. Moreover, as the wadi flood is intermittent, maintenance work can be carried out without any difficulty.

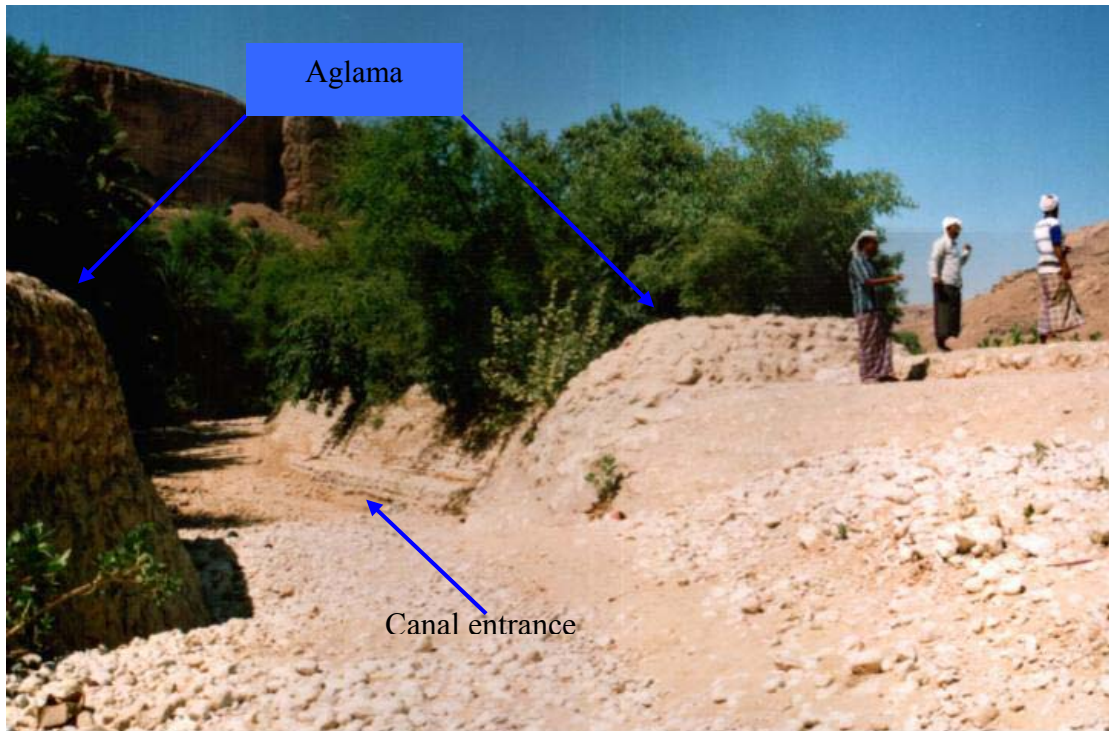


Figure 8 Head of the canal (*ras al-Saqiya*)

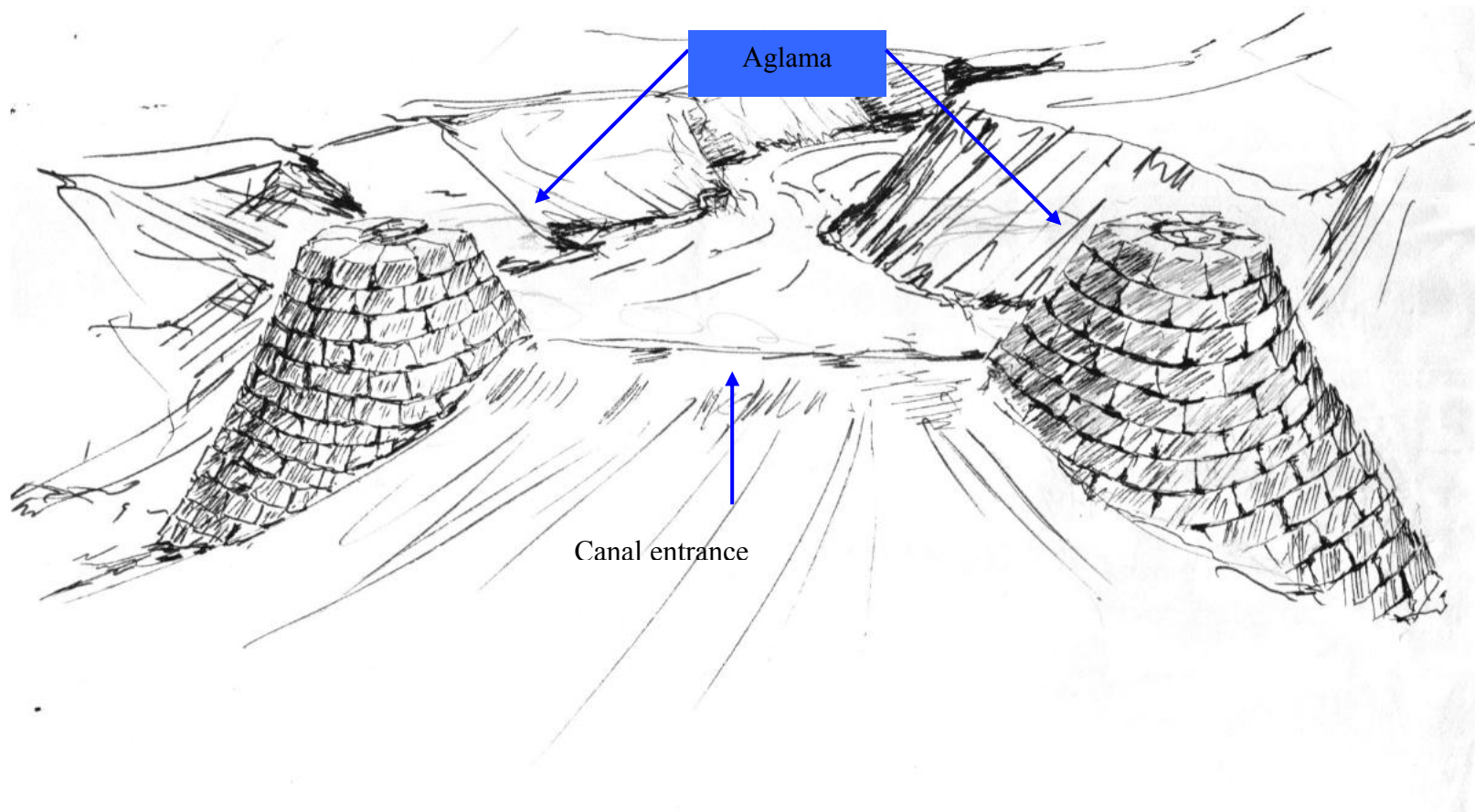


Figure 9 Head of the canal (*ras al- Saqiya*)



Figure 10 *Aglama* in wadi Beihan



Figure 11 *Aglama* in wadi Beihan

5.1.2 Canal body

The flood channel flows between two parallel walls, one adjacent to agricultural land and the other adjacent to main wadi canal. The last one is characterized by high strength so as to be able to resist the big pressure of floods in the wadi. The dimensions of the canal depend on the command area, the canal position in the wadi and wadi discharge. Often *Aglama* are part of the canal wall to support it and serve to reduce the risk of damage. The canal body may also contain some of the following structures:

1- *Al mansam*

Al mansam usually are found in the first 100 m of the *Saqiya* wall that is adjacent to main wadi canal. The *mansam* serve as canal escapes (see figure 12). They are often placed between two *Aglam* with a length of 3-7m. Their height is often 50 cm or more lower than the opposite canal bank. The difference is often filled up with a plug made of grass and tree branches, fixated with stones, so as to reach the same level as the opposite wall.

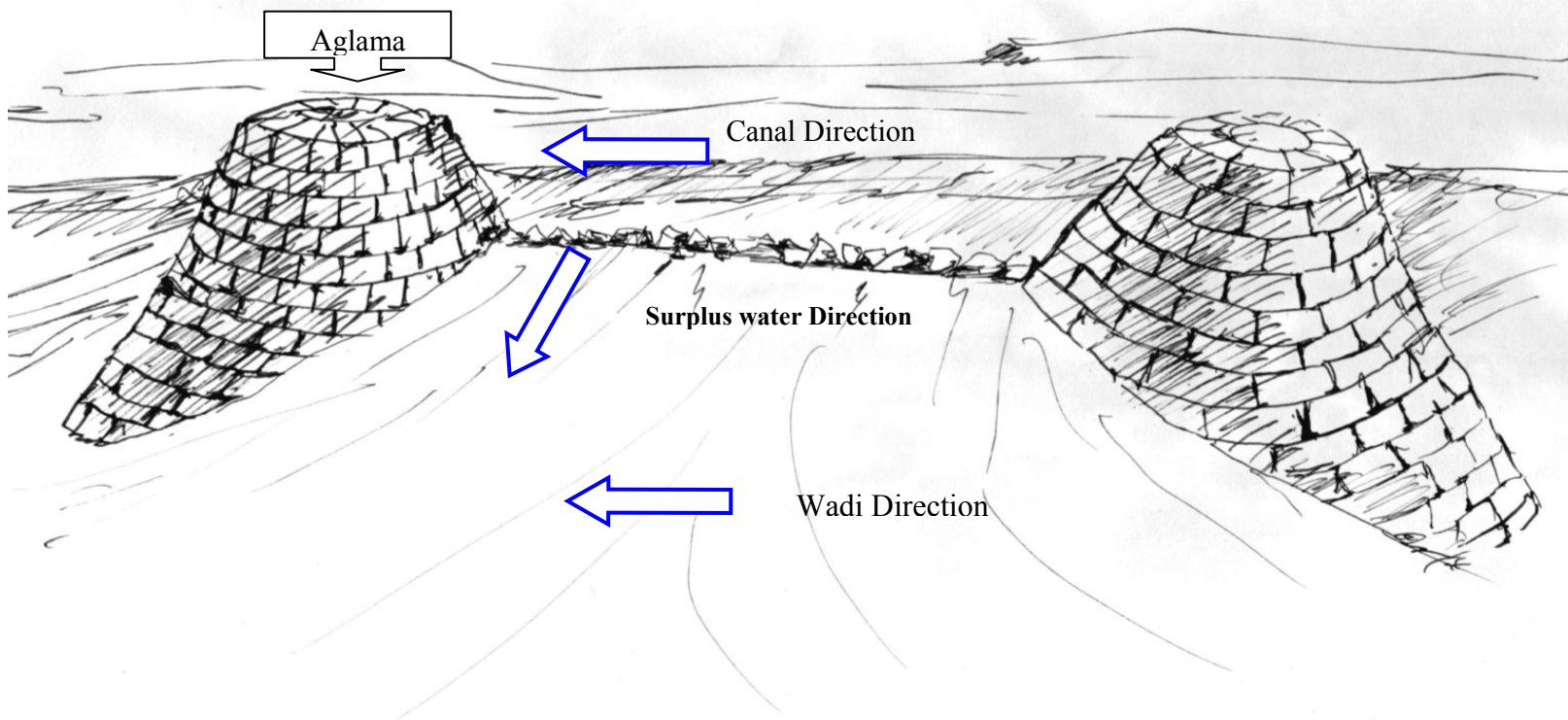


Figure 12. *Al mansam*

2- Al Ma'adher

Similarly *al Ma'adher* are constructed to act as a safety device for the canal system. They are part of the *Saqiya* canal bank and consist of unconsolidated stones in the base of the canal bank. Their main purpose is to get rid, if required, of the entire flow in *Saqiya* and return it to wadi, when there is no need for further irrigation or when the canal network is in danger. *Ma'adher* usually exist in the middle or in last part of *Saqiya* wall. They are opened during emergency by any farmer near to this place by pulling out some stones while the remaining stones in the wall will fall under the pressure in the canal.

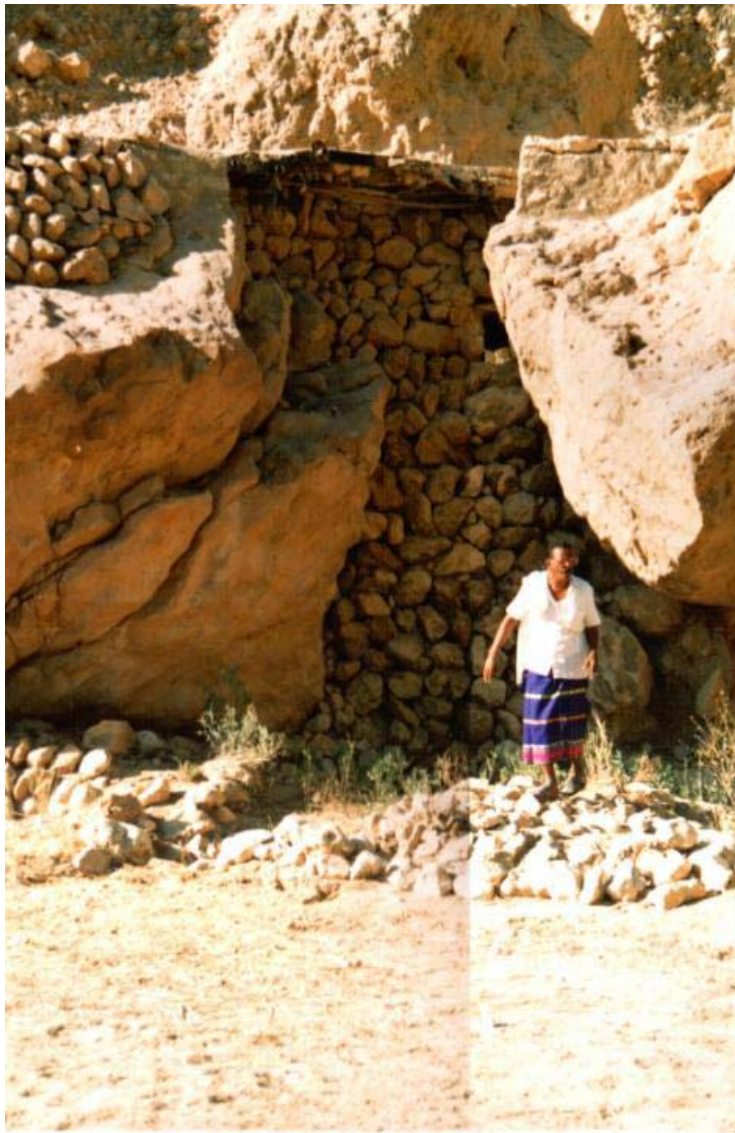


Figure *Al-Ma'adbar* safety control device to open at no need of water or the agriculture land facing a danger

3- Drop structures (*Al Masaqit*)

Drop structures are built in spate canals when:

- A canal has a steep longitudinal gradient
- The water is transferred from a higher canal to a lower one; or
- When the water is diverted from one field to another. The purpose is to dissipate flow energy so that scouring is minimized.

The structure is built on a foundation of dry stone, occasionally mixed with a little concrete. The remaining part of the structure is constructed with stones interlocked properly, the gaps filled in with smaller stones.

4- *Al-Masih*

This structure is constructed on the edge of the wadi to protect the agricultural lands adjacent to it which are vulnerable to floods. The function of this structure is similar to the function of retaining walls. *Al Masih* are usually built on the inclined embankments which form the land boundaries. The structures is typically made of round stones and the gaps are filled with stones of smaller sizes to prevent direct contact of the earth embankment with the water. The common vertical inclination of the structure ranges between 30° to 45°, but this depends on the angle of the supporting embankment. Stones used in construction are usually laid in one plane as a smooth surface to minimize the tangential flood force in the structure.

5- Spill ways (*Al-Masakhil*)

The purpose of spill ways is to control the quantities of water which enter the main spate canals. Spill ways are constructed on the side embankments of the feeder canals, not far away from the intake. Any discharge exceeding the capacity of the canal will return through this structure back to the wadi. The structure can therefore be considered as a safety valve to the main spate canals. Occasionally this type of structure is built to transfer spate water from one agricultural land to another when the difference between the ground levels is relatively high.

Al Masakbil are usually built on the earth embankments of the canals from medium sized stones. On both sides of the embankment the structure goes down deep into the foundation, so the supporting soil has no direct contact with the water. In construction, no cement is used or only on very rare occasions. Occasionally steps are built on both sides of the structure.

Al-Masakbil have a similar function as *Al mansaam* but as spill ways the excess water is automatically returned to the river bed. Under the *mansaam* structure, farmers can decide to use the high flows or not – to pull the plug or not. In some areas *Masakbil* structures are built to transfer spate water from one area to another when the difference between the ground levels is relatively high.

5.2 Gabions and Traditional Spate Structure

In recent years under several programs gabion structures have been introduced. Both imported and locally (Aden) produced gabions boxes are available. Many of them are provided under government programs such as the land and water conservation project (LWCP) and its follow up activities. Initially under LWCP the project contributed gabion boxes, and tractors for the transportation of stones, while the farmers provided all labor for stone collection and work on site. Later farmers also covered the diesel and lubrication oil cost. At present under the follow up activities of LWCP gabion boxes are distributed either free of charge or at 15% of the cost to farmers groups/ cooperatives.

There have been very few studies that compared the performance of the traditional permanent structures and the gabion structures. One study was done however for wadi Beihan done by Jameel Sallam (14). What is valid in Beihan may not be valid elsewhere, and what is applicable now may change in the next twenty or so years. Yet a number of poignant observations are made:

- Continuation of gabion works depends on the availability of gabion boxes, wires, transport and machinery which is not assured after the completion of in this case Beihan Agricultural Development Project;
- Farmers are reliant on the project for these materials. In contrast, the traditional structures do not need more than local materials, skills and machinery to construct them,

- It is unquestionable that the traditional structures last much longer, and their maintenance costs are lower, than equivalent gabions:
- Traditional structures have proved that they resist the flood force much better than the best constructed gabion structure in the wadis and
- The traditional structures appear more economical than the gabions.

An effort to encourage the construction of traditional spate structures, the Wadi Beihan project supported the construction of two structures by making available equipment for transport of stones and excavation and financing part of the labor costs. The farmers provided all labor for stone collection and work on site. A comparison of cost between a traditional and comparable gabion structure showed a slightly lower cost price in m³ for the traditional structure (10% less) of which the farmers themselves provided approximately 50 percent. However, in Wadi Beihan the number of traditional structures has been decreasing since the establishment of Wadi Beihan Agricultural Development Project in 1983, as a result of introducing gabions in the area. The farmers became totally reliant on gabions and ignored the traditional structures, although they are much more effective than the gabions in many ways.

6. The Legal Framework

The legal framework for water resource management in Yemen is based on three sources, which are very closely related to each other. Listed in order of precedence, these are: a) Islamic Law (or *Sharia'ab*); b) legislations: the constitution, laws and regulations; and c) customary law (or *'urf*).

Islamic law, or *Sharia'ab*, is truly the foundation of the country's legal system. Indeed, *Sharia'ab*, as pointed out in Article (3) of the Constitution, is "the main source of legislation". This means that no legislation (including the Constitution itself) can uphold legal principles which contradict the principles of *Sharia'ab*.

Sharia'ab originates essentially from two sources: Koran and *Sunnab* (Prophet's sayings and teachings). However; because of disputes over the interpretation of the meaning of some rules in Koran and *Sunnab*, several Islamic schools evolved (*Mazabeb* or creeds).

There are at least five such schools. These schools, which are named after their founders, are: *Shafii*, *Hanafi*, *Hanbali*, *Zaydi*, and *Maleki*.

Differences among *Mazhab* are generally minor, but each *Mazhab* (singular of *Mazhab*) is usually quite comprehensive; meaning that it comprises a comprehensive set of rules covering all aspects of interest. Taking an example from water rights; they may vary over the appurtenance of water rights to the land, and whether or not these rights may be sold separately; or over the ownership of the water inside a well, which depends on whether or not the well is considered a privately owned “receptacle”, or a legal means of appropriation like any other container.

The first component of legislation is the Constitution, which, as pointed out earlier, conforms to *Sharia’ah* principles. Laws, which form the second component, are of two types: public and private. Public laws are those, which apply to the government sector; such as: administrative, financial, etc. Private laws apply to the State as well as the general public. The foundation of all private laws is the Civil Law (number 19 dated 29/3/1992). This law consists of 1399 articles, of which only 38 articles in relation to land and water rights. Eight articles are general ones, which deal with the law itself and the land ownership rights, while the remaining 30 articles deal with land and water rights.

Civil law is essentially a present-day “modern” formulation of the *Sharia’ah* principles. In essence; therefore, civil law serves two purposes. First, it serves as a transformation of *Sharia’ah* principles into a modern” form of legislation. In Yemen, this transformation process is the responsibility of the “Committee for Legislating Islamic *Sharia’ah*”). The second function of civil law is that it serves as a legal instrument to implement certain interpretations of those rules of the Islamic law whose interpretation is disputed among various Islamic schools. This way, civil law helps to unify the legal system at the national and local levels by avoiding inconsistent rulings in similar court cases had each court relied on a different interpretation.

Finally, civil law is commonly called the law of laws “since it contains the necessary provisions to guide the preparation of specialized laws in the various fields or sectors (e.g., Water law, Commerce law, Local Authority law, Agrarian law, etc.). However, it is

also true that some *Sharia'ah* principles/ rules have not yet been formalized and incorporated into the civil law.

Custom, which is the third source or cornerstone of the legal system, is defined as “the continued repetition of certain actions or practices by a collectivity in the conviction that they are legally binding” Since customs must adhere to *Sharia'ah*, the customary rules in a given region are simply an instrument to implement certain *Sharia'ah* principles at the regional or local levels taking into consideration the physical circumstances and/or the recognized Islamic school in that region. That is why customary rules can vary regionally according to the physical and socio-economic circumstances (e.g.; climate, type of water source, land-use, predominant economic activity, etc) and/or the prevailing Islamic school. Although customs are rarely documented, the majority of Yemeni tribes recognize a set of customs, which form what is known as the “Document of Seventy Rules”. Drafted and signed by the various Sheikhs some 300 years ago, this document contains three rules, which relate to water, water rights and water structures.

The first rule (no. 36) deals with the “legal” status of wells. It gives a well owner the right to obtain free wood to construct or repair his well, regardless of where the wood is cut from, be it from trees in public property or in private property. Understandably, since people have the right to obtain drinking water from the well then they are obliged to share the construction and maintenance costs/ materials. The second rule (no. 43) declares that the roads which lead to country-side market-places and to major settlements are secured (safe), so that people can move in and out of these places to exchange “benefits”. This principle of public benefit may be applied to erection of pipeline systems. Finally, the third rule (no. 58) defines protection zones around wells.

To conclude, the system of water rights in Yemen, and in Muslim countries in general, is based on Islamic law (*Sharia'ah*), the Constitution, Civil law and Customary Law. However; all sources share the common feature that they all originate from, and form an integral part of, a single system, vis-à-vis; the Islamic system.

6.1 Water Rights

Although of the above legal framework and the approved water law since 2002, the “*Aurf*” or traditional customs rights is used to utilization spate water, where upstream

beneficiaries of spate water have first claim on water. This traditional water rights '*Aurf*' system tends sometimes to waste water resources because upstream farmers arbitrarily take their full requirement of spate water prior to releasing the flow for downstream users. This system of traditional spate operation presents questions of equity. However, the '*Aurf*' system seems to function on a relatively equitable basis during large floods where upstream users cannot divert the entire flow, as this may destroy their upstream irrigation system and structures. Since large floods do not occur often, due to the random nature of the floods, the downstream users sometimes do not get spate water for a number of years.

6.2 Water rights and irrigation systems

The differences in types of water rights in the various wadi areas and rainfed areas of high altitude, seem to be partly a reflection of the differences in technical irrigation practices, in rainfed areas of high altitude, cultivation is done in terraces and at the foothills in small plots. Each plot has its own canals, which collect rainfall for irrigation. These canals, with the land they serve, are the private property of the farmer.

In areas situated in secondary and small wadis, farmers have the right to irrigate their fields according to the sequence of irrigation starting from upstream according to the upstream right to water.

The principle of priority to upstream lands, "upstream right to water", does not apply uniformly to all wadis in the Yemen. Those wadis with an extensive irrigation network such as Wadi Zabid, Wadi Rima, Abyen and Tuban Delta, have a large body of local water laws, which to some extent put restrictions on upstream landowners.

6.3 Water distribution rules

There are several types of rules in spate irrigation and it is usual to find that two or more are applied simultaneously in any system. Although the water right is more complex in the highlands than the coastal area, most of the previous studies concentrate on water right of spate irrigation on the coastal area. The reason is that these studies were often

undertaken in relation to government or donor-funded projects. More work would need to be done to documents the water distribution systems in other areas.

1. Rule upstream right to water:

Though the principle of priority to upstream lands is general, there are some restrictions to this rule in the wadis under an extensive irrigation network.

2. Rule of the land priority:

When some of the lands have been reclaimed before others and have an established priority in the right of irrigation, then these have precedence in irrigation by seasonal flood flow. This is even though it may be regarded later as renewing the reclamation to other fields,

3. Rule of date:

In the big wadis, spate water distribution among upstream, midstream and downstream spate users according to agreed fixed dates each season,

4. Rule of first floods:

The water right of first floods of the season is differ from place to place, the right of the first flood for the following:

- a. For all farmers have the irrigation right, by distribute the spate water between them up to an ankle depth,
- b. For upstream users according to rules,
- c. No right for upstream, but see where the turn was stopped in previous season and continue from that place
- d. For trees only.

5. Rule of constant depth:

The maximum allowable depth of water is fixed, depth of water not exceeding certain level,

6. Rule of varying depth:

Different crops, different depth of water is given, the amount of irrigation required for grapes is greater than that for palms, which is greater than for tree crops, which is greater than for annual crops.

7. Rule of trees is first:

If a limited flood arrives, only lands cultivated by trees or palm trees are irrigated.

Under the rule of life cultivated land has priority over uncultivated land

8. Rule of second irrigation for some crops:

Some crops have a right to get second small irrigation, in spate irrigated areas. Usually crops are irrigated once per season except for some areas situated in the upstream of the wadi where certain crops such as sorghum and millet may be given two irrigations (“zahw”).

9. Rule of return irrigation, its include the following:

- a. Only one irrigation per season, if the command area larger than the irrigated area,
- b. In some area, the second irrigation is after irrigation of all land area,
- c. In some area, the second irrigation depend on the length of time period between two floods, (if a period less than two weeks, second irrigation is not allowed but, if the period about one month second irrigation is allowed.

10. Rule of the area “Marha’q” :

Certain areas are allowed to divert all spates water to a certain land

11. Rule of $\frac{1}{2}$ or $\frac{1}{3}$ of wadi discharge:

It is forbidden to close the entire wadi bed. Farmers are allowed to divert only part of spate water and will have to leave part to downstream users, that is about $\frac{1}{2}$ or $\frac{1}{3}$ of the total wadi discharge. These partitions are usually set according to traditional agreements and/or the location in the wadi and/or floods frequency and discharge of the wadi.

12. Rule of water way:

If someone owns a land located away from the water canal, the right of way for a channel to his land is granted.

13. Rule of structure cost sharing:

Cost in maintenance are shared on the basis of water right

14. Rule of maintenance cost sharing:

Contribute in maintenance according to land location sharing system (see O&M section) gives a water right. Water rights may be forfeited in case of absence or default in maintenance.

15. Rule of land preparation:

Unleveled land cannot get water,

16. Rule of the harmed:

Crop/land in peril gets water first. The water master, who distributes water between the farmers may decide which land and crop appears to be in peril and

should get water first. This rule is more pronounced in the spring irrigated land in the mountain area,

17. Rule of water is on demand:

This rule more clear and applicable under abundance of springs water in some lands in the mountain area.

18. Rule of power

Undeniably power play is important too and rules, even if traditionally agreed, are subverted by strong interests.

6.3.1 Water distribution from seasonal floods in the highlands

The water distribution rules differ between areas and between systems. As elsewhere there is a distinction between systems in the plains and in the highlands. Some of the rules that are particular for highland spate systems are:

1. For those with equal right to public water in the reclamation of land, as in the land along the flood path of the wadi, the rule is the upstream user first (literally the highest and then the next highest).
2. When some of the lands have been reclaimed before others and have an established priority in the right of irrigation, then these have precedence in irrigation by the seasonal flood flow. This prior right may be extended in case of reclamation of other fields.
3. New lands with a right to flood irrigation come in priority after those earlier, established lands. Excess water from a flood flow, after the older lands are irrigated, is for whoever has precedence in ownership of the newer lands. The priority of the upstream user is for a single flooding.
4. Irrigation is according to the customary practice of a certain place or certain wadi. Whoever diverges from the custom and causes harm on another is held accountable to compensate for the damage.

Among the most common practices in the mountains area are the following:

First: When the first of the flooding occurs and is diverted for irrigation, land owners can draw off the amount up to an ankle depth only, but then it must be sent to the next one in the sequence.

Second: When a limited flooding arrives so that only part of the land area is irrigated, then the next arrival of flood water is allocated as follows:

- a. When the flood comes again soon after the first, something like 8-10 days, then there is no right to the upstream user for a second application. He must not dam up the breaches through which the flood flows, but it will go on to the downstream users who did not receive water at the first flooding. This is necessary for fulfilling the downstream users needs.
- b. When a flood comes again after half a month has passed, then the upstream user has the right and it is denied to the downstream user until the former's needs are met. This is because the time the crop is maturing from the earlier irrigation has passed and the crop needs another application of water.
- c. When a flood comes again after the first flood has been used for irrigation of all the land area, then the upstream user can take more than an ankle, according to what his needs call for or until he is satisfied. Then the water continues on to the next one in the sequence.

Third: Another permanent arrangement for allocating water is by opening the major watergates with barriers alongside to turn back the flood flow to an area. Farmers fix the height of the barrier sufficient to cause the water for that area, so that when there is abundant water it flows over the top of the barrier and on to what is beyond. This continues until the end of the wadi. This permanent arrangement is prohibited from being altered.

7. Operation and maintenance

An essential element in each spate irrigation system is the establishment of adequate operation and maintenance (O&M) procedures. In traditional systems the seasonal repair and maintenance of the *Ogmas* and *Saqiya* was the responsibility of the farming community. With the implementation of new spate improvement works, part of these O&M activities were taken over by the government. Yet the current policy is to return back the responsibility of O&M to the farmers by establishment of Water User Groups (WUG), Water User Associations (WUA), Scheme Water User Federations and Irrigation Councils (IC). The Irrigation Improvement Project (IIP) process foresees in the establishment of these groups and committees in Wadi Zabid and Wadi Tuban.

The traditional techniques for construction, operation and maintenance of the irrigation systems have developed into quite sophisticated mechanisms, providing the base for irrigated agriculture in the area and maintaining a sensitive equilibrium of scarce water resources.

Starting from small spate canals, in rainfed areas of high altitude, cultivation is done in terraces and at the foothills in small plots. Each plot has its own canals, which collect rainfall for irrigation. These canals, with the land they serve, are the private property of the farmer. The construction, operation and maintenance of the terraces spate canals are full responsibility of each individual farmer.

In agricultural lands that are irrigated almost annually by spate floods in wadis relatively bigger than those mentioned above but without irrigation structures or improved irrigation networks, spate irrigation is achieved by diverting water from the wadi to the land directly (without any diversion canal) by means of temporary earth bunds (locally called *ubar*) across entire wadi bed, the construction, operation and maintenance full responsibility of landowners (by cost sharing). This type of earth bunds is usually flush each flood, that due to high slopes of wadis in the mountain area. The irrigated area per *ubar* is 0.1 to 2 ha.

In agricultural areas situated in the main wadis that are irrigated by spate at least twice a year (*Seif* and *Kharif* seasons) as well as by (semi-) perennial flow, the government has often modernized the systems. O&M has become government responsibility, though as mentioned a policy towards participatory irrigation management has started.

In agricultural areas in main wadis that are irrigated by spate twice a year (*Seif* and *Kharif* seasons), where no 'modernization' has taken place farmers continue using traditional spate system (*Ogmas* or *Saqiya*). The construction, operation and maintenance in these systems is responsibility of group of farmer, examples *Saqiya* systems in Hadramawt and Shabwa and *Ogmas* in some wadis of red sea coastal area. In several of the traditional systems however the local rulers used to play an important organizing role – as in Wadi Tuban prior to the modernization.

7.1 Farmer organization for O&M -*Saqiya* systems in Hadramawt and Shabwa

When a group of farmer decide to construct a spate canal '*Saqiya*', usually a farmer community is established at the same time, with farmer group defining the command area, canal capacity, canal head location, canal path and canal level, finally, total cost estimation of the construction. Cost sharing among the shareholders in a spate canal is usually takes into account a number of factors:

- Land area, the share being in accordance with the land share in the command area, so that big farmers contribute more than small ones;
- Location of the land, the distance between wadi and land determining the cost share;
- Land levels, with regards to the wadi and canal bed level with lands higher than canal level paying more than lower lying areas. This is related to the scour in some wadis and channels, that cause some lands to 'hang high'. In no way spate water will enter these fields unless the canal level is increased, which bring considerable cost.

The agreed sharing in construction cost is also applicable for operation and maintenance, particularly at small *Saqiya* systems (serve about 15 – 25 ha).

For the purpose of canal management usually a *Saqiya* committee is appointed. This will typically consists of 5-10 persons headed by a water master (*Al-kihila* or *shikh*). The committees is further often supported by a cashier and revenue officer *Ra'adh Saqiya* and *Ra'adh Alnagkial*.

7.1.1 The responsibility of water master (*Al-khila or shikh*)

- Arranges the priority of water rights to the various fields and farmers according to the historically developed water rights and cost sharing,
- Responsible for the repair and maintenance of *Saqiya* system,
- Supervise the overall system during floods.

7.1.2 The responsibility of *Ra'adh Saqiya*

- Monitoring the *Saqiya* main canal during irrigation,
- Takeout any obstructions come with spate water that may close the canal,
- Urgent canal reparation that may happen during floods.

7.1.3 The responsibility of *Ra'adh Alnagkial*

- Monitoring the *Saqiya* lateral canals during irrigation,
- Define the required water to each land, using stick (*Mara'adb*) about 45 cm length. During irrigation *Ra'adb* throw this stick at canal filed entrance, if the stick pass in the middle of the canal, it means the water right still for the field, but if the stick beat one side of the canal, it means the water start to return back from.
- Takeout any obstructions come with spate water that may close the lateral canals,
- Open and close the lateral canals.

8. Crop Under Spate Irrigation

Total rainfall in the highlands and Mountain Plains ranges from 300 to 800 mm in the normal years, with a potential evapotranspiration is of the order of 1500 mm/year, while in the coastal plain the Mean annual rainfall ranges between 350 at the foot of the mountains, to below 100 mm on the Red Sea coast and Gulf of Aden coast. The plain is hot and dry with a short erratic summer rainy season, and evaporation may exceed 2500 mm per year. Rains come during two main seasons, spring rains in March and April and summer rains in July and August.

Spate hydrology is characterized by a great variation in the size and frequency of floods, which directly influence the availability of water for agriculture in any one season.

Cropped areas and crop production vary considerably over the years because of the large variation in wadi run-off from year to year, season to season and day to day.

This is a unique form of irrigation, predominantly found in arid and semi-arid regions where use is made of occasional heavy floods of very short duration. Application of 40 - 100 cm of water in a single pre planting irrigation is sufficient for raising all spates irrigated field crops. Agricultural yields are, in general, low and may vary greatly from year to year depending on size and frequency of the spates. The data on the conjunctive use of groundwater, springs and spate irrigation is limited especially on the amount of water used and the effect on crop yield, in general most wadi development projects have shown a rapid expansion of groundwater exploitation for agriculture and also shown in several cases, though, the uncontrolled installation of tube wells has resulted in serious over-exploitation of the groundwater resources leading to a rapid lowering of the groundwater tables, sometimes combined with increased salinity hazards, although these project are in the same areas of spate irrigation but most of the farmers depend only on groundwater or spate water with small conjunctive use of groundwater and spate irrigation.

8.1 Main Crops

Most crops, except fruits and vegetables, are grown under spate irrigation. The main crops are: sorghum, Millet, sesame, cotton and maize. Bananas can be extensively cultivated near the mountain front of the coastal plains under spring flow from the wadi bed.

The main crops under rainfed - spate irrigation in the Highlands are Sorghum, Wheat, Alas, Lentils, Peas, Maize, and Highlands.

The main crops under spate irrigation in coastal area of Tihama, are Sorghum, Maize, Cotton, Sesame, Tomato, Vegetable, and some Fruits, while the main crops in the coastal area of Aden Gulf, are Cotton (Extra Long and Medium Staple), Sorghum, Millet, Sesame, Watermelon, and Groundnuts.

8.2 Crop Yields

Crop yields in the highlands vary greatly depending upon the agro-ecological zone, whether rainfed or irrigated farming system, and the management practices. In rainfed areas crop failures occur often because of abnormally low rainfall. The rainfed (dry land) cropping pattern in the Mountain Plains remains about the same whether a farmer has dry land or both dry land and irrigated fields, except the planting dates can be more rigidly selected under irrigation. It is difficult to find reliable data on crop yields under spate irrigation area in the highlands. As a proxy crop yields under rainfed cultivation and under groundwater irrigation may be taken, with the crop yield under spate irrigation is being inbetween these two yields (see table 3).

Table 3. Main crops and crop yields under Rainfed – irrigated area in the Highlands

Crop	Rainfed		Irrigated	
	Median yield (tons/ha.)	Ranges (tons/ha.)	Median yield (tons/ha.)	Ranges (tons/ha.)
Sorghum *	0.7	F-1.2	1.8	1.5-3.0
Barley *	0.7	F-1.0	2.0	1.5-2.5
Wheat *	1.0	F-1.2	2.0	1.0-3.0
Alas *	0.7	F-1.0	1.8	1.3-2.5
Lentils *	0.6	F-1.0	1.0	0.7-1.4
Peas *	0.6	F-0.9	1.0	0.7-1.4
Maize *	1.3	F-2.2	2.0	1.0-3.0
Millet **	0.8	F-1.2	-	-

* Assume the following Stover/grain ratios: sorghum 4.0, wheat and barley 1.0; maize 1.5; pulses 2.0.

** Green weight of six to seven cuts at 25% dry matter.

Source: Varisco, Daniel Martin. Land Tenure and Water Rights in the Central Highlands of the Yemen Arab Republic, 1985.

The crop yield in the coastal region fluctuates. The variation may be due to the several local cultivars grown, with different yield potentials, and grown at a wide range of planting dates during the two flood periods. Variation may also be due to the fact whether the crops is the main or secondary crops and whether fertilizers, herbicides and pesticides are used. See table 4 and 5.

Table 4. Main crops and crop yields under spate irrigation in the coastal area of Tihama (Red Sea coast)

Crop	Average yield (tons/ha.)	Ranges (tons/ha.)
Maize	1.3	1.1 - 1.5
Sorghum	2.75	2.0 - 3.5
Cotton	1.0	0.65 – 1.35
Sesame	0.7	0.7
Tomato	9.5	9.0 – 10.0
Vegetable	16.0	16.0
Fruits	17.5	15.0 – 20.0

Source: Abraham Adomi, Spate irrigation workshop 22-24 November, 1998.

Table 5. Main crops and crop yields under spate irrigation in the coastal area of Aden Gulf.

Crop	Average yield 8 seasons (tons/ha.)	Ranges (tons/ha.)
Sorghum and Millet	0.96	0.73 - 1.2
Cotton Extra Long Staple	0.91	0.865 - 0.95
Cotton Medium Staple	1.30	0.98 - 1.63
Sesame	0.50	0.36 - 0.64
Melons	10.90	7.78 - 14.1
Groundnuts	1.24	1.24

Source: Crop production under spate irrigation in coastal area Ab.S. Mu"Alaem, 1987

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