LOWER TARIM AND KONGQUE RIVERS FLOODPLAIN GROUNDWATER PROCESSES.

Notes by Ary van der Lely ([1])

Introduction

The Lower Tarim and Kongque River valleys are receiving less water than prior to the 1950's. The decline has continued into more recent times, and both rivers have retreated by hundreds of kilometres. Very limited flow now occurs downstream of Qiala on the Tarim, and the irrigation areas east of Yuli on the Konque River. Figure 1 is a sketch map of the area, showing principal directions of flow.

Since river flows and floods have diminished, the recharge to groundwater has also diminished. Some flow lines are no longer active, or active only infrequently, for instance the lower Kongque River, the Tarim River below Daxihaizi, the flow from Luohuluke swamp to Aksupu swamp, and the connection from the Kongque to the Tarim.

Compared to natural conditions the groundwater recharge from the river floodplain was initially augmented by recharge from irrigation, canals, and reservoirs, such as the Qiala reservoir. This has caused high groundwater levels and salting in some locations. The irrigation related recharge continues, but the river related recharge has diminished. The long term effects of changed groundwater conditions require consideration. This report aims at providing comment in this regard.

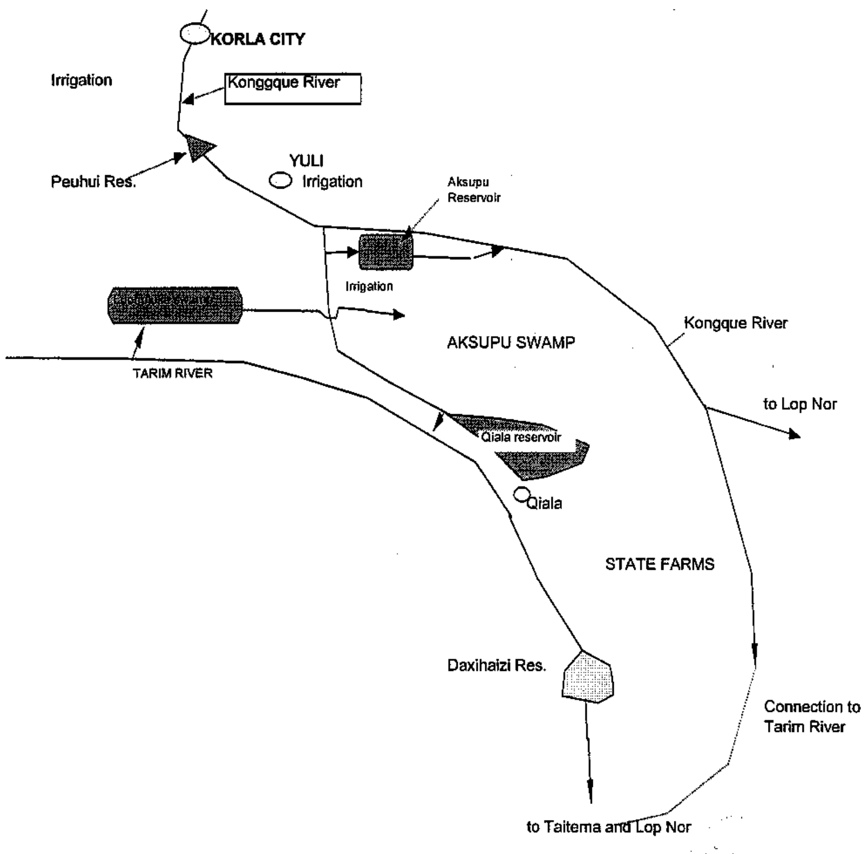

Figure 1: Sketch map of Lower Tarim and Lower Kongque River systems.

[1] On behalf of OPCV, Australia.

Hydrogeology

The physical conditions of the soils and stratigraphy have not been checked from hydrogeological information, this being scarce and of low accessibility. Judging from the evidence of seepage from reservoirs, and the occurrence of plants at long distances from recharge locations it is believed that the soils are generally permeable, and that the transmissive capacity of aquifers below the surface is high. Sands and gravel layers at several positions in the profile would be common. Near Korla city an alluvial fan occurs to as far as Yuli, and this has a significant slope, surface sediments are sandy to gravelly, and this is also likely for the deeper layers.

Despite this there is evidence that more silt has been deposited towards the lower reaches of these river systems. This affects the Lower Green Corridor areas downstream of Qiala and Daxihaizi reservoirs, an area of some 0.5 x 10^6ha previously consisting of areas with Poplar trees and grassed areas. At present the groundwater levels in that area have declined seriously due to a lack of stream flow and flooding. The levels, which previously were fairly high throughout the area, are now ranging from about 2 metres near Qiala Reservoir to about 11 metres below the surface between Yensu and Lake Taitema.

The silt deposition, where it occurs, would have an effect on rates of infiltration, patterns of re-wetting and volumes needed each year should flows be made available to flood the areas and restore parts of the Poplar and grass areas, totalling some 0.5 x 10^6ha between Qiala to Lake Taitema.

Main Groundwater Processes

The main processes are recharge, groundwater flow and discharge. During this process salts are being transferred to discharge locations.

Recharge

Under natural conditions the recharge was from the Kongque and Tarim Rivers. The main recharge would have occurred when the river was in flood from the associated floodplains. The occurrence of some silt in the river beds themselves reduces the rate of recharge per unit area from that source (see further below). Flooding locations tend to be associated with locations where Poplar diversifolia occurs or occurred. The Lower green corridor was dependent on these flood events. It is not certain what vegetation occurred previously in Aksupu swamp. This large swamp is several hundred thousand hectares, and located between the two river systems east of the Kuta canal. In the past it received flood water from both the Kongque and Tarim rivers, the latter via the Luohulike swamp area. There is an underpass under the Kuta canal, but this is limited in size. The construction of a reservoir of about 1000-2000ha in the north west of the Aksupu swamp area prevents flooding of this swamp from the Kongque River at that location. Further downstream the Kongque in the past transferred flows to the Tarim River. Both rivers ended up in Lake Lop Nor. Despite the perceived reduction of flooding, a satellite imagery for 1995 shows that several parts of Aksupu swamp were flooded in that year. The vegetation now occurring is mostly dry. At one north westerly location Camel thorn was found. This plant is a surviver in very dry conditions.

In the past therefore large areas adjacent to the rivers and the Luohuluke and Aksupu swamp areas received recharge on a regular basis. The recharge would raise groundwater in these areas and groundwater flow would occur to areas not flooded. The groundwater underneath the floodplains and swamp areas would have been relatively fresh. Underneath the not flooded areas groundwater would have been higher in salinity, dependent on through flow and extraction by plants (phreatophytes and others).

Under current conditions the recharge appears to occur mainly from irrigated areas and associated canals near Korla, near Yuli, east of the Kuta canal, and south of Qiala. There is also significant recharge from reservoirs, e.g. Peuhui reservoir on the Kongque, the Aksupu reservoir, the Quiala reservoir, and the Daxihaizi reservoir on the Tarim River. The rivers and associated floodplains may contribute a lesser a diminishing proportion of total recharge.

When the Tarim River levels do rise, large volumes of water are being lost to lateral locations. The Luohuluke swamp used to benefit from that and for instance to the south-west of Qiala reservoir the Tarim floods land between sand dunes of the Taklamakan desert, without there being stands of vegetation benefiting from the flooding..

The construction of some reservoirs does not appear to have been preceeded by soils investigations and planning to reduce the recharge phenomenon. The banks of the Qiala reservoir are located on the levee soils of an old river course of the Tarim. Such a position is conducive to high seepage rates. During a field visit local management told the group that the Qiala reservoir looses half its volume each year. The Peuhui reservoir performance is about the same, and the reservoir on the Aksupu swamp areas also leaks significantly. At Daxihaizi some water escapes via creek lines into the desert, constituting another source of recharge.

It is quite possible that the total recharge under current regimes is not much less that the total recharge which occurred under natural regimes, however, that is not the issue. The recharge is in different locations and the Lower Green Corridor is definitely is deprived of recharge, which now occurs elsewhere.

Groundwater Flow

Groundwater flow is in the direction of lesser elevation of groundwater height. The general direction is from west to east, because that is the gradient of the river systems themselves. Superimposed on that however there is a complex pattern of ground water flow in various directions, dependent on recharge locations. Along the Kongque this means flow from the westerly irrigation areas to the west, south and east. The irrigation areas east of Yuli are likely to produce groundwater flow to the south and east. It is probable that there is seepage into the Kongque River near Yuli, because it tends to be deeply incised ([2]). There would also be groundwater flow from the three main reservoirs to adjacent lands, for instance between the Qiala reservoir and the Tarim river there are many wet areas and evidence of salting.

Discharge is evident in low areas in which ponds exist, fed from groundwater. These appear to be 2-3 metres below ground surface along the Qiala road west of the Kuta canal where previously the Tarim River had flood runners via the Luohuluke swamp. Since these locations are at significant distances from irrigation, and the Tarim has not flooded for many years, it is clear groundwater may travel over long distances. Near the Qiala reservoir the surface expressions of groundwater is nearly at ground surface.

Discharge

Many areas show evidence of isolated young Phragmites plants growing from a groundwater supply. These plants tap groundwater from a depth up to four metres. In other areas there are still Poplar trees, some of which are growing on top of 5 metres high sand hills. The interpretation of this phenomenon is that the trees have been there for a long time, sand accumulated adjacent to the trees, which continued to grow from ground water. Young sprouts over decades replaced the older tree, and the stands were maintained. Poplar trees may withdraw groundwater from depths of up to ten metres ([3]).

Irrigation has occurred for some decades, and recently there has been little change in the area irrigated. The river recharge is diminishing, and therefore overall recharge is diminishing. With the same discharge ability of the total plant communities the groundwater level would decline. Obviously in many areas the groundwater is still high, at 2-4 metres from the soil surface. The few plants occurring in marginal areas extract groundwater at only slow rates. A full plant cover may consume up to 1000mm/year, but in areas with for instance less than one plant per square metre the consumptive use may be less than 50 mm/year. At that extraction rate and no replenishment the groundwater levels would decline by some 0.2 metres/year in sandy soils. There still is some recharge, hence a slower rate of decline in ground water levels is likely. In

[2] This is also a feature of the Water and Salt Balance Model for this area.
[3] The depth of extraction of both Poplar trees and Phragmites is based on information supplied by local experts (e.g. Mr Huang of the Agr. Sci. Academy.

other locations, with trees or more plants, the groundwater may drop faster, however these locations tend to be located closer to sources of recharge which are not at this stage diminishing. The process of dropping water tables in marginal lands obviously is a slow, insiduous process.

Consequences

The drop in groundwater level conditions has consequences. The number of plants surviving is likely to slowly become less, this has an effect on the grazing potential of the area. If the grazing continues at current levels then this will result in accelerated plant loss and soil degradation. Over grazing is a serious problem for most marginal areas, especially where there is population pressure and a slow decline in the plant communities. Many dust storms in the Korla area may originate from the local areas, not necessarily the deserts ([4]).

Areas where plants survive on a groundwater supply are also subject to degradation through salinity increases of the shallow groundwater. Dependent on the salinity of the groundwater there will be an accumulation of salts near the root zone of plants, resulting in a gradual decline of the ability of plants to cope. In areas where flooding still occurs the problem is likely to be small. In areas where flooding occurred previously, but not any more, the groundwater would remain fresh for a significant period, because the profile has a large volume of stored fresh ground water. The upper profile near the root zone however may salinise more quickly dependent on the rate of abstraction. The longer an area with plant communities has depended on a groundwater supply, and the further away it is from a fresh source of recharge, the more likely it is that groundwater salinity will become a problem.

The author is not aware of any groundwater salinity data for the areas in question.

Consequently, the Lower Green Corridor areas south west of the State irrigation farms at Qiala towards Daxihaizi may benefit from groundwater in the short to medium term, but in the long term the trees are unlikely to survive without regular flooding. Since the irrigation water salinity being used in this area is marginal anyway (2-3 g/L in some seasons) the time frame involved may only be short, say a decade or so. The salt tolerance of trees varies, but is unlikely to exceed about 10 g/L in the root zone.

No Poplar Trees at Qiala.

The issue was raised as to why no Poplar trees occur in the Tarim River Green Corridor section from just upstream of Qiala to Daxihaizi. The most plausible explanation appears to be that the area was not flooded previously from the Tarim River and trees did not establish, unlike other areas. In additions the groundwater levels are not being maintained from river seepage alone, since the bed of the river may consist of silt layers, reducing percolation. This situation has been changed with the construction of Qiala Reservoir, which allows vast volumes of recharge, but that factor does not produce a Poplar stand.

Restoration of Lower Green Corridor.

To restore the Lower Green Corridor, flood waters are needed to wet the profile, and to raise the water table, so that trees can re-establish, and grass can grow. The volumes needed to achieve such an objective is of interest.

There are some 0.2×10^6 ha of forest areas and about 0.28×10^6 ha of grassed areas between Qiala and Lake Taitema.

The tree areas were flooded on a regular basis in the past. Some areas were more dense than others. In many areas the canopy density was only 0.1 to 0.3, affecting rates of water use per year. A full canopy may require over 1000mm/year, a less dense canopy may survive with about 300mm/year. It is likely that trees in some areas were not flooded every year, but survived on groundwater between floods for say 2 to 3 years.

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[4] This appears to be a possibility, but has not been confirmed in any way.

The grassed areas appear to have been flooded less frequently. Judging from available data on stocking rates the average was only about 1 sheep/goat for every 10ha. It is likely therefore that flooding was infrequent, grass grew on the retreating flood waters, and stock utilised this until the next flood. It is estimated that the flooding frequency may have been only about 1:5 years.

If the forest areas require about 300mm/year to maintain health, and the grassed areas utilised about 400mm each time a flood occurred([5]), the total volume used by plants may be calculated as 0.6 x $10^9 m^3$/year for the trees and 0.22 x $10^9 m^3$/year for the grassed areas, total 0.82 x $10^9 m^3$/year. To this has to be added the volumes lost due to evaporation during the flood event. Over the whole area this is about 200 mm over a month of flooding. Assuming 1:2 flooding frequency for the trees and 1:5 flooding frequency for the grassed areas the loss would be about 0.31 x $10^9 m^3$/year. The overall annual average use therefore would be about 1.13 x $10^9 m^3$/year.

It would be important that the floods occur as irregular events involving large volumes, rather than the average amount each year.

During the first flood event the soil profile needs to be wetted up. Currently this is depleted of soil moisture down to the water table, on average perhaps 6 metres below the soil surface. For sandy soils with significant silt content is it reasonable to assume that the soil moisture deficit is about 150mm to saturation. With these assumptions a volume of about 1.5 x $10^9 m^3$/year may be calculated to raise the water table from six to one metres below ground surface for the treed area alone.

These are vast volumes of water, and it may be decided to pursue strategies with a lesser area to be restored. This could involve consideration of the area upstream of Yensu only. An even lesser strategy could be to just maintain tree and grass areas near the State Farms east of Daxihaizi. For instance a 2 km wide shelter belt of trees already receiving some drainage (surface, sub-surface) from the irrigated areas could be maintained. Some of these areas are currently at risk of salinisation by groundwater sources (as discussed). The maintenance of about 20,000ha of trees would require about 0.1 x $10^9 m^3$/year, including losses ([6]). This is about 9% of the volumes calculated above. No volumes would be needed to wet the profile of a deep water table.

Monitoring System

Whichever area is selected for restoration, some monitoring will be needed to check performance. In terms of groundwater monitoring piezometers should be installed. The piezometer set should be capable of monitoring the regional conditions twice a year, before and after flooding. A few selected piezometers may be selected for more intensive monitoring for .seasonal behaviour, say every 2-3 months

CONCLUSION

Recharge from rivers and floodplains under natural conditions was augmented by irrigation recharge when irrigation commenced. The latter changed the pattern of groundwater flow and its direction, and the locations where discharge by plants occurs. In some locations seepage into the Kongque River commenced. However, the vegetation of the Lower Green Corridor continued to exist until the river flows and the flooding incidence became less. The latter has become a dominant feature, and vegetation dependent on river recharge is now under severe stress where it has not already succumbed. Plant communities dependent on recharge from irrigation, reservoirs and canals on the other hand continues to survive. Some of these areas however are subject to the threat of increasing salt levels in the root zone over time. Where plant communities depend on both sources of recharge, there is likely to be a decline of their health with the drying up of the river recharge and dropping of groundwater levels. Apart from the loss of the Lower Green Corridor land degradation of significant areas could be the consequence. This would be aggravated by grazing pressure. The restoration of the Lower Green Corridor would require as much as 1.1 x $10^9 m^3$/year, but lesser strategies are possible.

[5] Some of this would percolate to the groundwater system.
[6] Possibly less dependent on how much drainage is received from the irrigated areas.