What is river health?
The concept of “river health” incorporates ecological and human values. A “healthy” river is one which has retained its ecosystem integrity. The health of a river depends on its ability to maintain its structure and function; to recover after disturbance; to support local biota (including human communities), and to maintain key processes, like sediment transport, nutrient cycling and energy exchange.

River health is important. Healthy rivers provide water for drinking, agriculture, and industry; fish and other produce for consumption; the assimilation of waste products; buffers against flooding; and recreational opportunities. As rivers become unhealthy, they lose their capacity to provide these valuable goods and services.

Assessing river health
Maintaining and improving river health requires an accurate assessment of the current ecological state of river ecosystems. This process can:
• Identify parts of river systems that are in poor health, or at risk
• Identify the likely causes of poor health
• Help prioritise funding for river restoration, and guide effective management actions
• Assess the effectiveness of management actions
• Allow for reporting on river health

Background to this document
This document has been prepared as part of the River Health and Environmental Flow in China Project. The work described was funded by AusAID as part of the Australia-China Environment Development Partnership. The project involved pilot studies in the Pearl, Liao and Yellow River Basins. This document summarises the results of a pilot river health and environmental flow study in the lower Yellow River.

The study area
The study focussed on the lower part of the Yellow River: a reach stretching around 800 km from Xiaolangdi Reservoir down to the river’s delta where it meets the sea. The lower Yellow River has a relatively small catchment area and is bound by flood dykes for nearly its entire length. Demands for water for agriculture, urban, and industrial across the basin are extremely high. The river transports an enormous annual sediment load and various factors have resulted in a perched riverbed, up to 10 metres above the surrounding floodplain. As a result, managing the transport of sediment is a high priority of the water managers. The study area includes a number of internationally significant wetlands and is an important stopover point for migratory birds.

Catchment facts
Drainage: 794,712 km²
River length: 5,464km
Annual rainfall: 368-670mm
Mean annual runoff: ~58 billion m³ (before a natural reduction that occurred around 1990)
Population: 110 million in the basin, plus ~55 million in areas outside the basin but irrigated by the Yellow River (data from 2000)
Findings and recommendations

• The combined environmental river health index scores suggested that hydrology was not the main limiting factor to ecological health of the lower Yellow River. It appears more likely that water quality limits the ecological health.
• The health of the Yellow River Delta is at risk of low sediment supply (a lot of sediment is needed to continually expand the delta) and encroachment of farmland into wetlands, although artificial watering has led to expansion of areas of open water and reed.
• The results show enormous improvements in water quality and hydrology since the late-1990s. It may take some time for these improvements to be reflected in improved biotic health scores.
• The approaches developed for water quality, hydrology, and biotic indicators should be broadly applicable to other regions in China, although river-specific reference values will need to be developed and refined.
• The work on social indicators was novel, and while the results should be regarded as preliminary, it suggested ways of quantifying some of the important social values provided by the river. The indicators showed a overall high level of social value provided by the river.

Further information

Further information on the project, including detailed technical reports on the Yellow river health assessment, is available at: http://www.watercentre.org/research/applied-research/acedp
Environmental flows

Environmental flow is the pattern of river flow, or flow regime, which leads to a healthy ecosystem. People benefit from environmental flows because a healthy river ecosystem provides safe drinking water, adequate water for cities, industry and agriculture, favourable conditions for certain animals and plants that people highly value, and rivers that are attractive for recreation and tourism. Environmental flow needs are assessed using a scientific method that relates the flow regime to the level of river health that can be achieved.

For each of the four reaches, recommended flows were specified, including detail on the required flow magnitude, mean annual frequency and duration, inter-annual frequency, maximum rates of rise and fall, and time of the year. The flow options were constrained by certain operational requirements, including the need to keep flow within the confines of the main channel, due to the risk to human life and socio-economic values that floods would present.

An asset-based, holistic environmental flows assessment was made for the lower Yellow River, which identified multiple objectives for a wide range of assets. The main steps in the process were:

- **Step 1:** Define reaches and identify key river assets and processes. The lower Yellow River was divided into four reaches, based on physical and ecological characteristics. Various wetlands, together with the delta and the river channel, were identified as key assets to be protected. The map below shows the lower Yellow River’s four reaches and its key ecological assets.

- **Step 2:** Set management objectives for each asset/process. A field inspection of the river that included consultation with local experts and river managers, was followed by a workshop involving Australian and Chinese experts. Here, ecological and hydrological objectives were identified for each asset or process, and within each river reach. Flows related to geomorphologic, vegetation, macroinvertebrate, fish, waterbird, and water quality objectives were specified.

- **Step 3:** Develop hydraulic models of representative sections. River surveys were conducted and 1-D and 2-D models used to determine the flow required to achieve certain hydraulic objectives, such as watering important wetlands and providing fish habitat.

- **Step 4:** Develop preferred hydrological (environmental flow) rules. Flow rules were set based on achieving the management objectives. Two environmental flow options were developed: one would present a low-risk to achievement of good river health, and the other a medium-risk.

Hydrology as an indicator of river health

The environmental flow assessment provides both recommendations for future operations of the river system, as well as a basis for assessing river health, relative to hydrology. To this end, the extent to which the recommended environmental flows were achieved annually was assessed using flow data for the period 1950–2008. The results of this have been incorporated into the overall river health index.
Report Card Results

Socio-economic indicators

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Critical</th>
<th>Poor</th>
<th>Fair</th>
<th>Good</th>
<th>Very Good</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood Risk</td>
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<td>Drought Risk</td>
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<tr>
<td>Water Consumption</td>
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<tr>
<td>Water Quality</td>
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<tr>
<td>Hydropower</td>
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<tr>
<td>Navigation</td>
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</tbody>
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Combined index score

Scores for socio-economic indicators for the lower Yellow River in 2008
Ecological survey site (2008)

Yellow River Delta National Nature Reserve

River channel

Delta physical form index

Growth rate index is based on measured area of the Delta. Physical form index is based on sediment concentration and load delivered to the Delta.

Delta vegetation composition index

Scores for the delta based on vegetation composition calculated using remote sensing technology, using 1984 as the reference condition.

Hydrological indicators

Degree of compliance with environmental flow recommendation made in this project
Water quality was assessed against the standards for two different grades of river under the Chinese national water quality standards (GB3838-2002):

- A Grade III river: This is the official target for water quality in the lower Yellow River. It is the minimum grade required for a drinking water source and as such appropriate for assessing river health as it relates to human water use.
- A Grade II river: This sets a higher standard, such as for rivers or river reaches that provide natural habitat for sensitive and rare aquatic species, or fish and crustacean spawning areas. This grade was considered more appropriate for achieving good ecological health.

Data was analysed for the four reaches in the lower Yellow River for the period 1994 – 2009. The national standards cover 24 parameters, which include physical parameters (temperature), bacterial parameters (faecal coliform), and chemical parameters (pH, metal and non-metal toxicants, nutrients, and measures of oxygen balance). Some parameters were not considered in the study, notably total nitrogen and total phosphorus, where the standards were considered inappropriate given the natural characteristics of the Yellow River.

By assessing monthly data, the extent to which the target grade was achieved for each parameter – during the wet and dry seasons as well as for the whole year – was calculated.

The results show that the target water quality for the river (Grade III) is currently met most of the time. However despite a massive improvement since the late 1990s, the water quality standard currently achieved is probably still too low to allow a high level of river health. This means that for water quality, the social expectations are met, but the ecosystem health values would benefit from an improvement in water quality.
Ecological indicators

Fish, macroinvertebrate, and riparian vegetation indicators were used to assess ecological health within the river channel. The data used was collected in 2008 as part of a river survey by the Chinese Academy of Sciences that included the four reaches of the lower Yellow River. Reach-specific reference values were derived from historical data, literature review, and expert opinion, to provide a score on ecological condition. A total of nine indicators were selected for inclusion in the report card. Scores were assigned based on the observed/expected ratio, and with different indicators weighted based on the importance of the indicator and the quality of related data.

Ecological indices selected for inclusion in the Yellow River health assessment

<table>
<thead>
<tr>
<th>Fish</th>
<th>Macroinvertebrates</th>
<th>Riparian plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total species</td>
<td>Total species</td>
<td>Total species</td>
</tr>
<tr>
<td>Piscivore species</td>
<td>Number of functional feeding groups</td>
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<tr>
<td>Migratory species</td>
<td>Total density</td>
<td></td>
</tr>
<tr>
<td>Freshwater species</td>
<td>(Reach 4 only)</td>
<td></td>
</tr>
<tr>
<td>Native species</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Reach 1 (Braided)

Reach 2 (Transitional)

Reach 3 (Meandering)

Reach 4 (Estuarine)

Legend

Indicator score
Overall reach score

very good
good
fair
poor
critical

Hydrological indicators

The current environmental flow practice in the Yellow River is similar to the low-risk baseflow component recommended by the project. As a result, compliance with the flow regime is now fairly high, with a notable improvement over the last decade with the operation of Xiaolangdi Reservoir and the introduction of an annual water resources regulation plan for the Yellow River.

The hydrological indicator figures show the annual compliance with the medium-risk environmental flow regime for all flow components combined. It shows an overall grade of good to very good at all stations from 2005. The reference period, before Liujiaxia Dam began operation in 1969, showed a very high degree of compliance. Compliance was lowest in 1997, but a significant improvement occurred after 1999, when Xiaolangdi Reservoir began operation.
**Delta health**

The ecological value of the internationally important wetlands in the lower Yellow River is heavily dependent on the health of vegetation communities. Vegetation is a source of food as well as habitat, it can lead to improved water quality, and it influences the hydrology, hydraulics and movement of sediment in the river. An index for wetland vegetation in the delta was developed through analysis of data from Landsat satellite images. The composition of the vegetation in terms of the three main wetland vegetation types, and loss of wetland area to agriculture were assessed relative to the conditions in the year 1984.

The results from 1997 to 2006 suggested a trend of declining and then improving health of the vegetation in the delta, with the improvement coming from an increase in the area of reed (which can be explained by the artificial watering of part of the delta since 2002). It is of concern that the area of farmland increased through time from 1984 to 2006, although the proportion of the delta area that was farmland stabilised in 2006.

The physical form index for the lower Yellow River focussed on the amount of sediment supplied to the delta for ongoing growth of the delta, which is important for maintaining its characteristic wetland vegetation. The results indicated that sediment loads have fallen since Xiaolangdi dam began operation in 1999, putting the Delta in a state of declining area, or risk of declining area.

**Social indicators**

The lower Yellow River sustains a large population of people by providing water for domestic, agricultural and industrial purposes, generation of electricity and navigation, as well as providing cultural, recreational and aesthetic values. By reducing flood and drought risk, and improving water quality, river managers can enhance the social values of the river. Socio-economic indicators provide information on the services the river gives the human population. In this study, indicators of water consumption, hydro-power production, navigation, flood risk, drought risk and water quality for human uses were considered. Results for the period 2005 to 2009 suggest that in general, the social value of the lower Yellow River is high relative to expectations.