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A review of policies in groundwater management in Pakistan 1950–2000

Frank van Steenbergen*, William Oliemans

Arcadis Euroconsult, P.O. Box 441, 6800 AK Arnhemm, Netherlands

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Abstract

This article reviews groundwater management policies in the four provinces of Pakistan in the last 50 years. The early part of this period was concerned with the control of high water tables in the canal-irrigated areas of the Indus plains and the promotion of tubewell irrigation outside of it. The focus until the nineties was almost exclusively on subsidies and on public investments in drainage infrastructure. Private tubewell development, however, has taken a large flight, particularly in rural Punjab and Balochistan and in the urban areas. It has changed the setting. Intense use of groundwater facilitated a strong increase in agricultural production and has helped to keep up with urban water demands, yet management is now required to address substantive overexploitation and groundwater quality issues. The most expedient in the large unconfined aquifers of the Indus Basin is the integrated management of surface irrigation, drainage and groundwater. In the mountain province of Balochistan local groundwater management needs to be supported, building on a number of promising examples. © 2002 Published by Elsevier Science Ltd.

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1. Introduction

The use of groundwater for irrigated agriculture in Pakistan has a long history. The existence of horizontal well systems (*karezes*) in Balochistan has been documented by Greek travellers to

Abbreviations: Associated Consulting Engineers (ACE); International Commission on Irrigation and Drainage (ICID); International Irrigation Management Institute (IIMI); International Water logging and Salinity Research Institute (IWASRI); Left Bank Outfall Drain (LBOD); National Engineering Services of Pakistan (NESPAK); North West Frontier Province (NWFP); Salinity Control and Reclamation Project (SCARP); Specialist Group Incorporated (SGI); SCARP Monitoring Organization (SMO); Second SCARP Transition North Rohri Pilot Project (SSTNRPP); Water and Power Development Authority (WAPDA)

*Corresponding author. Tel.: +31-73-523-0847; fax: +31-73-523-0849.
E-mail address: fvansteenbergen@compuserve.com (F. van Steenbergen).

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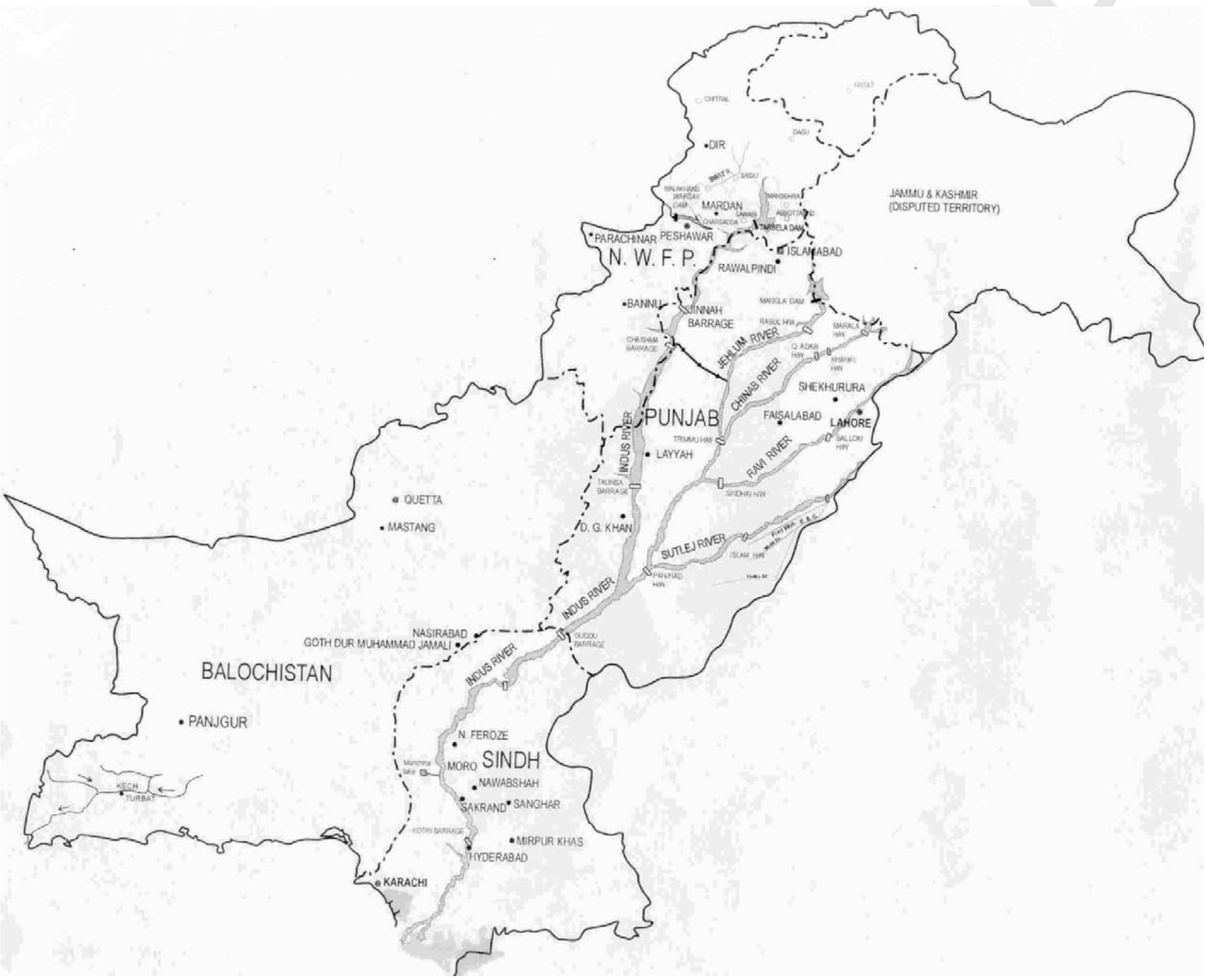
Balochistan as long as 2500 years ago. Similarly Persian wheels formed an important element in the flood recession agriculture in the Indus plains prior to the development of surface irrigation (Map. 1).

The present degree of groundwater exploitation in Pakistan, however, is unprecedented. The purpose of this article is to give an overview of the various policies with respect to groundwater use in Pakistan in the last 50 years and review the considerable management issues and challenges of today in the four provinces of the country. Though Pakistan is famous for its extensive 14 million ha Indus-based surface irrigation system, its groundwater resources are formidable as well. Estimates of total surface water resources in the country are 172 billion cubic meters. Estimates of groundwater resources are 57 billion cubic meters—60–70% of which is considered suitable for agriculture.

In 1960 groundwater accounted for only 8% of the farm gate water supplies in Pakistan's most populous Punjab Province, but 25 years later this had gone up to 40%. This figure is nowadays



Map 1.

generally considered to be on the conservative side.[1] Fresh groundwater in Punjab and Sindh province has been used conjunctively with surface water supplies. This way, intense shallow tubewell development in the Indus plain made up for many of the deficiencies of unreliable and insufficient water supplies in the world's largest contiguous surface irrigation system and more than anything else resulted in the spectacular in crease in productivity. Outside the large-scale irrigated areas of the Indus plains, groundwater development changed the face of many arid areas, in particular Balochistan, but also North West Frontier Province and the unirrigated tracts of Sindh and Punjab. According to official estimates the development of shallow wells and deep tubewells has played the main role in the expansion of area under cultivation in Pakistan in the last decades, with 75% of the increase in water supplies over this 25 year period attributable to public and private groundwater exploitation. It also enabled an increase in cropping intensity of 39% between 1960 and 1985. The agricultural water productivity of groundwater has been higher than that of surface water, as its application by nature is timely and it did not suffer from the high conveyance losses, common in the extensive canal networks. Groundwater development in Pakistan has—as elsewhere in South Asia (Llamas, 2000)—been a main contributor to food security and reduction in rural poverty.

With the dramatic increase in intensity of groundwater exploitation over the last decades, however, the policy challenges have been changing. The main issues in groundwater management nowadays relate to environmental sustainability and welfare: how to avoid declining groundwater tables and deteriorating groundwater quality in fresh groundwater areas; and how to ensure equal access to this increasingly important natural resource. For a long time, however, two very different policy themes dominated the political agenda. The first theme was the control of high groundwater tables in the canal-irrigated areas in the Indus Basin. The second theme was the active promotion of tubewell installation as a means to encourage agricultural development.

1.1. Controlling high groundwater tables in the Indus plains

The first theme of rising water tables was related to the inadequate provision of drainage facilities during the development of the canal irrigation system in the Indus plains. The extremely flat topography, the poor natural drainage, the semi-arid climate with high evaporation eventually resulted in water logging. The problem was first noted in the Rechna and Chaj Doabs at the turn of the nineteenth century. The Punjab Government at that time established a Water Logging Board in 1912 and later a Drainage Board (1917) to investigate the extent of the problem and identify solutions. A number of remedial measures were tried and implemented, such as extending canal closures, lowering of canal supplies, planting of eucalyptus groves, canal lining and the construction of storm water drains (Rehman et al., 1997). Water logging meanwhile in spite of these activities continued to increase. It took very serious proportions, after the floods of the fifties increased the already high water tables.

Water logging occurred throughout the Indus Basin. A nation-wide survey, undertaken in 1976–1979, established that in 22% of the Indus Basin the water table was within 6 ft of the ground surface and that in a further 30% the water table was within 10 ft. Associated with this

[1] vander Velde and Kijne (1992) state that groundwater from public and private sources constitute 70% or more of the total water use in many distributary watercourses in the Indus system.

water logging was the salinization of the soil, resulting from capillary rise and evaporation of the mineralised groundwater. This added to the existing salinity of the soil. Salinization was particularly prevalent in areas with fine textures, inadequate irrigation supplies and pre-existing marginal and saline groundwater. Where salinity and water logged occurred, it was often patchy in appearance: it concentrated on minor depressions in the generally flat area. Within these depressions the slightly elevated areas usually suffered most from salinity (Choudri, 1977).[2]

Government response to the alarming spread of areas with high water tables was a large-scale crash land reclamation programme, the so-called Salinity and Control and Reclamation Projects (SCARP). In this programme high groundwater tables were primarily combated by vertical drainage. In 1954, the first large tubewell drainage scheme started. Soon a second benefit of the drainage tubewells was realised. Where the tubewells pumped fresh groundwater, they would not only lower groundwater tables, but would augment surface irrigation supplies as well.

Concomitant with the start of the vertical drainage projects, the first legislation concerning groundwater was introduced. In 1952 the Punjab Soil Reclamation Act was promulgated. This act created the basis for the Soil Reclamation Board to control water logging and salinity through the development and operation of drainage tubewells. For the designated land reclamation areas, the board was in control of groundwater management and could also instigate a licensing procedure, permitting landowners to install private tubewells. Later on the Board was suspended and its executive powers were eventually transferred to the Provincial Irrigation and Power Department. At one stage in 1965 licensing rules were framed, yet they were never enacted.

Another act, announced in 1958, covers the same ground. This act, the Pakistan Water and Power Development Authority Act, is the legal basis for the establishment of the Water and Power Development Authority (WAPDA). This federal agency is responsible for the *development* of all major power, irrigation and drainage infrastructure, whereas the operation of irrigation and drainage infrastructure is usually transferred to the provincial irrigation departments. According to the 1958 Act WAPDA has control over Pakistan's groundwater resources and in the exercise of this control official area-specific rules will be issued. Such rules were never announced however. Moreover, on paper, the WAPDA Act conflicts with the earlier Soil Reclamation Act, which gives the provincial irrigation department control and responsibility in groundwater management. The relevant portions of both Acts, related to groundwater regulation, were however never operationalised.

In the meantime, however, a large number of SCARP Projects were undertaken. The SCARP projects typically consisted of the installation of batteries of high capacity electrically powered deep tubewells, pumping water from 40 to 120 m deep.[3] By 1995 more than 15,000 public deep tubewells had been installed in Punjab, Sindh and—to a limited extent—North West Frontier Province. Twelve thousand of these yielded fresh groundwater. Even in Sindh Province with extensive areas of saline groundwater, the drainage wells were mainly installed in areas with fresh

[2] The patchy nature of water logging and salinity in several areas means that the impact of the problem was somehow mitigated, as farmers were cultivating several plots at a time and generally had land that was affected and land that was not affected. In other areas the problems is more uniform and entire areas are abandoned.

[3] The preference for deep tubewells rather than shallow tubewells has been a matter of controversy, because in general groundwater at greater depths is more saline than shallow groundwater. Experts such as Ahmad (1993) argue that it increased pumping costs and resulted in bringing very saline water to the surface, which in the absence of a well maintained surface drainage systems inevitably accelerated soil salinity.

groundwater for want of adequate disposal arrangements in saline groundwater areas. The deep drainage-cum-irrigation tubewells were usually installed at the head of a tertiary channel (watercourse) and facilitated crop intensification. In areas with saline groundwater the deep tubewells either discharged in an open surface drain or mixed their saline effluent with fresh surface water in main channels or distributaries. Though most SCARP projects consisted of deep tubewells, some projects also made use of dugwells, open surface drains and subsurface pipe drains. The only systematic groundwater-monitoring programme in Pakistan was also initiated as part of the SCARP Programme. To assess the performance of the public deep tubewells the SCARP Monitoring Organisation measured groundwater level and deep groundwater quality in the designated SCARP areas—not outside of it.

1.2. Tubewell promotion for agricultural development

Besides the control of water logging and salinity, a second important government policy in the sixties, seventies and eighties was to stimulate private tubewell development. In canal-irrigated areas private tubewell development would help alleviate drainage problems. Outside the canal-irrigated areas private tubewells could foster economic development. In the unirrigated parts of the Indus Plains, in Balochistan and NWFP private tubewells would make it possible to bring large tracts of land under cultivation.

Private groundwater exploitation was promoted in several ways. Foremost was the provision of subsidised power supply to tubewell owners. Electric charges for tubewell owners in Punjab and Sindh were 40% less than the normal rate. In Balochistan and NWFP the subsidy even amounted to 60%. Tubewell development was also promoted in a number of government programmes through the provision of free pumpsets and wells and tubewell loans under soft conditions (Johnson, 1989).

Private tubewell development soon did not require public subsidisation to take a flight. Private tubewell ownership in the Indus Plains exceeded 400,000 in the early 1990s. By this time both in Balochistan and in NWFP, there were more than 10,000 tubewells. By the late eighties the Report of the National Commission on Agriculture concluded that groundwater development could now be left entirely to the private sector. By and large—but not completely—government support to private tubewell installation came to an end. The most important exception was the continuation of the low agricultural tubewell electricity tariffs.

2. Current groundwater issues

Groundwater policy of the last 50 years in Pakistan may be summarised by a number of characteristics:

- The focus was on the control of water logging and the stimulation of private tubewell development. Essentially government interventions were supply driven. There was little concern about overexploitation of aquifers or deteriorating groundwater quality.

- The policy relied on public investment and subsidies[4] rather than regulation. Whatever legislation was made was not enforced. There was ambiguity as to who should regulate groundwater exploitation, i.e. the federal government or the provincial governments.
- All policies were initiated and implemented from Province and Federal level. The involvement of local government bodies was minor. Neither was there any involvement of local farmer organisations. Both types of institutions are weak in Pakistan.

As mentioned, however, the spectacular increase in private tubewells numbers changed the setting entirely and invalidated old policies. In several fresh groundwater areas in the Indus Plains there has been a virtual volte-face. Where 30 years ago high groundwater tables were the major threat, groundwater levels have now declined due to private tubewell development. Salinization through capillary rise is no longer a threat, but the intense pumping poses other threats—in the shape sodification and soil salinity through salt disposal.

Similarly, in areas outside the canal-irrigated areas of the Indus plains, the promotion of private tubewell development is now heavily outdated. Groundwater is no longer the limitless resource it once was. In the absence of effective regulation, large number of tubewells have resulted in groundwater mining. In addition, the social issue of distribution of access to groundwater has come to the fore. Because tubewells are mainly privately owned, the question is how persons without a private tubewell are able to utilise groundwater. In the next section the current groundwater issues for the Indus plains and the mountain provinces are discussed subsequently. The final part of the section briefly pays attention to another emerging groundwater issue, i.e. urban groundwater pollution.

2.1. Groundwater issues in the Indus Basin

2.1.1. Punjab

Due to public and private groundwater development, water logging has disappeared from most *fresh* groundwater areas of Punjab. It persists, however, in isolated natural depressions and in areas with saline shallow groundwater, in particular the centres of the interfluviums (‘doabs’) and the southeastern part of the Province. As a result, Punjab is marked by the paradox of having areas that suffer from high water tables and areas where tubewell development has been so intense that water tables decline. A study undertaken in 1990 suggests that in Punjab the volume of groundwater extracted significantly exceeds the volume of water recharged. The study estimates the difference to be as much as 27% on a provincial basis (NESPAK/SGI, 1991), but this over extraction is concentrated in a number of fresh groundwater areas.

This localised overexploitation in fresh groundwater areas has already brought down groundwater tables with 2–4 m in some places. There are also fears that the intense use of groundwater will lead to a deterioration of groundwater quality, particularly where relatively high capacity private tubewells are used. The first reason for such a decline in groundwater quality is

[4] An interesting example is the subsidy on gypsum to treat sodic soils and water. After several years this was abolished, as the cost of it was unsustainable. Unfortunately with gypsum provided by the private sector the price increased, making it too expensive for a large number of farmers, particularly in Sindh and Balochistan where no local supplies have been developed. Quality of gypsum (purity and mesh size) by a substantial number of the crusher moreover deteriorated to the point of its use being irrelevant to address sodicity (ACE/HALCROW, 2001).

the intrusion of water from saline groundwater zones into the over pumped fresh groundwater zones (Ahmad & Kutcher, 1992). The second reason is associated with the heavy reliance on groundwater vis-à-vis surface water, particularly towards those tail-ends of the distributaries and watercourses, where surface water supplies are scarce and erratic. (Research by IIMI Pakistan indicates that unreliable tail supplies are related more to type of outlet than the distance from the distributary head). Because groundwater is generally far more saline and sodic than canal water, the increased reliance on groundwater in certain areas may bring more salts to the soils and results in a deterioration of soil and groundwater quality. vander Velde and Kijne (1992) speculated on the existence of this scenario for the tail ends of two distributaries in Punjab. The extent of groundwater-induced secondary salinization, however, is questionable and still needs to be established. In a study on the SCARP-1 project area, Beg and Lone (1992) looked at changing groundwater quality parameters in 1900 deep tubewells over a time span of 25 years. They established that overall groundwater quality deteriorated, particularly in residual sodium content levels. A large number of wells, where groundwater quality improved could be found side by side by an even larger number of wells where quality deteriorated. In another study, undertaken by IWASRI (1995), soil quality was monitored in SCARP areas. The IWASRI study, however, established that only 7% of the sample plots turned saline and/or sodic due to the long-term use of tubewell irrigation. These plots were mainly irrigated from tubewells with marginal water qualities. The study also found a large number of plots (41%) where soil salinity and/or sodicity had disappeared. In summary, the evidence on the extent of the changes in soil and groundwater quality due to secondary salinization is at the moment still inconclusive and contradictory. An alternative view is that groundwater-induced secondary salinization is more related to pumping from the deep public tubewells and that pumping from very shallow low capacity wells does not have the same marked effect on deteriorating soil quality (Rehman et al., 1997). A similar observation has been made for a fresh groundwater area in Sindh (ACE et al., 1997).

The spectacular increase in private tubewells in Punjab took off in the sixties with the installation of the so-called ‘black engines’. These were low speed prime movers that operated on crude oil. In the seventies, however, the rural electricity grid expanded and electricity became the preferred source of energy for the tubewells. Gradually, however, electricity tariffs—though still subsidised—went up.[5] Between 1989 and 1993 flat rates increased for instance with 126%. Electricity lost its popularity as the main source of energy. The big boom in private tubewell development in the eighties was generated by the availability of locally manufactured high-speed diesel engines (‘peters’).[6] These diesel engines typically had a capacity of 12–15 hp and operated centrifugal pumps, lifting between 20–30 l/s. Investment costs were relatively low (usually below US$ 1200), which opened up the sector to small farmers. Moreover, different from electric pumpsets there were no fixed energy charges. This was particularly useful in the conjunctive water

[5] Particularly where the tubewells are used in conjunction with surface water supplies, the hours of utilization as a percentage (the so-called operation factor) of the tubewells are low. This makes flat rate connections unattractive. However, even the metered connections have a fixed component, independent of the actual consumption, which makes electricity relatively expensive. Calculations made in 1993 established that electricity started to become competitive with diesel at operation factors of 24% and higher. As a result nowadays electrified tubewells are only common outside the canal command area in Punjab and Sindh. For the same reason electricity is popular in Balochistan.

[6] Second in importance to the diesel engines are tractors driving the centrifugal pump, the so-called ‘power take off points’ (vander Velde & Johnson, 1992).

use environment, where the hours of utilisation of the pumpsets were relatively low. In the irrigated areas of D.G. Khan and Layyah districts—in the cotton belt in the eastern part of Punjab—the number of tubewells doubled between 1981 and 1987 and then again doubled between 1988 and 1991. By 1993 tubewell density in D.G. Khan and Layyah amounted to 11.0 and 6.8 tubewells per 100 ha, up from 1.8 and 1.3 in 1981. Operation factors (the proportion of hours of utilisation) were 5.3% and 3.9%, respectively (van Steenbergen, 1993). In the rice–wheat belt in southwestern Punjab the growth in tubewell numbers was exponential too. vander Velde and Johnson (1992) collected data for the Lagar distributary of the Lower Chenab channel in Sheikhupura District and also established that the number of tubewells increased four-fold between 1980 and 1989. In 1989 tubewell density in the area also served by public SCARP tubewells was 5.5 private tubewells per 100 ha. In another canal command in the same area, the Mananwala distributary, studied by Malik and Strosser (1993), tubewell growth and density was comparable. The average operation factor was higher than in either of the two cotton belt areas at 9.4%.

Within the separate canal command areas there is no clear-cut pattern in tubewell densities. Intuitively one would expect the dependence on groundwater to be higher at the tail of the systems, where surface supplies are generally low. In the canal commands of D.G. Khan indeed tubewell densities increased steadily towards the tail of the distributaries, whereas tubewell operation factors were more or less constant throughout the command area. This indicates that in the tail areas of D.G. Khan there are short peaks, when water is in high demand and all tubewells are used intensively. In Layyah, on the other hand, groundwater utilisation is relatively uniform throughout the canal command area. The explanation is that due to rotational surface water supply the distribution of surface water scarcity is relatively equitable in Layyah. As a result, the demand for groundwater in Layyah is uniform in different parts of the command area. In Manawa tubewell density was comparatively high in the head reach and in the tail reach of the Distributary. The intense use of groundwater in the head reach is explained by the prevalence of rice in the head reaches. In the tail reach groundwater is used as a substitute for the sometimes altogether missing surface supplies (Malik & Strosser, 1993).

A remarkable finding in all four case study areas is that tubewell densities in areas with marginal groundwater quality do not substantially differ from those in areas with fresh groundwater. Yet particularly in many tail reaches, little good quality surface water is available to mix the marginal quality groundwater and leach accumulated salts, reason for some to speculate on the risk of groundwater irrigation-induced soil salinity in the tail-reaches (Murray-Rust & vander Velde, 1993), the extent of which is yet to be established. Recent data from the Punjab Private Groundwater Project indicated that even in saline groundwater areas as much as 19% of the on farm water supplies comes from tubewells, It is only in areas with very saline groundwater, such as the Fordwah Sadiqia area in the extreme Southwest of the Province, that tubewell densities are lower. The tubewells that are in use are usually multi-strainer wells, skimming the thin layer of fresh water floating on the saline water.

An issue related to the distribution of tubewells over the command area is the theme of equity in access to groundwater. Several authors in the early eighties argued that the access to groundwater was monopolised by a limited few 'water lords', who could afford the installation of a tubewell.[7]

[7] Group-owned tubewells are unusual. Malik and Strosser (1993) found that 65% of the tubewells are individually

In reaction others pointed out that the inequity in ownership was mitigated to some extent as less fortunate farmers could hire the tubewells (Meinzen-Dick & Sullins, 1993; Strosser & Kuper, 1993). Several ways were debated to make the water markets more effective in reaching non-owners. The question of access to groundwater has to be placed in a dynamic perspective, however. Some indications suggest that with the increase in tubewell numbers tubewell operation factors have gone down. A number of surveys were undertaken in D.G. Khan and Layyah. In 1983 operation factors were 5.3% and 6.0% in D.G. Khan and Layyah, respectively. A second survey in 1986 recorded higher operation factors: respectively, 9.5% and 8.0%. However, in 1992 tubewell operation factors were significantly lower, at 5.3% for D.G. Khan and 3.9% for Layyah. In the six-year period between 1986 and 1992 the number of tubewells in the two areas meanwhile had increased with respectively, 174% and 131%. What appear to have happened is that the demand for groundwater was slowly saturated in this period. The number of tubewells nevertheless increased. Particularly smaller farmers purchased their own tubewell, sometimes pooling resources with others. This decreased their dependence on tubewell water purchases from other farmers. For those who could still not afford their own tubewell, the situation nevertheless improved, as there were more providers. Water prices did not go up in this period, despite an increase in the water lifting costs. This further suggests that groundwater transformed from a sellers market into a buyers market. Results from the SCARP-1 area near Sheikhupara indicate a similar development in this part of Punjab—tubewell utilisation factors in 1994 reduced to 55–65% of what they were only five years earlier. The fast development of tubewells was a democratisation of groundwater access rather than acceleration in pumpage.

The tremendous growth in private tubewells also caused the Government of Punjab to reconsider its role in groundwater management. With vertical drainage being provided by private shallow wells the Government decided to gradually phase out the public tubewells in the fresh groundwater areas. Over the years operation and maintenance costs of the deep tubewells had become prohibitive, taking an estimated 50% of all public expenditures on irrigation and drainage in Punjab (as well as in Sindh). Moreover, the condition of the SCARP deep tubewells had deteriorated with 67% of the tubewells running at less than 50% of their original capacity. The policy of phasing out public tubewells was first given shape in the SCARP-1 area, where farmers were provided with a subsidy to develop a private tubewell in order to compensate for the discharge of the SCARP tubewell.[8] Before 2002 all SCARP tubewells in fresh groundwater areas will be closed down. The government's direct involvement in groundwater management in fresh groundwater areas will almost come to an end. Public deep tubewells will only continue to be operated in areas with saline groundwater to avoid intrusion of saline groundwater in fresh groundwater zones. It has to be said though that in many saline groundwater areas farmers

(*footnote continued*)
owned. Most of the remaining 35% of the tubewells are owned by a limited group of family members. The main exceptions to this pattern are the community tubewells established under the Second SCARP Transition Project since 1995. Here groups of 15–25 usually small farmers are given a lumpsum contribution to part-finance the development of a group tubewell. By May 1996 1100 of these community tubewells were in operation in the former SCARP-1 area.

[8] The closure of the SCARP tubewells has created inequities in water supplies in the watercourses. After the SCARP tubewells were installed, the watercourses were adjusted to carry the combined discharge of the canal supply and the SCARP tubewell. With the closure of the public tubewell, the watercourse is in many cases overdimensioned and the remaining surface water supplies can no longer reach the tail ends of the watercourses.

themselves have made efforts to close down the tubewell, so as to prevent the saline effluent—which was often inadequately disposed off—from spoiling their land.

Recently the wisdom of the closure of the SCARP tubewells came under criticism. After the unusual high rainfall in 1996 and 1997 water tables in the transition areas rose, due to the increased recharge and the lower pumping. A comparison with areas, where the public deep tubewells were still in operation showed a similar rise in groundwater tables in those areas for similar reason (Gohar, 1998): more recharge and less discharge, as on request of farmers even the SCARP tubewells were operating at lower utilisation factors.

2.1.2. Sindh

In comparison to Punjab private tubewell development has not taken a big flight in Sindh. A number of reasons explain this difference. The first explanation is that the surface irrigation supplies in Sindh are relatively generous, thus reducing the need for additional groundwater supplies (Ahmad & Kutcher, 1993). This is particularly true for the area on the west bank of the Indus. A second explanation is that groundwater is very saline in large parts (probably close to 70%) of the Province, though Ahmad (1993) has argued that even so in many areas of particular Northern Sindh a substantial layer of fresh water floats on the more saline layers. More shallow tubewell development is in principle possible through the use of skimming wells. Handtubewells already exploit the thin upper layer for drinking water in several parts of Sindh, using the fresh recharge from canals and distributaries.

At present, however, private tubewell densities in Sindh are far below those in Punjab. In Moro and Sakrand District—where shallow groundwater is fresh—there are for instance 2.0 private tubewells per 100 ha, even though fresh groundwater is available. As in the early stage of private tubewell development in Punjab most wells are owned by large landlords. There is relatively little selling of water from these tubewells. In Moro and Sakrand only 2% of the tubewell owners reported selling water to non-tubewell owners. The very skewed land distribution is an important factor. ‘Large landlords’ in Sindh typically own very large tracts of land. Most of the tubewell water is used on their own holdings and they have little interest in exploiting the well commercially. Smith and Pathan (1996) have observed for the fresh groundwater area of Moro and Sakrand that private tubewells are concentrated at the tail reaches, which receive very limited surface supplies. Rather than being used conjunctively, groundwater is used as a substitute for failing surface water supplies. Recent measurements under the SCARP Transition Project show no indication of groundwater-induced secondary salinization in Moro and Sakrand, but instead suggest that in recent years soil salinity has improved, due to increased tubewell development and the leaching this made possible (SSTNRPP, 1997).

Research in another distributary in Sindh, i.e. the Dhoro Naro Minor (near Nawabshah) in the Rohri Canal Command similarly suggests low but increasing tubewell densities of 2.5 tubewell/100 ha. Unlike the Sakrand and Moro area groundwater in this areas ranged from good to marginal and unusable, as tubewells exploit the fresh water lens overlying the saline groundwater layers—yet in several cases end up pumping marginal quality water (Lashari & Memon, 2000). A shape of things to come is the groundwater exploitation in the Kunner-2 Minor (near Hyderabad), where tubewell density is 6.6/100 ha—related to relatively better groundwater qualities and the proximity to a major market.

Because of the limited development of private tubewells salinity and water logging however persist in most part of Sindh, even in some fresh groundwater areas. The problems are particularly severe in the areas with 'non-perennial' canals. These canals receive very copious supplies in the kharif season, causing the water table to rise significantly, but to fall again in the winter season, when the canals are not functioning. This annual cycle of rise and fall of water table has brought the salts to the upper soil strata (Mukarram, 1984). The problems in the perennial channels in Sindh are different from the non-perennial channels. In the perennial channels the water duties are generally lower. Here salinity is concentrated on areas with deficient surface water supplies, where there is not enough water for leaching accumulated salts. This often concerns the tail reaches of the channels.

A little known problem, associated with the water logging, that affects so much of Sindh Province, is its effect on rural sanitation. High water tables are a major impediment to the disposal of domestic waste water and an important reason for the often appalling sanitation in rural Sindh and waterlogged parts of Punjab (Kamal, Simi, & Frank van Steenbergen, 1999).

Substantial investments are nowadays made to address the drainage problems in the Province. As in Punjab, the Government of Sindh has also started the closure of the SCARP deep tubewells in fresh groundwater areas. After a successful pilot in two units of the SCARP North Rohri, the closure of the fresh groundwater is now extended to the remainder of SCARP North Rohri as well as SCARP South Rohri.

Undoubtedly, the most important groundwater project of the recent years has been the Left Bank Outfall Drain (LBOD), which provides surface and subsurface drainage to an area of 510,000 ha in Nawabshah, Sanghar and Mirpur Khas Districts. Under the project the 'spinal' surface drain was constructed, which is supplied by a network of tributary surface drains. Subsurface drainage systems, mainly deep tubewells, pump up saline groundwater that is disposed in the surface drainage system and ultimately finds its way to the Arabian Sea. Where the LBOD has become operational declining water tables have been observed and spectacular increases in cropped area and crop yields. The LBOD however is at present still beset with a number of serious operational problems, in particular the generation of the required operation and maintenance funds, particularly in view of the costs and discipline required in running the 1600 deep saline groundwater tubewells.[9] At the moment the operation and maintenance of the subsurface drainage system is contracted out to special O&M contractors with funding by and large from multilateral loans. Clearly, this is a non-sustainable situation. Solutions are not uncomplicated, unfortunately. If the costs for the operation and maintenance would have to be paid by user charges, then water taxes or drainage cess would need to increase substantially, which in view of the low trust in the present revenue collection system is politically unattractive. An overhaul of the revenue system is required, consisting probably of flat rate taxation and charges to non-agricultural drainage service users, coupled with user-agency confidence building measures; and/or a drastic transfer of responsibilities to land owners. While the latter is not impossible, the technology issued in the current subsurface drainage installation militates against this option;

[9] The cost estimated to run the drainage wells was revised downward five years after the wells became operational, as it was found that the vertical drainage component in LBOD was seriously overdesigned. Water tables were kept in check with the drainage pumps running at less than 25% of their design utilization rate. This is partly related to the long row of dry years, but apart from that an overestimate of drainage requirements seems to have played a role as well.

relatively specialised pumping equipment and drainage service boundaries that are not always easy to delineate. The best option seems to be the transfer to the farmer organisations that are currently being formed at the distributary canal level. There is, however, still a genuine risk that the subsurface drainage works of LBOD meets the ignominious fate—but at a grand scale—of other recently completed subsurface drainage projects in Pakistan, such as Drainage IV (Punjab) and Command Area Development of Chasma Right Bank Canal. In the latter two tile drainage units, the number of operating units was down to below 50% only five years after completion.

2.2. Groundwater issues in the mountain provinces

2.2.1. Balochistan

Groundwater development in Balochistan has been very different from groundwater development in the Indus plains, but it has not been less dramatic in environmental and social impact. In many parts of this scarcely populated, semi-desert western Province groundwater is the only source of irrigation. Indus canal supplies are available in Nasirabad and Dera Murad Jamali districts only. In the remaining part of the Province spate flows and small surface stream irrigate a small portion of the land, but large tracts of land remain uncultivated.

For a long time the aquifers were only exploited by animal-driven Persian wheels, lifting water from shallow wells and by karezes. These karezes consist of a motherwell and a string of wells connected through a tunnel and usually convey and collect groundwater over a length of 500–3000 m. The slope of the karezes is less than the land gradient and they surface at a close distance from the command areas. The costs of establishing karezes are high[10] and in most cases prohibitive for individuals. The systems are typically constructed on a collective basis. A typical kareze in Balochistan will yield anything up to 200 l/s and will serve a maximum of 200 shareholding families. Not only establishment costs are high, kareze maintenance is equally expensive. The co-operative strength of the kareze shareholders is thus constantly tested.

In the second half of the sixties dugwells became a popular alternative to karezes. This development was stimulated by a range of government programmes that provided subsidised dugwells to farmers. Groundwater supplies were considered to be limitless. Moreover, the thinking in the sixties and seventies was that water was wasted from karezes, since they were flowing throughout the year, whereas commercial peak water requirements occurred during a three month interval in the summer, when high value fruit and vegetable crops needed to be irrigated.[11] In addition to the installation of subsidised dugwells, well development was further promoted through the provision of cheap electricity. For ease of collection of dues, a system of flat rates was used for most electrified tubewells, which further encouraged overpumping, because

[10] Nowadays kareze building is, barring of few exceptions very much, a thing of the past in most parts of Balochistan Province. A kareze that was constructed in Chagai District in 1968–1991, costed Rs. 2,700,000 (US$120,000).

[11] In the remaining part of the year, flows, if at all, were utilised on low value wheat and melons, crops that were considered not to justify the economic opportunity cost of water. A report from 1977 (WAPDA, 1977) for instance seriously looked into the possibility of replacing a series of functioning karezes in Mastung Valley with a large number of tubewells on the grounds that this would allow all water to be used for summer crops. Another report from the same period (Kemper et al., 1979) suggests to investigate the possibilities of stopping the winter outflow of kareze and store the water underground.

electricity charges bear no relation to consumption.[12] Efforts to abandon the flat rate system were aborted in 1999 at the intervention of the Chief Minister. The most serious distortion of market mechanisms however was the low recovery of electricity charges, which did not exceed 50%. Early 1999 the total arrears for agricultural tubewells in Balochistan had reached a staggering Rs. 4.15 Billion (or US$90 Million at the time).

In the same period, improvements in the transport network facilitated an upsurge in the cultivation of high-value fruits and vegetables. The expansion of groundwater irrigated agriculture was unstoppable. According to official figures, 21.8% of the perennially irrigated land in the Province was supplied by groundwater in 1989 (Agricultural Statistics, 1989–1990). In 1993 there were officially 9639 electrified agricultural wells in Balochistan. To this should be added the substantial number of electric tubewells without a legal connection as well as the diesel-driven wells in the valleys that were not yet connected to the electricity grid. Diesel pumpsets also became popular in the commands of the small and scattered surface irrigation systems, where they helped to safeguard adequate supplies in the summer irrigation season. In many valleys of Balochistan groundwater exploitation soon exceeded sustainable yields of the confined aquifers. Groundwater levels declined at a rate of 0.25–1.10 m a year (WAPDA, 1992).

There were winners and losers from the groundwater rush. Soon after the large-scale introduction of dugwells in the sixties, the flow of many nearby karezes was affected. This process had a hydrological as well as a social component. At the early proliferation of dugwells many parts of Balochistan were going through a dry climatic cycle, causing lowered groundwater tables, further accelerated by the increased withdrawal from the new dugwells. Karezes became less viable and often the first to release their share in the communal systems were the larger farmers, who had the resources to develop a private well. The heavy burden for maintaining the drying kareze then fell increasingly upon the smaller farmers. The final outcome often was the collapse of the traditional system (Syukurallah et al., 1990) and a polarisation in the access to groundwater. On the opposite side of the tally sheet were the landowners who traditionally had no share or a small share in the kareze supplies and who now availed of the new technical opportunities and invested in the development of dugwells. Water from these dugwells was also sold to farmers without a well of their own. Another common arrangement was water tenancy. Under this tenancy arrangement a dugwell owner provided all water to the land of a fellow farmer, for which he was usually compensated one-fourth or one-fifth of the crop.

In many areas, however, the decline of groundwater tables continued and even dugwells dried up. The only recourse left was the development of deep tubewells. This could only be done at high investment cost. Cost of a deep tubewell were close to US$25,000, a price which only some farmers could afford. In areas where the decline of groundwater tables was very large, therefore, access became ultimately concentrated with a limited number of farmers.

Neither under customary law nor under government jurisdiction rules existed to control the decline in groundwater tables. Neither did any government organisation have a mandate to handle the crisis. In a very few valleys in Balochistan, i.e. Panjgur, Kech and Mastung, kareze shareholders took the initiative to frame efforts to control groundwater exploitation and prevent overdraft (van Steenbergen, 1995, 1997). Generally, however, the only response to the crisis was to

[12] Vested interests continue the system of flat rates. By suggesting that all electricity, booked under the flat rates, is sold, linemen are able to sell electricity 'under the counter'.

reactivate the traditional harim rule. This harim has its origins in Islamic water law. It specifies a prohibited zone in the vicinity of kareze and wells, in which no other well or kareze can be made. In Balochistan minimum distances of 250 m in silty soils, and 500 m in gravely conditions applied. Depending on the locality, the harim was interpreted as the customary distance from the first wells of the kareze (called motherwell), or applied all along its length. The harim, however, originated in the era of karezes and Persian wheels and was in no way effective in regulating mechanised groundwater exploitation.

In the late seventies the Provincial Government however took a number of initiatives to address the destruction of Balochistan's groundwater reserves. The response was however mixed. While the public subsidies to dugwell and tubewell development and operation continued, funds were now also made available for artificial groundwater recharge. Throughout the Province so-called delay action dams were constructed, that collected water after the sporadic rain storms, in order for it to infiltrate and contribute to the groundwater stock. The cost effectiveness and hydrological effectiveness of these dams has been questioned: a recent study established, though, that several of the 110 delays action dams constructed in the Province up to 1997 had a noticeable impact on groundwater availability (Nippon Giken Inc., 1997). The average area served by the delay action dams was small though (85 ha).

The Balochistan Government was also the first—and so far only—provincial government to issue legislation to control groundwater mining. In 1978 the Groundwater Rights Administration Ordinance was announced.[13] The objective of the new Groundwater Right Administration Ordinance was 'to regulate the use of groundwater and to administer the rights of the various persons therein'.

Under the legislation the groundwater users were considered as individuals with a direct relation to the law implementing agencies. The 'rights of the various persons' were not quantifiable entitlements as such, but consisted of permissions to develop and operate groundwater abstracting infrastructure. The Ordinance established the procedures and framework within the district civil administration to issue permits for the development of new karezes, dugwells and tubewells. The relevant authorities were the District Water Committees, composed of government officials as well as two appointed local 'notables'. Before giving out a permit, the committees would first hear objections from surrounding landowners. Appeal could next be made to the divisional commissioner (representing the next highest administrative level) and the Provincial Water Board. The permits were indefinite, as a well owner could always replace a dried well with a new one.

The above-mentioned Provincial Water Board resembled the District Water Committees and consisted of appointed notables and Province-level bureaucrats. The Provincial Water Board was also charged with the task of formulating policies on groundwater withdrawal. The Ordinance specifically mentions the estimation of safe yields and existing levels of withdrawal, in particular the administration of all water points. Based on this information minimum distances could be specified for each region, that could serve as guidelines for the issuing of new water permits, thus introducing a system of modified overlying water rights to manage the collective resource. On paper, the legislation had the making for an enabling framework for local resource management

[13] Previously, groundwater disputes, that were presented to the government had been treated as land cases and had been dealt with either by the Board of Revenue or were given by the district administration to a tribal council to decide.

by involving the local administration as well as tribal elders and allowing flexibility in determining usage rules for the common groundwater property. In principle the strategy of promoting common property management regimes made sense in the valleys of tribal Balochistan, but unfortunately the announcement of the legislation was not complemented by an effort in establishing such local rules. Because it was not realistic to expect community initiatives to frame local groundwater management rules to evolve spontaneously, the legislation failed.

The only local rule issued under the Ordinance was a total ban on new wells in Quetta Valley, announced in December 1990, to safeguard the drinking water supply of more than 600,000 people, living in the provincial capital of Quetta. No other area-specific guidelines issued. Instead the ineffective harim rule was uniformly applied, which was not appropriate if the objective was to avoid overdraft. The use of the harim distances by the District Water Committees derived from these distances being quoted in the Ordinance as a mere example of a local rule. For lack of any other guideline, the District Water Committees applied these mandatory distances and in this manner they acquired a semi-formal status. When farmers in one area disputed the refusal of a water permit on the grounds that in their area the local minimum distance was 200 feet, instead of 750 feet, the chief minister reacted and by decree he endorsed the harim all over Balochistan Province in October 1990. In practice, however, even these harim distances were applied in a few cases only. In most valleys a 'free for all' applied and the Ordinance and its provisions were ignored.

2.2.2. North West Frontier Province

Due to the relative abundance of surface water resources, the higher rainfall figures and the fragmented nature of the landscape, the reliance on groundwater in NWFP has generally been lower than in Balochistan. Groundwater currently accounts for an estimated 11% of agricultural water supplies only (Kruseman & Naqavi, 1988). Nevertheless in recent years private initiative and development projects have led to an intensive exploitation of groundwater resources, particularly in the intermontane basins in the northern and central part of NWFP, such as Swat, Buner, Dir, Peshawar and Mardan. Data from the Farm Machinery Census estimate that there are some 12,000 tubewells in operation in the Province. Most of these (93%) are privately owned. Of the estimated public deep tubewells, approximately half are SCARP drainage-cum-irrigation wells, whereas the remainder primarily provide irrigation services. The majority of the tubewells run on electricity, as in Balochistan. With the water table beyond the depth that can be accessed by centrifugal pumps in large parts of the province and surface water supplies being more abundant, the 'peter engine' revolution has not taken place in NWFP and the reliance has been more on the relatively expensive turbine and submersible pumps.

Groundwater quality in NWFP is good to excellent. Valleys that were considered unproductive in the past have been taken into production. At the same time the risk of overexploitation has risen in several locations. Until not long ago, the only area in NWFP where overexploitation of the aquifer was recorded was Parachinar in the Federally Administered Tribal Area, close to Peshawar. The Shamozai and Kotlai valleys in Swat and Jandool and Adinzai valleys in Dir, however, are recent examples of looming overwithdrawal. Numerous tubewells have been constructed here, equipped with turbine pumps and often powered by tractors or former diesel truck engines. Many of the tubewells are funded by remittances from family members, working in the Middle East. In these areas landholdings are often small and fragmented. Selling of water from the wells is quite common. Often it is the only way to economically exploit the well. Water prices are still quite high, symptomatic of the as yet unfulfilled demand for groundwater. As in Balochistan lease and tenancy arrangements are common too in exchange for ensured irrigation supplies, particularly in areas where groundwater is the only source of water. In some intermontane valleys, in particular the main Swat valley, tubewells are installed in the commands of the traditional irrigation systems both to be used conjunctively and as a security to the sometimes faltering supplies in the traditional systems.

In other parts of the Province groundwater development is less intense. In the southern districts of Kohat, Karak, Bannu and D.I. Khan groundwater quality is mixed, with patches of good, moderate and poor quality groundwater with salinity as well as sodicity hazards.

So far the Provincial Government has taken a passive attitude towards groundwater management and in this regard NWFP resembles the other Provinces. No monitoring of groundwater levels or groundwater quality is done outside the few SCARP areas. From 1979 to 1986 a study was undertaken into the hydrogeology of NWFP. As part of the study a network of piezometers was set up, that remained unutilised after the completion of the study. Nominally the Provincial Planning, Environment and Development Department and the Provincial Irrigation Department would be responsible for groundwater monitoring, but neither Department has taken initiative in this field. Similarly essential legislation and regulation is lacking. In the one area with a long history of groundwater mining, Parachinar, legislation would not suffice either, as tribal law and authority still prevails in this area.

2.3. *Urban groundwater issues*

Most of Pakistan's major cities rely on private pumping for domestic water supply. The piped supply from the Water and Sanitation Agencies is generally far too limited and unreliable. Shallow private wells are sunk in large numbers to augment supplies—even where restrictions are in force, such as in the city of Quetta (Balochistan). The large scale exploitation of the aquifer underneath the cities has however led to falling water tables and to contamination of water supplies by leaking sewerage systems and septic tanks, as Rahman (1996) has documented for Karachi. In Quetta the overexploitation of the confined aquifer by agricultural users around the city has already led to a number of doomsday projections, predicting that in a foreseeable future even the supply from deep groundwater to the capital of Balochistan province will dry up. Another problem is the disturbance of the riverbeds near big cities, which are often used for the excavation of building material. In the Malir River near Karachi the disturbance of the riverbed has already resulted in a limited recharge of water flows and reduced water levels in wells in the adjacent area. Similarly the catchment of Lei Basin, feeding the twin cities of Islamabad and Rawalpindi is disturbed by quarrying and deforestation. In addition, the rapid expansion of the built-up area, the increased and unregulated private exploitation of groundwater for domestic consumption and the disposal of untreated or semi-treated sewerage in Islamabad and Rawalpindi has led to a decline in the water table of 1.4 m annually and an estimated 90% of the drinking water wells being contaminated with coliform bacteria (Malik, 1998). For the Lei Basin measures to improve the recharge of groundwater through designated recharge areas and controlling the contamination by raw sewerage are being proposed. A similar case for artificial groundwater recharge has been made for Lahore, where water tables have fallen at a rate of 0.55–

0.65 m annually over the last 30 years (Mashhadi & Anwar, 2000). As in other major cities the decline in Lahore is attributed to a lowered recharge capacity due to development of built-up area and loss of flow in the Ravi River as well as the increased abstraction, tripling over the last 20 years, by public and private tubewells (respectively 75% and 25% of the discharge).

So far these urban groundwater problems go unaddressed. The same applies to industrial groundwater contamination. There are indications that the uncontrolled disposal of industrial waste and waste water and the sludge of petrol pumps has contaminated groundwater supplies, but the problem is hardly monitored and even less controlled.[14]

3. Implications

Despite the enormous benefits that groundwater development has provided to the country's agricultural economy, it is difficult to be optimistic about groundwater management in Pakistan. As the study on the Indus Basin by Masood and Kutcher (1992:92) concludes: in all probability, the quality of groundwater, on which Pakistan depends for about one-third of its irrigation supplies, is deteriorating. Within a few years, most of it may be unusable, or out of reach of existing pumps. Given that tubewell farmers have been the singular bright spot in the sector for the last two decades, this prospect is most discomforting'. Though these observations may appear overly alarmist, there are signs of deteriorating groundwater quality and reduced water levels in several parts of the Indus plains. At the same time water logging persists in the areas with saline groundwater in the large-scale irrigated areas. In the mountain provinces, in Balochistan and in a number of areas of NWFP, the intensity of groundwater is already far beyond sustainable limits. The decline in groundwater tables, it appears, can only be stopped through a drastic reduction in tubewell numbers. The trend is however opposite and it seems that only the (dry) shore will stop the ship. Finally urban drinking water supply by private wells in several large cities is in jeopardy as well.

From a social perspective the development of groundwater exploitation has brought major changes too. The falling groundwater tables in Balochistan led to the decline of karezes throughout the Province and denied many farmers access to the vital resource. On the other hand, earlier 'have nots' gained access to groundwater by developing a dugwell. In areas, where groundwater has fallen beyond the level that can be exploited by a dugwell, deep tubewells appeared on the scene. Because the investment costs of these tubewells are high, access to groundwater was monopolised by those who could afford the tubewell.

To some extent selling of water from private tubewells mitigates the inequity. Relative intense water sales are reported from all Provinces. It is obvious however that non-owners are last in the cue, making groundwater supplies to them less reliable and in times of scarcity the subject of a favour. These problems are compounded by rights of way issues and conveyance losses. This explains why in many areas shallow tubewell installation—which is relatively expensive—continued, even in the presence of active groundwater markets. Ultimately, with the number of groundwater providers increasing, the market was saturated. Water lease prices decreased and

[14] An example reports on fluoride contamination in Kalalaanwala near Lahore, which has been linked to industrial waste disposal, although other reports suggest that fluorosis occurred in the area before its industrialization.

non-tubewell owners had a larger choice of tubewells from which they could take water. While this increase in installed capacity improved equity in access, the down side was that it also further contributed to overwithdrawal.

4. Recommendations

It has been argued that groundwater management should be part of a larger effort at integrated water resource management in Pakistan (Bhatti & Kijne, 1992). Ahmad and Kutcher (1992) argue that a reallocation of surface water supplies between on the one hand fresh groundwater areas with relatively low surface irrigation duties; and on the other hand fresh groundwater areas with high irrigation duties and saline groundwater areas would go a long way in reducing groundwater mining in the former areas and solving water logging in the latter areas. vander Velde and Kijne (1992) looked at various possibilities of redistributing surface water supplies along one distributary channel so as to improve groundwater quality in the middle and tail sections and concluded that insufficient surface water was available for the canal to achieve such an objective. Reallocation between and within canal distributaries are at present moreover politically unacceptable. Yet given the compelling need for integrating surface and groundwater management, one would hope that this will change and there will be more flexibility in redirecting surface supplies. The recent drought (2000) for instance brought with it a number of interesting observations in some of the areas with high irrigation duties in Sindh. The emergency rotations of surface water supplies introduced in response to the sudden shortage significantly reduced water logging. The integrated management of surface irrigation, drainage and groundwater at regional scale in Pakistan is long overdue.

Ahmad and Kutcher (1992) argue further that channel and water course lining should be undertaken in saline groundwater areas to reduce seepage from the surface irrigation systems. At the same time more investment in subsurface drainage is required. The costs of such investments however is substantial, whereas they probably avoid that the problem further worsens, yet would not remove them.

Yet even more is needed. For fresh groundwater areas, both in the Indus Basin and the Mountain Provinces, effective regulation is required. There is however a lot of ground to cover in this field. To start with the data available on groundwater is patchy and often outdated or irretrievable. Systematic monitoring is limited to the SCARP areas, where it is done by the Federal Water and Power Development Authority. Outside the SCARP areas very little monitoring is undertaken. There is an urgent need to improve monitoring of groundwater levels and groundwater quality. With respect to groundwater quality, there is also need to start investigating the contamination of groundwater by pesticides, particularly in the cotton growing areas, that account for the lion's share in pesticide consumption in Pakistan (World Bank, 1996).

This raises a second issue, i.e. the responsibility for groundwater management. For a long time there was confusion as to which organisation had the mandate in this regard. As explained for a long time there was even confusion on basic issues, such as whether the province or the federal government is responsible for groundwater management. The conflicting stands of the WAPDA

Act and the Soil Conservation Act were noted, the first confirming federal responsibility, the second one provincial responsibility. Even more confusion was added by an ordinance from 1979 (the Local Government Ordinance), that suggests that all groundwater falling within the local area of an urban council comes under the control of this local government body. In principle, the new and overriding Acts that have come into force in 1997 for the Provincial Irrigation and Drainage Authorities in all four provinces makes an end to the confusion and puts the responsibility for groundwater management, alongside responsibilities for irrigation and drainage operations, as well as cost recovery, clearly with the newly established Provincial Irrigation and Drainage Authorities. These new authorities are to ensure that groundwater monitoring is undertaken and have a mandate to initiate policies to address groundwater management problems.

Also, the Environmental Protection Agency Act, that was promulgated in 1996, offers the first beginning of a legal basis for groundwater quality management. This act established Environmental Protection Councils at federal and provincial level, charged among others with setting standards on groundwater quality. National environmental quality standards were established subsequently, dealing with industrial effluents rather than rural groundwater quality.

So far, these Acts have been issued, but little has happened in operational terms. The Provincial Irrigation and Drainage Authorities were formally notified in the second half of 1997. Realistically, one would expect them to be occupied with establishing themselves as revenue-generating and self-accounting bodies for some time to come, before they would be able to address the challenges in groundwater management. They moreover have had to overcome a lot of resistance and scepsis so far and with the exception of Sindh and NWFP the new Authorities risk to remain dead in the tracks. Similarly, there has not been much enforcement of environmental effluent standards, as industries groups argued that they lacked the resources to install water treatment facilities. Instead a system of self-monitoring by the industries was agreed upon, for whatever it is worth.

A third issue in groundwater management in Pakistan is the role of local organisations. On paper the Balochistan Groundwater Rights Ordinance created the scope for the development of local rules and the involvement of local groundwater users. Unfortunately the Ordinance was badly implemented and even demoralised groundwater users in one valley, who had developed their own common pool resource management regime. An important lesson from Balochistan is that Ordinances, Acts and Laws are meaningless without enforcement and without involvement of groundwater users. The question is, however, who will take the effort of organising the users of the new groundwater resource. In Balochistan and parts of NWFP this appears however to be the only way forward. In other areas, such a Punjab and Sindh the sheer number of groundwater users is too large to even think of a local resource management regime. Yet regulation is not less important, but it will have to depend more on public organisations, licensing and co-operation with the agree-service sector. For Punjab the formulation of such a regulatory framework is now considered. It will have to be supported however by a public awareness campaign, as awareness of the changed groundwater issues with farmers and political decision makers is very limited and much of the thinking is dominated by the period when water logging was still the main issue. Without such awareness enforcement of any regulation will be difficult.

Finally, the price of groundwater needs to be mentioned. In the discussion on water management it is often proposed that water prices should reflect its scarcity, so as to encourage more prudent use of it.[15] The question in Pakistan is how to implement such a pricing system. In current farm budgets the cost of extracting water is a very minor item and it is hard to see how in the foreseeable future the price for water would increase to a level that would encourage savings on this cost item. Moreover, the majority of tubewells run on diesel. It is hard to increase the price of diesel without hurting other non-agricultural diesel consumers. Besides, increases in diesel pumpset fuel efficiency appear possible (Reinemann & Saqib, 1991; Sutherland, 1999), potentially further reducing the cost of pumping. On the other hand, although the flat rates are being abolished—with the exception of Balochistan—, subsidies on electric supply to tubewells still continue. This is an anomaly, which should be terminated (if only for public budget reasons). The tragedy of Pakistan is that groundwater is a very precious resource, yet at the same time a resource that can be exploited at very low cost.

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[15] The only near attempt has been of the Capital Development Authority of Islamabad that has contemplated a charge on groundwater use.

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