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INTEGRATED ENVIRONMENTAL MANAGEMENT  
IN THE TARIM BASIN

*ENVIRONMENTAL MANAGEMENT STUDIES REPORT*

**Prepared by OPCV for the World Bank**

A Technical Assistance Project Funded by

**AUSAID**

**JULY 1999**

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## PREFACE

This Technical Assistance (TA) is entitled, “Integrated Environmental Management in the Tarim Basin (IEMTB), Xinjiang Province (XP or Xinjiang Uygur Autonomous Region), China”. Funding was provided by AusAid in response to a request by the World Bank (WB) to facilitate its support of the Chinese authorities’ wholistic planning of water resource rehabilitation and use in the Tarim River Basin (TRB) in relation to the WB funded “Tarim Basin II Project” (TB II).

The TA is to ensure as far as possible that the sustainable environmental management goals of the Governments of the Peoples’ Republic of China (PRC), XP and the relevant Prefectures, can rest on the best available information and an objective assessment of the value of the Lower Green Corridor (LGC) of the Tarim River (TR) in ecological and socio-economic terms.

## ABBREVIATIONS

BEPB	Bayingol Environmental Protection Bureau
GC	Green Corridor from Aler to Taitema
ha	hectares (10,000 m <sup>2</sup> = 15 mu)
XIDRIWRHP	Xinjiang Investigation Design Research Institute for Water Resources and Hydro-Power
IEMTB	Integrated Environmental Management in the Tarim Basin
LGC	Lower Green Corridor or GC from Qiala to Taitema.
mu	mu, the Chinese unit of area equal to 1/15 of a hectare
m <sup>3</sup>	cubic metre (1000 litres)
OPCV	Overseas Projects Corporation of Victoria Pty Ltd
PD	<i>Populus diversifolia</i> (Schrenk), commonly known as diversiform-leaved poplar, or poplar diversifolia
PRC	People’s Republic of China
TA	Technical Assistance
TB II	Tarim River II Project
TR	Tarim River
TRB	Tarim River Basin
TMB	Tarim Management Bureau
TBWRC	Tarim Basin Water Resources Commission
WB	World Bank
XP	Xinjian Province (or Xinjian Uygur Autonomous Region)
XPCC	Xinjiang Production and Construction Corps (generally refers to Division II)

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3. Surface Hydrology
4. Surface Water Quality
5. Groundwater Resources
6. River Modelling Requirements
7. Socio-economic Valuation and Restoration Evaluation
8. Workshop Findings

## EXECUTIVE SUMMARY

The Lower Green Corridor (LGC) is that area of the Tarim River and its floodplain, downstream of Qiala. It is approximately 428 km long and generally 3 to 10 km in width. By comparison, the entire Tarim River is 1,320 km long and has a floodplain up to 30 km wide. The LGC used to support about ¼ of the Tarim River's total area of poplar diversifolia (*Populus diversifolia*, Schenk), in addition to Tamarix woodlands and grass and shrub lands. These woodlands and grasslands were important resources for the Uygur herders (about 2000 in the 1950s) who depended on the natural cycle of flooding to maintain these ecosystems in a healthy condition for grazing, fishing, wood, herbs and other needs. There are now more than 40,000 people on State Farms in the LGC, but very few herders because of the almost total loss of grazing land over the past 20 years.

Reductions in the average annual volumes of water supplied to the LGC are the main cause of the decline in its ecological health and grazing land condition. Although this has been occurring along the entire GC the impact is most noticeable downstream of Qiala and particularly downstream of Daxihai.

Within the LGC almost all trees between Alegan and Taitema Lake, the lower third of the LGC, are dead and those between Yinsu and Alegan are severely stressed or dying. Taitema Lake is dry and there is no pasture. In the middle third, between Daxihaizi Reservoir and Alegan, only the trees and pasture near the reservoir are in moderate condition, due to groundwater fed by seepage from the reservoir and irrigation. The upper third, between Qiala and Daxihaizi Reservoir, is also in moderate condition, again due to seepage to groundwater from the Qiala Reservoir and irrigation. Secondary impacts of the flow reductions are over-grazing of the degraded pastures and secondary salinisation due to lack of soil flushing and increased river salinities.

It is not possible to save the entire LGC without reinstating annual flow volumes that approach the magnitude of those that occurred in and before the 1950s. Upward trending river salinity levels also need to be stabilised and reduced. Grazing pressures need to be matched to the reduced carrying capacities.

Significant rehabilitation, however, can be achieved if average annual flows of  $300 \times 10^6 \text{ m}^3$  can be reinstated as provided for in the recent Water Allocation Agreement, agreed to by the Prefectures at the "Second Standing Committee for the Tarim River Prefecture Water Use" held in January, 1999 – a committee of the Tarim Basin Water Resources Commission. Although an annual average flow of  $300 \times 10^6 \text{ m}^3$  is about ¼ of the average flow in the 1950s and perhaps 1/8 of the flow prior to any irrigation use in the Tarim Basin, it is estimated that  $300 \times 10^6 \text{ m}^3$  would largely restore the condition of the trees and pasture from Qiala to Yinsu, with partial recovery between there and Alegan. There would be little benefit downstream of Alegan and effectively no ecologically useful change at Taitema Lake. Initially such flows would need to be augmented to raise groundwater levels that have been reduced over the past 20 years since flows to the LGC effectively ceased. If these initial flows cannot be augmented, then it will take longer for the restoration to be achieved.

In addition to restoring flows, there is a need to spread and hold water on the floodplain for sufficient time for the natural flora to re-establish. Natural floods had the high discharges needed to do this. The restoration flows envisaged do not, and artificial structures in the Tarim River coupled with flood runners will be required if the height of the water in the river is to be raised and the water is to be spread over the flood plain.

Quantifying the socio-economic value of the LGC, however was restricted due to limited and incomplete data. In socio-economic terms sufficient evidence was gathered to suggest that the case to restore, save or even sustain the LGC downstream of Daxihaizi is very weak. None of the options investigated for delivering water to the LGC had a positive NPV at the discount rates considered. In effect all options will impose a cost on the Chinese economy if implemented. That cost is significant, in two ways. First, there will be lost socio-economic opportunities. It will cost the Chinese economy to save or partially restore the LGC and these funds could be better used to benefit the Chinese economy if they were used in other productive ways. Second, and due to transmission inefficiencies, unless the water required is sourced from the Kongque River, attempting to save or partially restore even some of the LGC, will cause more GC to be lost in higher reaches than can be saved or restored in the LGC.

Sustaining the GC along the higher reaches of the TR, however, has a relatively strong socio-economic justification

Analysis of the current condition of the LGC, its value in ecological and socio-economic terms, and the underlying causal factors is severely constrained by the available data. No quantified flow records exist prior to 1957 anywhere on the Tarim River but large scale irrigation water use existed prior to the 1950s. Hydrologic modelling is therefore needed to estimate the scale and nature of pre-1950 flows and link these with post 1950 data. There is only one flow recording station in the LGC and this is not a National Level station. The quality of data from this station might not match that of the National Level river monitoring stations at Aler and Xinqiman. There is even less information on water quality and biological parameters.

Data constraints are not unusual in river basin studies but in this case funding arrangements have caused data to become a "commodity" to be purchased to augment agency funds. This has given rise to a lack of interagency data exchange and a degree of adversarial competition between agencies to protect their perceived areas of responsibilities and expertise. This is not an efficient use of data or resources and results in a large, long-term economic cost to the Tarim Basin and the XUAR through inefficient policies and poor use of available natural resources. It seriously constrained this analysis and prevented the development of a better understanding of how the system works and how the prevailing condition of the GC in general and the LGC in particular came to be. It is an important issue because river basin management, by nature, is multi-disciplinary and requires a great deal of cooperation and interaction that at present simply does not exist.

The greatest need for monitoring in the future is to first correct data access and sharing arrangements so that a multi-disciplinary, inter-agency approach can make full use of past and future data. Without such changes there will be little value in collecting more data.

There is a need for much stronger coordination and oversight of water quality monitoring in the Tarim Basin. The TBWRC should have a much stronger role (similar to the Murray-Darling Basin Commission in Australia) in this regard and be responsible for coordinating Basin-wide data collection and management. The actual monitoring should be conducted by existing agencies within this coordinated holistic framework provided by the TBWRC.

Second, new data need to be collected with specific issues and hypotheses of the biophysical, socio-economic and management /administrative systems in mind. All three of these

hypotheses need to be developed in an interactive manner involving all relevant stakeholders and managers. The TMB will require additional support for it to manage such processes, coordinate data gathering and archiving, and use the analytical modules and systems needed to support TBWRC operations.



# 1. INTRODUCTION

## 1.1 PROJECT CONTEXT

The “Lower Green Corridor” (LGC) is the area naturally and artificially irrigated by the Tarim River, downstream of Qiala Reservoir to Taitema Lake, i.e. it is the Tarim River and its floodplain, including flood channels and “dry rivers”. This area is surrounded by the Kuluk Desert to the east and the Taklimakan Desert to the west (Figure 1). A full description is provided in Section 2.

The World Bank funded Tarim Basin I Project (completed in 1997) and Tarim Basin II Project (in progress) are intended to achieve socio-economic benefits for poor farmers through sustainable rehabilitation and development of irrigated agriculture. The projects also aim to improve the greatly deteriorated environment of the “Green Corridor”, which, at least at one time, had considerable socio-economic and ecological values.

This Technical Assistance (TA), “Integrated Environmental Management in the Tarim Basin, Xinjiang Province, China”, relates to whether and how water saved through the structural and management measures of the Tarim II Project could be used to improve the environmental condition of the LGC and thereby socio-economic conditions. The TA was also to quantify the ecological and socio-economic values, so that rational and objective decisions can be made about the reallocation of the scarce water resource saved through component projects of the Tarim Basin II Project. The five objectives of the TA are listed in Section 1.2.

Package 1 of this TA is to provide a preliminary assessment of these values and criteria, and establish a framework for an environmental monitoring program that can be conducted through the Tarim II Project. It also recommends specific environmental research studies to be conducted as part of Package II of this Technical Assistance. Package II is tentatively scheduled to begin in late 1999. This report is part of Package 1.

## 1.2 OBJECTIVES

The Tarim Basin Green Corridor Environmental Management component of *Package 1* has the following objective:

*To identify the broad constraints within which current and future development can occur without further destroying the Tarim River's environmental assets and to identify opportunities for restoration or enhancement.*

Through the preparation of an environmental baseline study, five specific objectives will be addressed:

1. To determine the major changes in the extent and character of the Tarim River and its “green corridor” since the inception of large scale water use and river regulation.
2. To make a preliminary assessment of the value of the river and “green corridor” in ecological and socio-economic terms.
3. To determine the broad water quality and quantity conditions that will maintain or restore the ecosystems of the Tarim River and its “green corridor” to levels that match agreed local and regional expectations.
4. To input environmental values, constraints and management options to the development of the Tarim Basin Master Plan primarily at the Insight Workshop.

5. To identify a framework for the development of monitoring needs and make recommendations for the environmental studies to be conducted in *Package 2*.

## **2. WHAT IS THE CONDITION OF THE LOWER GREEN CORRIDOR?**

### **2.1 THE “TARIM RIVER HOTPOT”**

The Tarim River (TR) can be likened to a frog in a pot of cold water. The story goes that if you heat it slowly enough the frog will not notice that the water is getting warmer and will remain oblivious to the danger until it is cooked. Similarly, changes to the TR have been very gradual. The damage was not done “yesterday”. It has developed progressively over much of this century and started even before river flow and other records began to be kept.

And now the “Tarim River Hot Pot” is more than half cooked. It is almost forgotten that the TR used to flow, not just to Taitema Lake, but joined by the flows of the Qarqan River, flowed a considerable distance further, at least in wet years, to Lop Nor Lake (Figure 1). That lake was two to three times the size of Bosten Lake earlier this century, but by the 1970’s was dry. The reduction in TR and Kongque River flows were both responsible<sup>1</sup>.

The deterioration of the Lower Green Corridor (LGC), i.e. that section from Qiala to Taitema Lake<sup>2</sup>, is just the most visible sign of the problem. The remainder of the Tarim River’s (TR’s) Green Corridor (GC), from Aler downstream and those of its tributaries, are also significantly degraded, but because of the “slowness of the cooking”, it has largely gone unnoticed and consequently there has been little retrospective action.

There is a danger in concentrating on the obvious deterioration in the LGC, the complete lack of water downstream of Daxihaizi Reservoir, the dead and dying trees, the encroaching desert, and ignoring the effects of increasing river salinities, land salinisation and deteriorating groundwater levels and quality. These are secondary causal factors in the deterioration of the whole GC, not just the LGC, due to the primary cause of reduced water availability. It is as important to understand the mechanisms of deterioration, as it is to know the extent and severity of the consequences. By understanding the mechanisms, predictions can be made and early warning signs recognised in areas less severely affected. Management can then be targeted to address these problems knowing the full scale of the issues, what integrated management is needed and what trade-offs are necessary. It also provides the advantage of proactive management in being able to prevent further deterioration, rather than attempt restoration after the damage has been done.

### **2.2 WHAT IS THE CURRENT CONDITION OF THE LOWER GREEN CORRIDOR?**

The lower one third of the LGC, between Alegan and Taitema Lake is already largely dead. There is no pasture and most of the poplar *diversifolia* trees are dead or nearly so. Mobile

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<sup>1</sup> The Kongque River flowed separately to Lop Nor Lake via a more northerly route, but also used to contribute flows to the lower TR in the vicinity of Qiala, via Aksupu Swamp and Tiganlike, via the Ailik River (now dry).

<sup>2</sup> The former extent to Lop Nor is being ignored in this study in terms of any attempts to recover it. The volumes of water required would approach those volumes that originally flowed. The re-allocation of water on that scale is outside the terms of reference of this study and is, to all intents and purposes, impractical.

dunes have formed over some of the 7,000 ha of abandoned irrigated farmland and in the bed of the TR at Alegan.

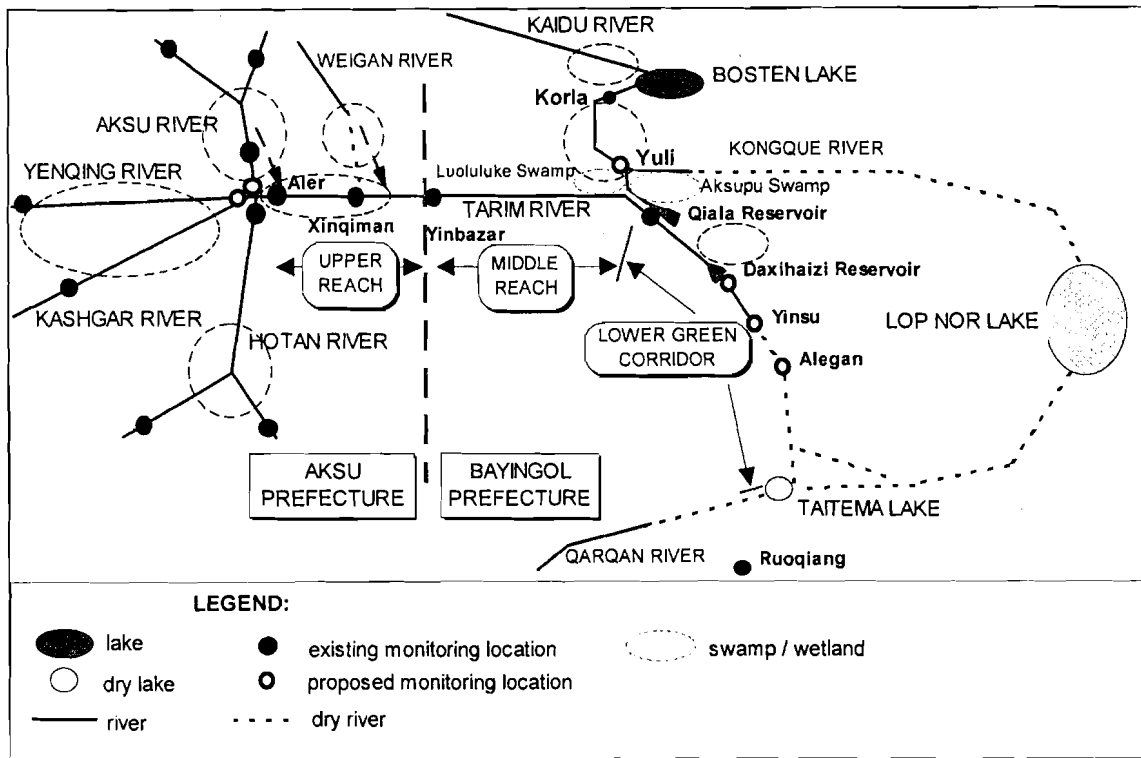


Figure 1: The location of the Lower Green Corridor and key features.

In the middle third of the LGC, between Daxihaizi Reservoir and Alegan, the pasture has deteriorated to the extent that only six of the original 28 grazed species remain and there is only temporary occupation of Yinsu each year by a few families. Grazing is now restricted to 11,000 ha of the “original”<sup>3</sup> 278,000 ha of grass and bush area. It is being maintained almost entirely by groundwater. However, the groundwater levels are progressively becoming deeper and most of this remaining area, including the tree cover, is likely to be lost to within a short distance of Daxihaizi Reservoir if regular flooding is not provided within 5 to 10 years<sup>4</sup>. Water levels in wells in the river bed at Yinsu are more than 6 m deep, or more than 10 m below the general floodplain level<sup>5</sup>. Between Yinsu and Alegan tree condition is poor and there is evidence of wind erosion of alluvial sediments, reflecting the lack of grass cover and absence of flooding. Currently the mature trees are still in moderate condition upstream of Yinsu, but there is essentially no establishment of new trees.

<sup>3</sup> This “original” area is calculated from the “Map of the Landscape of the Tarim River Drainage Area”. A full reference is provided in the References section. The date of the photography or satellite imagery that this map is based on is not known, but is likely to be relatively recent. Therefore the original extent of grassland in particular (less so for forest), could have been greater, i.e. the areas quoted in this report based on this map are likely to be conservative.

<sup>4</sup> This is a project estimate based on the biological information provided and the time which it has taken for the currently observed deterioration in tree health to occur at Yinsu, i.e. within 10 years of the last decent flood.

<sup>5</sup> Observation during a TA field trip 7 April 1999.

The upper third of the LGC, between Qiala and Daxihaizi Reservoirs, is in moderately good condition due to both surface and groundwater flows being maintained by irrigation water, albeit with different time and spatial patterns relative to the natural flows and floods that once characterised the TR. The flow of surface water in the river and in the main and subsidiary irrigation canals, all assist in maintaining groundwater levels, as do the major area-based recharge sources of the Qiala and Daxihaizi Reservoirs and the irrigation areas of the five State Farms.

River salinity levels range between 1 - 3 g/l (measured as “mineralisation”<sup>6</sup>). They appear to have increased since the 1960’s. Land salinisation is a significant issue. It is perhaps less prevalent in the upper third of the LGC than in the middle GC although relatively high salinity levels in the upper third of the LGC have forced the use of deep groundwater for drinking water.

### 2.3 WHAT ARE THE CAUSAL MECHANISMS?

The entire TR has an extremely arid continental climate and therefore experiences high summer temperatures of 30 to 40°C daily maximums and evaporation in excess of 2 m, and winter temperatures down to -30°C. There is less than 50 mm of average annual precipitation. Therefore all water is derived from river flows and the observed environmental changes have been primarily driven by the reduction in these flows. Land management issues, such as tree cutting and grazing, have exacerbated the situation brought about by the water shortage as the area and lushness of the GC has reduced.

River flow records since 1957 show that flows in the 1990’s at Qiala are only one third of what they were in the 1950’s and virtually all of this is used by the State Farms. Therefore there is no flow currently downstream of Daxihaizi Reservoir. In fact the reduction in flows is even greater, as significant areas of irrigation were already present in the tributaries prior to 1957. Cheng Qichou (1993) records in *The Research on the Tarim River*, that average annual flow of the Tarim River (at Aler), prior to any irrigation development, was likely to have been 10.0 - 12.0 x 10<sup>9</sup> m<sup>3</sup>, i.e. about double the average over the last 50 years (4.60 x 10<sup>9</sup> m<sup>3</sup>) and more than double the average for the last decade (4.17 x 10<sup>9</sup> m<sup>3</sup>).

River modelling, using historical daily data, is required to determine the true situation of natural flows and to determine changes induced by human water use (Working Paper 6).

The situation at Qiala is much worse. Relative to the 1950’s, the current flows are only 1/6th of the original and relative to the pre-development flows are perhaps only 1/12. In fact of the 211 x 10<sup>6</sup> m<sup>3</sup> currently supplied to the LGC, about 150 x 10<sup>6</sup> m<sup>3</sup> is water purchased from the Kongque River by the State Farms and diverted via the Kuta Main Canal.

Apart from two small releases in 1995, totalling 28 x 10<sup>6</sup> m<sup>3</sup>, which were largely confined to the river and didn’t reach Yinsu, there have been no floods downstream of Daxihaizi Reservoir since the mid 1980’s. Hence the remaining ecosystems have been relying on progressively decreasing groundwater levels.

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<sup>6</sup> The term “mineralisation” was not explained in the material provided to the TA. It has been assumed that it represents Total Dissolved Solids, TSD, or something close thereto, despite the following reference citing it as being the sum of the cations only: Xiangcan, Jin 1995 *Lakes in China: Research of their Environment*. Vol 1. China Ocean Press. pp 278-319).

The reduction in river flows has been accompanied by increasing river salinity, particularly in spring and early summer before the summer flood dilutes the saline irrigation drainage water and groundwater. Salinity levels peak at up to 6 g/l in spring at Aler due to return groundwater and surface irrigation drainage. However, spring levels peak at only 2.8 g/l at Qiala, apparently due to flow attenuation and dilution by Kongque River water.

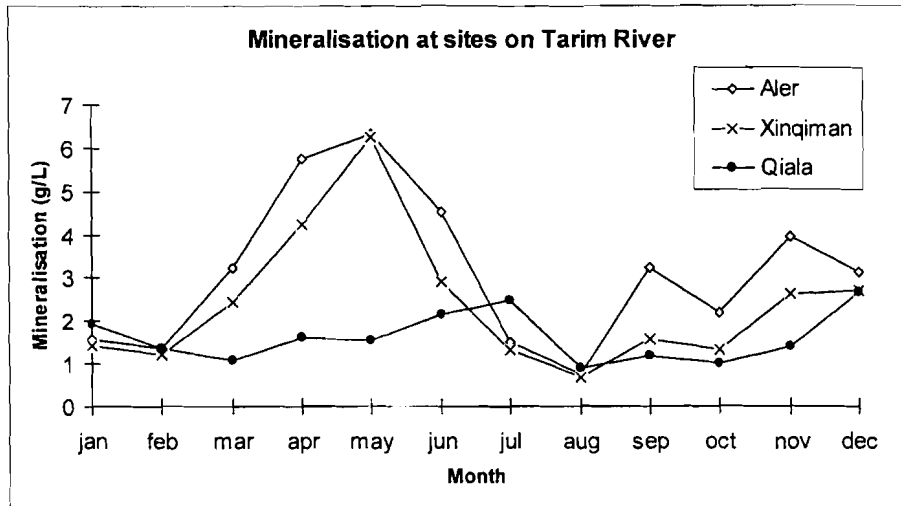


Figure 2: Tarim River mineralisation at Aler, Xinqiman and Qiala

There are insufficient data to conclusively quantify the changes over time, particularly as the diversion of water from the Kongque River has included releases to the Tarim River at unknown times since the mid 1970's and particularly since 1990. However, the data do indicate that salinity levels appear to have increased since the 1960's.

The supply of water to the LGC is contingent on the total volume supplied to Aler and also the transmission efficiency of the upper and middle Tarim River reaches.

As previously stated, all flows in the Tarim River are supplied by its tributaries; the Hotan, Yarkant/Kashgar Rivers and the Aksu River at its head, and the Kongque River at the upstream end of the LGC. The Weigan River once contributed relatively small volumes ( $200 \times 10^6 \text{ m}^3/\text{yr}$ ) but no longer does so. As discussed below, average annual flows to the Tarim River are now less than half those which are estimated to have prevailed prior to any irrigation in the TB. Much of this reduction took place prior to the commencement of flow records in 1957.

The middle and upper reaches of the GC, ie. from Aler to Yinbazar and thence to Qiala, have shrunk laterally and become drier in most locations. The exceptions are relatively small areas now receiving more water than previously due to enlarged overflow locations made by excavations. These diversions have been dug by local people, including herders, in response to the reduced flooding frequency and resultant decrease in pasture extent and health. However, because these diversions have no regulators they result in much higher water losses at low and medium flows than previously. As discussed below, the increase in low flow losses is almost certainly more than equalled by the reduced losses at high flows, due to the decrease in flood size and frequency caused by irrigation use in the tributaries.

Figure 3 shows the reduction in annual flows by decade from the 1960's to the 1990's. Flows reaching Aler have decreased by about  $1 \times 10^9 \text{ m}^3$  over the period. Taking into account the  $150 \times 10^6 \text{ m}^3$  transferred from the Kongque River (included in the volumes presented in Figure 3), there has been a similar annual reduction at Qiala. Therefore, although it appears as if losses have increased between the two stations, because the proportion of flows at Qiala is now less relative to Aler, this is only a proportional difference and is not a true change in the relationship in annual flows between the two.

Hence the apparent increase in the volume lost in the upper and middle reaches, often cited by some stakeholders as being due to increased floodplain losses, is in fact largely due to irrigation use upstream of Aler. The upper and middle GCs are as much a victim of reduced tributary flows to the Tarim River, as the LGC. Working Paper 3 provides a more detailed temporal and spatial analysis of the flow relationships between the stations along the TR.

The pattern of losses within years could not be analysed using the available monthly data. Daily data exists for Aler, Xinqiman and Qiala from 1957, but was not provided to the project team because of "confidentiality", "intellectual property" and the size of the requested payment of RMB  $1.6 \times 10^6$  yuan (for Aler and Xinqiman data only). Daily flow data is required to determine the changes in low, medium and high flow losses, as individual events would need to be "tracked" downstream to resolve the loss component. However, given that some excavated floodouts (distributary channels) have inverts lower than the river bed, it is reasonable to conclude that losses at low flows are now greater than previously. However, these are unlikely to equal the reduction in high flow losses due to reduced flood size caused by upstream water use.

In fact it is this reduction in high flow losses that has in part hidden the total increase in consumptive water use of  $2.2 \times 10^9 \text{ m}^3$  upstream of Qiala. In addition to the  $1 \times 10^9 \text{ m}^3$  increase upstream of Aler, discussed above, most of the Aler to Qiala allocation of  $1.25 \times 10^9 \text{ m}^3$  between has developed since the 1960's. If were not for a reduction in overall annual losses, annual flows at Qiala would be negative, even with the average annual transfer of  $150 \times 10^6 \text{ m}^3$  from the Kongque River to Qiala.

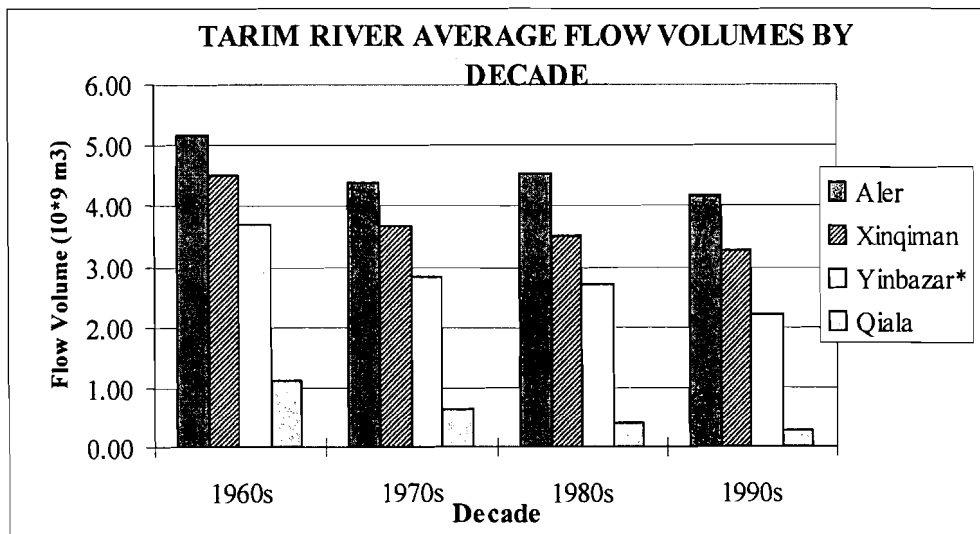


Figure 3: Tarim River average flow volumes by decade

## 2.4 WHAT IS THE MANAGEMENT SITUATION?

Translation of the awareness and concern about the environmental deterioration into effective action is being both hampered and facilitated. It is facilitated by some good research and monitoring of critical parameters, although, as always, there are gaps and more would be most beneficial. It is also facilitated by the progress towards water use quotas, controlling unauthorised access to water and implementing measures to manage grazing pressure, medical herb collection, firewood collection and tree cutting.

However, it is hampered by the lack of agreed environmental outcomes. Outcomes against which changes to the prevailing extent and condition of the green corridor can be measured. It is further hampered by the lack of an agreed set of overall conceptual models within which appropriate sets of corrective action can be devised and through which such actions must then be implemented.

At least three inter-related conceptual models are needed. The first of these involves understanding the key processes that drive the fluvial geomorphology and riverine ecosystems. A second, involves understanding the socio-economic and technical functional relationships that link the human, agricultural cropping, livestock and water use systems that have been, are currently and could be practiced in various reaches of the GC or parts thereof and how these actions in each reach or part thereof impact on each other. A third, involves understanding how the incentives and disincentives created by the prevailing administrative and policy environments impact on the actions of those who live in or are otherwise dependent on the GC and/or use the land and/or water resources that have determined the prevailing and will determine the future extent and condition of the GC.

Attempts to derive agreed positions on all of these points plus the inter-relationships that exist between them demands a concerted collaborative effort that involves a number of disciplines, administrations and decision making entities. A range of prefectures, institutes, bureaus and agencies are involved and each of these entities have differing perspectives with regard to what constitutes desirable sets of environmental outcomes. They also differ with regard to their understanding of the conceptual models involved and how they should be used to achieve a particular result with regard to a particular part of the GC. As a result, the level of collaboration needed to save or restore the LGC is high and will be difficult to realise.

Achieving the levels of collaboration required is currently being severely hampered by several factors, not the least of which is the restricted sharing of data between agencies. This restricted sharing of data is occurring for several reasons. These include differing perspectives, "confidentiality" and/or the high price put on data (e.g one agency was quoted a fee of RMB  $1.6 \times 10^6$  Yuan to access 40 years of historical river flow data at 2 or 3 gauging. In addition, the LGC system is currently being treated as a "black box" from which "products" are extracted, such as crops, livestock, timber, firewood, desert barrier, etc. There are few cases of an explicit understanding of the processes that determine whether the GC lives or dies being worked into management decisions and even less when these management decisions impact on several prefectures, institutions, bureaus and other agencies.

As a result, such understandings as do exist suffer from a lack of data that has been specifically collected to address particular issues and/or quantify processes in terms that are relevant to available management actions. But at present there are few measurable goals for sustaining the ecosystems of the LGC for their own sake, i.e. for their intrinsic value without an explicit human use.

If the intrinsic values of the GC, or parts thereof are sustained, then the human uses of all or parts of the GC are also likely to be sustained. Such sustainable management is achieved by

identifying the limits of natural resource use for each level of environmental condition that could be managed towards. Each management option is then assessed against the resource limits and agreed environmental goals, through the analysis of the three conceptual models described above.

### **3. WHAT METHOD WAS USED TO VALUE THE LOWER GREEN CORRIDOR?**

The major outcome of this study was to determine the ecological and socio-economic value of the LGC. This value was required to help people and agencies with an interest in the LGC (the stakeholders) answer the question “Why save the Lower Green Corridor?”.

A combined approach was used in which the opportunity cost of water was derived for each of the major reaches of the Tarim River, the upstream tributaries and the Kaidu-Kongque River, based on past commercial use for cropping and grazing livestock. These opportunity costs were then used to value the volumes of water that are required to be forgone in those locations to supply the necessary volumes for a range of scenarios to save the LGC. The scenarios and the values so derived are “contingent” on current uses and on the adoption of that level of action being agreed and implemented. At present the LGC has effectively zero socio-economic value downstream of Daxiahizi Reservoir, as no water is being released and all families are being moved out.

Using a contingent valuation approach, the LGC has no single value. Every stakeholder has a different set of values with regard to the GC and the extent and condition to which it or parts of it should be saved. These sets of values are often influenced by commercial considerations. These commercial considerations are often dependent on the extent to which each stakeholder has a financial involvement that is directly dependent on what happens to all or parts of the GC including the LGC. Hence the answer to the question “What is the value of the LGC ?” is contingent on the collective opinion of all stakeholders.

In addition, decisions made in response to what is assessed to be happening to the LGC and what action can be taken within the available resources is then determined by the weighted opinions of those involved in the decision making processes.

Such decisions will invariably mean some stakeholders have to give up the possibility of using some resources in order to use them to save or restore the LGC. That use may be a future use. It may be an existing use. What actually happens will be the result of how those responsible for implementing these decisions (who are also stakeholders) respond. In some instances some stakeholder may quite validly claim to be in a position of not wanting to give up a commercial benefit, but still claim to have a non-commercial interest in saving or restoring all or part of the GC. The question then becomes one of how much, if any, resource some are prepared to give up to save or restore some and which parts of any or all of the GC.

In effect, the only measure of the value of the GC that can be derived with any certainty are the values implied by past actions and the decisions that might be taken now between alternative future but realistic alternative courses of action. Under these circumstances the value of the GC or parts thereof will be determined by the options that are actually implemented in the future.

Finally, even this analysis will vary since the options that can be regarded as realistically applicable in the future will change over time and themselves be determined by the actions of the past. As a result a series of intermediate questions have to be asked. First to “precipitate”



a value based on the actions of the past and, second, to determine the range of options that can be regarded as realistic course of action at each point in time in the future.

The questions that need to be asked take the form of "If we are prepared to use this amount of water to achieve this much restoration, what is the value of the foregone benefits?". This question was "asked" by modelling the opportunity costs of foregoing water use in upstream reaches to supply economic and ecological benefits in the LGC. This was done for four scenarios the first being an average annual volume approximating those of the 1950's, i.e.  $1,004 \times 10^6 \text{ m}^3$  per year. The other three represent various estimates of the volumes that might be sufficient to save basic features and functions of the LGC, or at least parts of it, and that might be realistically made available through TB II. They are  $120 \times 10^6 \text{ m}^3/\text{year}$ ,  $150 \times 10^6 \text{ m}^3/\text{year}$  and  $300 \times 10^6 \text{ m}^3/\text{year}$ , the first being the lowest estimate advised (TMB) and the last, the amount provided for in the TR water allocations after implementation of TB II. Even if they are inadequate to restore the whole LGC, they might be sufficient to maintain the area from Daxihaizi Reservoir to Yinsu and achieve partial restoration to Alegan (after an initial wetting up period to re-establish groundwater levels).

The socio-economic opportunity costs calculated below, only include the commercial value of the LGC. Figure 4 shows that the LGC and its ecosystems support both commercial and non-commercial values. The commercial and non-commercial values are inextricably linked and to varying degrees in ways that will also vary in each reach of the TRB. It is important to note that both the commercial and non-commercial values are supported by the physical, hydrological and ecological resource base.

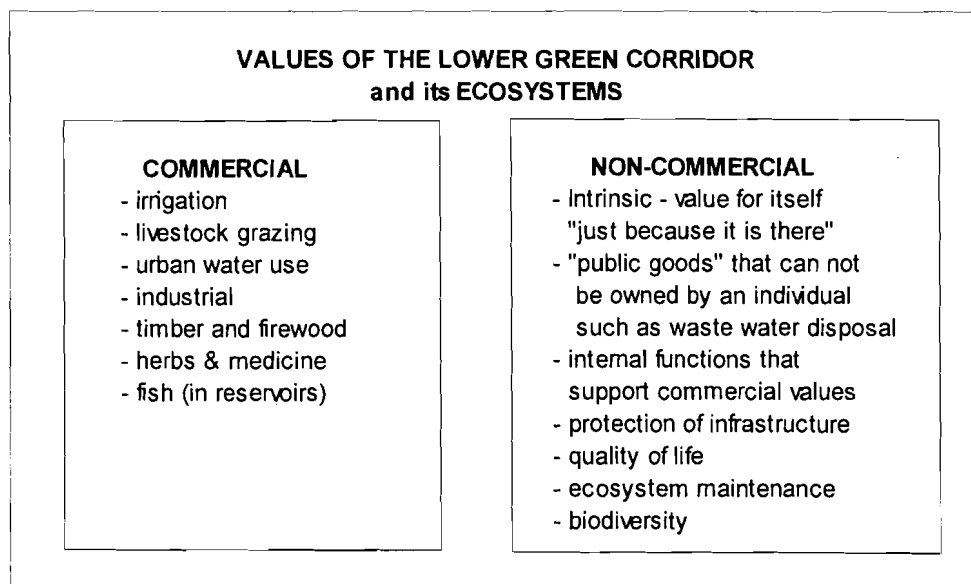


Figure 4: Types of values supported by the Lower Green Corridor

## **4. WHAT IS THE VALUE OF THE LOWER GREEN CORRIDOR?**

### **4.1 SOCIO-ECONOMIC VALUES**

#### **4.1.1 BETWEEN-REACH TRADE-OFFS**

The value of the benefits currently earned from commercial socio-economic activities in any reach of the GC less any costs that are currently saved or deferred provide an indication of the value that past stakeholders placed on that reach of the GC today. This is a simple point in time benefit-cost analysis. The results are presented in Table 1. They do not include the costs to upstream areas associated with any prior reductions in the extent and condition of the GC in the upper and middle reaches that occurred as a result of reduced grazing and wood production. Further reductions of this nature are inevitable if the pre 1950s flood frequencies that have already occurred due to large scale water use in the tributaries are further reduced by the TB II works.

Therefore, whilst the eight regulators proposed in TB II will help reduce the overly wet areas and therefore be beneficial in ecological terms and water saved, they are unlikely to achieve inundation of the broader areas of the upper and middle GCs that have become drier due to the reduced flood frequency. This drying will be worsened by the construction of levees, which, even if flood frequencies had not been reduced, would cause a lower frequency of floodplain inundation than that which occurred naturally.

The actual relationship between flood extent and river height/flood volume, needs to be ascertained for different management regimes after implementation of TB II, if it has not already been done. No information could be supplied to the TA regarding these relationships, which is critical if the assumption that the proposed regulators and levees will have no adverse impact on the upper and middle GCs is to be objectively confirmed.

#### **4.1.2 CURRENT SOCIO-ECONOMIC VALUE**

There will be a net gain to the economy if the Daxihaizi - Taitema reach of the GC is allowed to die and a net loss to the economy if either of the Aler – Yinbazar, or Yinbazar - Qiala reaches of the GC are allowed to die. In other words, the absolute gain to the economy rises when water is allowed to flow down to but not beyond Daxihaizi. Water that goes past Daxihaizi can be more profitably used elsewhere. Allowing it to go past Daxihaizi is currently costing the Chinese economy about RMB 325 Yuan/ha of LGC /year in foregone commercial benefits. This is a foregone opportunity cost. It is also saving (or deferring) a one off cost of about RMB 170 Yuan/ha of LGC that will be incurred if and when the households currently dependent of the LGC need to be resettled. This is a foregone opportunity benefit. Accordingly, if all water currently flowing past Daxihaizi could be cut off and all the resettlement were to be carried out in one year the value stakeholders' past decisions are currently placing on each hectare of LGC would be about RMB 155 Yuan/ha of LGC.

However, this is a purely hypothetical case to derive a current value for the GC. The timeframe over which the alternative currently foregone commercial socio-economic activities can be brought into production, the current earnings generated from the LGC fall to zero, and any household resettlement costs are incurred can not be predicted. As a result this analysis does not extend to the calculation of Net Present Values and the opportunity costs used in this discussion are those that include the resettlement costs.

Uses of the GC in the other reaches have strong positive values of RMB 3,820 Yuan per hectare of GC sustained in the Qiala - Taitema reach and of RMB 1,042 Yuan per hectare of GC sustained in the Yinbazar - Taitema reach. Averaged over the entire TR GC, from Aler to

Taitema, they drop to RMB 460 Yuan per hectare. These results are a direct reflection of the assumption that the areas of GC sustained in each reach have been estimated by dividing the quantity of unaccounted for water in each reach by 4,500 m<sup>3</sup>/ha (see Table 6, Notes Method 2). Ideally, they should have been estimated from current satellite imagery with the condition of the GC in selected locations being ground truthed to provide some objective information as to its current status. This could then have been compared to the quantity of water that has produced this situation.

Unfortunately the data on which all this analysis is made are out of date, crude and incomplete, reducing the credibility of the absolute figures derived, but it is all the information that could be made available. As a result about all that can be concluded is that the available information is inadequate for planning purposes and that the case for sustaining the LGC, down stream of Daxihaizi, is very weak in socio-economic terms. Conversely, a relatively strong case appears to exist for sustaining the GC in higher reaches of the TR GC.

**Table 1: Benefits and Costs Associated with Using all Water Upstream of Aler, Yiubazar, Qiala, and Daxihaizi**

<b>Tarim River Gauging Station → or point of flow measurement→</b>	<b>Aler</b>	<b>Yinbazar</b>	<b>Qiala</b>	<b>Daxihaizi</b>
<b>1990s flows x10<sup>6</sup> m<sup>3</sup></b>	4,170	2,210	480	50
<b>TR GC reaches from to</b>	Aler Taitema	Yinbazar Taitema	Qiala Taitema	Daxihaizi Taitema
<b>Benefit</b> '000 Yuan				
<b>(A) Value if water used upstream:</b>	436,221	22,695	15,266	3,838
<b>Costs</b> '000 Yuan				
<b>(B) Commercial value of downstream losses:</b>	42,023	19,337	4,071	233
Relocation of households numbers relocated:	10,495	6,122	2,728	27
<b>(C) Cost of relocation</b> '000 Yuan:	734,673	428,563	190,983	1,890
<b>Area of GC allowed to die (ha/reach)</b>	<b>740,347</b>	<b>408,104</b>	<b>47,059</b>	<b>11,094</b>
<b>Net Benefit (+)/Cost (-) [(A) - (B) - (C)]</b>				
<b>Per reach</b> '000 Yuan:	<b>(340,485)</b>	<b>(425,205)</b>	<b>(179,788)</b>	<b>1,715</b>
<b>Opportunity Cost per hectare of GC lost (by reach)</b> Yuan				
<b>Once-off:</b>	<b>(460)</b>	<b>(1,042)</b>	<b>(3,820)</b>	<b>155</b>
<b>Annual On-going*:</b>	532	8	24	325

\* Annual Opportunity Cost once the resettlement costs have been settled

The values of non-commercial socio-economic benefits can not be derived in monetary terms with any reliability. Social values relating primarily to standard of living criteria, reflected by income per capita, are included in the commercial value. Non-commercial or monetary components of “quality of life” values, such as health and environmental aspects such as access to water, air quality, exposure to dust, or simply being able to sit under a tree or catch a fish, are more difficult to quantify. These non-commercial components also includes the intrinsic value of the ecosystem and general environment. Not only do these natural systems support the commercial values to a greater or lesser degree, they have value in their own right. Intrinsic values are real and valid but they are a matter of personal, organisational and/or governmental opinion. They can be assessed but only indirectly. These indirect assessments generally involve examining the opportunity cost of the actual courses of action taken.

Under most courses of action to restore the LGC, there will also be changes in the extent and condition of the GC in more upstream reaches of the Tarim River. When this occurs, the extent and/or condition of the GC in one reach of the Tarim River are being substituted for those in another. In such cases, decisions will have to be taken as to how these substitutions should be weighted. A one for one weighting would mean each hectare of GC is given the same value regardless of where it is located. As with intrinsic values this weighting would be partially a matter of opinion, but would also be dependent on the assessment of the uniqueness of the LGC ecosystems.

#### 4.1.3 POTENTIAL SOCIO-ECONOMIC VALUES

To explore the cost and consequences of proceeding with an attempt to save the LGC an analysis was made of four scenarios (Table 2). These values can also be seen as the potential value of the LGC if and when a particular scenario is implemented. In each scenario, the water delivered to Daxihaizi would be for the exclusive benefit of the Daxihaizi to Taitema reach of the LGC. Except for Scenario D, the existing volumes used by the State Farms would remain for their use and are additional to these volumes. The 1,004 x 10<sup>6</sup>m<sup>3</sup> figure is about the average annual volume of water received by the LGC in the 1950s. The other volumes are those quoted at the LGC Workshop (Working Paper 8) as being a range of volumes that might be made available to “save” the LGC. The potential sources of water listed in Table 2 are discussed in Section 5.3.2.

Table 2: Description of Future LGC Water Source Scenarios and Options

Associated Annual Volumes & Area of LGC	Scenario			
	A	B	C	D
Average Annual Volume delivered to Daxihaizi (10 <sup>6</sup> m <sup>3</sup> )	1,004	300	150	120
Area of Green Corridor restored* in the Daxihaizi - Taitema reach of the LGC (10 <sup>3</sup> ha)	223	67	33	27

- Assuming 4,500 m<sup>3</sup>/ha average annual inundation

Percentages of water delivered to Daxihaizi by source and option				
Source	Options (Percentage Accessed from Each Source)			
	1	2	3	4
Kongque River	100	33.33	25	20
Tarim River Aler - Yinbazar reach		33.33	25	20
Tarim River Yinbazar - Qiala reach		33.33	25	20
Tarim River tributaries upstream of Aler			25	20
Tarim River Qiala - Daxihaizi reach (at the expense of State Farms)				20

Table 3 summarises the results derived and discussed in Working Paper 7. A discount rate of 12% is probably the most appropriate rate and is relatively conservative given the high growth rate of the Chinese economy. All NPV's are negative (shown by brackets) and represent a cost to the Chinese economy. Thus the best option from a socio-economic perspective is shown by the largest (but smallest negative number (ie. -2.41 is a higher NPV (and therefore preferable) to - 3.67) . The Table also shows the change in area of Green Corridor in the various reaches that results from the various options.

Table 3 Summary of LGC Value and Rehabilitation under Future Water Source Scenarios and Options

Scenario & Option	Net Present Value (Yuan x 10 <sup>9</sup> ) by Discount Rate (negative NPV in brackets and represent an economic cost)			Change in GC Area ('000 ha) (reductions in brackets)				
	9%	12%	15%	Total A - T	By TR GC reach*			
					A-Y	Y-Q	Q-D*	D-T
<b>A 1</b>	(2.41)	(1.81)	(1.40)	223				223
<b>2</b>	(2.29)	(1.75)	(1.36)	(271)	(316)	(178)		223
<b>3</b>	(4.24)	(3.17)	(2.43)	(147)	(237)	(133)		223
<b>4</b>	(3.67)	(2.77)	(2.13)	(73)	(190)	(107)		223
<b>B 1</b>	(0.92)	(0.71)	(0.55)	67				67
<b>2</b>	(0.74)	(0.57)	(0.45)	(81)	(94)	(53)		67
<b>3</b>	(1.32)	(0.99)	(0.76)	(44)	(71)	(40)		67
<b>4</b>	(1.13)	(0.86)	(0.67)	(22)	(57)	(32)		67

<b>C 1</b>	(0.48)	(0.37)	(0.29)	33			33
<b>2</b>	(0.40)	(0.31)	(0.25)	(40)	(47)	(27)	33
<b>3</b>	(0.69)	(0.52)	(0.41)	(22)	(35)	(20)	33
<b>4</b>	(0.59)	(0.45)	(0.35)	(11)	(28)	(16)	33
<b>D 1</b>	(0.38)	(0.29)	(0.23)	27			27
<b>2</b>	(0.33)	(0.26)	(0.21)	(32)	(38)	(21)	27
<b>3</b>	(0.56)	(0.43)	(0.33)	(18)	(28)	(16)	27
<b>4</b>	(0.48)	(0.37)	(0.29)	(9)	(23)	(13)	27

A = Aler, Y = Yinbazar, Q = Qiala, D = Daxihaizi, T – Taitema

\* The Daxihaizi to Qiala reach is assumed to be area neutral in this analysis as losses from the State Farms irrigation and storages are maintaining groundwater levels to a large extent. Hence there will be relatively little transmission loss (0.2 is assumed) in this reach during the supply of the above volumes to Daxihaizi. Those volumes will assist maintain the existing vegetation in a more healthy state.

**Interpretation** The results suggest there can only be an overall saving of GC in Option 1 of all Scenarios. In these Option 1's the water required is sourced entirely from the Kongque River. All other options lose more GC in higher reaches of the TR than can be restored in the LGC.

No option in any scenario has a positive NPV at any discount rate. In effect all options in all scenarios are going to impose a cost on the Chinese economy if a decision is taken to implement any one of them. Moreover, that cost is significant, in two ways. First, there will be lost socio-economic opportunities. It will cost the Chinese economy to save or partially restore the LGC and these funds could be better used to benefit the Chinese economy if they were used in other ways. Secondly, unless the water required is sourced from the Kongque River, attempting to save or partially restore even some of the LGC more GC will be lost in higher reaches than can be saved or restored in the LGC.

Table 3 shows that the total cost of individual Options in any Scenario ranges from Yuan 210 million (Scenario D Option 2) up to Yuan 4,240 million (Scenario A Option 3). If a decision is taken now to implement any one of these options the cost of that option will indicate the value that the decision-makers have placed on the LGC when that decision is taken. Relative to the results derived in Table 1, the cost of all individual future options (Table 3) exceed the value past decisions have placed on the LGC of about Yuan 180 million (see Table 1 Qiala, Net Benefit (+) /Cost of Yuan 179,788). This means that a decision to implement any one of the options to save the LGC, or parts thereof, examined in Table 3 will be placing a significantly higher value on the LGC than has been placed on it in the past.

On a per 10<sup>3</sup> hectares of LGC saved or restored under the Option 1's of all Scenarios over all discount rates, the value that would have to be placed on the LGC ranges from Yuan 6.28 million (Scenario A, Option 1 at 15% discount rate) to Yuan 14.5 million (Scenario C, Option 1 at 9% discount rate) and for Options 2, 3 or 4 in Scenarios A through D it sits between Yuan 7.78 million (Scenario D, Option 2 at a discount rate of 15%) to Yuan 19.01 million (Scenario A, Option 3 at a discount rate of 9%).

The analysis presented in Table 3 also indicates that options that source some water from higher reaches of the TR result in a net loss of GC. This means a stakeholder choice that

implements any one of these options is placing a higher value on a hectare of the LGC than is being placed on a hectare of GC in higher reaches. The substitution ratios that appear range from 1.33 to 2.21 for Scenario A Options 2, 3 and 4. This means that for every hectare of LGC saved between 1.33 to 2.21 will be lost in higher reaches of the GC. For Scenarios B, C and D the ratios range from 1.32 to 2.24. However, these outcomes are a direct reflection of the number of cubic metres of water that have to pass Aler in order to have one cubic metre of water pass Qiala (the transmissivity) assumptions used and the need to supply 4,500 m<sup>3</sup> of water to sustain a hectare of GC and can be deduced if not specifically quantified without this analysis.

The cash flows generated for each option within each Scenario incur different magnitudes of costs and generate different magnitudes of benefits over more than a decade. However, these variations in the timing of outlays, losses of currently generated benefits or the generation of future benefits do not change the ranking of the Options by NPV within Scenarios when they are discounted using discount rates that range from 9 to 15 percent.

The analyses presented in Tables 1 and 3 were structured around the availability of data. That data is crude, out of date and incomplete. In addition, the analyses have been primarily conducted to derive a value for the LGC, not generate information that can be used to choose a future course of action. Even so the results obtained suggest that from a socio-economic perspective there is little point in attempting to save or restore LGC below Daxihai and it would be better to concentrate on sustaining but not expanding the State Farm activities between Qiala and Daxihai and saving GC upstream of Qiala.

The results suggest there can only be an overall saving of GC in Option 1 of all Scenarios. In these Option 1s the water required is sourced entirely from the Kongque River. All other options lose more GC in higher reaches of the TR than can be restored in the LGC. The total cost of all Options ranges from Yuan 210 million up to Yuan 4,320 million. On a per 10<sup>3</sup> hectares of LGC saved or restored under the Option 1's of all Scenarios over all discount rates it ranges from Yuan 6.28 million to 10.8 million per 10<sup>3</sup> hectares and for Options 2, 3 or 4 in Scenarios A through D it sits between Yuan 7.87 million to 19.01 million per 10<sup>3</sup> hectares.

Options that source some water from higher reaches of the TR result in a net loss of GC. A stakeholder choice that implements any one of these Options implies that a higher value is being placed on GC in the LGC than is being placed on the value of GC in higher reaches. The substitution ratios that appear range from 1.33 to 2.21 for Scenario A Options 2, 3 and 4. This means that for every hectare of LGC GC saved between 1.33 to 2.21 will be lost in higher reaches of the GC. For Scenarios B, C and D the ratios range from 1.32 to 2.24. However, these outcomes are a direct reflection of the transmissivity assumptions used and the need to supply 4,500 10<sup>3</sup>m<sup>3</sup> of water to sustain a hectare of GC and can be deduced if not specifically quantified without having to go through all this analysis.

The cash flows generated for each option within each Scenario incur different magnitudes of costs and generate different magnitudes of benefits over more than a decade. However, these variations in the timing of outlays, losses of currently generated benefits or the generation of future benefits do not change the ranking of the Options by NPV within Scenarios when they are discounted using discount rates that range from 9 to 15 percent.

## 4.2 ECOLOGICAL VALUES

### 4.2.1 GENERAL VALUES

Any ecological value placed on the LGC by stakeholders is included in the socio-economic values already derived. This is because any ecological values foregone are the direct result of stakeholder's past (Current Socio-economic value) or future (Potential Socio-Economic value) decisions. However, the socio-economic values so derived do little to indicate the nature, function or worth of the ecological values *per se* that have been foregone. To do this other parameters need to be compared and quantified. Such parameters include the total area of the GC in the upper (Aler to Yinbazar), middle (Yinbazar to Qiala) and lower (Qiala to Taitema) reaches (the last being the LGC), the area of poplar *diversifolia* trees (*Populus diversifolia*, Schenk), grass and wetlands, the location of rare species and habitats and the use of each area by migratory species.

The analysis was restricted by the nature of the ecological and biological data available. Most data about species related to either the whole TB or the GC as a whole. There are few quantified ecological data specific to the LGC, hence few quantitative comparisons could be made. Other comparisons were based on interpretations of habitat types and conditions, in relation to likely habitat preferences.

The total area of each type of habitat is presented in Figure 2. Relative to the total area of Green Corridor habitat, the LGC accounts for 20 %, including 23 % of the total area of poplar *diversifolia*, i.e. originally it accounted for about one 1/5 to 1/4 of the total habitat and forest area. However, most of the poplar *diversifolia* in the LGC was "sparse", at the time of mapping. It is not known whether this would have been the case prior to large scale irrigation use upstream, as the date of the base imagery is not known.

It was concluded that the LGC's ecosystems, habitat and species were not unique, either prior to degradation or now. This conclusion is based on the information provided to the TA (Working Paper 2) and observations made during field trips to the upper, middle and lower GC. This information indicated that the physical and vegetative habitat and the species occupying each of the three major reaches were essentially the same and that the diversity within each reach, equalled or exceeded that between the reaches.

The most distinguishing features of the LGC are the higher silt and clay content of the floodplain soils, the ephemeral swamps and salt marshes extending into the Taklimakan Desert between Qiala and Daxihaizi and the inflow of lower salinity surface and groundwater from the Kongque River. These differences have not produced a discernible difference in species composition that has been noted by studies to date, at least to the extent where they are obvious and therefore noticed.



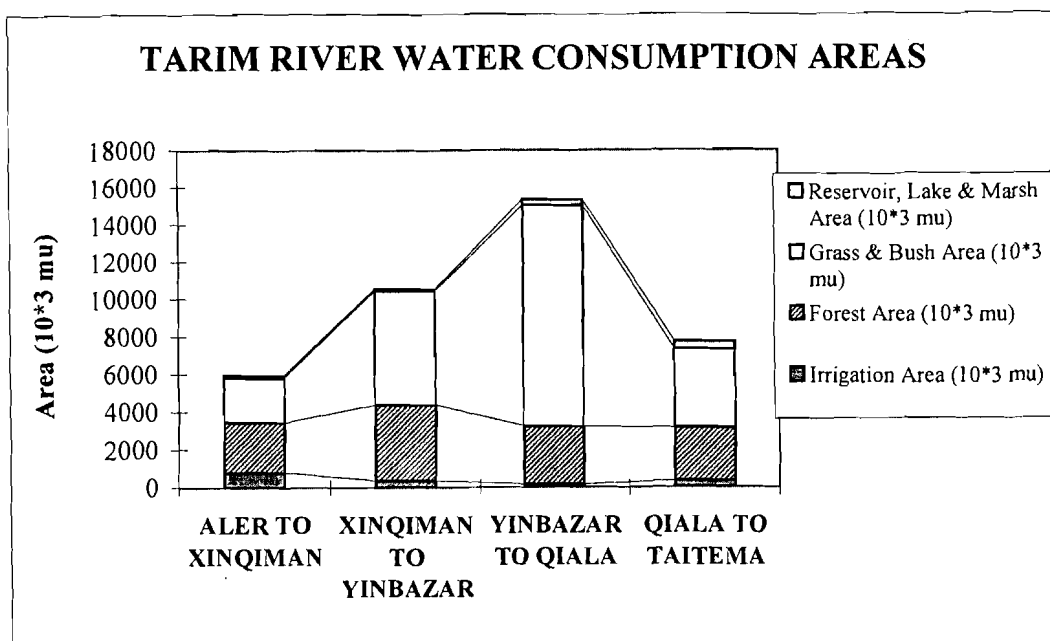


Figure 2: Areas of major habitat types and land use by reach

#### 4.2.2 WHAT ARE THE SPECIFIC FUNCTIONS OF THE LGC?

If the LGC environment and/or ecosystems are not unique, then why the concern regarding its demise? This can be answered by listing the functions that have been ascribed to the LGC by various stakeholders (Table 4). They have commercial and non-commercial aspects, but it is the former together with the social values that have generally been considered most highly with less emphasis on the actual ecology for its own (intrinsic) sake.

Table 4: List of functions (practical values) of the LGC by stakeholders

Function/Value	Comment
1. Provide grazing for stock owned by herdsmen and State Farms	<ul style="list-style-type: none"> <li>There is now little grazing downstream of Daxihaizi due to lack of water.</li> </ul>
2. A green oasis for people living in the State Farm areas	<ul style="list-style-type: none"> <li>The efforts of current and past generations of State Farm people has been tremendous and their commitment to remaining in the area and defending what they have built up is second to none.</li> </ul>
3. Protect inhabited areas, including irrigation areas in the LGC from the encroaching deserts	<ul style="list-style-type: none"> <li>The amount and frequency of river and floodplain flows is obviously essential to maintaining the LGC.</li> <li>Specific mechanisms need to be more fully understood. Groundwater is obviously important in maintaining vegetation on and between semi-mobile dunes adjacent to the GC, i.e. the greatest stabilising effect of vegetation is in the dune areas, not in the GC itself. Scouring flood flows are the most important mechanism for removing aeolian sand within the GC.</li> </ul>
4. Protect inhabited areas upstream of the LGC, including Korla	<ul style="list-style-type: none"> <li>A scientifically proven link between the LGC and</li> </ul>

City and settlements and irrigation in the middle and upper reaches

protection of these areas has yet to be demonstrated.

- The width of the LGC is only about 3 km at Qiala and therefore it is unlikely to protect upstream areas by itself, but is much broader taking into account Aksupu Swamp between the Kongque and Tarim Rivers. Protection is via the mechanisms cited in the comments for the preceding function. Hence, Aksupu Swamp, which is fed by both the Kongque & Tarim Rivers, is a critical feature. However, management proposals to date have not considered protection of the source and frequency of its joint water supply, nor the swamp's role in halting desert expansion.
  - If the irrigated State Farm areas were to be abandoned, there may be additional impacts caused by polluted dust containing pesticide residues used on the farm land.
  - The highway and telephone line are the only two infrastructure. They are little used beyond State Farm 35 because there are now few people there. The technology is well developed to stabilise sand dunes using cut reeds, as is already done along the highway and the Desert Highway. The deciding factor will be the cost efficiency of such methods verses the cost efficiency of using water.
  - No data or conceptual models exist to objectively determine the likelihood of the LGC significantly contributing to the source of dust and sand if it degrades further. As there are much greater adjacent areas of unvegetated desert and degraded rangeland adjacent to Korla, the issue needs a holistic analysis and explicit consideration of sources relative to areas affected, the role of the GC in removing dust and sand, which particle sizes cause specific problems, etc.
  - Consideration also needs to be given as to whether the dominant sand dune moving winds are necessarily the same as those that create the dust storms and disastrous weather, i.e. they are not necessarily from the SE and often the storms are from the desert towards the GC.
  - Action needs to be taken on these policies by developing measurable and achievable goals, based on demonstrable processes and values, and agreed to by all stakeholders. At present the desired outcomes are not sufficiently clear to be managed towards and monitored.
  - As for '7'.
  - There is comparatively more of this species and riverine forest habitat, which has a wide range in the TB, than other more restricted habitats, such as wetlands and floodplain lakes. Overall habitat protection priorities need to be assessed. The issue with regard to PD is more of habitat quality as most areas throughout the GC are
5. Maintain the transport and communication corridor in the LGC
  6. Reduce the occurrence of dust storms and "disastrous" weather
  7. To meet the stated policies of the National Peoples' Congress to "save the LGC"
  8. To meet the stated policies of the Xinjiang Peoples' Congress to "save the LGC"
  9. Maintain the area of *Populus diversifolia* (PD)

- suffering reductions in flooding frequency and/or duration.
10. Provision of habitat for important and/or rare species
    - Whilst the LGC is not unique, it did and does have important habitat for rare species, as does the GC upstream. It also contributed about ¼ of the total area of GC prior to degradation. Therefore it is important to maintain and restore as much as is possible, without compromising the maintenance of the GC in upstream reaches, where such targets may be more easily met and may more easily serve both commercial and non-commercial values.
  11. Provision of a link between wet habitats in northern and southern Xinjiang and Tibet, and places further north and south
    - Many species using riverine habitats are highly mobile or migratory, particularly in arid environments where droughts can decimate populations and recolonisation and migration are important mechanisms for species survival. Such species include fish and waterbirds, the latter including species that are included in the China Australia Migratory Bird Agreement (CAMBA) and the Ramsar Agreement on Internationally Significant Wetlands. Between the eastern side of the Gobi Desert to the Hotan River in the west, the TR provided the only link between the south of China and the north; that link is now broken.
  12. Maintenance of the lake and wetland habitat of Taitema Lake
    - The dry condition of this lake over the past 20 years is due to lack of flows from both the Tarim and Qarqan Rivers. The relative contributions need to be established, as the Qarqan River being shorter and having double the slope could, in principle, supply water far more effectively than the TR. It could be an important low altitude habitat for migrating waterbirds in early spring/late autumn.

The functions listed in Table 4 need to be explicitly considered in any future management decision to rehabilitate the LGC. The extent to which these functions need to be rehabilitated will be the goals against which the success of management actions can be tested.

## **5. WHAT CAN BE DONE TO SAVE THE LOWER GREEN CORRIDOR?**

### **5.1 WATER ALLOCATIONS**

The Tarim Basin Water Resources Commission (TBWRC) has recently determined irrigation allocations, which are designed to achieve the average annual flows in the river recorded in Table 3. These are normally referred to as “allocations”, but there is no formal mechanism to ensure that these flow volumes are met in any one year. In actual fact, the river “allocations” are targets that are generally reviewed after each year. Only in years where the inflows are very obviously less than normal, is the TBWRC’s Executive Committee convened to determine the amount by which irrigation quotas should be reduced to meet the river allocations. The lack of real-time data dissemination on river flows between agencies and Prefectures, appears to be a significant impediment to the early identification of flow shortages. In above average years, the Tarim River should receive “bonus” flows as the rules

stipulate that additional irrigation should not be undertaken in these years. There is some anecdotal evidence that extra water use does occur, but to what extent is not known.

**Table 5: Annual Tarim Basin water “allocations” ( $10^9 \text{ m}^3$ )**

Sub-basin	Average Annual Catchment Run-off***	Irrigation Allocation	Actual Water Allocation	Water Agreement Allocation
Kaidu-Konque	3.58	N/A	0.15 0.20*	<b>0.15</b> <b>0.25*</b>
Aksu	8.04	4.550	2.9	<b>3.3</b>
Kashgar	4.58	N/A		
Yenqing (Yarkant)	7.28	6.776	0.1	<b>0.3</b>
Hotan	4.37	2.520	1.2	<b>1.0</b>
Weigan	3.40	N/A	Nil	<b>Nil</b>
Tarim River Main-stem	irrigation drainage only	1.25	4.35 at Aler	<b>4.75 at Aler</b>
Tarim R. downstream of Daxihaizi	Nil	Nil	Nil	<b>0.3**</b>
<b>Total:</b>	<b>24.88</b>	<b>15.096</b>	<b>4.35</b>	<b>4.75</b>

Source: Working Paper 1: Tarim River Basin Water Resources Management - Table 1-1 and “The Water Volume Allocations for each County” A draft report by the TBWRC Executive Office January, 1999.

\* These figures provided by the TMB. Other sources quote various figures as low as 0.15 for the actual average flows diverted

\*\* This amount is to be supplied from savings in irrigation water use efficiencies and reduced river losses through implementation of TB II

\*\*\* These volumes from “Tarim River Surface Runoff Volume Sources”, Aug. 1998 Exec. Office TBWRC

Note: The diversions from the Kongque River are purchased and are therefore not “allocations” as such

The water allocations nominally require  $0.3 \times 10^9 \text{ m}^3$  to be provided to the LGC, downstream of Daxihaizi Reservoir. All estimates supplied to the TA regarding the amount of water required to “save” the LGC are equal to or less than this amount.

## 5.2 WHAT AMOUNT OF THE LOWER GREEN CORRIDOR CAN BE SAVED?

### 5.2.1 PREVIOUS ESTIMATES

It stands to reason that if the objective is to “save” the LGC in all its original extent and diversity, then almost all upstream water use would need to cease to restore the original river flows. There is no “free lunch” and only limited water use efficiencies can be imposed on natural systems before they are not natural systems with a high degree of diversity, but are managed plantations and irrigated grasslands. Complete restoration clearly can not be achieved as it is not possible to reduce human water use by the amounts required.

This fact needs to be explicitly recognised by all stakeholders. Consequently, all estimates that have been made to date, being much less than the natural average volumes, can only ever achieve partial restoration, in terms of extent and/or quality.

Various estimates of the amount of water required to “save” the LGC were supplied to the TA. Three estimates provided at the LGC Workshop and mentioned during various other interviews, were 120, 150 and 300 million  $\text{m}^3$ . The later figure is supported by being the

nominated allocation in the recently agreed water allocation agreement between the Prefectures<sup>7</sup>. Apparently the smaller figure of  $120 \times 10^6 \text{ m}^3$  is the most recent estimate (no source or basis supplied) and the  $300 \times 10^6 \text{ m}^3$  the older estimate.

It is useful to compare these volumes to the likely original average flow past Qiala, although an accurate figure is far from possible, due to lack of data. The analysis in Working Paper 5 indicates that up to  $1.9 \times 10^9 \text{ m}^3$  may have been the natural average annual flow to maintain the LGC ecosystems.

### 5.2.2 REVIEW OF EXISTING ESTIMATES

One source of empirical information suggests that each hectare of GC on average requires about  $4,500 \text{ m}^3$  per annum to stay in a viable condition<sup>8</sup>; grasslands might require less and poplar diversifolia more (about  $4,800$  to  $6,000 \text{ m}^3/\text{ha}$  for bare survival and  $9,750 \text{ m}^3/\text{ha}$  for good timber, Xu De Yan pers com). These volumes are average annual amounts, they do not have to be applied every year. In fact, the ecosystem has evolved on the basis of periodic floods interspersed with varying numbers of smaller annual flows. It is a situation in which the return periods of larger floods are as critical to ecosystem extent and condition, as are the intervening smaller flows. Hence, there is a need to analyse flood frequency and flow percentiles in addition to annual average flows (see Working Paper 3).

Method 2 in Table 6 compares the area that could be restored to a relatively natural condition, using the above average unit area requirement, to other empirically derived unit area estimates. Larger areas would of course be partially restored by the downstream movement of groundwater from these watered areas.

**Table 6: Area Of Lower Green Corridor that could be "saved"**

		Annual Average Water Allocation				
		Scenario*: (Million m3)	A 1004	B 300	D 120	C 150
Method		Area of LGC (ha)				
1	Area = annual average allocation/4,800 m <sup>3</sup> /ha/yr	209,167	<b>62,500</b>	<b>13%</b>	25,000	31,250
2	Area = annual average allocation/4,500 m <sup>3</sup> /ha/yr	223,111	<b>66,667</b>	<b>14%</b>	26,667	33,333
3a	Area = annual average allocation/2,600 m <sup>3</sup> /ha/yr	386,154	<b>115,385</b>	<b>24%</b>	46,154	57,692
3b	Area = annual average allocation/3,500 m <sup>3</sup> /ha/yr	286,857	<b>85,714</b>	<b>18%</b>	34,286	42,857
4	Area = annual average allocation/9,750 m <sup>3</sup> /ha/yr	102,974	<b>30,769</b>	<b>6%</b>	12,308	15,385

**Note:** Original area of LGC Forest & Grassland downstream of Qiala: 480,000

<sup>7</sup> The "Second Standing Committee for the Tarim River Prefecture Water Use" held in January, 1999 – a committee of the Tarim Basin Water Resources Commission.

<sup>8</sup> This figure was derived from the division of the total area of GC (as calculated by the TMB from the "Map of the Landscape of the Tarim River Drainage Area", referenced in the reference section), divided by the natural average annual flow (as estimated in Cheng Qichou, 1993).

% = percent of the LGC area downstream of Qiala (flows are downstream of Daxihaizi)

\* As defined in Section 4.1.3, Table 2

<b>NOTES:</b>	<b>Method 1:</b> The Xinjiang Forestry Bureau quoted 4,800 - 6,000 m <sup>3</sup> /ha/yr as being the minimum for PD survival.
	<b>Method 2:</b> The figure of 4,500 m <sup>3</sup> /ha/yr was derived by dividing the estimate of the natural average flow at Aler by the total area of GC downstream of Aler, measured from the "Map of the Landscape of the Tarim River Drainage Area" 1995.
	<b>Method 3a:</b> This average use figure is based on the area of LGC forest (200,000 ha) & grassland (280,000 ha) with average use rates of 3000 m <sup>3</sup> /yr and 800 m <sup>3</sup> /yr respectively (grassland is assumed to only need inundation every 5 years) plus 200 mm/mth evaporation x 1 mth, as per the Groundwater Specialist's assumptions in Working Paper 5.
	<b>Method 3b:</b> Same as 3a, but assuming grassland inundation every 2 years on average.
	<b>Method 4:</b> The Xinjiang Forestry Bureau Research Institute quoted 9,750 m <sup>3</sup> /ha/yr as being required for good tree health for timber.
	<b>Note:</b> All methods also require an initial groundwater recharge volume to raise groundwater levels to within 6 m of the surface. This would be about 1.5 x10 <sup>9</sup> m <sup>3</sup> for the whole of the original LGC area (and proportionally less for each of the above scenarios, depending on the percentage of area restorable.

Scenario B has been highlighted because of its endorsement in the water allocation agreement discussed above. It is also the largest volume that is likely to be made available within the current socio-economic and political framework, as indicated by the successive reductions in estimates since that volume was first proposed.

If an annual average allocation of 300 x 10<sup>9</sup> m<sup>3</sup> is supplied, the area that can be restored, assuming 4,500 m<sup>3</sup>/ha/yr, is 66,667 ha, or 14% of the original area of the LGC downstream of Qiala. Using the other empirical estimates of unit area water requirements gives restorable areas ranging from 6% to 24% of the LGC area below Qiala, however, as Method 4 is based on timber quality tree production levels, the lowest area that is likely to be restored is 62,500 ha, or 13% of the original area.

To these areas must be added the area between Qiala and Daxihaizi that is already being maintained by irrigations flows to some extent, albeit in a somewhat degraded condition. Hence the actual proportion of the LGC that is restorable is greater than the percentages shown in Table 6, but can not be calculated at present as the areas of the LGC "upstream Daxihaizi" verses "downstream Daxihaizi" were not available.

In addition to the on-going average annual requirements, an initial "wetting up" period will be required to recharge the depleted groundwater aquifers (see Working Paper 5). Consequently, Method 2 for instance would also require an initial groundwater recharge volume of about 2.1 x10<sup>8</sup> m<sup>3</sup> to raise groundwater levels to within 6 m of the surface, i.e. 14% of 1.5 x10<sup>9</sup> m<sup>3</sup>.

It is not possible to accurately predict the distribution or geographic extent of this restoration with current data. Most benefits would be realised upstream of Yinsu, with progressively fewer functions being restored between there and Alegan. In all cases, except Scenario A which replicates 1950's conditions, only limited restoration would be achieved downstream of Alegan and there would be little benefit at Taitema Lake. Assuming Method 2, Scenario A

would restore about half or more of the LGC area (taking into account the existing partially maintained area upstream of Daxihaizi).

It is possible to increase and manage which areas of the LGC receive benefit from these volumes through the construction of works in the Tarim River channel, flood runners and on the floodplain. These works would be strategically located and designed to spread and/or retain the water without having to achieve high discharge rates. The extent to which this is possible and desirable, needs to be determined in the next phase of decision making. It is important to recognise, however, that there remains “no free lunch” and that such measures are limited in their ability to reduce the unit volume of water required per unit area. This is because of fundamental physical laws governing the inseparable flow of water and salt. Salinisation of land is a major limiting factor in reducing unit area water volumes. A flushing component is required to prevent near surface salt accumulation and shallow lateral translocation of salt that impacts on adjacent areas.

There is also a trade-off. Such structures will slow the passage of water down the LGC. This can occur to the extent that water use efficiencies actually decrease. There are secondary problems. These include salt accumulation, impediments to fish passage and homogenisation of the natural variety and consequently, biodiversity of the LGC. That is, unless carefully balanced these trade-offs can begin to defeat the original purpose of the works, at least with respect to some of the functions documented in Table 4. There is also an increasing construction, operation and maintenance cost the more extensive and complex such structures become.

### **5.3 WHERE CAN THE WATER BE SUPPLIED FROM?**

#### **5.3.1 REVIEW OF PRIORITIES AND REHABILITATION EFFICIENCIES**

Assuming that the current water allocations are endorsed and strengthened through additional management measures, begs the question “From where can these volumes of water be supplied and at what cost?” The cost with respect to the socio-economic values, has been answered above. It remains to ask, “what is the best thing to do ecologically”?

Prior to assuming that action is required in the LGC, it is pertinent to look at the GC as whole, to check that the proposed use of resources to save the LGC are indeed best utilised there.

The conclusion noted in Section 5.1, that the LGC’s habitat and ecosystems are largely non-unique, means that substitution is possible in principle, i.e. it is possible to rehabilitate GC habitat upstream of Qiala, in the upper and middle reaches of the Tarim River, in preference to rehabilitating LGC habitat, which because of transmission losses, can be considered to be a more “expensive” user of water. However, it must be remembered that most of these “losses” are in fact benefiting ecosystems in the upper and middle GCs as the flows pass through. Not even the “non-beneficial evaporation” (NBE) can be considered a true loss because of the following factors.

Firstly, surface flooding is almost certainly the major groundwater recharge mechanism and the longer the duration, the greater the recharge, hence ponded areas provide a long duration. It is clear from the continuing presence of shallow groundwaters in the vicinity of Aksupu Swamp and between Qiala and Daxihaizi, that groundwater moves long distances laterally once recharged, benefiting the vegetated areas of the GC, including the LGC. Secondly, evaporation from ponded areas is a non-reducible consequence of open water bodies, and such water bodies are an absolute necessity for many species. The identification of the entire

volume of non-draining swamps or other depressions, as “losses” is to disregard the importance of these areas to fish, waterbirds, flora and other wildlife.

### 5.3.2 POTENTIAL SOURCES

The commercial cost analysis in Section 4.1.3 provides estimates of the opportunity cost of supplying different average annual volumes to the LGC from a number of potential sources. The option discussed in detail was the supply of  $300 \times 10^6 \text{ m}^3$  as defined in the recent TR Water Allocation Agreement.

As discussed in Section 4.1.3 (Table 2), more water could be supplied to the LGC by:

1. Increasing the amount of water diverted from the Kongque River via Kuta Main Canal;
2. Reducing the amount of water used in upstream of Aler in the TR’s tributaries;
3. Reducing the amount of water used in the Aler to Yinbazar reach of the Tarim River;
4. Reducing the amount of water used in the Yinbazar to Qiala reach of the Tarim River; and/or,
5. Reducing the amount of water used in the Qiala to Daxihaizi reach of the Tarim River;

The first four options require that less water be used upstream of the LGC. The fifth requires that more water be made available for the environment from sources within the LGC. The first option requires that this water use saving be achieved to a large extent upstream of Bosten Lake in the Kaidu River system, as otherwise salinity levels will rise to unacceptable levels for users downstream of the lake, particularly for human consumption, including Korla city. Presently, the lower salinity water from the Kaidu - Kongque system is used to mix with Tarim River water to obtain salinity concentrations that are less damaging to plant growth. Even so, the salinity is still too high for most of the year (i.e.  $> 1 \text{ g/l}$ ) to meet health criteria for human consumption.

The second option is not part of the TB II project and is therefore unlikely to be achieved. In fact there have been recent moves to increase Aksu Prefecture’s irrigation water allocation. The third and fourth sources require a reduction in either non-beneficial evaporation (NBE) and/or an increase in irrigation water use efficiency, including canal efficiencies. Measures to address both aspects are part of TB II and therefore this is a viable source.

Section 5.1 briefly discussed the issue of the 150 km of embankments proposed along the middle GC as part of TB II. They are intended to augment the eight proposed off-take regulators in the upper and middle GCs. Both measures are designed to reduce NBE. The regulators have the potential to achieve the objective without a high likelihood of reduced GC health in the upper and middle GCs, if managed in accordance with known environmental needs in those areas. The effect of the embankments, however, will be to reduce flood frequency over the floodplain below natural levels. As there has already been a large reduction in overbank flows caused by upstream water use, the effect of the embankments will be to compound this reduction in flooding.

The fifth option effectively requires a decrease in NBE associated with irrigation and non-commercial uses. It could also be achieved through the re-allocation of water between irrigation and non-commercial uses, so that more water goes to the environment with no increase in efficiencies. As with the upstream areas, there is physically scope to improve water use efficiencies with the institution of management and structural measures, but as the State Farms are excluded from TB II, this is not likely to be achieved. In effect, by excluding State Farms from TB II any measures to reallocate more water to the environment, will benefit



them. State Farms should not be treated any differently from any other irrigation area. To do so creates distortions and inequities, both for the State Farm people and others. In particular, it creates yet another layer of secrecy about data and makes it all the more difficult for agencies like the TMB to manage the river based on accurate and timely data.

There is no question that the single most important measure that can be used to source larger volumes of water to the LGC in a sustained manner, is the determination and implementation of firm average annual water allocations between the Prefectures. These must be defined in such a way that:

1. All stakeholders, particularly the Prefectures and Counties, understand and agree to abide by the allocation principles;
2. They are measurable in real time so that water use adjustments can be made to protect flows immediately;
3. The real time decisions can be audited within a short time of the end of the water year to assess compliance and correct any problems with the involvement of all stakeholders;
4. They reflect the natural annual and intra-annual flow variability that existed prior to large scale water use;
5. They take account of natural water losses in each reach of the TR; and,
6. They can be adjusted to allow for changing circumstances and information on the condition of the GC in all reaches, upper, middle and lower, gathered through on-going monitoring.

The second most important measure in sourcing water, is to prevent the illegal or quasi-legal reclamation of land for irrigation which is still occurring. This would be best done by altering the funding arrangements of some County and Prefecture level agencies, such that they do not gain such significant financial benefits through land reclamation fees, land management fees and water management fees. In part it has been addressed by the recent decision requiring all approvals to be forwarded to the relevant Prefecture agencies for endorsement. However, such is the level of over use of water in the TB, that all water use should be capped and new developments required to buy allocations from existing users. Such transferability of allocations should include a substantial percentage reduction in volume, to regain some water for the environment, as there is ample evidence that the whole river system is significantly stressed by water shortage and the attendant increase in water and land salinisation.

## **6. MONITORING FRAMEWORK**

### **6.1 KEY ISSUES AND CONCEPTUAL MODEL DEVELOPMENT**

The need for three conceptual models was raised in Section 2.4. This monitoring framework is based on the type of preliminary conceptual system diagrams shown in Figure 5. These diagrams can be developed further, to collectively become the “Natural Processes” conceptual model which would address the hydrologic, ecologic and geomorphic interrelationships.

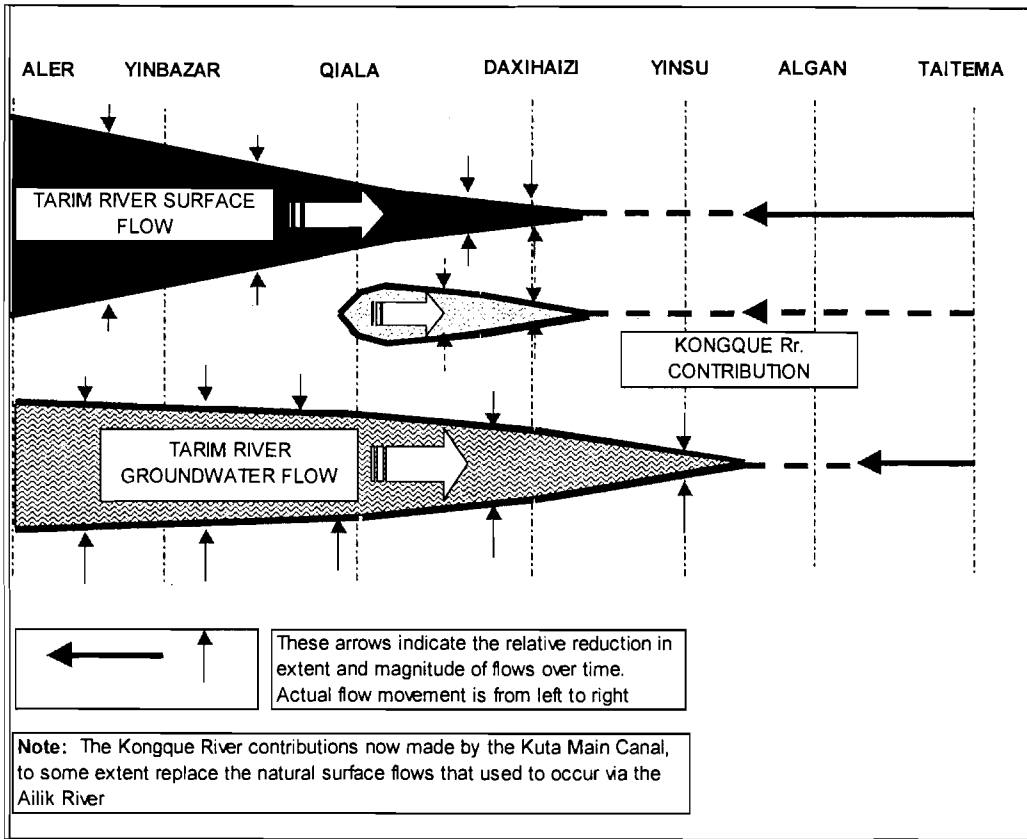


Figure 5a: “Napoleon March Diagram” of surface and groundwater flows

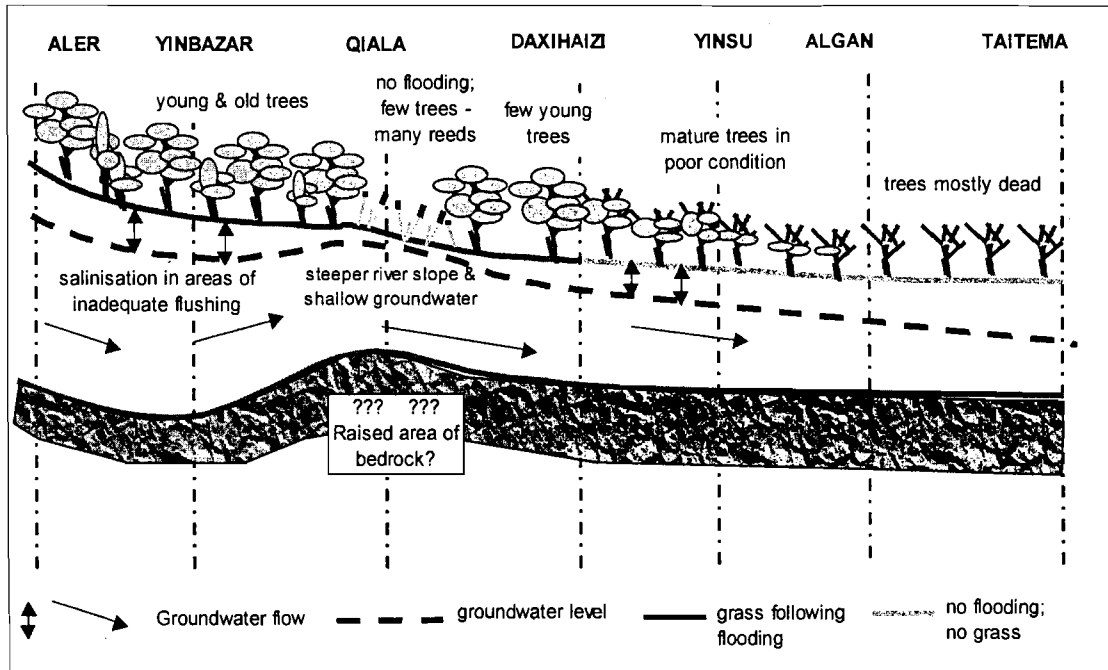
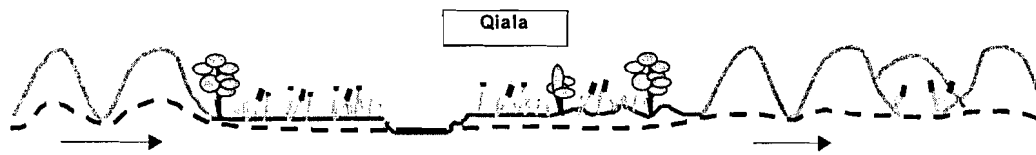
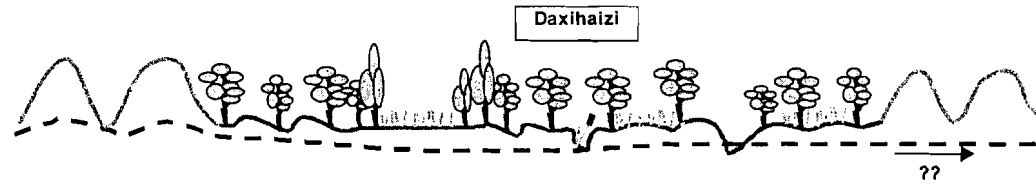


Figure 5b: Schematic long-section of key GC features



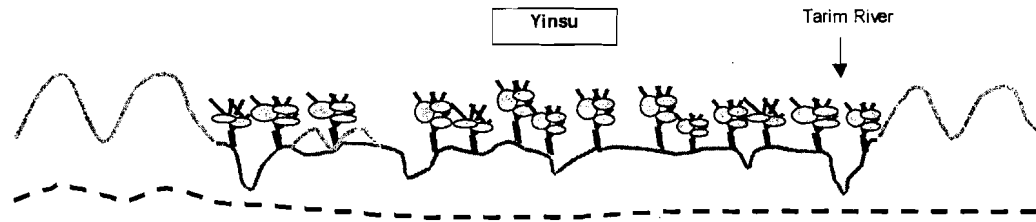
**Qiala**

**Key Features:** shallow groundwater, little flooding, coarse sandy soils, moderate cover of reeds, red willow, other shrubs, few trees, apparently steeper longitudinal river slope, lateral input of groundwater from Aksupu Swamp and Qiala Reservoir, salt lakes extending into dunes - some solely groundwater fed, river capacity about 75 m<sup>3</sup>/s



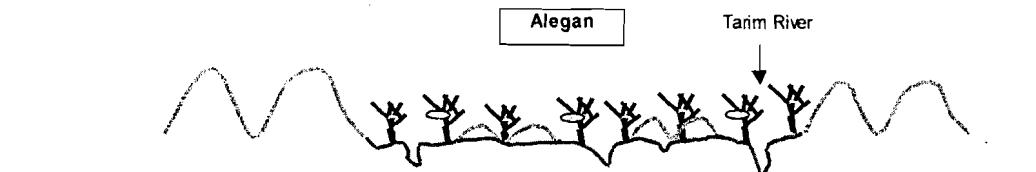
**Daxihaizi**

**Key Features:** deeper groundwater, some flooding, finer sandy soils with higher clay content, some flood channels including the Nar Shan River, healthy mature trees, few young trees, flatter longitudinal river slope, lateral loss of groundwater to Taklimakan Desert, floodplain topography more variable, irrigated State Farms, planted grey poplar windbreaks



**Yinsu**

**Key Features:** groundwater > 10 m deep, no flooding or river flows, many dry flood channels, highly variable floodplain surface, dying mature trees, no young trees, no grass, temporary occupation by a few herder families only, no irrigation, some sand dune invasion and wind erosion of floodplain sediments



**Alegan**

**Key Features:** groundwater > 10 m deep, no flooding or river flows, narrower floodplain, narrow river channel, some (dry) flood channels, highly variable floodplain surface, mobile sand dunes invading floodplain, almost all trees dead, no grass, no habitation or use

Figure 5c: Schematic cross-sections of key GC features

Figure 5: Component system diagrams for the “Natural Processes” Conceptual Model

## **6.2 GEOMORPHIC PARAMETERS**

### **6.2.1 KEY ISSUES**

1. River channel erosion and sedimentation.
2. Maintenance of important physical floodplain features, including wetlands and flood channels.
3. Stability of desert sediments adjacent to the GC.
4. Assessment of the causes and mitigating factors related to dust and sand storms.

There is currently no bedload movement monitoring and little coordination between agencies to integrate the findings of what data is collected (see the comments in the water quality section below). There is a need to develop conceptual models of the way in which river flows, groundwater and floodplain flows contribute to the maintenance of the GC. Current hypotheses require refinement for monitoring to be able to enumerate the links suggested above. There is little river channel erosion in the LGC, however, there is substantial erosion in upstream reaches and the major tributaries. It is from these sources that the cascade of temporary sediment stores derive their material. The changes in supply, transport and deposition, brought about by human activities requires a more integrated development of system diagrams and eventually, conceptual models, of how the whole process works.

### **6.2.2 MONITORING FRAMEWORK**

1. Determine locations and scale of erosion. Utilise remote sensing to determine lateral movement of the river channel at benchmark locations from Aler to Alegan.
2. Conduct studies to determine the scale and frequency of alluvial sediment movement, including suspended and bedload sediment transport in the river and floodplain deposition. Field studies are required to determine the type of sediments being eroded, including particle size characteristics, the geomorphic features being eroded and the rate of erosion relative to likely natural rates. These studies need to be integrated with the hydrologic assessment.
3. Assess the role of channel formation by meandering verses channel avulsion (i.e. sudden changes in channel location) in creating floodplain features, including flood channels and wetlands.
4. Determine the role of fluvial verses aeolian processes in shaping the TR floodplain in each reach. Reduced river flows and flooding lead to increasing movement of sand in and adjacent to the GC. Dune stability adjacent to the GC will need to be assessed with respect to the stabilising effects of semi-arid vegetation dependent on groundwater. Transport of aeolian material deposited on the floodplain requires study through stratigraphic examination of floodplain sediments, as well as entrainment/burial studies conducted during current floods to determine the extent of reworking of aeolian sediments.
5. Monitor sand and dust storms at benchmark locations. Parameters should include wind direction and strength during and prior to each event, prevailing weather patterns, time of year, vegetation cover/condition in the upwind direction and at the monitoring site, alkalinity and particle size distribution of the sediments, chemical pollutants, effects in terms of crops, livestock, human health, roads, other infrastructure and human activities.

## **6.3 HYDROLOGIC PARAMETERS**

### **6.3.1 SURFACE WATER**

#### **6.3.1.1 Key Issues**

1. Access and use of existing historical data sets.
2. Data requirements for the LGC if flows are re-instated.
3. Analysis and integration of monitoring into real-time decision making.
4. Monitoring of flow breakouts and irrigation diversions.

#### **6.3.1.2 Monitoring Framework**

1. Existing data collected at Aler, Xinqiman and other National level stations need to be made available in real-time to the TMB and to all relevant Prefecture agencies. Currently those data can not be considered to be part of the monitoring network as they are not made available at the time of recording, even in preliminary form, and the archived data is not capable of being used, even by the TMB, without referral and payment to the relevant department. Daily flow data should be available daily.
2. All existing gauging stations would benefit from a review of the data collection procedures including the lateral extent of high flow gauging, calculation of rating curves, conversion of stage heights to discharges, data storage and labelling. The use of river flow data as a basic input to many other analyses places greater emphasis on data assurance for this parameter.
3. There are no gauging stations downstream of Qiala. The reinstatement of flows will require flows to be monitored at Yinsu, Alegan and Taitema. Gauging stations will need to be established at those locations, with the exception of the later if flows are only targeted to Alegan.
4. Flows are to be determined for all occasions that water quality samples are taken for the calculation of loads and for correlation with discharge rates.
5. Existing information on diversions for irrigation and pasture need to be upgraded by accurate monitoring of all significant diversions. These data should be made available to the TMB within 6 months of the event. Periodic gauging of all major breakouts is also needed to confirm the location and scale of river "losses".
6. Return irrigation drainage flows and any other return flows to the TR should be monitored.
7. All data should be either daily, or capable of being disaggregated to daily flows by recording homogenous periods. The actual dates on which conditions change should be recorded in the raw data.

### **6.3.2 SURFACE WATER QUALITY**

#### **6.3.2.1 Key Issues**

1. Increasing salinity levels particularly in spring.
2. High levels of suspended sediment.
3. Potential eutrophication.
4. Lack of coordination and access to data.

5. Poor data labelling, including lack of dates and definition of terms.

Water quality monitoring in the Tarim Basin appears to be fragmented. It is possibly done at infrequent intervals by different agencies, with little exchange of data between them. Consequently, the value of any such monitoring for management on a basin wide perspective is limited. The first recommendation would therefore be to address this, and centralise all monitoring under the control of one lead body, such as the TBWRC, which should be responsible for coordinating Basin-wide data collection and management. The actual monitoring should be conducted by existing agencies, within a coordinated holistic framework provided by the TMWRC. The coordination would include the prescription of sampling and analysis methods, frequency, data archiving formats and protocols, data quality coding (indicating for example compromised data or estimated data), data sharing procedures and reporting.

Secondly, the objectives of the monitoring program would need to be clearly defined, and the monitoring program tailored around these objectives. A primary object would be to minimise the impacts of salinity/mineralisation on the water quality of the Tarim River, and of its major tributaries. However, other potential water quality problems such as sediment load and eutrophication should not be ignored.

Thirdly, a water quality monitoring program will need to meet the resource management needs of the basin. This should come through the setting of objectives, where the level of water quality protection required will also need to be defined. This level may include protecting the environmental quality of the surface water, protecting irrigation water quality, or protecting a raw drinking water source for humans and animals, or for industrial or domestic use.

### **6.3.2.2 Monitoring Framework**

The following are two sampling monitoring programs, one detailed, the other more fundamental, for consideration to meet future water quality needs, as appropriate. They are based on the water quality monitoring program undertaken on the Murray-Darling system in Australia by the Murray Darling Basin Commission. A systems diagram of the Tarim River and the proposed monitoring network is presented in Working Paper 4.

#### **1. Detailed Program:**

This program is based on the water quality monitoring program of the Murray Darling basin Commission, superimposed on the Tarim Basin.

**Sampling Sites.** Sampling sites should be located along the mainstream of the Tarim River and on all tributary streams, both upstream of irrigation areas, and downstream. It may also be necessary to establish monitoring points on the major irrigation drainage channels leading out of the irrigation areas and discharging back into the Tarim River or its major tributaries. These points will not only give an indication of the suitability of the water entering various sections of the Tarim River and its tributaries for irrigation and other human use, and for environmental protection, but also the downstream monitoring will give an indication of any impacts on water quality caused by activities within these areas. Coupling water quality results with river flow data will allow the calculation of loads of pollutants entering and leaving various parts of the river system. Suggested sites are:

1. The mainstream Tarim River sites should include Aler, Xinqiman, Yinbazar, and Qiala. Another site further downstream at Alegan is suggested, to monitor the water quality of environmental releases for the lower "Green Corridor".

2. The Hotan River sites should include Uruluwati and Tongguziluke, located on the two major branches of the Hotan upstream of the irrigation area, and Xiao Ta, on the Hotan just upstream of its discharge point to the Tarim River.
3. There should be at least two sites on the Yenqing River, one upstream of the irrigation areas, and one just prior to its discharge point to the Tarim River.
4. The Aksu River has two major branches upstream of the irrigation area. The existing hydrographic monitoring stations on each of these branches, at Shuliguilanke and Shihelu should also be used as water quality monitoring stations. The site on the lower Aksu River is still within the irrigation area of this river. Another site further downstream, closer to the Aksu's junction with the Tarim, so that the majority of the irrigation areas are upstream, would be preferred if possible. Drainage waters from the Aksu irrigation area will require monitoring, as these are discharged back to the river.
5. Monitoring sites on the Kashgar and Weigan Rivers would be of benefit, even though these rivers do not contribute surface water flows to the Tarim. Monitoring of irrigation drainage returns from the Weigan irrigation area that flow to the Tarim River need to be monitored.
6. A monitoring point on the Konque River at Yuli or Puhui, or another location upstream from where diversions to Qiala Reservoir occur, should also be included in the monitoring program.

**Parameters to measure.** The parameters to measure should focus on those known to cause water quality problems in the river system, are considered likely to have an impact, such as mineralisation and suspended solids. However those indicative of the overall ecological health of the river system such as pH or dissolved oxygen should also be included. Suggested parameters include:

Of primary importance (Class 1), pH, salinity/mineralisation/electrical conductivity (one of these 3 parameters is sufficient), turbidity, and temperature. Most of these could be measured in the field, *in situ*, if the appropriate field instrumentation, backup support and training were provided.

Additionally important parameters (Class 2) would include nitrate, total nitrogen, total phosphorus, suspended solids, COD and BOD<sub>5</sub>.

Class 3 parameters would include the major cations and anions, in particular sodium, magnesium, calcium, chloride, sulphate and bicarbonate.

**Sampling Frequency.** Class 1 parameters could be measured weekly, especially if measured *in situ* in the field. However fortnightly may be sufficient if samples have to be delivered to a laboratory for analyses. Class 2 and Class 3 parameters should be sampled monthly.

## 2. Basic Program

This program suggests a basic sampling program to meet the resource management and environmental protection needs of the Tarim Basin, but acknowledging the budgetary and other constraints under which the resource management agencies must work.

**Sampling sites.** Sampling sites should include Aler, Xinqiman, Yinbazar and Qiala along the mainstream Tarim River, and sites on the Hotan, Yenqing and Aksu Rivers just upstream of their confluence with the Aksu. Major irrigation drainage outfalls should be monitored close to where they discharge to the rivers. The diversion between the Konque River and Qiala Reservoir should also be monitored.

**Parameters to measure.** Salinity/mineralisation is of major importance. Other parameters that will provide basic coverage of the water quality in the mainstream Tarim River include pH, suspended solids, total nitrogen, total phosphorus, dissolved oxygen, COD, sulphate and chloride. Nitrate could also be measured. These parameters provide sufficient coverage of the water quality to be able to assess compliance with both the Chinese environmental quality standard for surface water (GB 3838-88), and irrigation water quality (GB 5084-92).

**Sampling frequency.** Neither of the two Chinese water quality standards (environmental quality or irrigation quality) specify a sampling frequency. However Point 2.1 of the environmental quality standard does stipulate “it is not allowed to employ the single instantaneous monitoring value when using this standard”. Therefore a routine monitoring frequency is necessary. The minimal monitoring frequency suggested for salinity/mineralisation assessment would be monthly, although this could be carried out more frequently if dependable in-the-field monitoring can be achieved. The other parameters that require laboratory analyses should be monitored preferably monthly, but at quarterly intervals at the very minimum. A more frequent sampling frequency may be considered necessary at high priority locations such as Aler, and during certain periods of the year, such as just prior to and throughout the irrigation period.

### 6.3.3 SOIL AND GROUNDWATER PARAMETERS

#### 6.3.3.1 *Key Issues*

1. Salinisation of land within irrigation areas and natural areas of the GC.
2. Declining groundwater levels throughout the GC, but particularly, the LGC downstream of Daxihaizi.
3. Increasing groundwater salinity in all areas and particularly near irrigation areas.
4. Lack of knowledge about groundwater recharge rates, lateral flow rates and discharge rates/areas.

#### 6.3.3.2 *Monitoring Framework*

1. Groundwater monitoring piezometers should be installed within and adjacent to all irrigation areas. Additional piezometers should be installed at representative locations along surveyed cross-sections across the entire floodplain. There should be at least three cross-sections in each reach, i.e. Qiala to Daxihaizi, Daxihaizi to Yinsu, Yinsu to Alegan and Alegan to Taitema Lake preferably coincident in timing and location to sites where surface water is monitored.
2. Water levels should be monitored every 3 months for 2 years to determine seasonal variations, then twice a year after that before and after the summer flood. Water quality samples should be taken on one occasion in the first year and analysed for TDS, pH, major ions, alkalinity, mineralisation (as defined by Xinjiang agencies for comparison to historical river data). The same parameters should be analysed each year for selected sites. Dates are to be recorded for all sampling. Ongoing measurement of salinity should be conducted using calibrated field equipment.
3. Pump tests should be conducted on a number of new monitoring bores sunk to at least 20 m. One monitoring bore in each of the Qiala to Daxihaizi and Daxihaizi to Yinsu reaches would be required to give some idea of geophysical conditions (single or multiple aquifers) and transmissivities. Full particle size analyses should be conducted on samples from each strata taken during the bore drilling.



4. Surface salinisation should be monitored using satellite imagery and ground verification. The area of salinisation should be calculated for each year for each reach, using pre-flood imagery, unless other seasons prove more reliable. For instance, vegetation stress indices may be able to be developed that reflect salinity levels rather than moisture stress, to augment mapping of bare soil salinisation. Salinisation maps/images (complete with dates, methodology, etc) need to be made available to all relevant stakeholders, not just the enumerated figures for each reach, as the location of such areas relative to irrigation and other areas, is critical to determining their importance in terms of cause and effect.

## **6.4 ECOLOGICAL PARAMETERS**

### **6.4.1 KEY ISSUES**

#### **6.4.1.1 *Aquatic and Terrestrial Fauna***

1. There is little information on fish and other aquatic biota.
2. Fisheries based on the 3 endemic species have collapsed and those species are either extinct or nearly so.
3. There is little or no information on the aquatic ecology of the TR in relation to critical hydrologic, geomorphic and nutrient/food parameters.
4. There are no specific data on the presence and requirements of terrestrial animals and waterbirds in the LGC.

#### **6.4.1.2 *Green Corridor Vegetation Condition***

1. The condition of the LGC is severely degraded, but not quantified for management goal setting.
2. The relationships between the condition of the GC and human uses for grazing, firewood, herbs, shelter, windbreak/dust suppression, desert barrier, aesthetics, etc, are not established.

### **6.4.2 MONITORING FRAMEWORK**

#### **6.4.2.1 *Aquatic and Terrestrial Fauna***

1. Fish monitoring is required near each of the major hydrologic monitoring stations along the river so that all parameters can be easily analysed for establishing habitat condition. The locations should include river, wetland and backwater areas. Sampling effort should be quantified so that catch per unit effort can be defined for each species. Age class, species, sex and other biological parameters should be collected that permit catch and release. Only a small sub-sample, if any, should be killed for more information on sexual condition, etc. No specimens of endangered species should be killed.
2. Macroinvertebrate sampling should be conducted near each of the major hydrologic monitoring stations, to determine the composition of taxa (identified to family level at least) and if possible abundance (through semi-quantitative sampling techniques).
3. Monitoring of terrestrial reptile and mammal fauna is required at benchmark locations in each reach of the GC. This should be conducted using techniques specific to each type of

animal but quantified where possible in terms of search effort, by area and time, so that abundances can be ascribed and compared over time.

4. Monitoring of waterbirds is required in autumn and spring, so as to pick up migratory species. It may be possible to use volunteer assistance by international bird watching organisations. By covering their costs only, this may be a cheap and effective means of obtaining the information, whilst communicating the importance that China places on the rehabilitation of the LGC to the world. Monitoring locations should be throughout the GC. In the LGC, they should include Qiala and Daxihaizi Reservoirs, salt lakes on the periphery of the GC, wetlands, the TR, flood channels and irrigation areas. Sightings should be recorded by species, sex, time of day, date, location, habitat, breeding status, behaviour, etc.

#### **6.4.2.2 Green Corridor Vegetation Condition**

1. At present the only activity between Qiala and Daxihaizi is conducted by the State Farms. The only information that is made available on State Farm activities is provided in State Farm Year Books. This information can be difficult to access and does not report on all State Farms to the same extent each year. The study team was unable to access any information from the State Farms on the extent and condition of the GC in the Q-D reach.
2. Below Daxihaizi there are less than 100 herder households. There will be none by 2000 if current plans to relocate these households are carried out. In effect there will be no resident populations to report on and/or monitor the extent and condition of the GC downstream of Daxihaizi.
3. However, there is a need to monitor both the extent and condition of the GC in both the Q-D and D-T reaches and to assess the extent to which artificial tree planting and maintenance is being undertaken by the State Farms in the vicinity of cropping activities.

Monitoring the extent and condition of the LGC could be a costly business in the absence of a resident population and difficult to access State Farm data. It can of course be done by using satellite imagery (or aerial photography) and ground truthing. If these techniques cannot be reliably funded and sustained over several decades alternative measures should be considered.

For example, it might be possible to evolve an ongoing approach that is affordable and can be sustained using existing resources and some strategic observation points. The aim would be to observe changes in the extent and condition of the LGC and to correlate these with the presence or absence of possible causal factors. An initial hypothesis would be required that can be progressively evolved against empirical observation to provide a better understanding of how the extent and condition of the LGC actually changes in response to prevailing circumstances. To do this the monitoring might focus on:

- (a) the location of existing wells, the depth to water in these areas (or well depth if dry), and an annual check on a selected sample of these. If the wells are being used the well users could be asked to collect this information on a more regular basis.
- (b) the distance to significant sand dunes from selected and easily identified points along the road and/or major water channels of the TR system.
- (c) several (maybe 5 perhaps 10) observation areas that should be set up according to a stratified statistical design. These areas need to be marked to the extent that they can be reliably returned to in the future. Individual replicate areas might cover areas of perhaps

100 to 250 m<sup>2</sup>. In these areas a detailed documentation of all flora should be periodically made by species and condition.

The key points to take into account in setting up and monitoring these observation areas would include:

- frequency of documenting all flora should be related to the location of the observation area, the flora it contains and the incidence of events that might influence the extent and condition of the flora in each area. In some instances it may be worth documenting the area annually for a few years. In some instances it could be every two years, every five years and in some instances perhaps longer;
- choosing the season in which the flora is to be documented. In most instances this will be a season in which plant growth can be observed. At these times species, if present, are more readily found, more easily identified, the numbers present can be more accurately assessed and some assessment of the condition of each species can be made;
- locating one or two observation points close to wells;
- locating most observation areas where there are:
  - a number of species to be observed so that changes in the number and condition of the species will provide enough information to recognise and map the extent and condition of the GC and allow this to be compared with a range of possible causal factors.
  - the presence of factors that it is hypothesised might influence the extent and condition of the GC.. These factors would include; specific types of riverine geomorphology; a possibility of a river flow; the suspected presence of groundwater (even if not it is not possible to physically check its existence and depth in all instances), the presence and numbers (grazing pressure) of any human and/or livestock and/or native fauna; and evidence of sand blast and/or wind erosion;
- observation areas should be selected both along and across the GC within areas where some flora remains alive. For each area there should be an underlying hypothesis that will allow the information collected to be used to:
- define landforms and systems within the GC;
- test and further evolve initial hypotheses as to the factors that give rise to these land forms and systems; and
- eventually derive some empirical norms for sustainable GC management by landform;
- the possibility of locating some if not all of the observation areas along transects. Variations in the existence of flora and fauna by species and condition along the transect, over time could then be recorded and related to the presence of factors that are hypothesised to cause the variations observed.
- the need to periodically change the location of some observation points (close existing and open new points) and some transects. This would be done to progressively derive a better distribution of observation points relative to the types of

information about the extent and condition of the landforms that make up the LGC and .

- (d) using local knowledge, building on existing programs and employing herders who did or still live in the LGC.

For example, these herders could be used to locate the wells, record depth to water or depth of dry wells, identify appropriate observation points, possible transects, identify and count the plant populations in the observation points and pace out distance to nearest sand dunes at selected road/river channel locations. They could be trained to do this in the areas in which they are currently residing and working and be periodically transported to the LGC to make the observations required. If they were also engaged to do this in various sections of the Yinbazar to Qiala reach there would be an opportunity to develop techniques to observe and record cropping, other land uses and human and livestock areas, numbers and activities. In addition to biomass and depth to water table in the Yinbazar to Qiala reach, herders could be used to record the depth, extent, and times over which surface water may be present and where salinisation is occurring. The additional information would assist develop the hypotheses and empirical norms for better managing the GC. It would be particularly useful to better managing the LGC if and when additional water can be made available and some level of restoration starts to occur.

Evolving an on-going affordable approach to monitoring the extent and condition of the GC should be a joint effort by the Bayingol Forestry and Animal Husbandry Bureaus. It could be prepared as a free-standing project. Over a five year period it could be developed to leave a number of community watch type operations sustainably in place. The ultimate objective would be to create a resident community that would be the custodians of the environments they currently exploit and a primary source of verifiable field level data.

A project approach would provide an opportunity to fund some basic equipment and establish some initial hypotheses. It would also provide an opportunity to introduce and adapt appropriate techniques for monitoring fragile desert type environments from elsewhere in the world. These would include the need to:

- evolve appropriate conceptual models;
- define realistic measurable environmental outcomes;
- identify and use specific natural features and indicator flora and fauna species to discern improvements and/or the degradation in various land forms and habitats; and
- evolve community watch groups and auto-recording by the land users themselves, as critical elements in any attempt to devise sustainable and affordable protective or restoration programs.

## 6.5 SOCIO-ECONOMIC PARAMETERS

Total populations of people and households by gender and age should be kept and collated by hamlet and village. The utilities (water, electricity, effluent disposal), communications (road, post, telephone), social (health and education) and extension (agriculture, livestock, forestry and environmental management) services that are available at hamlet and village level need to be documented. The extent to which all of these can be physically accessed, financially

afforded by the local community according to household income, and are actually used (how often, by whom each month or quarter), needs to be assessed.

The numbers of households by annual disposable income for each of the different types of households in each hamlet and village needs to be estimated and recorded. It also needs to be expressed on a return per labour day basis.

The nutritional adequacy of local diets relative to international norms needs to be assessed. The number of households by type of household actually experiencing internationally acceptable levels of nutrition need to be determined. Methods of identifying and assisting households not experiencing these levels of nutrition, need to be devised.

The impact of prevailing policies, guidelines and directives on the incentives and disincentives that prevail at the individual household, individual investor, county, prefecture, province and regional levels need to be analysed, reported and monitored. The impact of these policies, guidelines and directives on the various organisational investors, institutes, bureaus and commissions who are, or may be in a position to influence, decision makers also needs to be analysed, reported and monitored.

## 7. CONCLUSIONS

1. The present condition of the LGC is highly degraded. The lower two thirds is largely dead, i.e. downstream of Yinsu, and all herdsmen have been moved out. There appears to be little wildlife remaining and there is no surface water a short distance downstream of Daxihaizi Reservoir at any time of the year.
2. The entire LGC, from Qiala to Taitema Lake, is not capable of being "saved" without restoring very large volumes of water on an annual basis. A minimum quantity in the order of  $300 \times 10^6 \text{ m}^3/\text{year}$  will be required to even maintain and restore the upper portions of the LGC between Qiala and Yinsu and partial restoration of the reach from there to Alegan. Groundwater is the main mechanism slowing the degradation since the last significant surface flows in 1974, but as groundwater levels have been falling, there is a large volume that needs to be made up initially, probably in the order of  $1.5 \times 10^9 \text{ m}^3$  for the whole LGC reach.
3. Anything much more than the minimum volume quoted above is unlikely to be made available in the foreseeable future given the increasing economic and population pressures in the basin.
4. The economic value of the LGC is for all practical purposes, at least equal to the value of the foregone production if the volume of water supplied to the LGC to restore it, were to be used elsewhere. Therefore the greater the volume of water used to restore the LGC the greater the value that is placed on it. **Until action is taken** the value is effectively the economic and social value of the State Farms only, with zero value for the remainder. **The socio-economic value of the LGC is currently RMB 180 million Yuan.** On an ongoing annual basis, excluding relocation costs (i.e. social costs), the economic value is RMB 11.2 million Yuan.
5. The social value is largely confined to preventing the relocation of about 30% of the 40,500 people (say a total of 2,700 household relocations) from the five State Farms if the LGC were to collapse and the only water available to State Farms was reduced to the

water that can be purchased from the Kongque River, as all herdsmen have previously been relocated or are in the process of being moved (only 50 families remain).

6. The most unique ecological value prior to degradation was the physical link to the southern regions of the basin, including the Tibetan Plateau. This link has been broken and consequently the movement of individual fish, terrestrial fauna, plant propagules (seeds, bulbs, cuttings, etc), birds and genetic flow, is now disrupted. The remaining link is the Hotan River and the semi-arid and montane areas of Kashgar to the west.
7. The actual habitat of the LGC is not significantly different to that of other areas of the green corridor along the Tarim River or its major tributaries, which in any one area is highly diverse and dynamic over short periods of geological time. Even in human life times, significant natural changes can be observed in flow paths and vegetation. Human land and water use have accelerated many of these changes and slowed others.
8. Restoring the LGC has the potential to (negatively) impact significantly on the ecological and socio-economic values of the middle Green Corridor in particular, because of the river embankments proposed in the Tarim Basin II Project, to minimise the spill of water in that reach. There are no existing studies that quantitatively assess these potential impacts.
9. The ecological value of any one area of the Green Corridor anywhere in the Tarim Basin can not be properly assessed without knowing the extent, character and health of the entire Green Corridor.
10. The flow of salt and sediment needs to be more intensively studied and managed. There is a paucity of information on which to base effective management decisions. In both cases, the optimal solution involves modifying the human factors that have lead to increased salt and sediment inputs to the Basin's rivers. However, many other measures will be required to deal with existing loads and secondary problems.
11. The natural environment of the GC, including that of the LGC is not wasteful of water as is common perception. Average annual water use was in the order of 4,500 m<sup>3</sup>/ha, a small volume compared to irrigation water use which ranges from 7,000 to 15, 000 m<sup>3</sup>/ha in the TB. Therefore, in seeking the large volumes required to restore the LGC, it is not possible to significantly reduce overall annual water use by the environment in the upper and middle GCs. Any increases in spills in those reaches due to excavated breakouts are relatively insignificant compared to the reductions in high flow "losses" caused by reduced flood size and frequency through upstream water use, i.e. the upper and middle GC is already significantly degraded though a halving of water availability.
12. Sustainable environmental management of the TR's GC depends on evaluating the whole GC resource and managing it in an integrated manner that recognises links and water allocation constraints. These links and constraints will be key to the establishment of priorities for environmental restoration between and within reaches.

## 8. RECOMMENDATIONS

### 8.1 RECOMMENDED MEASURES FOR REHABILITATION OF THE LOWER GREEN CORRIDOR

1. If a decision is taken to deliver water to the LGC to assist meeting environmental needs, then a firm average allocation of at least  $300 \times 10^6 \text{ m}^3$  should be made and implemented. However, this **should not** be at the expense of the upper and middle GCs' environments. This water would, in effect, come from the Kaidu/Kongque system.
2. Establish a monitoring program based on the outline in Section 6.
3. All monitoring and analysis for the specific management of TR flows, diversions, irrigation returns, water quality and land salinisation, should be developed and coordinated through the TBWRC supported by the TMB. Other agencies would supply monitoring services using budgets explicitly allocated for the purpose, via the TBWRC. All relevant data not directly commissioned by the TBWRC would be made available at minimal cost and with no restriction on its use except on-selling for monetary gain. The TBWRC is to oversee the resolution of any areas of dispute.
4. Develop and constantly refine conceptual models for the ecological/physical processes, socio-economic processes and planning/policy/administration processes. These models must be capable of simplification for presentation, discussion and agreement amongst all stakeholders. Where agreement can not be obtained, this will highlight areas to be investigated through specific research programs.
5. Integrate the management of the State Farms into overall TR management so that they are treated the same as other irrigation areas. This may require a change of State Farm reporting structures from National to Provincial governments.
6. Alter land and water management administration to provide for the free flow of data in a timely and low cost manner. The issue of agency funding is inseparable from this analysis and overhaul.
7. Increase the funding and technical capacity of the TMB so that it can carry out its charter as established by the TBWRC, i.e. the integrated management of the TR and related resources. Strengthening the Bureau's ecological, modelling and remote sensing capacity is critical to the TBWRC developing an effective management capability, for in-house work and the coordination of services by more specialised agencies.

## 8.2 RECOMMENDED RESEARCH PROGRAM

### 8.2.1 KEY MANAGEMENT QUESTIONS

Further research is needed to determine the following:

#### *Goal setting questions:*

1. What ecological and socio-economic values do all the green corridors of all the rivers in the Tarim River basin have? i.e. what is the total resource and its value?
2. What proportion of those values/functions were performed by the upper, middle and lower green corridors of the Tarim River and its major tributaries, prior to large scale water resource development and now?
3. What quantity and quality of habitat do the people of China, Xinjiang and the Tarim Basin want overall and in individual rivers and the upper, middle and lower Tarim River? What stakeholders need to be involved and what processes can be used to facilitate the determination of these measurable goals?

#### *Hydrologic and geomorphological questions:*

With respect to the Tarim River main stem and the major tributaries:

1. What volume and quality of water is required to achieve various levels of restoration?
2. What is the seasonal timing, flow rates and durations required at different locations?
3. From where and how might that water be supplied?
4. What is the effect of land use and water management on sediment supply to the major rivers, including river bank erosion?
5. What are the changes in sediment supply, transport and deposition since large scale water resources development and land reclamation?
6. What are the specific effects of water storage, abstraction and river training works on sediment flow and river channel stability?
7. What effects do saline surface and groundwater returns to the rivers have on channel stability?
8. What is the effect of grass and trees in the green corridor on sediment dynamics?

#### *Ecological questions:*

1. What fauna utilise the different habitats within the green corridors?
2. How does the aquatic and floodplain ecology function in terms of energy flows and trophic levels?
3. What species are increasing in numbers and/or range ? What species have static numbers/range ? And what species are decreasing and/or becoming extinct?
4. What are the migration patterns of fish, birds and terrestrial fauna?
5. What are the critical components or parameters of the hydrologic and physical environment for key and/or endangered species?
6. Is it possible to model some critical elements of ecosystem response to river flows, particularly flooding, so that real-time decisions, or at least retrospective assessments of water utilisation, can be made in ecologically relevant terms?



*Monitoring questions:*

1. What parameters are the most efficient in terms of management knowledge per dollar, to effectively monitor the condition of the green corridor?
2. What data are best captured by remote sensing, ground based surveys or by indirect means, such as known relationships to river flows?
3. How should the data be collected, stored, distributed, analysed and linked to improved management decisions?

## 9. REFERENCES

- Anonymous (1995) **Map of the Landscape of the Tarim River Drainage Area**, scale 1:500,000, Published December 1995 by the Xinjiang Cartographic Publishing House for the China National Petroleum Corporation Comprehensive Scientific Excursion to the Taklimakan Desert. Compiled by the Lanzhou Institute of the Desert, The Xinjiang Institute of Biology, Pedology and Desert of the Research Academia Sinica.
- Anonymous (1992) **False colour aerial photograph mosaic of the Tarim River from Aler to Yinsu**. Photographed in September 1992, printed at 1:70,000 scale. Held in the office of the Tarim Basin Management Bureau.
- Anonymous (1995) **False colour multispectral (Bands 4,5,7) Landsat MSS mosaic of the Tarim River Basin**. Image date August 1991, printed at 1:500,000. Held in the office of the Tarim Basin Management Bureau.
- Anonymous (1987) **Tarim River Water Balance Model and Analysis of Results**, Tarim River Administration Bureau, Hydraulic Engineering Department, Tsinghua University. pp 46, May 1997 citing data for end 1988.
- Cheng Qichou (1993) **The Research on the Tarim River**. Hohai University Press. Various papers by the author, some in English, most in Chinese. .
- Fan Zili (ed.), Huang & Zhang (co-eds) (1998) **The Resources, Environment and Sustainable Development of the Tarim Basin**, Published by the Sustainable Research Centre of the Chinese Academy of Science with the assistance of the Xinjiang Ecology, Pedology & Desert Research Institute and Xinjiang Geology Institute of the Acad. of Sci, and the Tarim Basin Management Bureau. Chinese Science Press.
- Qian Yingqian (ed. in chief) (1997) **Journal of Chinese Biodiversity**, 1997, Oct Vol 5, ISSN 1005 - 0094 CODEN SHDUEM. Sponsored by the Chinese Academy of Science, Biological Diversity Committee. Chinese Arid Area Biological Protection Conference. Contains a number of articles relating to the riverine areas of the Tarim Basin.

## 10. ANNEX 1 LIST OF CHINESE COUNTERPARTS AND CONTACTS

PERSONNEL IN EACH AGENCY	POSITION AND/OR DIVISION
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Mr. Tang Shu Hong	Deputy Director of Operational Divisions (currently 5)
Mr. Zhou Hai Yaje	Vice Director of the Water Planning & Eco-Environment Division (is to become 2 Divisions eventually)
Md. He Yu	Engineer hydrologist
Mr. Chen Bao Liu	Expert on the Lower Green Corridor (LGC)
Mr. Chu Yong Hong	Senior Design Engineer
Mr. Wang Fu Yong	Engineer (expert on the middle GC river gauging, etc)
Mr. Herway	Vice Chief Planning Division
Mr. Wumaierjiang	TMB, Vice Division Chief of the Lower Tarim River (Uygur)
Mr. Wang Shi Fu	Driver
<b>Xinjiang Survey and Design Institute (XSDI)</b>	part of the Xinjiang Water Resources Bureau
Mr. Yu Hai Ming	Director
Mr. Do Benli	retired senior Engineer and expert
Mr. Liu Xie Ting	Director, Environmental Impact Assessment Division
Mr. Xie Hai Qi	Environmental Impact Assessment Division
Mr. Zhang Feng	Environmental Impact Assessment Division
Mr. Mao Ling	Engineer, Environmental Impact Assessment Division
Miss Yang Rui Li	Assistant Engineer, Environ'tal Impact Assess't Division
Mr. Zhou Sheng Fu	Environmental Engineer in Economics
Mr. Wang Shui Sheng	Hydrologic Engineer & Hugh's hydrologic counterpart
Mr. Jung Hung	Director Environmental Protection Division
Mr. Wang Shi Shu	Engineer
Mr. Huang Yunxiang	Groundwater Specialist
<b>Regional PMO (of Tarim II), Xinjiang Water Resources Bureau</b>	
Mrs Lieu Gai Li	Chief, Water Resources Office
Mr. Mu	Vice Chief, Water Resources Office
Md. Zang Yanling	Engineer and translator

Md. Hu	
<b>Environmental Evaluation &amp; Research Institute</b>	Is part of the XSDI or another Bureau ?
Mr. Zhang Fa Cheng	Senior Engineer and former Director of the Xinjiang Environmental Evaluation Department
<b>Xinjiang Environmental Protection Bureau (XEPB)</b>	
Mr. Xie Zhi Qiang	Assistant Chief & Senior Engineer
Mr. Zhao Zhi Gang	Xinjiang Environmental Monitoring Station
<b>Xinjiang Hydrologic Bureau</b>	
Mr. Zhang Jian Gang	Vice Director
<b>Xinjiang Agricultural Research Institute</b>	
Mr. Hung Shi Xio	Vice Director
<b>Xinjiang Academy of Science</b>	
Mr. Gu Jing He	Biological & Geographical Division
Prof. Fan Zi Li	Ecology & Geographical Research Institute
<b>Xinjiang Agricultural University</b>	
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Mr. Xu De Yan	Research Institute
Mr. Liang Guo Dong	Natural Protection Division
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Mr. Hu Wei Dong	Director
<b>Bayingol Forestry Bureau</b>	
Mrs. Zhang Zecen	?Senior "Engineer" and/or Chief of the Wildlife Protection Office
Mr. Gu Zheng Qin	Wildlife Expert

Mr. Lai	Forest species expert
<b>Bayingol Environmental Protection Bureau (BEPB)</b>	
Mr. Batar	Vice Director
Mrs. Cheng	
<b>Bayingol Animal Husbandry Bureau</b>	
Mr. Weng	
Mr. Abdulla	
<b>Bayingol Water Resources Bureau</b>	
Mr. Wu liu Ye	Director
<b>Bayingol Project Management Office (of Tarim II)</b>	
Md. Qiang Tao	Vice Director
Mr. Alikan	Engineer (Uygir)
<b>Bayingol Agricultural Production Bureau</b>	
Mr. Le En Chou	

ANNEX 2

**INTEGRATED ENVIRONMENTAL MANAGEMENT  
IN THE TARIM BASIN:  
*ENVIRONMENTAL MANAGEMENT STUDIES REPORT***

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**ECOLOGICAL INFORMATION  
AND NATURAL FEATURES**

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Prepared by Hugh Cross  
OPCV May 1999

## ANNEX 2

# ECOLOGICAL INFORMATION AND NATURAL FEATURES

### PROJECT TEAM

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# 1. INTRODUCTION

## 1.1 PROJECT CONTEXT

The “Lower Green Corridor” (LGC) is the area naturally and artificially irrigated by the Tarim River, downstream of Qiala Reservoir to Taitema Lake, i.e. it is the Tarim River and its floodplain, including flood channels and “dry rivers”. This area is surrounded by the Kuluk Desert to the east and the Taklimakan Desert to the west (Figure 1). A full description is provided in Section 2.

The World Bank funded Tarim Basin I Project (completed in 1997) and Tarim Basin II Project (in progress) are intended to achieve socio-economic benefits for poor farmers through sustainable rehabilitation and development of irrigated agriculture. The projects also aim to improve the greatly deteriorated environment of the “Green Corridor”, which, at least at one time, had considerable socio-economic and ecological values.

This Technical Assistance (TA), “Integrated Environmental Management in the Tarim Basin, Xinjiang Province, China”, relates to whether and how water saved through the structural and management measures of the Tarim II Project could be used to improve the environmental condition of the LGC and thereby socio-economic conditions. The TA was also to quantify the ecological and socio-economic values, so that rational and objective decisions can be made about the reallocation of the scarce water resource saved through component projects of the Tarim Basin II Project. The five objectives of the TA are listed in Section 1.2.

Package I has provided a preliminary assessment of these values and criteria, and established a framework for an environmental monitoring program that can be conducted through the Tarim II Project. It also recommends specific environmental research studies to be conducted as part of Package II of this Technical Assistance. Package II is tentatively scheduled to begin in late 1999.

## 1.2 OBJECTIVES

The Tarim Basin Green Corridor Environmental Management component of *Package 1* has the following objective:

*To identify the broad constraints within which current and future development can occur without further destroying the Tarim River’s environmental assets and to identify opportunities for restoration or enhancement.*

Through the preparation of an environmental baseline study, five specific objectives will be addressed:

1. To determine the major changes in the extent and character of the Tarim River and its “green corridor” since the inception of large scale water use and river regulation.
2. To make a preliminary assessment of the value of the river and “green corridor” in ecological and socio-economic terms.
3. To determine the broad water quality and quantity conditions that will maintain or restore the ecosystems of the Tarim River and its “green corridor” to levels that match agreed local and regional expectations.

4. To input environmental values, constraints and management options to the development of the Tarim Basin Master Plan primarily at the Insight Workshop.
5. To identify a framework for the development of monitoring needs and make recommendations for the environmental studies to be conducted in *Package 2*.

## 2. LOCATION AND EXTENT

The Tarim River basin has an extremely arid continental climate. The many large and small rivers draining the high mountains in the west, north and south of the catchment generally flow into the two main rivers, the Tarim River and the Kaidu-Konque River system (Figure 1). About 99% of the Basin's water resources are in the major rivers or the associated aquifers. The Tarim River and its "green corridor" are about 1320 km long (Zhou Hai Yaje, pers com) and are the only arable areas in the middle and eastern areas of the basin.

The surface and groundwater components of these two main systems join at the upper end of the LGC in the vicinity of Aksupu Swamp, which used to receive water from both rivers, then diverge.. Both formerly flowed to Lop Nor Lake, the lowest point in the Basin, the Kongque River via a northern route and the Tarim River via southerly one. The Tarim River used to be joined by the Qarqan River, just to the east of Taitema Lake, before flowing east to Lop Nor Lake.

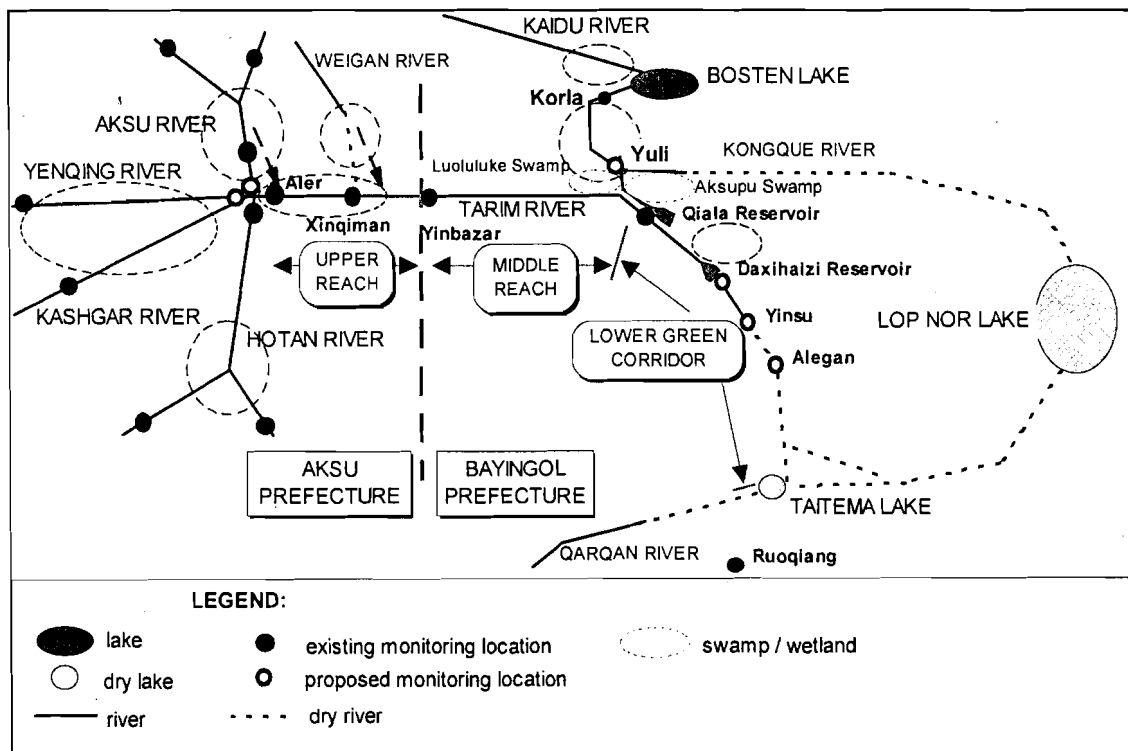
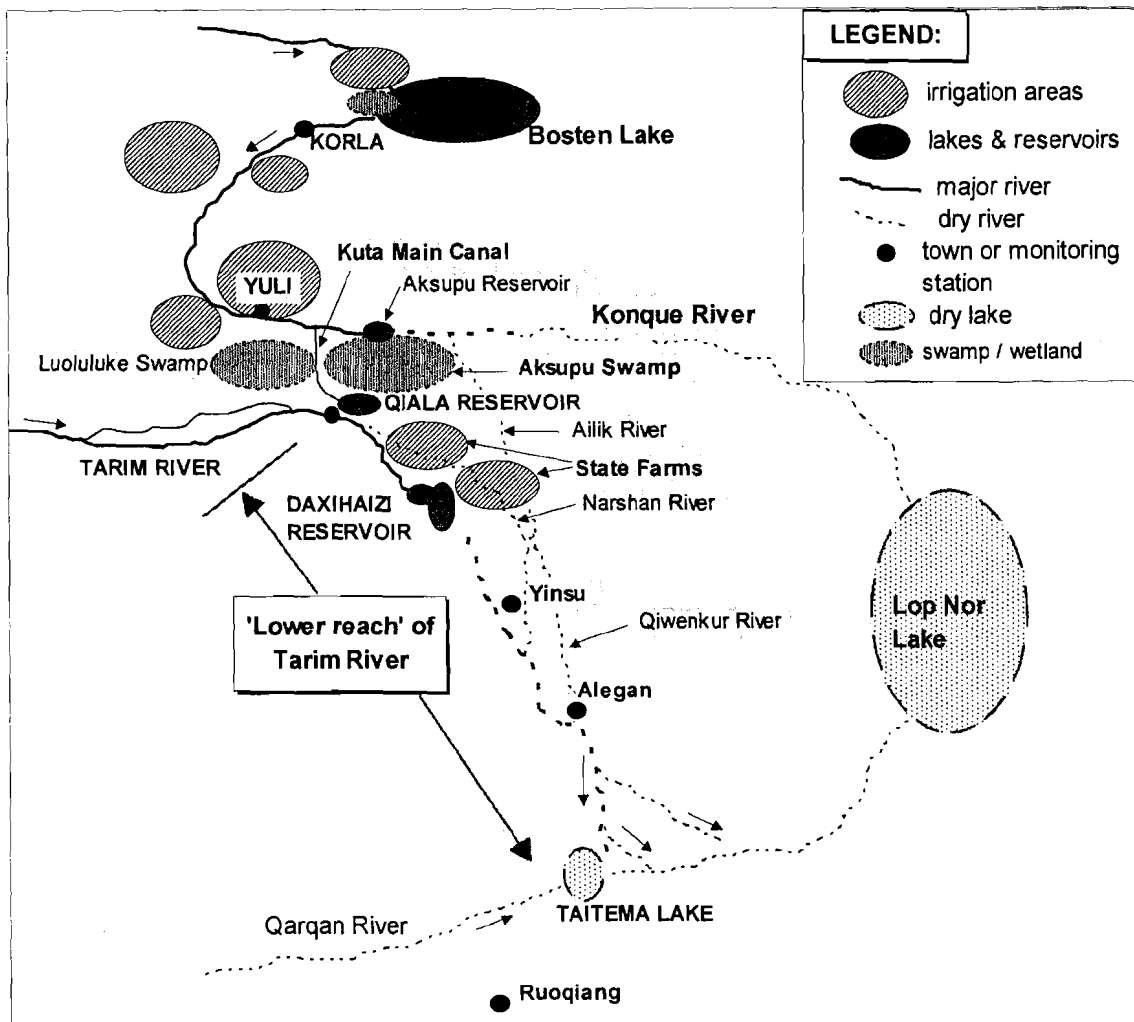


Figure 1: Location of the Lower Green Corridor in the Tarim River Basin



**Figure 2: Key features of the Lower Green Corridor**

Neither the Tarim or Kongque Rivers now reach Lop Nor, which began shrinking in the 1950's and was dry by the early 1970's. Lop Nor Lake used to have a surface area of over 3000 km<sup>2</sup> earlier this century, three times that of Bosten Lake. Neither does the Tarim River reach Taitema Lake and it appears that neither does the Qarqan River, as Taitema Lake has been dry since about 1974 (Cheng, 1993, p183).

For the purposes of this report, the previous extent of the Tarim River from Taitema Lake to Lop Nor Lake will be ignored, except to note the already reduced flows and river extent, prior to the commencement of river flow records.

### 3. NATURAL FEATURES

#### 3.1 TOPOGRAPHY, SOILS AND GEOMORPHOLOGY

The floor of the Tarim Basin is formed by the Tian Shan Geosyncline and the Tarim Platform (Cheng Qichou, 1993). The entire basin is surrounded by mountains rising to over 6,000 m, except to the east, where the mountains are lower and located beyond the Gobi Desert. The Tarim River is located at the northern side of the Tarim Platform which is composed of Mesozoic and Cenozoic strata overlain by about 800m of unconsolidated alluvial Quaternary sediments in the vicinity of the LGC. The most recent of these sediments include the alluvium of the Tarim River and the aeolian (wind blown) sands of the Kuluk and Taklimakan Deserts.

The LGC is 428 km long from Qiala to Taitema Lake. It is about 5 - 30 km wide between Qiala and Daxihaizi Reservoirs, and 1 - 3 km wide downstream of Alegan (Figure 1). Some alluvial sediments underlie the desert sands, and in many areas there are deposits of aeolian sands on the active floodplain. This is the result of shifts in the dynamic equilibrium between the alluvial and aeolian forces. Periodic flood flows remove and redistribute invading dunes which encroach on the floodplain during the periods between floods. This explains the decreasing width of the LGC; the attenuation and reduction in flows downstream reduces the power available to remove the aeolian sands.

Longitudinal river slopes are about 1/4000 to 1/5000 from Aler to Yinbazar, 1/5000 to 1/6000 Yinbazar to Qiala and about 1/4500 between Qiala and Daxihaizi Reservoirs (TBMB). This slightly steeper slope in the last reach is linked to the lack of trees in the upper portion of the reach where the slope is probably even higher. The combination of higher river slope and flow attenuation in the middle reach, leads to a much reduced flooding frequency in upper portion of the Qiala and Daxihaizi reach.

Data apparently exists to plot a longitudinal profile of the river bed, but only a small portion of this could be accessed by the TA towards the close of this package. Those data that were obtained, were surveyed from February 1990 to February 1991 (TBMB) and apparently by the Bayingol Water Resources Bureau with financial assistance from the XPCC. The chainages (distances) on the portions of long-sections obtained, would indicate that the entire river has been traversed, as they are consistent with the known distances between those locations. A longitudinal profile of the whole river, from Aler to Taitema, would assist in identifying the causes of water losses, flooding frequency and the implications for sediment transport and deposition, particularly where works are proposed to confine the river.

The cross-sectional information shows that the cross-sectional area of the Tarim River channel decreases downstream in all three reaches. At Xinqiman the bank-full capacity is about 700 - 800 m<sup>3</sup>/s, which, due to 1.0 - 1.8 m of bed sedimentation over the past five or six years, has been reduced from about 1,500 m<sup>3</sup>/s. Qiala it is about 75 m<sup>3</sup>/s and at Yinsu it is about 27 m<sup>3</sup>/s (LGC Workshop, see Annex 8 of the LGC Report). This progressive reduction is a consequence of flow attenuation, due to friction and storage losses as river flows traverse each reach. The lack of tributaries along the Tarim River main-stem leads to a progressive reduction in flow volume and peak discharges via this mechanism.

Observations during field inspections confirmed that the soils of the LGC are comprised mostly of alluvial material, but include some aeolian sands. Little specific information could be obtained on soil properties, such as particle size analysis, soil chemistry, structure and soil horizons, however general soil descriptions in various reports, for Green Corridor soils

overall, indicate that there is little soil development. The corridor's soils are largely unmodified alluvial soils with little organic content, horizon development and structure. Cheng (1993) reports that the alluvial sediments become finer in the downstream direction and also as the floodplain is traversed laterally, from the river bed to the floodplain and higher benches.

Fan Zi Li (1998) reports soil salinity levels (TDS) of 6.5 g/l in the top 60 mm of forest meadow soil, but these levels drop rapidly to 1.2 g/l between 60 - 270 mm depth and to 0.043 g/l below 270 mm. This reflects the surface accumulation of salt due to evaporation. However, where groundwater levels were between 2 - 4 m, the salinity was about 5 g/l, between 6 - 10 m, 5 - 10 g/l and in some areas up to 10 - 20 g/l. Hence, at deeper levels, the salinity levels rise again due to the evapotranspiration concentration of groundwater.

### 3.2 CLIMATE

Summary tables of average climate data are provided in Tables 1 to 4. Korla, Yuli and Rouqiang best reflect the Lower Green Corridor (LGC), whilst Luatai is representative of the middle Green Corridor (GC) (Figure 1).

It is evident that the basin has an extreme continental climate with sub-zero winter temperatures and very high summer temperatures. Sunshine hours exceed 3000 hours/year in most places, reflecting the very low rainfalls shown in Table 3. As a consequence, almost plants and animals in the lower elevations of the Tarim Basin rely on river flows and river fed groundwater, for their survival. Some desert plants probably have the ability to accumulate moisture the autumn and winter fogs to augment the meagre and erratic rainfall, for a brief growing period in spring. Many desert plants near the GC also make use of groundwater, as is evidenced by the decreasing density of plants within the dune areas with increasing distance from the river. In fact, normally floodplain species, such as *Populus diversifolia* (poplar diversifolia) can be found in dune areas, apparently as a relic of times when the floodplain formerly occupied those sites, but have been invaded by dunes as the river has changed course. They are often quite healthy by surviving on groundwater.

**Table 1: Monthly Average Temperature by County**

(Source: Bayinguoleng Statistical Yearbook 1998, Table 1-6, page 126 )

	Korla	Luatai	Yuli	Ruoqian	Qieme	Yanji	Hejing	Heshou
Ave.	12.4	12.3	11.4	12.4	11.1	9.4	9.1	9.0
Jan	-4.4	-5.1	-6.3	-5.3	-5.0	-8.2	-8.1	-8.5
Feb	-0.5	-1.2	-2.8	-1.4	-1.9	-4.9	-4.3	-4.9
Mar	10.5	9.4	8.9	9.4	8.2	6.0	6.8	6.4
Apr	18.1	17.9	16.8	17.3	15.6	14.7	14.8	14.9
May	23.6	22.7	23.1	23.4	20.9	19.9	19.8	20.4
Jun	23.9	23.9	24.4	26.1	23.6	21.1	20.9	21.4

Jul	27.4	27.3	27.1	28.6	26.4	24.0	23.5	23.6
Aug	24.7	25.0	24.7	26.0	23.5	22.2	22.1	21.9
Sep	19.8	20.6	19.0	20.0	18.0	17.4	16.4	16.4
Oct	11.9	12.7	11.1	11.7	10.5	10.4	9.3	8.4
Nov	0.2	0.8	-0.7	-0.5	0.2	-1.2	-2.0	-2.2
Dec	-6.7	-6.6	-8.2	-7.0	-6.7	-9.2	-9.7	-10.3

**Table 2: Monthly Sunshine Hours by County**

(Source: Bayinguoleng Statistical Yearbook 1998, Table 1 - 7, page 126)

	Korla	Luatai	Yuli	Ruoqiang	Qieme	Yanji	Hejing	Heshou
Ave.	3052.3	2866.8	3261.8	3147.7	2670.7	3235.4	3002.6	3264.6
Jan	210.0	177.3	221.4	203.8	187.3	216.6	194.9	224.6
Feb	233.2	216.1	250.2	238.7	209.9	235.2	227.5	244.2
Mar	241.5	210.4	261.0	266.4	239.1	264.8	242.9	286.3
Apr	321.1	279.2	318.6	298.9	257.6	319.9	309.9	336.5
May	321.8	263.3	312.1	272.8	242.0	316.0	306.2	333.6
Jun	271.1	245.1	301.4	275.1	211.1	292.1	265.1	295.4
Jul	318.4	315.9	328.3	321.5	266.1	339.0	315.3	306.1
Aug	247.2	259.4	269.0	284.5	231.3	288.0	268.2	253.9
Sep	274.1	272.3	302.8	295.9	238.5	305.2	293.7	299.6
Oct	279.1	270.9	290.6	296.4	243.0	290.1	251.9	286.0
Nov	174.4	170.8	202.1	202.3	174.9	198.8	182.0	197.9
Dec	160.4	166.1	204.3	191.4	169.7	169.7	144.5	200.5

**Table 3: Monthly Precipitation (mm) by County**

(Source: Bayinguoleng Statistical Yearbook 1998, Table 1 - 8, page 127)

	Korla	Luatai	Yuli	Ruoqiang	Qieme	Yanji	Hejing	Heshou
Ave.	44.3	58.2	38.1	13.9	21.8	96.5	69.8	107.0
Jan				0.2	0.1			
Feb								
Mar	0.1	7.1						
Apr								
May	19.0	18.8	14.4	8.4	13.6	27.3	13.1	26.7
Jun	17.6	18.4	13.0	1.4	0.3	54.4	41.3	56.5
Jul	1.8	5.3	1.4	0.7	0.6	5.9	8.6	4.3

Aug	5.7	8.6	8.6	3.1	7.2	8.9	6.3	15.7
Sep							0.1	0.2
Oct								
Nov	0.1		0.7	0.1			0.4	3.6
Dec								

**Table 4: Frost Free Period (days) by County**

(Source: Bayinguoleng Statistical Yearbook 1998, Table 1 - 9, page 127)

	Korla	Luatai	Yuli	Ruoqiang	Qieme	Yanji	Hejing	Heshou
1996	175	195	190	196	185	191	175	173
1997	234	233	221	219	218	196	194	176

The climate is a consequence of the Basin's location in the centre of the Asian land mass and the surrounding mountains. The low precipitation is the main limiting factor on plant growth and animal survival. This is compounded by the low winter temperatures, down to  $-30^{\circ}\text{C}$  and summer temperatures up to  $39^{\circ}\text{C}$ . In winter the Tarim River is covered by ice up to 0.6 m thick, which begins to form in December and lasts until March. In summer evaporation exceeds 0.2 m in July. Summer accounts for the bulk of the 2 m annual evaporation.

Various figures are quoted for the frequency of "disastrous weather" and the changes in frequency and severity over the past few decades. This term is taken to mean sand and dust storms. It is not necessarily relevant to quote those figures as the criteria could not be ascertained, but the effect on crops can be severe. For instance, in 1998, the cotton crop had to be planted three times before it was successful. In some cases this is due to burial by sand or wind erosion. Caution is needed however, in ascribing all of this misfortune to adverse weather conditions alone. The high spring salinity of the river water could also be a contributing or primary factor, the drying winds being the last straw in pushing the already salt stressed seedlings beyond the recovery point.

The second point that needs to be made with respect to sand and dust storms, is the need to objectively assess the likely sources of the wind blown material and the relative contributions of those sources. Most reports that were made available to the team, implicitly assumed that the degradation of the Green Corridor (including the LGC) was responsible for the increase in frequency of events, i.e. there was a causal link with respect to the source of material and therefore frequency and severity. It may be true that the Green Corridor could lessen the impact of such events on crops and road maintenance, by at least dropping out some of the sand fraction, but is unlikely that it would stop a dust storm. Nor would degradation of the LGC be likely to significantly increase the amount of fine wind blown material, except locally with respect to the sand fraction, as its area is very small relative to the desert and rangeland areas. This could not be established with any certainty, due to the above mentioned lack of available information on the criteria used to define "disastrous weather".

The dust storms, observed during the field inspections supported the view that the major sources of material are the general rangelands and desert. The wind on one occasion was from

the north west, from the mountains and desert, and was drifting sand across roads and towards the Green Corridor. The trees and bushes within a healthy Green Corridor would help remove the sand fraction by reducing ground wind speeds, which in fact was observed, but the actual dust storm and the “event” was by no means ameliorated within the Green Corridor.

### 3.3 MAJOR HABITATS OF THE LOWER GREEN CORRIDOR

The LGC’s habitats are not unique compared to habitats provided by the middle and upper GCs. This conclusion was reached after examination of the available data and observations made during the field trips to the middle and lower GCs (Appendixes D and E). On average, it would appear that poplar *diversifolia* forests and other habitats were drier than those upstream, receiving water in fewer years and possibly, for shorter durations. Certainly, flows reach the LGC later than at upstream locations, up to 4 weeks later it would appear. The floodplain is also much narrower than in the middle GC. The wettest and most frequent flooding locations tend to be associated with locations where poplar *diversifolia* still occurs, or previously occurred. The Lower Green Corridor was dependent on the frequency and volume of these flood events.

There is considerable variation in the habitat along the LGC. Adjacent to the most upstream sub-reach (Qiala to Daxihaizi) is Aksupu Swamp of several hundred thousand hectares, and located between the two river systems east of Kuta Main Canal. More properly it should be considered to be an integral component of the LGC, as it is fed by flood flows from the Tarim River, via the Luohulike Swamp area, as well as the Kongque River. There is an underpass under Kuta Main Canal, which can transmit flows from one swamp to the other, but this is limited in size. Surface flow is perhaps possible from Aksupu Swamp to the Tarim River floodplain, but whilst this is not certain, there is almost certainly a groundwater contribution.

It is not certain what vegetation occurred previously in Aksupu Swamp. The construction of Aksupu Reservoir of about 1000-2000 ha<sup>1</sup> in its north west corner prevents it from receiving flood waters from the Kongque River. Despite the observed reduction of flooding from analysis of the hydrologic record, a satellite image for 1991 shows that several parts of Aksupu swamp were flooded in that year.

Further downstream, the Kongque River in the past also transferred flows to the Tarim River via the Ailik River. However, it is now dry due to a lack of flows in the Kongque River past downstream of Aksupu Reservoir.

The upper portion of the Qiala to Daxihaizi reach also displays an unusual feature; there are virtually no trees in the upper third of the reach, apparently due to the lack of flooding (Mr. Lai pers com., see Appendix D) because of the steeper longitudinal slope. Conversely, there is a moderate to good cover of reeds and shrubs, apparently supported by the high groundwater levels in this reach. The remainder of the LGC has trees scattered throughout, at various stand densities, in some areas rivalling that of densest stands in upstream reaches, and in others, being relatively sparse. Considerable areas of *Tamarix sp.* occur in the LGC in drier locations than those that support *Populus diversifolia*.

The “Map of the Landscape of the Tarim River Drainage Area” (Anonymous, 1995b) shows ephemeral salt lakes and marshes between the sand dunes along the fringe of the Taklimakan Desert, between Qiala to Daxihaizi. Some of these are flooded seasonally by Daxihaizi

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<sup>1</sup> This area seems too large, but was an oral quote supplied during a field inspection of the reservoir



Reservoir, but most now do not receive flooding. Some never did receive direct surface flows, being isolated by intervening sand dunes, and are fed solely by groundwater. Most support little vegetation, what does exist is generally around the perimeter, as can be observed from the available false colour aerial photography and Landsat imagery (Anonymous, 1992, Anonymous, 1995b). These types of habitats are potentially very important for migratory waterbirds, but no records exist because of the high seasonal productivity of ephemeral wetlands when they flooded (due to nutrient release dynamics). Some similar areas exist along the upper and middle GCs.

Qiala and Daxihaizi Reservoirs provide considerable wetland habitat for waterbirds and fish. To some extent they may replace some of the original more permanent wetland habitat.

The Tarim River's aquatic habitat in the LGC is not large compared to upstream reaches considering the much narrower width (100 m maximum, compared to over 1000 m at Aler). However, whether this narrow channel contains more than the average amount of ponded areas at cease to flow, the only refuges for aquatic life in the very low flows and freezing conditions of winter, is not known.

#### **4. LAND AND WATER USE IN THE LGC**

##### **4.1 GRAZING**

All the land to the north-east of the Tarim River, between Qiala and Daxihaizi Reservoirs, and around the latter, is owned and controlled by the State Farms. These areas can not be grazed without the approval of the State Farm. Approval has been granted local Uygurs to graze their animals on the area around Daxihaizi Reservoir. Herdsmen were able to graze on State Farm Land prior to 1980.

Downstream of Daxihaizi Reservoir, outside of the State Farm areas of No. 34 and 35 Corps, the only restrictions on irrigated crop cultivation are the need to obtain the County Land Management Bureau permission and a lack of water. Similarly, for grazing a herdsman must belong to a local village and pay a fee to the Tarim Township, if in Yuli County, or Rouqiang if in Rouqiang Township County. Water is a significant factor in the degraded LGC rangelands and lack of stock water.

Grassland in the whole Yuli County was  $11 \times 10^6$  MU in 1983,  $3.5 \times 10^6$  MU in 1989 and  $3.06 \times 10^6$  MU in 1994.

The Government plans to move the remaining herdsman (50 families) from the LGC prior to 2002. In the last 10 years the Government has moved 500 to 600 households.

In the early 1990's the County developed more than 14,000 mu for pasture for relocated LGC herdsman, but it was used for cotton in the hope of making more money.

Pasture land is destroyed by digging of herb. A herb factory in Yuli requires 1,500 - 2,000 herb-grass roots per year. This is a major pressure on pasture land in the LGC, as it is possible to make RMB ¥ 20/day collecting and selling these herbs. The factory employs 500 workers. In 1988, Yuli County planted an area of herbs, but this was converted to cotton, hence the pressure remains.

##### **4.2 IRRIGATION LAND RECLAMATION FOR IRRIGATION**

There are about 25,000 ha of developed irrigable land, of which perhaps 13,000 ha is planted in any one year. Reclamation for irrigation is restricted to the State Farms in this area and

therefore there are no diversions from the Tarim River in the LGC apart from the State Farms. Current water use by the State Farms in the LGC is about  $550 - 600 \times 10^6 \text{ m}^3$ . About half of this is bought from the Kongque River.

Prior to the 1970's the herdsmen also conducted some irrigation. Apparently the soil is very good for cropping, in part due to the relatively low salinity (compared to areas upstream of the LGC).

Just upstream of Qiala Reservoir (i.e. upstream of the LGC) there are a number of private pumps. These are operated by private investors who pay Yuli County and Tarim Township for the right to reclaim and irrigate these lands. Downstream of Daxihaizi Reservoir, outside of the State Farm areas of No. 34 and 35 Corps, the only restrictions on irrigated crop cultivation are the need to obtain the County Land Management Bureau permission and a lack of water. The latter is insurmountable, however, as the State Farms own and operate the reservoirs and have the capacity divert all the residual flows that escape upstream irrigation diversions and losses.

The extent to which the control of structures drives water management decisions, is reflected in the TBMB's proposal to construct a canal around Daxihaizi Reservoir to overcome the potential lack of cooperation by the State Farms in making downstream environmental flow releases. The more logical solution is to gain agreement on the reservoir operating procedures, to match incoming flows and total release requirements; to meet both environmental and irrigation needs.

#### **4.3 FORESTRY AND FIREWOOD**

Firewood is now only (legally) collected from dead twigs and sticks. Cutting of live trees is now not allowed. The XPCC pays RMB 50 - 100 Yuan/year to each person in the State Farm areas so that they can buy legally cut fuel, rather than cut the Poplar *Diversifolia* trees and Red Willow.

There is 990,000 MU of PD trees, along the 490 km of the LGC, of which about 2/3 are dying. Yuli Forest Bureau recently established a PD Tree Station (four staff) to protect the forest and maintain a PD nursery and plantation. Yuli County has a budget of RMB 500,000 to plant trees in the whole County in 1999. The County planted 27,000 MU of forest in 1998.

Trees are planted along most of the secondary and tertiary canals, with further plantings in towns where ever water can be delivered and in small strips within the irrigated areas. There are no large plantations.

#### **4.4 CONSERVATION OF NATURAL ECOSYSTEMS**

There are no reserves in the LGC. Apart from the recent Water Allocation Agreement, there are no other specific measures to maintain or restore the LGC's ecosystems. China is a signatory to the Ramsar "International Agreement on Wetland Habitat, Especially for Migratory Waterbirds" and the "China Australia Migratory Bird Agreement" (CAMBA). Both of these agreements are relevant to the LGC due to the natural and artificial wetland habitats.

Consideration needs to be given to the control of various land management activities that may be reintroduced on re-establishment of river flows. One or more reserves similar to the poplar *diversifolia* reserve in the middle GC may be appropriate, particularly as places for benchmarking ecological condition.

## **5. SOCIO-ECONOMIC CONDITIONS**

### **5.1 DEMOGRAPHICS**

About 400 households, 2,000 people were living along the LGC in the 1950s (the figures need to be reconfirmed). The herdsmen grazing between Qiala to Daxihaizi, were moved to Tarim Township, settled in the 100,000 mu of cultivated land developed by the State Farms. The farms then moved to the herdsmen's home land. More than 500,000 mu of land were reclaimed since, some were given up later because the drying up of the Tarim River. The population of the six State Farms, No. 31 to 36, is about 40,500. In the 1960's, there were about 15 hamlets in the Yinsu area. They were engaged in both agriculture and animal husbandry. There are now only 30 households left. Since the water began to dry up in the 1970's, people began to move to Rouqiang (the last flood was in 1982). Since the 1990s Government began to move people to irrigated land near Ruoqiang and gave about 4 mu each. Six families could not adapt and moved back, only to move again later. One family moved up to four times.

### **5.2 HEALTH AND BIRTH CONTROL**

Each family has dug a well which are 6 to 10 m deep. These are their only water source.

The few herdsmen/women the project team met seemed in good health. When they got seriously sick, according to the interviewed herdsmen, they could hardly afford to see the doctors at the State Farm clinic which is located about 30 km away. The deposit for check-in the hospital is over 1,000 yuan. Unlike the farmers living in villages, the herdsmen received very little assistance or education in birth planning until three years ago. According to Government policy, numbers of children should be restricted, but are more generous than for city dwelling Han people. The two families interviewed have seven and eight children each the youngest of whom was eight.

### **5.3 EDUCATION AND TRAINING**

A primary school was established in Yinsu with the assistance of Rouqiang County in 1982. Since that time, almost all the children of school age went to school for 6 years. However, the school closed in 1994 when most the herdsmen were moved away. Now about half of the children go to the schools near the County while the rest don't go to school at all.

It is very difficult for the young herdsmen to remain in LGC to get married because no girls would like to come to settle down in such a harsh conditions.

### **5.4 ECONOMIC CONDITIONS**

Life was comparatively easy for herders until 1970s. They sowed wheat on the land after flood and were self-efficient in grain supply. There was no need to plough and the soil was rich. The herdsmen were perhaps more well-off than current farmers in the area. The economic situation was not too bad until the last flood in 1982. The trees and grass survived until 1992, about 10 years after the flood. Since then, corresponding to the deterioration of the environment, the herdsmen are struggling to survive and the situation is becoming worse every year.

The goats raised by herders are lean and can not be sold for a good price. In addition to the goats they keep for their own needs, they have to keep the same number of the State Farm's flock. The only income from the goats was the fine wool, which they sold for RMB 1,400

Yuan last year, but after tax they received just RMB 130 Yuan. The taxes include the pasture management fee and the water management fee. They believe the levies are not fair because the government did not provide them with water or managed the grassland. The tax was calculated according the numbers of animals, at five yuan per head. One family interviewed lived on the salary of one son who worked for the high way maintenance team and the sale of camels. He earns RMB 200 Yuan a month. One camel can be sold for over RMB 1000 Yuan.

## 5.5 ADMINISTRATION AND MANAGEMENT

Administratively, the 30 remaining households belong to Yinsu Animal Husbandry Team of Tiganlike Township, Rouqiang County. Another 20 households are scattered from Qiala to Daxihaizi belong to Tarim Township of Yuli County. The herdsmen in Yinsu are strictly forbidden to graze their animals across the county boundary.

Most the herdsmen do not own the animals they graze. They either graze for the village collective, the township or their friends or relatives. The household we interviewed graze 150 goats for the township. They are required to keep the same number of animals each year, otherwise they have to a pay penalty.

According to the Prefecture's "Herdsmen Resettlement Scheme", all herdsmen need to be settled with the assistance of the county they belong to, before the year of 2001. The township is supposed to provide the herdsmen with housing, goat shelters and arable land. The herdsmen family needs to pay 30% of the cost of the house. The resettled herdsmen's households, in Tarim Township we interviewed, received land, but they paid for the house themselves. They owe the Township 23,000 yuan because the goats they used to raise were contracted from the Township and now 2/3 have died because the pasture has gone.

All State Farms No.s 31 to 35 in the LGC belong to Division II of the Xinjiang Production and Construction Corps (XPCC). Each State Farm has a number of Branches, which are in different locations. Each Branch has a number of Cadres. A Branch of State Farm No. 34 downstream of Alegan was abandoned over 10 years ago due to lack of water.

## 6. FLORA AND FAUNA OBSERVATIONS

Appendix A lists the species of wild birds and animals observed in the Tarim River Basin, whilst Appendix B lists the natural and planted tree and shrub species. Appendix C lists those animal species (mammals, birds and fish) that are protected in Bayingol Prefecture. There are no records specific to the LGC for any species or group.

Whilst the habitats of the LGC are not unique compared to habitats provided by the middle and upper GCs, there are (now) fewer people in the LGC, as indicated by the population statistics for Yuli and Ruoqiang in Table 5.

**Table 5: Land Area (km<sup>2</sup>), Population and Population Density (Nos./km<sup>2</sup>)**

County:	Bayingol	Korla	Luatai	Yuli	Ruoqiang	Yanji	Hejing	Bohu
Land area	482665	7117	14511	59526	208226	1547	36976	3721
Population	980303	322509	84324	92223	28724	115366	169872	54602
Density	2.03	45.3	5.8	1.5	0.1	75.2	4.6	14.7

These data provide a crude indication of the potential disturbance to wildlife in each area. Yuli County covers the upper portion of the LGC to just upstream of Yinsu, whilst Rouqiang County covers the lower portion. It is clear that the low population density offers some sanctuary to wildlife and their habitat, due to the lower level of human activity associated with the smaller and less dense populations in these two counties. Against this immediate security from land management actions and hunting, is the disadvantage of being at the lower end of the river and therefore subject to all water quality and river flow changes caused by upstream land and water management.

Qiala and Daxihaizi Reservoirs and the Tarim River are stocked with introduced fish species, the native species having become locally extinct, or near extinct, in the Tarim River. All species that exist are therefore introduced and are mainly various species of carp. The rarest of the native species, the big-head fish (*Aspiorhynchus laticeps*), is classified as “protected” (Appendix C). Only one or two have been caught anywhere in the Tarim River in the past five years.

## **7. RESTORATION REQUIREMENTS**

### **7.1 DEFINING “RESTORATION”**

There are a number of steps in moving from the current situation to a fully restored LGC. These are discussed in the sections below. Restoration to each level will require a greater allocation of water to the environment and perhaps, additional management and/or structural measures. Each level will have correspondingly higher opportunity cost, principally because of the additional water use. Where the restoration measures involve significant financial resources, there will also be a capital (financial) opportunity cost. The most degraded functional areas will require restoration to start with the lowest level. Less degraded areas may require fewer stages as they have higher level of residual ecosystem condition.

### **7.2 ENVIRONMENTAL WATER NEEDS**

#### **Maintenance of Remaining Trees in Good Health:**

Requires annual flooding of at least 14 days and groundwater levels < 6 m deep at the beginning of spring.

#### **Establishment of New Trees:**

Requires an above average flood to achieve 30 days flooding and probably groundwater levels < 3 - 4 m deep at the beginning of the following spring (project estimate) so that groundwater levels can help sustain tree growth following the annual flood. Such conditions are only required once or twice every 10 years or so.

#### **Establishment of New Trees and Restoration of Grazing Pastures:**

A minimum of 14 days flooding is required annually to maintain a minimum level of pasture with perhaps only the 6 species of grass, but a month or longer is necessary for good pasture growth and the full range of up to 28 grass species. It is likely that many of the more palatable species have the higher water requirements.

### **7.3 SETTING MEASURABLE GOALS**

The Tarim Basin II project has as one of its major goals, the rehabilitation of the natural ecosystem of the LGC, however, to date this goal has not been adequately defined for

management purposes. There is no documentation that records specifically and quantitatively, even in the broadest sense, what components of the ecosystem are to be restored and to what level of health.

The current objective remains a general mission statement, i.e. "to save the green corridor". For this to be achieved, there must be agreement on what the "green corridor" was like prior to large scale water use upstream. This description must be quantified in terms of extent, types of habitat and the health of that habitat. It should also describe the wildlife, birds, fish and other fauna that inhabited the area.

The next requirement is to understand the linkages between the biological components of the ecosystem and the hydrological and physical components. This is necessary to quantify the amount of water and land use management changes that are required to achieve each level of restoration. The main LGC Report includes some system diagrams (Figure 5) that begin this process.

#### **7.4 CURRENT PERCEPTIONS**

There is a wide spread view within agencies and other stakeholders in the Tarim Basin, that the green corridor, including the LGC, is wasteful of water and that "water resources have low ecological benefit" (page 3, "The Economic Research Institute of Xinjiang Social Academy and Xinjiang Executive Office of the World Bank Loan Project", 1997). This is not the case.

If the original estimated average annual inflow to the Tarim River at Aler, of  $100 - 120 \times 10^8 \text{ m}^3$  is averaged over the total area of the green corridor downstream of Aler, it gives an average water consumption of  $4,500 \text{ m}^3/\text{ha}$  ( $300 \text{ m}^3/\text{mu}$ ) (see Annex 3). This about half that of current irrigation use.

#### **7.5 WHAT CAN BE DONE?**

Annex 3 addresses the extent to which water can be used to restore the LGC. Various assumptions have to be made, based on little information, to make these predictions. Monitoring will be required to confirm these relationships and to monitor the success of any environmental flow allocations. If an average annual allocation of  $300 \times 10^6 \text{ m}^3$  was made available and assuming the above unit area efficiency, then about 24% of the original LGC habitat could be restored.

### **8. CONCLUSIONS**

1. The ecosystems of the LGC are highly degraded downstream of Daxihaizi Reservoir. The habitat can be restored if sufficient flows are made available. Whether the original animal species are locally extinct can not be determined due to lack of data. Therefore it can not be established to extent the fauna will recover given the partial or complete restoration of habitat.
2. There is insufficient information on which to establish the success or otherwise of any restoration measures into the future.
3. Water from the Tarim and Kongque Rivers is the key requirement for the maintenance of the existing relic habitats. Both sources will be key to the restoration of additional habitat, especially the major wetland habitats of Luoluluke and Aksupu Swamps. The latter has not been considered part of the LGC in the past, but its restoration is integral to the

restoration of the LGC, both as habitat and as a conduit for surface and groundwater to the LGC.

4. The habitats of the LGC are, by and large, not unique when compared to the upper and middle GC of the Tarim River. However, there are large areas of habitat, including about  $\frac{1}{4}$  of the total poplar diversifolia forest prior to degradation and the large wetland area of Aksupu Swamp, a separate, but integral component of the LGC's hydrology and habitat. For these considerations alone, it is worth while attempting the restoration of at least the upper portion of the LGC.
5. Due to the limitations of water management and structural measures, any attempt to restore the LGC will extend down a considerable part of its length and result in a new location of the ecotone along the transition from riverine to desert habitat. Structural measures should be aimed at maximising the area of the LGC that is towards the wetter end of this ecotone, as the drier areas are already well represented given the impacts of human water use. They should not be aimed at trying to spread the water as far as possible; that would result in salinisation and habitat of limited value to wildlife and fish.

## **9. RECOMMENDATIONS**

1. Develop "system diagrams" and conceptual models of key interactions between river flows, habitat and wildlife, both direct and indirect. These will provide the tools by which to predict the success of various restoration measures.
2. Establish realistic and measurable goals for environmental restoration in each reach of the LGC and through and with all key stakeholders. Document these goals and the data needs for effective management. These data are to be made freely available to all relevant parties.
3. Establish environmental monitoring in accordance with the "Monitoring Framework" outlined in Section 6.4.2 of the main LGC Report.
4. Undertake special wildlife surveys of the upper, middle and lower GCs to determine the relative wildlife species compositions and abundances. These studies should be conducted at similar times of year and/or similar times with respect to the summer flood season. Location, habitat, dates and flooding conditions should be recorded for all observations, in addition to the normal biological data.
5. Utilise voluntary bird watching organisations, such as "Birdlife International" or the "The British Trust for Ornithology" (see section 11) to monitor birds in initially, particularly migratory species in autumn and spring to determine numbers by species, habitat preferences, timing, breeding, direction of movement and other ecological information. Costs only would need to be covered, making this a cheap means of augmenting busy agency staff. It would also send a positive message to the international community of the achievements in saving the LGC.
6. Store all data in computerised relational databases that can be queried by field (parameter) and also linked to spatial records of wildlife observations in a Geographic Information System (GIS). As indicated in Annex 6, spatial modelling techniques will be important in investigating links between flood extent and duration, with ecological condition.
7. Utilise remote sensing data, in particular satellite imagery, to record the condition and type of habitats throughout the GC. This will be a very cost effective means of recording the

success of restoration efforts and comparing the areas and types of habitat available in the LGC to elsewhere. Use of quantification techniques, available through digital analysis of satellite imagery, will enable direct comparison of multi-temporal data. Such measures include indices such as the Normalised Digital Vegetation Index (NDVI) that record the amount of photosynthetic leaf area, i.e. growing vegetation, and remove all other differences between the images taken of the same area but on different dates.

8. Modify initial restoration measures, both structural and non-structural, based on monitoring data, to improve the achievement of the established environmental goals. Where necessary, modify those goals to make them more realistic and achievable, but only through the involvement of all stakeholders and with the coordination of the TBWRC.
9. Undertake the "Recommended Research Program", outlined in Section 8.2 of the main LGC Report.

## 10. REFERENCES

- Anonymous (1995a) **Map of the Landscape of the Tarim River Drainage Area**, scale 1:500,000, Published December 1995 by the Xinjiang Cartographic Publishing House for the China National Petroleum Corporation Comprehensive Scientific Excursion to the Taklimakan Desert. Compiled by the Lanzhou Institute of the Desert, The Xinjiang Institute of Biology, Pedology and Desert of the Research Academia Sinica.
- Anonymous (1995b) **False colour multispectral (Bands 4,5,7) Landsat MSS mosaic of the Tarim River Basin**. Image date August 1991, printed at 1:500,000. Held in the office of the Tarim Basin Management Bureau.
- Anonymous (1992) **False colour aerial photograph mosaic of the Tarim River from Aler to Yinsu**. Photographed in September 1992, printed at 1:70,000 scale. Held in the office of the Tarim Basin Management Bureau.
- Anonymous (1987) **Tarim River Water Balance Model and Analysis of Results**, Tarim River Administration Bureau, Hydraulic Engineering Department, Tsinghua University. pp 46, May 1997 citing data for end 1988.
- Cheng Qichou (1993) **The Research on the Tarim River**. Hohai University Press. Various papers by the author, some in English, most in Chinese.
- Fan Zili (ed.), Huang & Zhang (co-eds) (1998) **The Resources, Environment and Sustainable Development of the Tarim Basin**, Published by the Sustainable Research Centre of the Chinese Academy of Science with the assistance of the Xinjiang Ecology, Pedology & Desert Research Institute and Xinjiang Geology Institute of the Acad. of Sci, and the Tarim Basin Management Bureau. Chinese Science Press.
- Qian Yingqian (ed. in chief) (1997) **Journal of Chinese Biodiversity**, 1997, Oct Vol 5, ISSN 1005 - 0094 CODEN SHDUEM. Sponsored by the Chinese Academy of Science, Biological Diversity Committee. Chinese Arid Area Biological Protection Conference. Contains a number of articles relating to the riverine areas of the Tarim Basin.



## **11. USEFUL CONTACTS**

### **Birdlife International**

Huntington Road,  
Gurnton, Cambridge, Cambs, United Kingdom

### **The British Trust for Ornithology**

“The Nunery”,  
Thetford, Norfolk, United Kingdom

## APPENDIX A

### LIST OF WILD BIRDS AND ANIMALS IN THE TARIM RIVER BASIN

Source: Bayingol Forestry Bureau, Wildlife Protection Office

TARIM BASIN SPECIES:	OCCURS TARIM RIVER GREEN CORRIDOR:
<b>BIRDS</b>	
1. Podiceps auritus	yes
2. P. cristatus (Linnacus)	
3. P. ruficollis	
4. Pelecanus onocrotanus	
5. Phalacrocorax carbo	yes
6. Ardele cinerea	yes
7. Egretta alba	
8. Botaurus stellaris (Linnacus)	
9. Croconia nigra (Linnacus)	yes
10. Anser anser (Linnacus)	
11. Anser fabalis	
12. Cygnus cygnus	yes
13. Tadorna ferruginea	
14. Tadorna tadorna (Linnacus)	
15. Anas platyrhynchos (Linnacus)	yes
16. Anas crecca (Linnacus)	
17. Anas querquedula	
18. Anas clypeata	yes
19. Netta rufina	yes
20. Aythya ferina	
21. Aythya fuligula (Linnacus)	
22. Mergus merganser	yes
23. Milvus korschun	yes
24. Accipiter gentilis	yes
25. Buteo rufinus (Cretzschmar)	yes
26. Aquila pennata (Gmelin)	

27.Circus cyaneus (Linnacus)	
28.Falco subbuteo (Linnacus)	yes
29.Circus aeruginosus (Linnacus)	yes
30.Columnix coturnix (Linnacus)	
31.Phasianus colchicus (Linnacus)	yes
32.Porzana parva (Scopoli)	
33.Gallinula chloropus (Linee)	
34.Fulica atra (Linnacus)	
35.Otis tetrax	
36.Vanellus ranellus (Linnacus)	
37.Charadrius alexandrinus	
38.Tringa totanus (Linnacus)	
39.Tringa hypoleucos (Linnacus)	
40.Hinantopus himantopus (Linnacus)	
41.Grus grus	yes
42.Anthropides virgo	
43.Larus argentatus	
44.Larus ridibundus (Linnacus)	
45.Sterna hirundo (Linnacus)	
46.Syrhaptus paradoxus (Pallas)	
47.Columba livia	perhaps
48.Streptopelia decaoto	
49.Streptopelia senegalensis	
50.Streptopelia turtur	
51.Cuculus canrous	yes
52.Bubo bubo	
53.Athene noctua	
54.Asio flammcus (Pontoppidan)	yes
55.Asio otus (Linnacus)	yes
56.Apus apus	yes
57.Caprinmulgus sp.	
58.Dendrocopos leucopterus	
59.Picoides tridactyus	yes
60.Upupa epops (Linnacus)	yes
61.Alcedo atthis (Linnacus)	

62. *Coracias garrulus*
63. *Calanclrella rufescens*
64. *Calandrela cinerea*
65. *Galerida cristata*
66. *Eremophila alpestris* (Linnaeus)
67. *Hirundo rustica*
68. *Motacilla cinerea pallas*
69. *Motacilla cinerea*
70. *Motacilla alba*
71. *Anthus campestris*
72. *Lanius cristatus*
73. *L. excubitor*
74. *Oriolus oriolus* (Linnaeus)
75. *Sturnus vulgaris* (Linnaeus)
76. *Pica pica* yes
77. *Podiceps hendersoni*
78. *P. biddulphi*
79. *Corvus monedula* (Linnaeus)
80. *Corvus corone* (Linnaeus)
81. *Corvus corax*
82. *Prunella atrogularis*
83. *Luscinia svecica* (Linnaeus)
84. *Phoenicurus ochruros* (Gmelin)
85. *Saxicola torquata*
86. *Oenanthe hispanica*
87. *Oenanthe isabellina*
88. *Turdus merula*
89. *Turdus ruficollis*
90. *Phopophilus pekinensis*
91. *Acrocephalus arundinaceus*
92. *Hippolais caligata*
93. *Sylvia minula*
94. (*S. nana*)
95. *Regulus regulus*
96. *Muscicapa striata*

- 97. *Parus cyanus*
- 98. *Certhia familiaris*
- 99. *Remiz pendulinus*
- 100. *Tichodrome muraria*
- 101. *Pusser ammodendri*
- 102. *Passer hispanio lensis*
- 103. *Passer montanus* yes
- 104. *Pertronia petronia*
- 105. *Carduelis flavirostris* (Linnacus)
- 106. *Leucosticte nemoricola*
- 107. *Rhodopechys githagineus* yes
- 108. *Rhodopechys obsoleta*
- 109. *Carpodacus erythrinus*
- 110. *Emberiza schoeniclus*
- 111. *Erithacus rubecula*
- 112. *Ixobrychus minutus*
- 113. *Larus ichthyaetus*

**ANIMALS**

- 1. *Hemiechinus auritus*
- 2. *Pipis trell* yes
- 3. *Pipis trellus*
- 4. *Crocddura suaveolens*
- 5. *Tarimolagus yarkandensis* yes
- 6. *Meriones meridianus*
- 7. *Dipus sagitta* yes
- 8. *Mus musculus*
- 9. *Cricetulus migratorius* yes
- 10. *apodemus sylvaticus*
- 11. *Mustela nivalis*
- 12. *Mustela eversmanni*
- 13. *Vormela peregusna* yes
- 14. *Felis liyca* yes
- 15. *Felis manul* yes
- 16. *Vulpus corsac* yes

- |     |                                 |     |
|-----|---------------------------------|-----|
| 17. | <i>Vulpus vulpus</i>            | yes |
| 18. | <i>Cervus elaphus</i>           | yes |
| 19. | Yerquiang <i>Cervus elaphus</i> | yes |
| 20. | <i>Gazella subgutturosa</i>     | yes |
| 21. | <i>Sus scrofa</i>               | yes |
| 22. | <i>Canis lupus</i>              | yes |
| 23. | <i>Ondatra zibethica</i>        | yes |

## APPENDIX B

### LIST OF TREE SPECIES IN THE TARIM RIVER GREEN CORRIDOR

#### NATURAL TREE SPECIES

1. *Populus diversifolia* (Schrenk)
2. *Populus pruinosa* (Schrenk)
3. *E. mooreroftii* (Wall et Schlecht.)

#### NATURAL SHRUB SPECIES

1. *Tamarix ramosissima* (Lab)
2. *Tamarix laxa* (Wild)
3. *Tamarix hohenackeri* (Bge)
4. *Tamarix arceuthoides* (bge)
5. *Myricaria alopecuroides* (Schrenk)
6. *Myricaria platyphylla* (Maxim)
7. *Halimodendron holodendron* (Pall Voss)
8. *Ephedra przewalskii* (Stapf)
9. *Haloxylon ammodendron* (Bunge) (Class II protection)

#### ARTIFICIALLY PLANTED SPECIES

1. *Populus alba bachofeni* (Wierzb)
2. *Populus nigra* (Linnacus) cv *italica*
3. *Salix alba* (Linnacus)
4. *Salix babylonica* (Linnacus)
5. *Salix matsudana* var. *umbra cifiseni* (Kehd)
6. *Elaeagnus moorcroftii* (Wall)
7. *Ulmus pumila* (Linnacus)
8. *Ulmus densa* (Titw)
9. *Sophor japonica* (Linnacus)
10. *Robinia pseudoacacia* (Linnacus)
11. *Morus alba* (Linnacus)
12. *Populus diversifolia* (Schrenk)
13. *Populus pruinosa* (Schrenk)
14. *E. mooreroftii* (Wall et Schlecht.)

## OTHER SPECIES

1. *Pyrus betulafolia* (Byc)
2. *Pyrus* sp.
3. *Malus pumila* (Mill)
4. *Armeniaca vulgaris* (Lam)
5. *Amygdalus persica* (Linnacus)
6. *Zizyphus iujuba* (Mill)
7. *Lycium potninii*



APPENDIX C

LIST OF PROTECTED ANIMALS IN BAYINGOL PREFECTURE

CHINESE NAME	SCIENTIFIC NAME	PROTECTION LEVEL	COMMENT
MAMMALIA			
1.	<i>Cuon alpinus</i>	II	mountain areas
2.	<i>Urus arctos</i>	II	desert areas
3.	<i>Martes foina</i>	II	desert areas
4.	<i>Felis lybica</i>	II	Tarim
5.	<i>Felis lynx</i>	II	
6.	<i>Felis manul</i>	II	
7.	<i>Panthera tigris</i>	I	
8.	<i>Panthera uncia</i>	I	
9.	<i>Equus kiang</i>	I	
10.	<i>Camelus ferus</i>	I	
11.	<i>Cervus elaphus</i>	II	
12.	<i>Bos mutus</i>	I	
13.	<i>Procapra przewalskii</i>	I	
14.	<i>Procapra picticaudata</i>	II	
15.	<i>Gazella subgutturosa</i>	II	
16.	<i>Pantholops hodgsoni</i>	I	
17.	<i>Capra ibex</i>	I	
18.	<i>Pseudois nayaur</i>	II	
19.	<i>Ovis ammon</i>	II	
20.	<i>Lepus yarkandensis</i>	II	
AVES			
1.	<i>Podiceps auritus</i>	II	
2.	<i>Pelecanus sp.</i>	II	
3.	<i>Ixbrychus minutus</i>	II	
4.	<i>Ciconia ciconia</i>	I	
5.	<i>C. nigra</i>	I	
6.	<i>Platalea leucorodia</i>	II	Tarim River and Tian Shan Mts.
7.	<i>Cygnus cygnus</i>	II	
8.	<i>C. columbianus</i>	II	
9.	<i>C. olor</i>	II	

10.	<i>Aquila chrysaetos</i>	I	
11.	<i>Haliaeetus leucoryphus</i>	I	
12.	<i>Gypaetus barbatus</i>	I	
13.	<i>Milvus korschun</i>	II	
14.	<i>Accipiter nisus</i>	II	
15.	<i>Buteo rufinus</i>	II	
16.	<i>B. buteo</i>	II	
17.	<i>Aquila pennata</i>	II	
18.	<i>Circus macrourus</i>	II	
19.	<i>C. aruginosus</i>	II	
20.	<i>Aegypias monachus</i>	II	
21.	<i>Accipiter gentilis</i>	II	
22.	<i>A. badius</i>	II	
23.	<i>Buteo lagopus</i>	II	
24.	<i>Circus cyaneus</i>	II	
25.	<i>Falco cherrug</i>	II	
26.	<i>F. peregrinus</i>	II	
27.	<i>F. subbuteo</i>	II	
28.	<i>F. tinnunculus</i>	II	
29.	<i>Lyrurus tetrix</i>	II	
30.	<i>Grus grus</i>	II	
31.	<i>G. nigricollis</i>	I	
32.	<i>Anthropoides virgo</i>	II	
33.	<i>Grus leucogeranus</i>	I	
34.	<i>Crex crex</i>	II	
35.	<i>Porzana parva</i>		
36.	<i>Tetraogallus himalayensis</i>	II	
37.	<i>T. tibetanus</i>	II	
38.	<i>Bubo bubo</i>	II	
39.	<i>Otus brucei</i>	II	
40.	<i>Athene noctua</i>	II	
41.	<i>Asia otus</i>	II	
42.	<i>A. flammeus</i>	II	
43.	<i>Nyctea scandiaca</i>	II	
PISCES			
1. Big-head fish	<i>Aspiorhynchus laticeps</i>	I	

## APPENDIX D

### LOWER GREEN CORRIDOR QIALA TO TAITEMA LAKE FIELD INSPECTION 6 - 7 APRIL 1999

#### **Present:**

Hugh Cross (OPCV), Madam Zang (Interpreter), Mr. Do (XSDI), Mr. Hu Wei Dong (Division 2 of the Xinjiang Protection and Construction Corps) Mr. Wang Shui Sheng (XSDI Hydrologist), Mr. Wang (XSDI), Mr. Chen Bao Liu (Bayingol TBMB), Mr. Wang Fu Yong (Bayingol TBMB Environment and Hydrology officer), Mr. Zhou (XSDI), Mr. Lai (Bayingol Forestry Bureau), Mr. Abdulla (Animal Husbandry Bureau).

#### **FIELD TRIP ITINERARY**

##### *Tuesday 6 April:*

Travelled from Korla to Yuli, then to Qiala and Daxihaizi Reservoir. Stayed at the Ti Gan Li Ke Hostel at XPCC No. 34 Corps about 15 km east of Daxihaizi Reservoir. The 34<sup>th</sup> Corps has 8,000 members who work 80,000 MU.

##### *Wednesday 7 April:*

Continued to Yinsu, about 40 km south east of Daxihaizi Reservoir. Returned to Korla via the same route.

#### **GENERAL DESCRIPTION:**

- The whole area is in Bayingol Prefecture, Yuli County.
- The road is in poor condition from about 5 km south of Yuli. Only 25 km/hr can be averaged on the dirt road in a bus, whilst a 4WD can average perhaps 40 km/hr at the most. This road is a major impediment to the movement of labour, materials and agricultural produce.
- There are 5 State Farms: XPCC No. 31, 32, 33, 34 & 35. The last two are downstream of Daxihaizi Reservoir.
- Yinsu is at the 930 km road mark, Qiala Reservoir at the 790 km mark.
- The Lower Green Corridor (LGC) has been divided into three reaches by previous workers:
  - ⇒ Qiala to Daxihaizi
  - ⇒ Daxihaizi to Yinsu
  - ⇒ Yinsu to Taitema Lake

This subdivision corresponds to the prevailing hydrologic and ecological conditions. The three sub-reaches or sections can be referred to as the upper, middle and lower LGC.

## **GEOMORPHOLOGY:**

- Between Yinbazar and Qiala the river has many floodplain channels and the Green Corridor is wide. Qiala Reservoir is located at the point where the river regains a single channel. It appears that this may be due to a major structural (bedrock) control underlying the alluvial sediments in the vicinity of Qiala. The LGC is very narrow at this point, being less than 3 km wide adjacent to the reservoir. The north-eastern side of the reservoir is formed by the sand dunes of the Kuluk Desert. The dunes of the Taklimakan Desert are easily visible across the largely treeless LGC on the south west side.
- The river channel has a capacity of about 120 m<sup>3</sup>/s at Qiala according to Mr. Hu Wei Dong. This reduces to about 30 m<sup>3</sup>/s at Yinsu. In part this is due to the steeper longitudinal slope and relatively straight channel at Qiala (as noted by Mr. Lai) as well as the larger cross-section. At Qiala the cross-section is relatively rectangular and about 50 m x 2 m compared to the more triangular cross-section at Yinsu, where the bed is 2 to 4 m wide x 5 m deep and 20 m between the top of banks. The high sinuosity and short wavelength of the meanders at Yinsu indicates a slower velocity.
- The conclusion that there is shallow bedrock at, and upstream of, Qiala Reservoir is in part due to the above noted channel characteristics, but also due to the evident high water tables. This is reflected in the relatively good condition of floodplain shrubs and reeds, and in the presence of occasional groups of poplar diversiflora trees on sand dunes on the edge of the desert. Advice from the Bayingol Forestry Bureau is that once groundwater levels fall below 10 m, tree condition suffers and ultimately ends in death. Evidently therefore, the young, healthy PD trees on the top of dunes 6 m high must have regular access to groundwater well within 4 m of the surface of the floodplain. Indeed some water was observed in depressions and excavations within 1 to 2 m depth.
- The ephemeral lakes between the dunes in on the south-western edge of the LGC may also be indicative of high groundwater levels. These lakes are opposite and downstream of Qiala Reservoir. The closest and largest are, or were, probably fed by surface flows as well, but the more distant ones could only be groundwater fed, if indeed they are lakes, as is suggested from the water and vegetation response in MSS satellite imagery.
- Groundwater levels may be supported, in part, by the south-eastern movement of groundwater from Aksupu swamp, an area that is mainly fed by Kongque River flows. Apparently that area is not as healthy as it once was.

## **HYDROLOGY AND WATER QUALITY:**

### **Qiala Reservoir**

- Capacity is 140 x 10<sup>6</sup> m<sup>3</sup>. Maximum depth when full is 4 m, whilst the average depth is 1 - 2 m. It dries up in some years. March is generally the lowest month.
- Most water is supplied from the Kongque River via a constructed channel. This channel discharges water directly into the top end of Qiala Reservoir. It costs the State Farms RMB ¥ 0.0024/m<sup>3</sup> to purchase this water from the Bayingol Prefecture Government (?Bayingol Water Resource Bureau).
- Water can only be diverted from the Tarim River during flood flows, otherwise there is insufficient head, as there is no weir across the Tarim to assist gravity diversion.
- All five State Farms (Corps of the XPCC) are supplied from Qiala Reservoir. No. 31, 32 & 33 Corps are supplied from the channel between Qiala and Daxihaizi Reservoirs. This

channel has a capacity of 100 m<sup>3</sup>/s and water takes 3 to 5 days to travel the distance. The transfer efficiency is 0.8 - 0.9, compared to the Tarim River's 0.6.

- The Kuta Main Canal (30 km long) was built in the 1970's. It will be lined as part of Tarim II. It currently goes as far as Aksupu but will be extended to Qiala as part Tarim II. The extension will be called Kuta Dong.

### **Daxihaizi Reservoir**

- We were advised (incorrectly) that Daxihaizi Reservoir occupies a depression on the northern floodplain of the Tarim River (it does in fact impound the Tarim River – see below). It was built in 1957, however, an extra embankment was built in 1994 to increase the depth and to limit the surface area. The design capacity is 186 x 10<sup>6</sup> m<sup>3</sup> and the operating volume is 160 x 10<sup>6</sup> m<sup>3</sup>. However, the normal full capacity is in the order of 80 to 100 x 10<sup>6</sup> m<sup>3</sup> and the effective portion of this that can be used in any one year is about 40 x 10<sup>6</sup> m<sup>3</sup>. At the time of inspection it was holding 80 x 10<sup>6</sup> m<sup>3</sup>. The maximum depth is about 4 m, whilst the average is only 1 to 2 m. Evaporation is >2 m/yr.
- The salinity of Daxihaizi was about 2.7 g/l at the time of the inspection. In the flood season it is about 2.1 g/l. Mineralisation, temperature and perhaps some other parameters are regularly monitored.
- We were advised (incorrectly) that the river continues around the reservoir, enabling flows to bypass it at times. It appears that all flows up to a certain discharge will enter the reservoir by gravity diversion via a canal, above which the remainder will continue pass the reservoir in the river. The latter situation rarely if ever occurs now. Apparently, it takes an average annual flow of > 35 m<sup>3</sup>/s at Daxihaizi for this to occur (i.e. 1.1 x 10<sup>9</sup> m<sup>3</sup>). Hu. In any case, we were advised, most flows now enter the reservoir from the Qiala Canal. However this is not the case either, as Qiala Canal is that canal which takes water from the Tarim River at Qiala and feeds the State Farm areas. Even the Qiala Release Canal does not reach Daxihaizi Reservoir, but joins Qiala Canal.

The above information about the location of the reservoir is incorrect, as can be clearly seen on satellite and aerial imagery in the TBMB office. The river is impounded by Daxihaizi Reservoir as all involved parties should know.

- The TBMB is working with the XPCC to achieve some flooding downstream of Daxihaizi Reservoir. To date this was successful in 1995 when 28 x 10<sup>6</sup> m<sup>3</sup> was released over 18 days at 12 m<sup>3</sup>/s. This water just reached "The Miller's Place", about 2 km upstream of Yinsu. There was no overbank flow.
- The last "natural" flow to reach Yinsu was in 1991, however whilst leading to the germination of some PD trees in the channel, it did not go overbank and assist the trees on the floodplain. The last flood was in the early 1980's.
- About 20,000 people live in the Daxihaizi area and work 50,000 MU of agricultural land commanded by the reservoir. In the past two years about 300,000 MU has been planted, including the tree plantings.
- The priority of water allocation is forestry then agriculture. Trees include fruit trees and shelter belts, there are no plantations as such. Trees require about 700 m<sup>3</sup>/MU/yr, whilst agriculture requires 600 - 700 m<sup>3</sup>/MU/yr. There are about 120,000 MU of trees. Fruit trees include apples, pears, dates, peaches and apricots.

## **HUMAN ACTIVITIES AND LANDUSE:**

- The only settlements are associated with the reservoirs and the State Farms. There are few herdsmen away from the settlements as they are no longer nomadic, but are settled and grow irrigated pasture for their animals.
- There is some unplanned development along the LGC using water pumped from the Tarim River just upstream of Qiala Reservoir.
- Grazing values for herdsmen have deteriorated to the extent that there is no one downstream of Yinsu. At Yinsu the last few herdsmen only come in winter. Water in the village well is about 6 m or more below the surface in the bottom of an old channel of the Tarim River.
- There are about 50,000 people in the State Farms (XPCC). The Yuli XPCC was established in 1958. The original settlers are now mostly retired and the second generation are now the workers. More workers are being encouraged to join the Corps. This is primarily to support the aging population.
- The XPCC has developed about 100,000 MU for irrigation near Tarim Township (outside of the LGC) which it has handed over to herdsmen. There are about 2000 herders, with 100 to 200 animals per family. The animals graze the river areas, not the farm land.
- Living and agricultural conditions are poor. In some years crops need to be planted three times, resulting in more water use.
- In years when no water reaches Daxihaizi, the Government pays people so that they do not move away (eg. 1993). In those years only 30,000 MU is planted.
- The XPCC plants both poplar *diversifolia* and grey poplar as shelter belts around agricultural areas and settlements.
- Mr. Abdullla noted that Yuli County is half agriculture and half grazing. 250,000 cattle are grazed within the LGC; there are none grazed outside it.
- In the 1980's the quantity and quality of the grazing lands deteriorated with the decrease in water. Of the 28 species of palatable grasses originally present, only 5 to 6 remain. Consequently, the herdsmen have no choice but to settle permanently and irrigate grass for their stock. It was noted that new reed growth (*Phragmites sp.*) offers good grazing; old growth, apparently not.
- The natural pastures of the LGC are more dependent on volume than duration, as this is what establishes the extent of flooding and therefore the extent of pasture. However, the duration is also important as a minimum of 15 to 20 days flooding is required for good grass growth.

## **ECOLOGY:**

- RMB ¥ 50 - 100 is paid to each person in the LGC by the XPCC to prevent poplar and red willow cutting for fuel.
- There are few wild animals, apparently due to the deterioration in pasture. Only wild hares were noted.
- Mr. Lai noted that the lack of trees near Qiala is due to the lack of overbank flows, both prior to water development and since. Flood waters are needed to distribute and germinate the seeds. A minimum of two weeks of shallow flooding is required for germination.

- Tree cutting is responsible for the lack of trees in other areas. In the 1950's, the main areas of reclamation were within treed areas of the LGC. This practice has been stopped and now the trees are protected as much as possible. People now respect and value the trees for the protection against the desert sands and wind storms.
- Established trees can survive up to 10 years without flooding. When a tree is punctured (for instance by a growth-ring corer), the water can flow horizontally up to one metre. This is taken as an indication of the very strong water pressure within the tree bringing water up from the roots. It may also be due to the hydraulic head of passive water stores within the trees'.
- A type of caterpillar eats the leaves of PD. Previous reports were that this caterpillar ("worm") is now worse in areas receiving little or no water.
- The overall condition of the LGC between Qiala and Daxihaizi is moderately good considering the changes in water availability. Pasture condition and lack of tree establishment are undoubtedly the most visible signs of deterioration. Existing trees appear quite healthy, probably because groundwater levels are still being supported to some degree by the losses from the canals, river and irrigated areas.
- Between Daxihaizi and Yinsu, the situation deteriorates rapidly. There is no pasture or even thorny "Bell Bushes" in most areas. There are no new trees. Areas of wind erosion are evident in treed parts of the corridor right up to the Tarim River. The Tarim has no aquatic vegetation in it. It is a dry dusty depression indistinguishable from the rest of the corridor apart from its depth.
- Downstream of Yinsu was not inspected. However, reports are that live trees extend to Alean, but not much further and those trees are dying or dead.

## APPENDIX E

### MIDDLE GREEN CORRIDOR FIELD INSPECTION 3 - 4 APRIL 1999

#### **Present:**

Hugh Cross (OPCV), Madam Zang (Interpreter), Mr. Do (XSDI), Mr. Wang Shui Sheng (XSDI Hydrologist), Mr. Wang Shi Sheng (XSDI), Mr. Chen Bao Liu (Bayingol TBMB), Mr. Wang Fu Yong (TBMB Environment and Hydrology officer)

#### **SATURDAY 3 APRIL: Korla to Xaya County (Aksu Prefecture)**

- Lunch was taken at Kuqa (pronounced "Kuche") the second largest town in Aksu Prefecture. It is over an hour's drive from there to the river through the Xayar Irrigation District (pronounced "Shaya") which is supplied from the Weigan River, as are two other irrigation areas. There is a gradual fall towards the Tarim River in the form of a large fan. The slope is only noticeable from the direction of supply channels, drains and the levelled irrigation plots. As the Tarim River is approached the water supply is from that river.
- Spent the night at Xayar town in a comfortable hotel. Dinner was hosted by Mr. Hua, Director of the Xaya County Hydrographic Division and Mr. Shi (Deputy Director).

#### **Xinqiman Hydrographic Station on the Tarim River**

##### *General Description:*

- Visited Xinqiman Hydrographic Station office and accommodation compound, which is about 1 km from the river - locked at the time of our visit with no one present. The County has recently constructed a major drainage channel past the Station. This has caused the Station's well to become unusable due to an increase in the salinity. The officers, who are stationed there on rotation for 1 to 3 months at a time, now have to get water from the river or elsewhere. The staff are from the Aksu Prefecture Hydrographic Division Office. Mr. Wang Fu Yong used to be one of the officers some time ago before joining the TBMB.
- General drainage water salinity is in the order of 3 to 4 g/l (ie. 3000 to 4000 mg/l). Mr. Do advised that data from representative periods over the past 30 years can be provided. He estimated the volume of drainage water from the whole Weigan River area to be about 10 m<sup>3</sup>/s.

##### *Hydrology, Geomorphology and Water Quality:*

- The reach at Xinqiman is the straightest and narrowest in this section of the river. This is why it was chosen for the bridge and gauging station.
- The gauged section is about 1 km upstream of a pontoon bridge over the river, which is directly south of the Hydrographic Station. The river's dimensions at the bridge are approximately 600 to 800 m wide between top of banks and 2 m from the top of the left bank to the water level. The low flow channel was about 60 m wide by 0.5 to 1.0 m deep



maximum and is against the left bank (looking downstream). Discharge was 20 m<sup>3</sup>/s and salinity about 3 to 4 g/l.

- The 1994 flood was 1,700 m<sup>3</sup>/s (146,900 ML/D)- which was perhaps the largest on record according to Mr. Shi (the Deputy Director of the Xaya County Hydrographic Division). The 1998 flood was 1,240 m<sup>3</sup>/s (107,100 ML/D).
- Discharge at bank full is 700 to 800 m<sup>3</sup>/s (60,000 to 70,000 ML/D). Prior to 5 to 6 years ago it was about 1,500 m<sup>3</sup>/s. The decrease is due to about 1 m of sedimentation in the bed of the river according to Mr. Wang Fu Yong.
- Mr. Wang Fu Yong says that the river is moving towards the left bank and has significantly reduced the distance between the river and the Hydrographic Station.
- The river is gauged every day in the flood season (i.e. July, August, September) and every 15 days over the remainder of the year, as the Station is a “National Level Basic Station”. A boat is attached to the cable way that is slung from two towers on either bank. No mention was made of how overbank flows are measured.
- Other data that are sometimes collected include mineralisation, clarity, suspended sediment, pH, temperature,.... These samples are taken by special staff from the Water Quality Monitoring Centre of the Aksu Prefecture Hydrologic Station.

#### *Ecology:*

- There are no recorded data on ecological parameters for this Station.
- Big Head Fish have “Level 2 Protection” under a National law. Herdsmen have seen them in the past two years and even filed a suit in one case where a structure being built by an agency was going to block the fish’s access to breeding areas. It would appear that the breeding areas might be lakes and flooded areas of the Green Corridor.
- There used to be three species of fish; Big Head Fish (the only remaining species and then only in small numbers), an “easily caught fish” achieving lengths over 0.6 m, and a “red fish”. Shrimps can still be caught and some small fish about 60 mm long were observed at the edge of the river.
- Terrestrial animals observed in this reach of the Green Corridor include wild pigs and hares. There were few tracks of insects in the sand and none of reptiles or small mammals, such as rodents. Whilst it is early in the season, none of these animals were mentioned by the people present.
- The Diversified poplar (DP) forest is less than 1 km wide on the left bank and of indeterminate width on the right bank. Large areas of trees on both banks have been lopped for fire wood, generally about 2 to 3 m above the ground. Some areas of trees on the left bank have been completely cleared, as noted by some of those present, compared to previous visits. Harvesting of branches on multiple occasions has led to moderate sized trunks of up to 0.3 m diameter supporting small rounded crowns of many small branches only 30 to 50 mm in diameter. Even the un-cut trees are not large. In fact there are few trees on the left bank taller than 4 to 5 m. Trees on the right bank are larger, with trunk diameters up to 0.6 m and heights up to 8 to 10 m where they have not been lopped.
- There is little understorey apart from young PD trees, of which there are moderate numbers. Only a few species of shrubs are present. There are no grasses or other ground cover. Only dead PD leaves cover some of the hollows in the uneven sandy surface. In

some areas, the fine sand is covered with a darker layer of finer sediment, either indicative of lower velocities in the flood season and/or lower levels on the floodplain.

#### **SUNDAY 4 APRIL: Xaya to Korla via Yinbazar (Bayingol Prefecture)**

- It is not possible to drive along the river or even through or on the edge of the Green Corridor. There are no roads, only rough tracks and is likely that most of these would have difficult to negotiate sandy and boggy sections. Therefore it is necessary to back track via Xaya to the main Aksu to Korla highway, which is joined at Xinhe. The highway is left at Luntai. The first half in to Yinbazar from this direction is on a bumpy narrow sealed road, but on joining the new road constructed by the Oil Development Agency, it is mostly a fast drive. If coming from the direction of Korla, this oil road can be used for its entire length, from where it leaves the highway about half an hour's drive out of Korla, to the river (a 2 hour drive). From the river, this road becomes the "Desert Highway".

#### **Yinbazar Hydrographic Station on the Tarim River**

##### *General Description:*

- The Yinbazar Hydrographic Station office and accommodation compound is located in the new village of Yinbazar. The village is immediately adjacent to the northern (left bank) abutment of the Tarim River Bridge and has sprung up since the bridge's construction in 1995 by the Oil Development Agency.
- It appears from maps, satellite imagery and the field inspection, that the Green Corridor is much wider at this point than at Xinqiman. This is due to break-outs at and downstream of Xinqiman. A major route of these flood waters on the northern bank is crossed about 15 km north of the river. Further north, about 40 km from the river there are large areas of wet saline land, reed beds (*Phragmites sp.*) and some areas of stunted "red willow" (probably not *Salix sp.*). These areas are probably mostly fed not from the Tarim River, but from groundwater and minor surface flows from the irrigation tailwater of the Weigan River area and from the mountains to the north. It is possible that some of the floodwaters of the Weigan River could also contribute.
- The new road tends to impound and redirect water on the floodplain of both river banks, but this is probably not significant on anything but the local scale.

##### *Hydrology, Geomorphology and Water Quality:*

- Stream flow data are obtained by the staff of the Bayingol Hydrographic Station under the direction of Mr. Chen of the Bayingol TBMB. They use the bridge (600 m long between the left and right river banks) to take the gaugings. The frequency of gaugings was not asked. No mention was made of how overbank flows are measured.
- Interestingly, the TBMB had written a message on the bridge railing to the effect that "All water use from the Tarim River should be in accordance with the requirement to obtain a licence".
- The floodplain displays a greater variation in surface levels than Xinqiman and has areas of static and semi mobile dunes on both banks. It is likely that this is due to the lateral relocation of the major break outs and associated flood runners. Even the apparently higher areas with dunes support apparently healthy PD trees, although no young trees are present in those areas.

*Ecology:*

- The Bayingol Forestry Bureau has established a Protected Forest Area that extends downstream from just west of Yinbazar, to about half way to Qiala. The actual boundaries provided by the Bayingol Forestry Bureau are 84° 15' to 85° 30' East, 40° 55' to 41° 15' North.
- Other data have been collected as part of the Tarim I (?) Project in 1995-96, by the Environmental Evaluation and Research Institute of the Xinjiang Academy of Science under the direction of Mr. Zhang Fa Cheng. Local staff assisted during these sampling occasions, but apparently do not have the skills to undertake them independently. The data included water quality parameters, ecological information, amount and direction of sand movement and perhaps some other data. This monitoring has been discontinued due to lack of funds since the completion of Tarim I.
- The condition of the PD forest was similar to that at Xinqiman in the well watered areas. However, the greater variation in surface topography and greater width of the Green Corridor, is reflected in a greater diversity of condition and age structure, as noted above.
- The soil of the Green Corridor also reflects the variation in surface level, with higher areas being more sandy, to the extent of becoming mobile dunes in some areas. Underlying such areas there is a horizontal layer of finer darker material, a "hard pan", which probably reflects the original floodplain surface. These hard pan surfaces are visible in many areas of the northern edge of the Taklimakan Desert where it extends north of paleo-channels that are over 20 km south of the current river.
- It would appear that none of the areas near the road retain water after the three month flood summer season. The areas of reed and red willow, noted above, beyond the northern edge of the Green Corridor, would appear to be indicative of more permanently wet conditions. Perhaps such conditions are unsuitable for PD trees as they were absent from both reeds and thick red willow areas.
- PD trees do not begin to bud until late April or early May. Flowering begins in early April with separate male and female trees. The flowers of male trees are red, whilst the female trees' are green.

