b) Sand prevention and sand fixation, another key regulation service provided by forest ecosystem, is realized through reduction of wind-resulted soil erosion and closely relates to such factors as wind speed, rain precipitation, temperature, soil, terrain and vegetation. The wind prevention and sand fixation performance of forest ecosystem is assessed with amount of sand fixed (the difference between potential wind erosion and actual wind corrosion) and sand fixing rate (the ratio between the amount of sand fixed and potential amount of sand lost from wind corrosion).

Revised Wind Erosion Equation (RWEQ) is adopted to calculate the amount of sand fixed and sand fixing rate and such factors as wind speed, rain precipitation, temperature, soil texture, terrain and vegetation cover are mainly considered during assessment of soil erosion and water and soil conservation.

$$\mathrm{SR} = S_{L潜} - S_L$$

$R_K = SR/S_{L潜}$

$$S_L = \frac{2 \cdot z}{s^2} Q_{MAX} \cdot e^{-(z/s)^2}$$

$$\mathrm{S} = 150.71 \cdot (WF \times EF \times SCF \times K' \times C)^{-0.3711}$$

$$Q_{MAX} = 109.8[WF \times EF \times SCF \times K' \times C]$$

$$S_{L_{潜}} = \frac{2 \cdot z}{s_{潜}{}^2} Q_{MAX潜} \cdot e^{-(z/s_{潜})^2}$$

$$Q_{MAX潜} = 109.8[WF \times EF \times SCF \times K']$$

$$S_{潜} = 150.71 \cdot (WF \times EF \times SCF \times K')^{-0.3711}$$

Therein, SR is the amount of sand fixed (t km^{-2} a^{-1}); R_k is the sand fixing rate; $S_{L_{潜}}$ is the potential wind erosion value (t km^{-2} a^{-1}); S_L is the actual amount of soil erosion (t km^{-2} a^{-1});

Q_{MAX} *is* the maximum transfer amount (kg/m)*; Z i*s the distance (m) when the maximum wind corrosion occurs; *WF* is the weather erosion factor (kg/m); *K* is the land surface roughness factor*: EF* is soil erosion factor*; SCF* is soil crust factor and *C* is vegetation cover factor.

Weather factor WF

$$\mathrm{WF} = \mathrm{Wf} \times \frac{\rho}{g} \times SW \times SD$$

Therein, WF is weather factor with kg/m as unit. The summation of 12-month WF results in annual average WF. W_f is the annual average wind factor $(m/s)^3$ for each month; ρ is air density (kg/m^3); g is gravitational acceleration (m/s^2); SW is average annual soil humidity for each month (non-dimensional); SD is snow cover factor (non-dimensional).

Soil erodibility factor EF

EF is calculated with the following equation.

$$\mathrm{EF} = \frac{29.09 + 0.31sa + 0.17i + 0.33\left(\frac{sa}{cl}\right) - 2.59OM - 0.95caco_3}{100}$$

In the equation, sa is grit content (%); si is silt content (%); cl is clay content(%); OM is organic matter content (&); $caco_3$ is calcium carbonate content（%）, which can be excluded from consideration and valued as 0.

Soil crust factor SCF

The quantification equation of soil crust factor SCF:

$$\mathrm{EF} = \frac{29.09 + 0.31sa + 0.17i + 0.33\left(\frac{sa}{cl}\right) - 2.59OM - 0.95caco_3}{100}$$

In the equation, cl is clay content (%); OM is organic matter content (%).

Vegetation cover factor C

The value of each vegetation cover factor C is worked out in reference to different coefficients:

$$\mathrm{C} = e^{-0.1535(SC)}$$

Here, SC is vegetational coverage (%) and the annual average egetational coverage is worked out through taking the average of the maximum values of 36-period vegetational coverage data each year;

Surface roughness factor K'

The following formula is used to calculate surface roughness factor K'

$$\mathrm{K}' = e^{(1.86K_r - 2.41K_r^{0.934} - 0.127C_{rr})}$$

$$K_r = 0.2 \times \frac{(\Delta H)^2}{L}$$

Here, K_r is earth ridge roughness calculated with smith- Carson equation (cm); C_{rr} is random roughness, which is usually 0 (cm); L is hypsographic feature parameter; ΔH is the sea-level elevation difference within the range of distance L, which is obtained through calculating topographic relief difference between neighboring DEM data table cells with Neighborhood statistics tool in GIS.

Sand fixing rate R_k

Sand fixing rate R_k: the ratio between amount of sand fixed and potential amount of sand lost from wind corrosion, reflecting the sand fixing performance of an ecosystem.

$$R_k = SR/S_{L_{潜}}$$

4. Water conservation

Water conservation means that forest ecosystem intercepts, saturates and accumulates atmospheric water through interacting with water by virtue of its unique structure, and regulates water flow and water cycle through evapotranspiration, and it could ease surface flow, supplement underground water, mitigate seasonal fluctuation of river discharge, detent flood to replenish dry places and guarantee water quality. The water conservation quantity is taken as an indicator to evaluate the water source regulation performance of forest ecosystem.

Water flow decomposition model based on precipitation and evapotranspiration is adopted for evaluation.

$$\mathrm{WY} = -\mathrm{ET}$$

$$\mathrm{ET} = \frac{P(1+\omega\frac{PET}{P})}{1+\omega\frac{PET}{P}+(\frac{PET}{P})^{-1}}$$

Here, WY is the water conservation quantity, substituting for water conservation service capacity; P is mean annual precipitation, ET is evapotranspiration rate, PET is mean annual potential evapotranspiration; ω is underlying（land cover) influence coefficient, valued pursuant to land use type. Here, highly generalized land surface coverage factor is adopted, therefore, the evaluation result needs to go through uncertainty analysis and parameter sensitivity analysis to ensure reliability.

Table 6-1-1 ω values for reference

Type of forest area	High coverage rate	Low coverage rate
ω value	2	1

Note: high coverage rate is higher than 30%, while low coverage rate is lower than 30%.

4. Identify and map forest areas

Based on the above analysis, GIS technology is adopted to analyze ecosystem values of each type of forest area and the results will be combined according to certain rules to obtain integrated ecosystem values of the forest areas.

Output

Forest areas and their ecosystem values identified and mapped in this module will be taken into consideration for mapping in Step 4 and Step 8.

6.2 Module 4B: Identify and Map Agricultural Priority Areas

Purpose

Agricultural priority areas refer to farmland, including long-cultivated field, newly-developed field, reclaimed field, consolidated field, and fallow field (rotation field); land mainly given to farm crop (vegetable) planting but interplanted with fruit trees, mulberry trees or other kinds of trees; cultivated beach land and tidal marsh where one season crop harvest can be guaranteed. The farmland include fixed ditches, channels, roads and ridges whose width is less than 1.0 meter in south China and 2.0 meters in North China, as well as land for temporary planting of herbal drugs, grass sod, flowers, seedling, etc.

Agriculture – whether for grain, fiber, fruit, vegetable, flower, poultry, fish or livestock production – provides substantial environmental, social and economic benefits, and food security, and at the same time may lead to pollution of air, water and soils.

Objective

This module aims to identity and map the benefits and environmental effect of agricultural priority areas and the details are as follows:

- Identify and assess the environmental effect of agriculture, whether for grain, fiber, fruit, vegetable, flower, poultry, fish or livestock production.
- Provide policy advice to different types of agricultural priority areas through identifying and assessing agricultural benefits and the environmental effect.

Output

Agricultural production activities are likely to influence air, water and soil and such influence can be assessed in market value method or expert assessment method.

1. Market value method

Range of application: the environment affected by agriculture can be partly or completely recovered through rehabilitation and regulation with feasible cost and technology.

Rehabilitation expense (F) comprises of conceptual development cost (B), cost of materials (T), monitoring and testing fee (M), effect evaluation fee (A), supervision cost (G), cost of manpower (U), etc. and the formula of computation is as follows:

$$F = B + T + M + A + G + U$$

2. Expert assessment method

This method is adopted when environmental losses resulted from agriculture can't be estimated in market value method.

Expert selection: the number of experts will be determined as required but not be less than 5 and experts should meet the following conditions:

a) Have senior professional title and authority and be engaged in R&D in current field for a long term;

b) Be work-proficient, experienced, well-known and representative;

c) Be familiar with economic value of the objects to be assessed.

Assessment procedure:

a) Select experts in reference to the conditions of each object;

b) Gather dynamic data in recent 3-5 years on the area for assessment;

c) Organize experts to go to the assessment area the peripheries and contrast areas for on-the-spot survey;

d) Screen, count, analyze and sort the acquired materials in combination with the result of on-the-spot survey;

e) Form expert opinions with expert signatures.

Handling of expert opinions

Appraisers will combine their own judgment with expert opinions to form the conclusion and common methods are as follows:

a) Averaging method: the arithmetic average method is used to work out the average mean of prices proposed by experts and this average mean shall be the regarded as the estimated value.

During mean value calculation, weighted average method can also be adopted by weighting the expert opinions according to the authority of each expert.

b) Mode method: the opinion that appears the most shall be adopted to evaluate the environmental effect of agriculture.

3. Benefits of agricultural areas

The benefits of agricultural areas are described with agricultural product price, which takes the mean market price then and there. If the mean market price then and there can't be obtained, then the mean market price in recent three years will be used. The mean market price is subject to the price published by government sectors or obtained through field survey.

4. Identify and map benefits and environmental effect of agricultural areas

Based on the above analysis, GIS technology will be used to assess benefits and environmental effect of agricultural areas, and land zoning will be done in reference to the assessment result.

Output

Benefits and environmental effect of agricultural areas identified and mapped in this module will be taken into consideration for mapping in Step 4 and Step 8.

6.3 Module 4C: Identify and map mineral resource priority areas

Purpose

Mining and other extractive industries may create extensive waste around their operations and they may generate positive and negative externalities.

Objective

The objective of this module is to assess the presence of minerals in an area, whether low-value material such as rock and sand, or high-value ores, and the details are as follows:

- Identify and map the presence of mineral resources in certain area.
- to estimate the scale of externalities now and in the future, and the opportunities to protect non-urban 'green' land from, or with, mining activity

Output

Mineral resource exploitation rate and utilization efficiency are usually considered during analysis of mineral resource externalities, and mineral resource reserve-production ratio (%), rate of recovery (%), ore dressing recovery rate（%）, comprehensive utilization ratio (%), integrated utilization efficiency (ton/10,000 yuan) are all key indicators of mineral resource externalities.

1. Reserve-production ratio (%)

The reserve-production ratio refers to the ratio between actual annual mining capacity (or designed annual mining capacity) of current mining area and the recoverable deposits, reflecting how the recoverable deposits guarantees the mining capacity.

2. Rate of recovery (%)

Rate of recovery, a key indicator to measure the mineral resource utilization degree and mining technology, refers to the ratio between extracted ore (or recovered ore) and the consumed industrial reserve in current mining zone, namely the rate of recovery = daily mining capacity (ton)/consumed industrial reserve (ton)×100%

3. Ore dressing recovery rate

Ore dressing recovery rate, namely the ratio between the mass of certain valuable element in the dressing products (usually concentrated ore) and the mass of such valuable element in the chosen ore, is a key indicator to assess and measure the ore dressing technology, management of a mining company as well as the degree of recovering valuable elements in the chosen ore.

The formula of computation for ore dressing recovery rate is as follows:

$\varepsilon=\gamma\times\beta/\alpha\times100\%$

here， ε is the recovery rate of certain element in the product(%)；α is the grade of such element in rude ore(%)；β is the grade of such element in product(%)；γ is the yield of current product(%)。

When yield is measured during ore dressing (it is quite difficult in practice), the theoretical recovery rate is often used to replace the actual recovery rate. The theoretical recovery rate is calculated as follows:

$\varepsilon_{理}=\beta(\alpha-\theta)/\alpha(\beta-\theta)\times100\%$

Herein, α, β are the same as above; θ is the grade of such element in the ore tailing(%). The loss of valuable elements during ore dressing is taken into account in the actual recovery rate instead of the theoretical recovery rate, thus the actual recovery rate is lower than the theoretical one.

4. Mineral resource integrated utilization efficiency (ton/10,000 yuan)

It (N) refers to the ratio between the gross output value of mineral resource exploitation (TV) and utilization and the mass sum of associated useful elements in the used resource reserve (W) and is computed as follows:

$$N = a \times \frac{TV}{W} \times 100\%$$

Therein, the price adjustment coefficient (a) is the ratio between the mean price of last survey year and that of current survey year; the mass of associated useful elements is calculated according to the grade equivalent and then mass sum of useful elements in the used resource reserve will be worked out.

5. Mineral resource externalities identification and mapping

Based on the above analysis, GIS technology is adopted to analyze each indicator in the mineral resource priority area, and the results will be combined according to certain rules to get the integrated externality indicator.

Output

The mineral resource externality map identified and mapped in this module can be referred to when assessing the opportunities to protect non-urban Green Land from, or with, mining activity. Mineral resource externalities identified and mapped in this module will be taken into consideration for mapping in Step 4 and Step 8.

6.4 Module 4D: Identify and map soil conservation areas

Driver / Purpose

Valuable soils disappear under urban development, but just as significantly valuable soils are lost due to contamination, erosion, salinization, desertification and similar processes of overuse and neglect. Such processes can be reversed if the soils are highly valued.

Objectives

The objective of this module is to assess and map the areas where soils are being lost, and areas at risk of erosion, salinization, desertification and other destructive processes, as input to the overall analysis of non-urban Green Land. Specifically, the objectives of Module 4D are as follows.

- To document and map the areas which are being lost and at risk of erosion, salinization, desertification or other destructive processes in the UREMP area.
- To provide comprehensive and credible input to planning decisions about the directions and nature of urban development and the distribution of land uses in the UREMP area, so that high-value soil areas are fully protected from urban development, urban sprawl and overdevelopment.

Outputs

Soil erosion sensitivity analysis is based on Universal Soil Loss Equation (USLE). Rainfall erosivity R value, soil texture, terrain waviness and vegetation type are selected as main impact assessment factors for assessment. Desertification sensitivity analysis refers that regional desertification sensitivity degree can be assessed through humidity index, soil texture, sandy wind days, etc. Stony desertification sensitivity analysis is assessed according to whether assessment area belongs to karst land-form or not, soil thickness, vegetation coverage, etc.

1) Assess and classify the sensitivity of soil erosion

Use "ecological function zoning techniques interim order" to make sensitivity assessment of soil erosion, and identify the region easy to form soil erosion. Use the universal soil erosion equation to assess, including rainfall erosivity (R), soil texture factor (K), slope length factor (LS) and surface factor (C). According to the Chinese soil erosion and ecological environment related research, determine the factors' sensitivity levels. Calculate soil erosion sensitivity index, in accordance with the "ecological function zoning techniques interim order" sensitivity grading standards.

Table 6-4-1 The classification of sensibility of soil erosion

Classification	No sensitivity	Mild sensitivity	Medium sensitivity	High sensitivity	Extreme sensitivity
R	<25	25-100	100-400	400-600	>600
Soil texture	Gravel, sand	coarse sand, fine sand soil, clay	Surface soil, loam	Sandy loam soil, silty clay, loam clay	Sandy silt, silty soil
Topographic relief degree (m)	0-20	20-50	51-100	101-300	>300
Vegetation	Water body, herbaceous swamp, paddy field	broad-leaved forest, coniferous forest, meadow, bush and coppice forest	Sparse shrub grassland, ripe twice a year, ripe twice a year for paddy-dryland	Desert, one harvest a year	No vegetation
Scale assignment (C)	1	3	5	7	9
Scale standard (SS)	1.0-2.0	2.1-4.0	4.1-6.0	6.1-8.0	>8.0

2) Assess and classify the sensitivity of soil salinization

Salinization sensitivity analysis refers that regional salinization sensitivity degree can be assessed through humidity index, soil texture, sandy wind days, etc. Specifically, the index and scale standard are as follows.

Table 6-4-2 The classification of sensibility of soil salinization

Index	No sensitivity	Mild sensitivity	Medium sensitivity	High sensitivity	Extreme sensitivity
humidity index	>0.65	0.5-0.65	0.20-0.50	0.05-0.20	<0.05
The number of days when the wind speed is more than 6m/s in winter and spring	<15	15-30	30-45	45-60	>60
soil texture	bedrock	clay soil	gravelly soil	loam soil	sandy
vegetation coverage (winter and spring)	Dense	moderate	less	sparse	bare
Scale assignment (D)	1	3	5	7	9
Scale standard (DS)	1.0-2.0	2.1-4.0	4.1-6.0	6.1-8.0	>8.0

The salinization sensitivity index calculation method is as follows

$$DS_j = \sqrt[4]{\prod_{i=1}^{4} D_i}$$

DSj refers to the index of unit j；Di refers to the scale assignment of factor i.

3) Assess and classify the sensitivity of soil desertification

Stony desertification sensitivity analysis is assessed according to whether assessment area belongs to karst land-form or not, soil thickness, vegetation coverage, etc. Specifically, the index and scale standard are as follows.

Table 6-4-3 The classification of sensibility of soil desertification

Index	**Carbonate outcropped area percentage（%）**	**soil thickness**	**vegetation coverage**	**Scale assignment（SS）**
No sensitivity	≤10	≤5°	≥0.8	1
Mild sensitivity	10—30	5°-8°	0.6-0.8	3
Medium sensitivity	30—50	8°-15°	0.4-0.6	5
High sensitivity	50—70	15°-25°	0.2-0.4	7
Extreme sensitivity	≥70	≥25°	≤0.2	9

The desertification sensitivity index calculation method is as follows

$$S_i = \sqrt[3]{D_i \times P_i \times C_i}$$

Si refers to the index of unit i；Di、Pi、Ci refers to Carbonate outcropped area percentage, soil thickness and vegetation coverage of unit i.

4.Assess and map–based on the above analyses – the relative value of soil conservation areas

Based on the above analyses, GIS technology is adopted for analyzing sensitivity of individual impact factors. The impact factors are overlaid and integrated according to certain rule, thereby obtaining integrated sensitivity distribution map. Sensitivity levels are assessed and zoned, and these areas can be divided into different levels.

Output

The Step 4 map (Indicative non-urban Green Land environmental protection and zoning) and the ultimate Step 8 UREMP instrument (showing the red line, yellow line and green line protection zones) are informed by valuable soil conservation areas in this module.

6.5 Module 4E: Identify and Map Priority Hazardous Areas

Purpose

Some areas of non-urban land which are used for productive purposes, or have potential to be used for productive and/or urban purposes, are constrained by being prone to earthquake, volcanic eruption, landslip, mudslide, rockfall, inundation, subsidence, and other hazards.

Objective

The objective of this module is to identify, assess and map the threats to non-urban Green Land and the details are as follows:

- Identify, assess and map the natural disaster risk, environmental risk and ecological sensitivity of non- urban Green Land.
- The result of the last step can be factored into the integrated assessment of environmental value.

Output

Risks of priority hazardous areas can be assessed through environmental risk assessment, natural disaster risk assessment and environmental sensitivity assessment.

1) Environmental risk assessment

Environmental risk assessment aims to establish effective risk countermeasures to minimize the negative influence and the environmental risk/ accident rate (%) is adopted for the assessment.

2) Natural disaster risk assessment

Natural disaster risk refers to possible losses foreseeable before natural disaster occurrence. Upon natural disaster risk assessment, disaster-causing factors (risk) and bearers (vulnerability) will be graded and classified respectively, and an assessment matrix will then be set up for risk assessment. A general method at the present time is to assess the potential risk level using the following model:

$R=H\times V$ （1）

Namely risk =（natural disaster）hazard ×（victim）vulnerability

In the formula, R (risk) involves natural disaster intensity and occurrence possibility. Natural disaster risk assessment is a complicated and difficult process as the causes to quite a few natural disasters are still unknown, therefore, an advisable practice is to grade and classify natural disasters and victims by risk and vulnerability respectively. The occurrence possibility is graded in accordance with risk occurrence frequency and intensity is determined by subsequent losses. Finally, a risk assessment matrix is set up to represent the risk level of each natural disaster.

Table 6-5-1 Risk levels of natural disasters

Aftereffect grade / Possibility grade		Low	Relatively low	Medium	High
		4	3	2	1
Minimal	4	16	12	8	4
Unlikely	3	12	9	6	3
Likely	2	8	6	4	2
Very likely	1	4	3	2	1

3) Risk assessment of ecologically sensitive areas

It aims to protect environmentally sensitive areas and maintain ecological balance and two indicators are often used for assessment:

a) the share of areas requiring special protection in the total area (%)

b) the share of ecologically sensitive and vulnerable areas in the total area (%)

4) Priority hazardous areas identification and mapping

Based on above analysis, GIS technology is adopted to analyse the risk of each factor relating to priority hazardous area protection, and the results will be combined according to certain rules to get an integrated risk distribution map. Then risk grading and zoning will be done.

Output

Priority hazardous areas identified and mapped in this module will be taken into consideration for mapping in Step 4 and Step 8.

6.6 Module 4F: Indicative Green Land Protection Zoning and Mapping

Purpose

All data and maps produced in Modules 4A to 4E are combined to delineate land that has high degrees of environmental value, against various criteria. This combined map shows the indicative Green Land zoning, to be integrated, in Step 8 (Integrate all outputs in an Environmental Protection Zoning Instrument), in a UREMP instrument showing the red line protection zone and the yellow line protection zone.

Objective

The objective of this module is to combine all data and maps produced in Modules 4A to 4E and details are as follows:

- Combine all data and maps produced in Modules 4A to 4E to delineate land that has high degrees of environmental value.
- The combined map shows the indicative Green Land zoning, providing comprehensive and credible input to planning decisions about the directions and nature of urban development and the distribution of land uses in the UREMP area.

Output

Indicative Green Land zoning map combines all data and maps produced in Module 4A to 4E to delineate certain land that has high degrees of environmental value, against various criteria.

1) Ecological values of forest priority areas

Forest areas include forest land, shrubbery land and others, classified with shade density and coverage and valued in accordance with water and soil conservation, water source conservation and wind prevention and sand fixation functions. Such values are combined according to certain rules to get the integrated ecological service value of forest areas.

2) Positive and negative externalities of agricultural priority areas

Agriculture provides substantial environmental, social and economic benefits, and at the same time may harm environment. To begin with, to classify agricultural areas, then to assess the values and environmental hazards of different types of agricultural areas in market value method or expert assessment method to get integrated externality indicators. After that, GIS is used to grade and zone agricultural areas in reference to the assessment result.

3) Positive and negative externalities of mineral resource priority areas

Mining and other extractive industries may create extensive waste around their operations and may generate positive and negative externalities. The integrated externality indicators of mineral resource priority areas are obtained through identifying the presence of minerals, and combining the assessment results of such indicators as mineral reserve-production ratio (%), rate of recovery (%), ore dressing recovery rate (%), integrated utilization rate (%) and integrated utilization efficiency (ton/10,000 yuan). After that, GIS is used to grade and zone mineral resource priority areas.

4) Soil erosion sensitivity

Valuable soils disappear under urban development, but just as significantly valuable soils are lost due to contamination, erosion, salinization, desertification and similar processes of overuse and neglect. Universal soil loss equation (USLE) is adopted for soil erosion sensitivity analysis with rainfall erosivity R value, soil texture, topographic relief and vegetation type as primary influencing factors. Desertification sensitivity analysis adopts such indicators as humid index, soil texture and number of stormy days. Stony desertification sensitivity analysis indicators include Karst landform or not, soil thickness, vegetation coverage degree, etc. Based on the above analysis, GIS is adopted to analyze the sensitivity of each factor influencing soil conservation and the results are combined to get an integrated sensitivity distribution map. The map will be used for sensitivity grading and zoning.

5) Risks of priority hazardous areas

Risks of priority hazardous areas can be assessed through environmental risk assessment, natural disaster risk assessment and environmental sensitivity assessment. Based on the above analysis, GIS is adopted to analyze the risk of each factor relating to priority hazardous area protection, and the results will be combined to get the integrated risk distribution map. The map will be used for risk grading and zoning.

6) Indicative Green Land protection zoning and mapping

Based on the above analysis, GIS is adopted to make overlay analysis of aforementioned five indicators in accordance with certain rules to complete indicative green land protection zoning and mapping and thereby to grade each area by its environmental value.

Output

Indicative Green Land protection zones and maps identified and mapped in this module are required for mapping in Step 8.

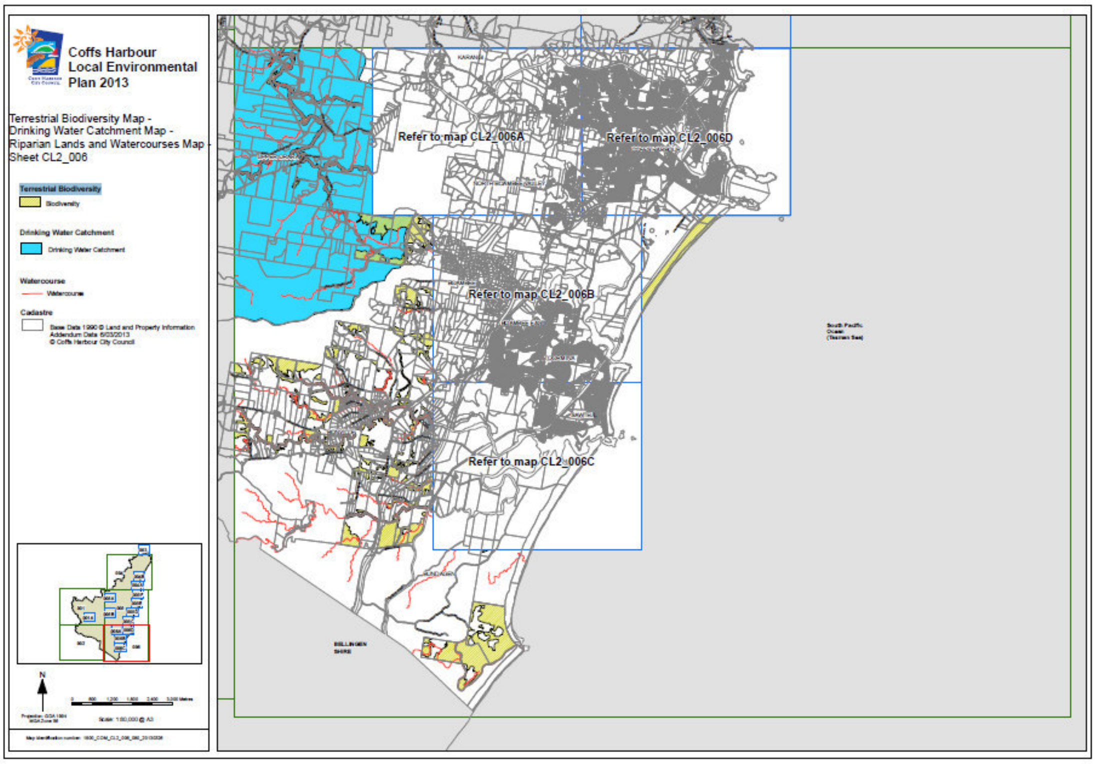


Figure 6-6-1 Coffs Harb. CL2_006 1800_COM_CL2_006_080_20130326

The map standards of Australian environmental planning has strict and scientific requirements. As the example of No. CL2_0061800_COM_CL2_006_080_20130326 drawing, its figure number is rigorous and scientific. CL2 is the category, which means map of terrestrial biodiversity, water basin map, map of riparian land and waterways; No.006 represents that the drawing is in the sixth chapter, sub-chapter are added by final syllable ABCD etc; No.080 represents the top map in this region, sub-chapter is No.020; No.20130326 is the date of map. The category is clear, which involves map title, map boundary and compass. And map scale is 0,100,200,300,600,1200,1800,2400,3000 meters, etc. Map scale expressed as 1:20000@A3, 1:80000@A3, etc, according to the map size. Coordinate system adopts GDA1994(Australia geocentric reference 1994)

As to environmental planning map, as an example of *urban environmental planning in Australia NSW WYONG*, the map elements are complete, such as figure captions, map boundary, compass, scale, proportion, legend, signature, icon, text description, map specification, drawing number, order of drawing number. Coordinate system adopts GDA1994(Australia geocentric reference 1994). Legend consist of boundary, roads, river system and water. The natural and environmental elements in the maps are clear, which are represented rigorously and scientifically, and also has a strong reference value.

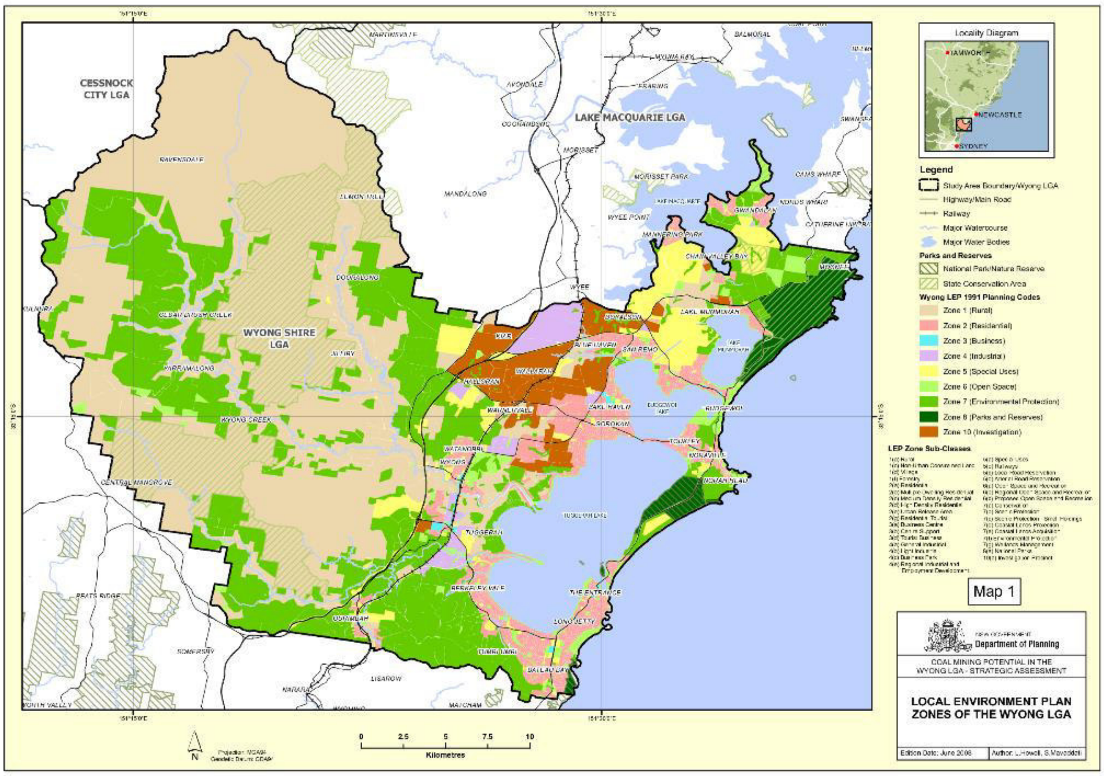


Figure 6-6-2 Urban environmental planning map in Australia NSW WYONG

From the point of Australia environmental planning content, the elements are clear, but the natural elements are expressed incompletely, especially the biodiversity. There are many status maps, but little planning map. And the regional environmental planning released does not include analysis map. Overall, content of Australia environmental planning is mostly expressed by words. the reference value of planning map is more significant than practical value, and the organization way of map code has strong reference significance.

7 Technical Modules in Step 5: Prepare an Indicative Zoning Map for Water Quality Protection

7.1 Purpose of this Guideline

Environmental space control is the necessary requirement for environmental protection planning to link up and coordinate with the urban planning and land-use planning, and for implementing the requirements of environmental protection. However, from the points of view of content of environmental planning and technical methods, environmental protection planning focus on the pollution control task and engineering design ever since a long time ago; it lacks of starting point and corresponding technical methods on master space protection, as well as graphic expression based on geographic information for its achievement expression; especially, the requirements in the planning cannot be implemented in the areas needs to be strictly controlled for development; it is not only incompatible with the requirements of universal planning, but also lacks of platform for connecting and coordinating with the "graphic" planning such as urban master planning and general land use planning, etc. Therefore, since it is unable to realize the space implementation of requirements of environmental protection, it is very difficult to a good foundation that coordinates urban-rural economic development and environmental protection, which results in that the original and tectonic urban environmental problems cannot be effectively solved. Determining the detailed content of environmental space control, defining the technical methods for environmental space control and providing good control measures for environmental space are the key parts for realizing the environmental space control. Therefore, it is necessary to measure, map and analyse water quality.

Objectives in Measuring, Mapping and Analysing Water Quality

Carry out the system structure analysis on water , base on the evaluation of structure sensitivity, fragility of process and ecological function importance of water, recognize their differences on spatial distribution, and establish the resonable corresponding grading standards, delimit the management and control zones on water environment, with matching grading control requirement, establish a integrated system for classification management and control.

Partition goal control unit of ‘watershed-control area-control unit’ should be established in accordance with principles of goal-orientation, regional full coverage, responsibilities of administrative regions at all levels on water environmental quality in jurisdictions, land and water combination, load determination with water, etc. It is used as basic framework of water pollution prevention and management. Water environmental capacity and water resource load bearing capacity are measured on the basis of control unit. Control of total water pollutants and other water environment load adjustment optimization suggestions are proposed.

Measuring progress towards objectives

The overriding goal of protecting Green Land from urban development, urban sprawl and overdevelopment will only be achieved under conditions of sustainable urban development. Peoples Governments at all levels will need measurable and staged objectives, to guide urban management personnel and resource consumers to develop to directions beneficial for urban environmental development.

Indexes are proposed to quantify and integrate progress towards objectives. Four sets of indexes are proposed: ecological pattern category, environmental carrying category, environmental quality category and environment public service category, and each category includes several indexes. The relevant water quality indexes are shown in Table 01.

In the table, the bottom line index refers to the environmental bottom line that should be guaranteed in urban development process. Medium and long-term index systems are recommended. These can be adjusted as appropriate to local conditions.

Table 7-1-1 Medium and Long-term Target Index System Recommended for UREMP: Water quality indexes

Field	No.	Index	Base year	Recent target year	Long-term target year	Bottom-line/binding force
Safe and stable ecological pattern	3	Water environment class I control zone area proportion (%)				
Environmental resources with sustainable utilization	8	Ten-thousand yuan industrial added value water consumption (cubic meter/ten thousand yuan);				
	9	Per capita domestic water consumption (liter/ person. day) (according to resident population)				
	9	Effective utilization coefficient of farmland irrigation water				
	10	Water environment overload unit COD load-carry duty (%)				
	11	Water environment overload unit ammonia nitrogen load-carry duty (%)				
Healthy and safe environmental quality	15	Proportion of drinking water sources with qualified water quality (%)				
	16	Urban river water quality				
	17	Urban area state-controlled and province- controlled cross section water quality compliance rate (%)				
	18	Farmland soil environmental quality				
Fair and sharing environment public services	19	Population proportion enjoying safe drinking water (%)				
	21	Urban sewage disposal system coverage proportion in urban and rural communities (including villages in city) and rural settlements (including administrative villages and natural villages) (%)				

7.2 Module 5A: Determine scope of water environment and spatial control units

Data Preparation

Graphical data: water (environment) function zoning, terrain (30×30 grid data), water system and administrative division (1: 50,000 digital map is recommended), section (point location) distribution, sewage outfall distribution, pollution source distribution and water quality monitoring sections (point location).

Text data: water (environment) function zoning related information, river flow and function area section (point location) water quality data.

Graphic processing software: ArcGIS, or ArcView, or Mapinfo etc.

Determine the Scope of the Water Environment / Available Water Resources

1) Determination of Water Scope

Water scope determination is the basis for determining control unit scope. Achievements of water (environment) function zoning of the studied city can be adopted as reference. Water (environment) function zoning basic data includes water scope, length, area, status use function, status water quality category, planned dominant functions, function goal, starting section and ending section names, latitude and longitude as well as other information.

Figure 7-2-1 Map of the water resource in Guangzhou

2) Determination of Land Scope

Related order of ArcHydro hydrological module in ArcGIS is applied to divide catchment area (watershed) of water (environment) function areas. Water flow direction and catchment scope of collecting area are determined, and they are converted into shape format. Related catchment areas (larger than or equal to one) should be gradually judged aiming at each river section in water (environment) function zone. They are combined into one region, namely land scope of corresponding water (environment) function zone river section.

Water Environment Situation Analysis and Problem Identification

First, analyse characteristics of river distribution in the city (including size, etc.) and environmental functions positioning; Secondly, analyse the distribution of drinking water sources in research city and surrounding cities; Thirdly, grasp the quality of the existing water (including water quality compliance rate, COD and ammonia concentration, etc.). Accordingly, recognize the problems of water quantity, water quality and water function in the city.

Figure 7-2-2 Map of the water environment function zoning in Guangzhou

Water Environment Control Unit Division

Dividing water environmental control unit can establish correspondence between water functional areas and land environment, identifying responsible areas which affect the water environment function zones, achieving convergence between water control and administrative areas. That makes it easy to put the water environment classification assessment, goal setting and grading control into specific control unit.

1) Division principle

(1) Reflect characteristics of water environment's ecological functions, especially highlight the functional requirements of water conservation areas and special species protection.

(2) Consider the integrity of the natural water system. Natural water systems are the benchmarks for land division. According to the natural catchment characteristics and artificial pipe network, determine the scope of land, and initially form the land and sea combined control unit.

(3) Management feasibility and operability. Considering the existing administrative system regarding county as grassroots administrative units of environmental data survey and statistics, for the operability of spatial control, control unit should try to reflect the integrity of the county or township administrative boundaries. Suggest that make the county as a minimum space matched unit.

2) Division method

Water environmental control unit is space management unit consisting of land and waters two parts. According to division principle, determine the land range corresponding to the water environment function zones. Methods of dividing the control unit as follows:

First, determine the range of water. Determining the range of water is the basis for determining the range of the control unit. Basic data for use includes waters' location, the size, the function, the water quality, the planning dominant function, the functional goals, the starting section and end section and other information. Water environment function zones in the research area can be referenced.

Then, determine the range of land. Use the related commands of ArcHydro hydrological modules in ArcGIS to divide the catchment area (watershed) of water environment function zones. Determine the direction of flow and catchment range, and turn it into Shape format. For each river in water environment function zone, one by one to determine the relevant catchment area (greater than or equal one), and merge into an area that is the range of land corresponding to water environmental function zone.

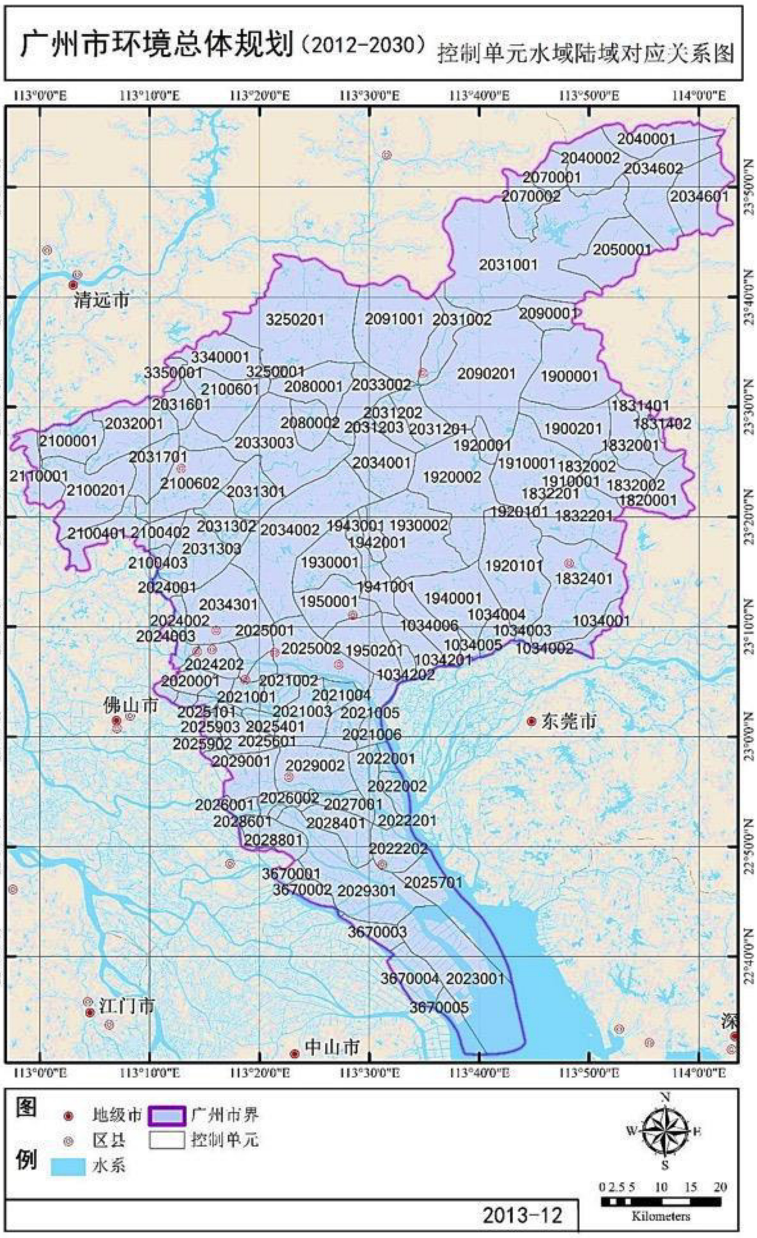


Figure 7-2-3 Map of the Water Environment Control Unit in Guangzhou

7.3 Module 5B: Develop surface water quality models

Data Preparation

Graphical data: water (environment) function zoning, water system and administrative division (1: 50,000 digital map is recommended), cross section (point location) distribution, sewage outfall distribution, water quality monitoring sections (point location) and so on.

Text data: water (environment) function zoning, water quality protection goal related information, control pollutant index, river flow, annual runoff, degradation coefficient, river depth, functional area section (point location) water quality data, etc.

Data Processing Software: ArcGIS, water environment capacity and so on;

Computing Unit Division

Computing unit is unit object of model application. Control unit is generally adopted as computing unit in order to realize land and water coordination corresponding to project access and control. In addition, capacity falling into the river section is calculated corresponding to control of sewage outfall. Division of control unit is shown in section 5.4.1. Division with river section as computing unit follows the following principles:

Catchment of larger tributaries or river diversion;

Catchment of greater estuary discharge outlet;

Important drinking water source suction port;

Single computing unit length more than 10km;

In addition, river sections can be divided according to stage water environmental function zoning and setup condition of actual state-controlled, province-controlled and city-controlled monitoring cross sections.

Calculation Model For Water Quality

City area in China is generally larger. UREMP strategic feature is combined. General compliance calculation method should be used. Calculation formula is shown as follows:

$$W = 86.4Q_0(C_S - C_0) + 0.001KVC_S + 86.4qC_S$$

In the formula, W refers to water environmental capacity, kg/d; Q_0 and C_0 respectively refer to inflow flow and water quality concentration of inlet section; q refers to lateral inflow flow; C_S refers to water quality standards for water bodies; V refers to water volume; K refers to water quality degradation coefficient.

Non-uniformity coefficient is introduced for correcting calculation results of water environmental capacity in order to compensate the defect of larger result in the method:

In the formula, α refers to non-uniform correction coefficient between 0 and 1.

Table 7-3-1 Non-uniform Coefficient of Rivers, Lakes and Reservoirs [1]

Type	River with (m)/lake-reservoir area (km^2)	Non-uniformity coefficient
River	0-50	0.8-0.1
	50-100	0.6-0.8
	100-150	0.4-0.6
	150-200	0.1-0.4
Lake and reservoir	0-5.0	0.6-1.0
	5-50	0.4-0.6
	50-500	0.11-0.4
	500-1000	0.09-0.11
	1000-3000	0.05-0.09

If key watershed calculation water environmental capacity has higher requirements on precision, control end face compliance method can be selected. Related achievements can be adopted as reference aiming at detailed methods.

Example: Evaluation and Calculation of Water Environmental Capacity

In concrete calculation of pollution load and water environmental capacity, we have adopted different calculation method by taken into consideration factors such as urban pollution discharge characteristics and data size, etc., in the piloting process.

Table 7-3-2 Measurement and Calculation Model Selection and Calculation Method Of Carrying Capacity Of Water Environment

	Fuzhou	Yichang	Guangzhou	Weihai

Evaluation scope	16 control units were classified combining water-collecting area and functional area of water environment	375 control units were classified combining water-collecting area and functional area of water environment	120 control units were classified combining water-collecting area and functional area of water environment	43 reaches were divided combining water environment functional area of main rivers and actually monitored sections
Foothold	Control unit	Control unit	Control unit	Reach
Measurement and calculation method for environmental capacity	One-dimensional model and 2d model were adopted based on classification, and uneven coefficient was introduced for correction.	Runoff volume method	One-dimensional model and 2d model were adopted based on classification	Runoff volume method
Measurement and calculation method for pollution load	Non-point source: experience coefficient method; Point sources: investigation & statistical method	Area pollution source: experience coefficient method; Point sources: investigation & statistical method	Area pollution source: experience coefficient method; Point sources: investigation & statistical method, To each pollution outlet	Area pollution source: experience coefficient method; Point sources: investigation & statistical method

Through practical exploration, we believe that different evaluation unit and calculation method could be adopted based on different data availability and characteristics of urban water environment.

Control unit, as well as specific reach, can be used as unit for the evaluation and calculation of carrying capacity of water environment. The delimiting of control unit should take into consideration the water-collecting area, functional area of water environment and administrative area, and pay attention to the connection between natural features and administrative management characteristics. If specific reach of river is adopted as evaluation unit, water environment functional area of main rivers and actually monitored sections should be combined, with administrative areas considered, to implement the evaluation and management by reaches and administrative areas.

One-dimensional and two-dimensional water quality models can be adopted in the measurement and calculation of environmental capacity, with uneven coefficient introduced to rectify the measurement and calculation of water environmental capacity. For cities with insufficient data, runoff volume method can be used for evaluation and calculation of water environmental capacity.

In the measurement and calculation of urban pollution load, traditional empirical coefficient method is recommended for non-point source pollution load, and investigation & statistical method is recommended for point source pollution load. However, based on the richness of data, the precision degree in specific investigations can be different. If the data quantity is allowed, it is advised to investigate each pollution outlet.

7.4 Module 5C: Assess priorities for protecting rivers, lakes, wetlands and reservoirs

The vulnerability assessment method of water environment

Water environment system fragility is that the interference and destruction of natural, man-made and other factors, cause the system to lose its stability and coordination, and cannot be restored status and function of the original system.

The environmental capacity of COD and ammonia in urban water environment regards as indicator of fragility assessment, dividing into three levels, namely the most fragile, moderately fragile, and general fragile. The control units of natural environmental capacity of COD per watercourse length <1t/km•a and the natural environmental capacity of ammonia per watercourse length <0.1t/km•a are the most fragile control units, delimited as water environment red line areas. The control units of natural environmental capacity of COD per watercourse length at 1-400t/km•a and the natural environmental capacity of ammonia per watercourse length at 0.1-10t/km•a are the moderately fragile control units, delimited as water environment yellow line areas. The rest of control units are general fragility, delimited as the water environment green line areas.

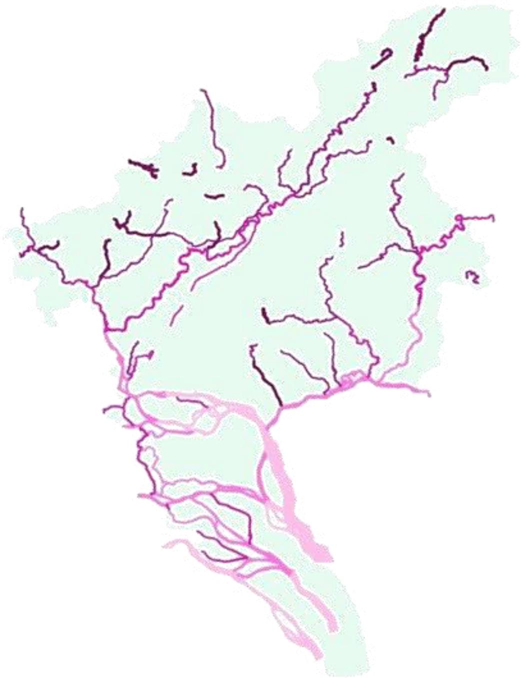


Figure 7-4-1 Map of the vulnerability assessment result of water environment in Guangzhou

The sensitivity assessment method of water environment

Based on the surface water environment function zone, assess the sensitivity of water environment (Table 2-2). Sensitivity indicators mainly reflect whether the higher sensitivity objects to the water environment exist in the control areas, such as rare species protection areas, fish spawning areas and other nature reserves, and forest parks and other important habitats protection areas.

Table 7-4-1 Sensitivity evaluation table of water (environment) function regions

Function types	Subentry	Executive standard	Very sensitive	Medium sensitive	General sensitive
Natural conservation areas	National natural conservation areas	I	√		
	Local natural conservation areas	I、II	√		
Drinking water protected areas			√		
Fishery water areas	Precious fish reserve	II	√		
	General fishery water areas	III		√	
Industrial water areas		IV			√
Landscape recreational water areas	Natural bathing and swimming areas contacted with the body directly, etc	II	√		
	Landscape recreational water area contacted with the body indirectly	IV、V			√

Agricultural water area		V			√
The transition areas and mixed areas					√

The most sensitive control units in table are delimited as water environment red line areas, including nature reserves, drinking water source protection areas, the precious fish protection areas in fishery water areas, direct contact with the human body's natural beach and swimming areas in landscape recreational water areas. The moderately sensitive control units are delimited as water environment yellow line areas, including the general fishery water areas. The general sensitive control units are delimited as water environment green line areas, including industrial water areas, non-direct contact with the human body's landscape recreational water areas, agricultural water areas, the transition areas and the mixing areas.

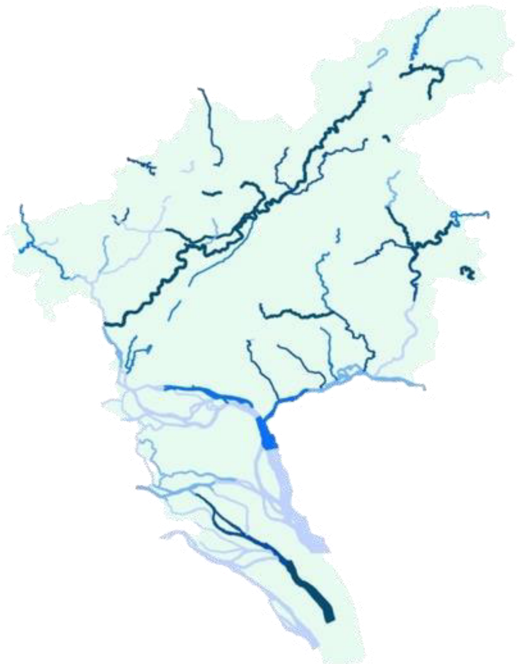


Figure 7-4-2 Map of the sensitivity assessment result of water environment in Guangzhou

The assessment of water resource load bearing capacity

1) Assessment method

The recommended technical methods include the follows: single index assessment method and multi-objective assessment method.

(1) Single index assessment method

Single index assessment method is characterized by intuitive and simple operation and insufficient consideration, which is applicable to cities with insignificant urban water resources and water environment characteristics.

①Data Preparation

Hydrological data: total water resources, annual precipitation, etc;

Population data: urban population statistical data over the past five years, etc.

Critical value data: water resource stress critical value, water resource shortage critical value, etc.

② Calculation and Assessment Methods

Firstly, total utilizable water resource, actual water supply, actual population and other basic conditions of the studied cities are analyzed.

Secondly, water resource population bearing capacity and population bearing capacity indexes of studied city are calculated. The formula is shown as follows:

$$V_{wp} = \frac{V_w}{C_w}$$

$$K_w = \frac{V_{wp}}{P_r}$$

Wherein: V_w refers to water resource amount (m^3), C_w refers to per capita the critical value of water resource (m^3/person), P_r refers to actual population (persons), V_{wp} refers to critical load bearing capacity of water resources (persons), and K_w refers to water resource carrying index.

Results of the study at home and abroad are adopted as reference. Actual condition of the studied city is combined for adopting appropriate water resource per capita possession as per capita water resource critical value. Tense critical value of water resources is 1700 m3/person according to international standards, and the critical value of water resource shortage is 2000 m3/person. Water consumption in southern cities is more, 2000 m3/person can be selected as critical value of water resource. 1700 m3/person can be selected as critical value of water resources in northern cities.

Water resources load bearing capacity is divided into four categories: good status, general status, alert status and critical status. Concrete division standards are shown in Table 1-4.

Table 7-4-2 Water Resource Load Bearing Capacity Index Classification

Water resource bearing index	Characterization status	Water resource bearing capacity grade
>1.171	Good status	Grade I
0.833-1.171	General status	Grade II
0.585-0.833	Alert status	Grade III
<0.585	Critical status	Grade IV

(2) Multi-objective assessment method

Water resource bearing capacity multi-objective assessment method: single and multiple indexes are selected for reflecting regional water resource status and thresholds. Regional water resource bearing capacity status can be comprehensively reflected. The method is applicable to cities with more significant urban water resources and water environment as well as higher management level.

①Construction of Index System

Conflict analysis of urban social economy, resource environment, technology management and other systems are combined for selecting society, economy, population, resource environment and technical management class indexes. Specific reference indexes are shown in the following Figure City can adjust according to actual situation.

②Determination of Index Weight

Expert scoring method and AHP method are comprehensively adopted for empowering all concrete indexes.

Multi-objective Index Assessment System of Water Resource Bearing Capacity

Table 7-4-3 Water Resource Bearing Capacity Multi-objective Assessment

Water Resource Bearing Index	Characterization status	Water resource bearing capacity grade
0.8-1	Good status	Grade I
0.5-0.8	General status	Grade II
0.3-0.5	Alert status	Grade III
<0.3	Critical status	Grade IV

2) Analysis of water environment bearing condition

Point source pollution load and non-point source pollution load are statically analyzed on the basis of water environmental capacity calculation results.

Point source pollutant water entrance amount calculation formula is shown as follows:

$$P_{\mathrm{I}} = \mathrm{Y}W_{\mathbf{p}} + \boldsymbol{\theta}\mathrm{Y}\beta_{\mathbf{1}}$$

In the formula, P_{I} refers to point source pollutant river entrance amount, $W_{\mathbf{p}}$ refers to direct emission of industrial pollutant, $\beta_{\mathbf{1}}$ refers to point source pollutant river entrance coefficient (generally 0.8-1.0); θ refers to emitted pollutant of sewage plant.

Non-point source pollutant calculations should be divided into two major categories: urban non-point source pollution and rural non-point source pollution.

Urban surface pollution river entrance amount calculation formula is shown as follows:

Where, $P_{\text{面}1}$ refers to urban non-point source pollution river entrance amount; $N_{\mathbf{1}}$ refers to urban population (part not connected to urban sewer network); $\alpha_{\mathbf{1}}$ refers to urban non-point source emission coefficient; $\beta_{\mathbf{2}}$ refers to urban non-point source pollutant river entrance coefficient (generally 0.6-1.0).

Rural non-point source pollution water entrance amount calculation formula is shown as follows:

Where, $P_{\text{面}2}$ is rural non-point source pollution river entrance amount; $N_{\mathbf{2}}$ refers to rural population (part not connected to city sewer network); $\alpha_{\mathbf{2}}$ refers to rural non-point source emission coefficient; $\beta_{\mathbf{3}}$ refers to rural non-point source pollutant river entrance coefficient (generally 0.2-0.5);

Pollution discharge coefficient method is adopted for above non-point source pollution calculations, which is characterized by less data demand and used easily. If the data is more abundant, more elaborate model can be selected for simulation analysis. SWMM (Storm Water Management Model) model should be selected for estimating urban non-point source pollution generally, and SWAT (Soil and Water Assessment Tools) model is recommended for estimating rural non-point source pollution.

Basic data required by SWMM model is rainfall intensity (refined into five minutes), catchment area data, pipe network detailed CAD data, pipe network node elevation, pollutant accumulation simulation parameter of different land utilization types, and erosion parameters. Pipe network design applicable to urban built-up area, suspended solids, COD, ammonia nitrogen, TN and TP pollution load produced by urban non-point source catchment area are predicted and stimulated.

SWAT model adopts watershed as computing unit. Required input data includes meteorology, soil properties, terrain, vegetation, land management practices, etc., pollution load values of ammonia nitrogen, TN, TP, etc. applicable to rural areas. COD stimulation should be further improved.

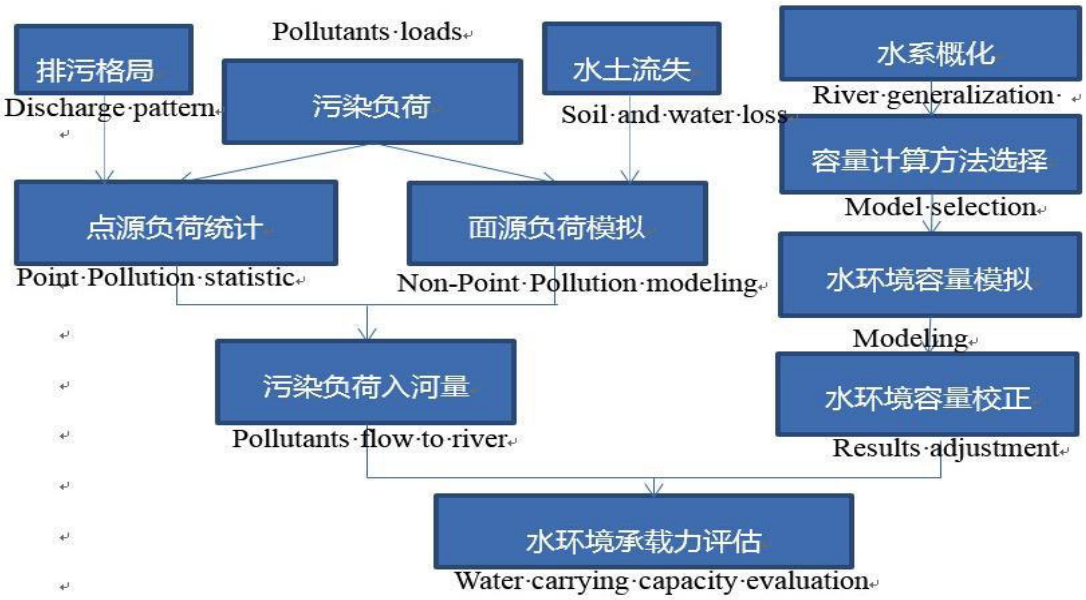


Figure 7-4-3 Water Environment Bearing Capacity Assessment Process

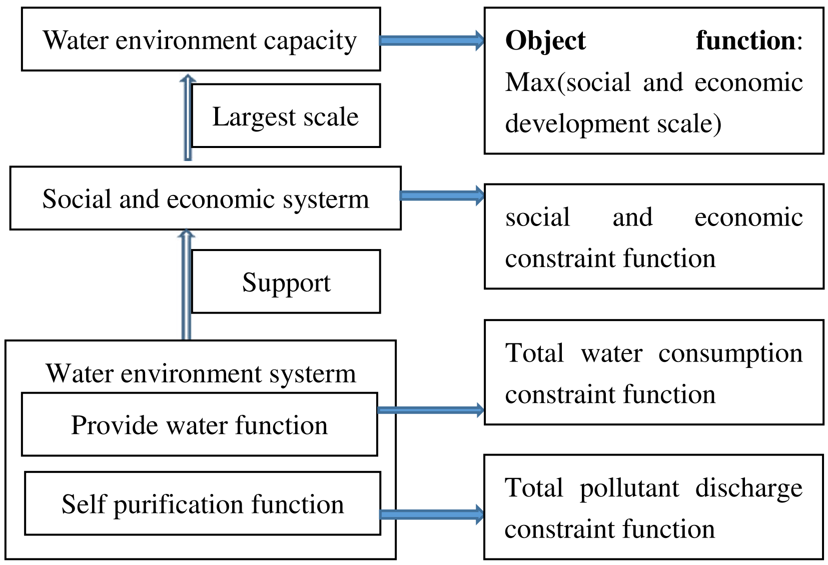


Figure 7-4-4 Water Environment Bearing Capacity Industrial Structure Optimization Model Construction Technology Road-map

3) Water environment bearing regulation plan

Water environment bearing regulation plan refers to energy-saving and pollution control plan formulated aiming at overload area according to water resource and water environment bearing pattern. Steps are shown as follows:

Model construction steps are shown as follows:

(1) Objective Function

Economic development is the objective of sustainable development, which is object carried by resource environment, therefore maximum economic scale should be achieved, and the objective function is shown as follows:

$$\text{MaxGDP} = \sum_{i=1}^{5} x_{pi} + \sum_{j=1}^{13} x_{sj} + x_t \quad (1)$$

Population size is the prerequisite and guarantee for sustainable development, therefore the largest population should be achieved, and objective function is shown as follows:

$$\text{MaxPOP} = x_u + x_r \quad (2)$$

Table 7-4-4 Same Variable and Meanings of Objective Function and Constraint Functions

Variable	Meanings	
Xpi	Added value of all departments in the first industry	i=1 refers to crop farming-farmland
		i=2 refers to crop farming-irrigable land
		i=2 refers to crop farming-farmland
		i=4 refers to crop farming-dry land
		i=5 refers to animal husbandry
Xsj	Added value of all departments in the second industry	j=1 refers to mining industry
		j=2 refers to agricultural and sideline foodstuffs processing industry
		j=3 refers to beverage manufacturing industry
		j=4 refers to textile and garment industry
		j=5 refers to wood product industry
		j=6 refers to paper-making industry
		j=7 refers to petroleum and chemical industry
		j=8 refers to pharmaceutical industry
		j=9 refers to non-metallic minerals product industry
		j=10 refers to metal smelting and processing industry
		j=11 refers to equipment manufacturing
		j=12 refers to energy industry
		j=13 refers to construction industry
Xt	Added value in the third industry	
Xu	Urban resident population	
Xr	Rural resident population	

Note: industry in the table is only an example, and suitable industry and industry quantity should be selected in actual plan according to actual condition of the first industry and the second industry in the city (the same as below)

(2) Constraint Functions

Constraint functions typically include environmental constraints and socio-economic constraints. Constraint functions can be modified according to the actual situation of the city. Concrete implementation indexes of three red lines from water conservancy department can be adopted as reference for total quantity control.

Environment constraints

Total water consumption control:

$$\sum_{i=1}^{5}(x_{pi}\times w_{pi})+\sum_{i=1}^{13}(x_{sj}\times w_{sj})+x_t\times w_t+x_u\times w_u+x_r\times w_r+EW\leq TW \quad (3)$$

In the formula, w_{pi} refers to unit added value water consumption of all departments in the first industry, w_{sj} refers to unit added value water consumption of all departments in the second industry, w_t refers to unit added value water consumption in the third industry, w_u refers to domestic water consumption quota for urban residents; w_r refers to domestic water consumption quota for rural residents; EW refers to ecological water consumption; TW refers to total water consumption.

Total COD emission control:

$$\sum_{i=1}(x_{pi}\times c_{pi})+\sum_{j=1}(x_{sj}\times c_{sj})+x_t\times c_t(1-t\times r_c)+ \quad (4)$$

In the formula, c_{pi} refers to unit added value COD emission of all departments in the first industry; c_{sj} refers to unit added value COD emission of all departments in the second industry; c_t refers to unit added value COD emission in the third industry; c_u refers to per capita COD generation of urban residents; c_r refers to per capita COD emission of residents; and TCOD refers to total COD emission.

Point-source COD emission control:

$$\sum_{i=1}^{13}(x_{sj}\times c_{sj})+x_t\times c_t(1-t\times r_c)+x_u\times c_u(1-t\times r_c)\leq PCOD \quad (5)$$

In the formula, $PCOD$ refers to point source COD emission.

Total ammonia nitrogen emission control:

$$\sum_{i=1}^{5}(x_{pi}\times n_{pi})+\sum_{j=1}^{13}(x_{sj}\times n_{sj})+x_t\times n_t(1-t\times r_n)$$
$$+x_u\times n_u(1-t\times r_n)+x_r\times n_r\leq TAN \quad (6)$$

In the formula, n_{pi} refers to unit added value ammonia nitrogen emission of all departments in the first industry; n_{sj} refers to unit added value ammonia nitrogen emission of all departments in the second industry; n_t refers to unit added value ammonia nitrogen emission in the third industry; n_u refers to per capita ammonia nitrogen generation of urban residents; n_r refers to per capita ammonia nitrogen emission of rural residents; TAN refers to total ammonia nitrogen emission.

Point source ammonia nitrogen emission control:

$$\sum_{i=1}(x_{sj}\times n_{sj})+x_t\times n_t(1-t\times r_n)+x_u\times n_u(1-t\times r_n)\leq PAN \quad (7)$$

In the formula, PAN refers to point source ammonia nitrogen emission.

Social economy constraint

Per capita GDP constraint

$$\sum_{i=1}x_{pi}+\sum_{i=1}x_{sj}+x_t\geq(x_u+x_r)PGDP \quad (8)$$

Urbanization rate constraint

$$\frac{x_u}{x_u + x_r} \geq CR \quad (9)$$

Agricultural acreage constraint:

$$CAL \leq \sum_{i=1} \left(\frac{x_{pi}}{a_{pi}}\right) \leq CAU \quad (10)$$

Grain yield constraint:

$$\sum_{i=1} \left(\frac{x_{pi}}{a_{pi}} \times y_{pi}\right) \geq GY \quad (11)$$

Non-negativity constraint:

$$\left\{ x_{pi} \geq 0; x_{sj} \geq 0; x_t \geq 0; x_u \geq 0; x_r \geq 0 \right. \quad (12)$$

In formula (8) - (11), $PGDP$ refers to the lowest per capita GDP; CR refers to the lowest urbanization rate; CAL refers to minimum agricultural acreage; CAU refers to the largest agricultural acreage; GY refers to the lowest grain yield.

Added value condition of each industry can be obtained according to the optimal solution calculated from the model, thereby judging optimization direction of industry structure in the city. Meanwhile, related industry layout can be rationally planned on the basis of spatial water environment bearing condition and sewage discharge condition of concrete industry.

4) Example: Evaluation and Application of Carrying Capacity of Water Resources

The technical approach for calculating the carrying capacity of water resources is basically the same, also taking the analysis on balance of water demand and supply as basis. However, on concrete calculation methods, calculation result expression of carrying capacity of water resources and guidelines and policies, the pilot cities have carried out different exploration.

Table 7-4-5 Ideas and Technical Methods for Measurement and Calculation of Carrying Capacity of Water Resources

	Fuzhou	**Yichang**	**Guangzhou**	**Weihai**
Evaluation scope	Whole city	Whole city	Whole city	Whole city
Technical approaches	Analysis on balance of water supply	Analysis on balance of water supply	Analysis on balance of water supply	Analysis on balance of water supply
Evaluation method	A multi-objective indicator system for carrying capacity of water resources was established, and it combines the indicator evaluation and analytic hierarchy process.	Based on average quantity of water resources in many year of all districts and counties, population carrying capacity of water resources was calculated	Quantitative calculation of gap between the water resource capacity and the actual water consumption	Quantitative calculation of gap between the water resource capacity and the actual water consumption
Calculation results	Carrying capacity index of water resources of all districts and counties	Limit population for carrying capacity of water resources of all districts and counties	Gaps of water resource capacity and water demand of all districts and counties	Gaps of water resource capacity and water demand of all districts and counties
Policy direction	Advices for water resource allocation	Strictly implement management of red lines for development and utilization of water resource and the utilization efficiency of water resource; carry out industrial restructuring based on water consumption characteristics of	Plan for water resource prediction and allocation	guidance on red lines for development and utilization of water resource and the goal of utilization efficiency of water resource; guidance for industrial restructuring

		industry.		

Based on population carrying capacity, carrying capacity and carrying capacity index were adopted as indicators by Yichang City to evaluate the water resource carrying capacity of all districts of Yichang, and management of red lines for development and utilization of water resource and the utilization efficiency of water resource was strictly implemented.

By quantitative calculating the water resource capacity and actual water consumption of all districts and counties and clearly determining the gap of the two, Guangzhou and Weihai have proposed red line for development and utilization of water resource, control of utilization efficiency of water resource, plan for prediction and allocation of water resource, as well as the guidance for corresponding industrial restructuring.

At present, there is no unified and mature research method for carrying capacity of water resource. Domestic research method for carrying capacity of water resource mainly include background analysis method, conventional trend method, comprehensive evaluation of indicators (including vector model, analytic hierarchy process and fuzzy comprehensive evaluation method, principal component analysis), systematical analysis method, system dynamics method and multi-objective decision making method. Background analysis method is simple and easy to implement, but its analysis is limited to the static history background; conventional trend method pays more attention on the development trend of single carrying capacity factor, but it ignores the correlation between the bearing factors; comprehensive evaluation of indicators is a convenient method for preliminary comprehensive evaluation of carrying capacity of water resource.

Through planning, practice and exploration, we believe that multi-objective indicator evaluation method, which can choose single or multiple indicators for reflecting the current situation and threshold value of regional water resource and is illustrative and simple in operation, can comprehensively indicate the situation of carrying capacity of regional water resource, making it relatively applicable.

The key point of multi-objective indicator evaluation method is to establish the indicator system, and to determine the weights of indicators. In the establishment of indicator system, contradictory analysis on urban society, economy, resources, environment, technical management, etc., should be combined, and indicators on social economy, population, resource, environment and technical management should be selected; the detailed information is seen in the following picture. Determination of weights for specific indicators should comprehensively use the expert evaluation method and analytic hierarchy process.

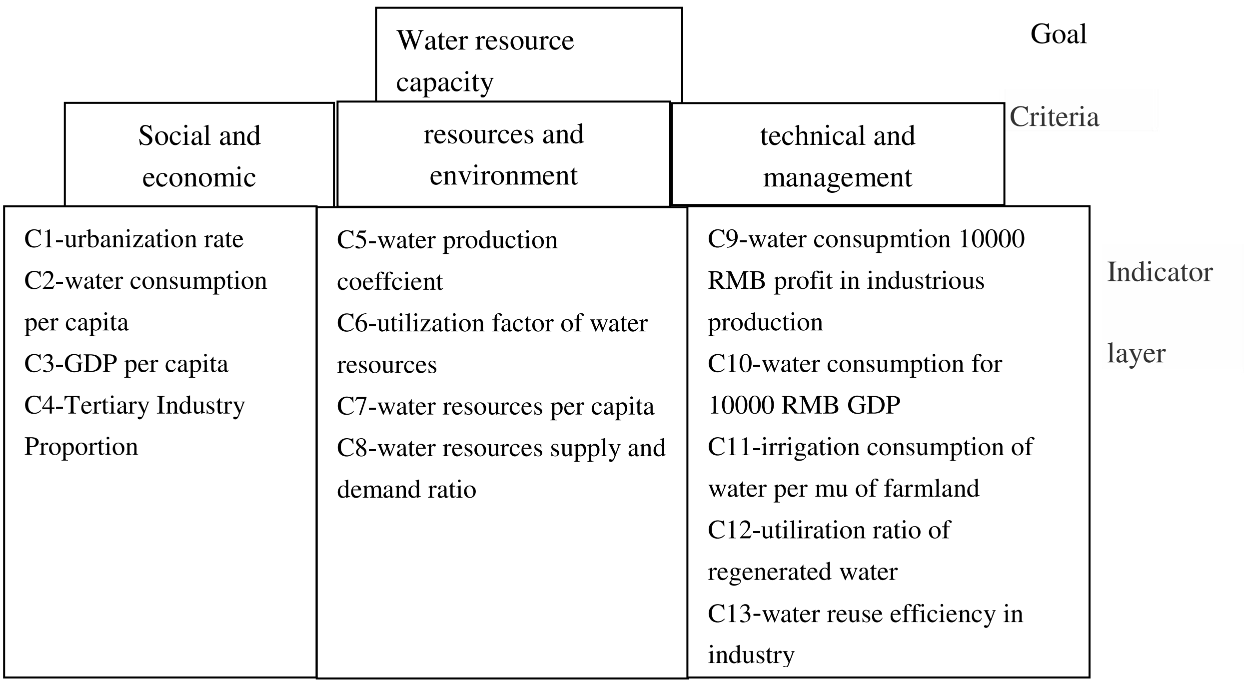


Figure 7-4-5 Multi-objective Evaluation Indicator System of Carrying Capacity of Water Resource

7.5 Module 5D: Assess priorities for flood risk management

Assess the importance of flood risk management about different types of water bodies, the formula is as follows.

$$Q_i = F_{pre} \times Q_w$$

$$\mathrm{Q} = (Li_{max} - Li_{min})/(dem - Li_{min})$$

Q_i refers to the flood risk management indexes of wet lands; F_{pre} refers to the precipitation factor; Q_w refers to the area ratio of water body in the control unit, computed through the land cover data; Q refers to the flood risk management index of a wet land; Li_{max} refers to maximum water level; Li_{min} refers to minimum water level; dem refers to the altitude in the control unit.

Further, use the Quantile function in GIS to classify the importance of flood risk management into three levels, including most important, moderately important and general important. The most important control units are delimited as water environment red line areas. The moderately important control units are delimited as water environment yellow line areas. The general important control units are delimited as water environment green line areas. Then combined with the assessment result the importance of water quality protection, use GIS spatial overlay technology to divide the city water environmental into red line areas, yellow line areas and green line areas.

7.6 Module 5E: Assess priorities for water source protection

Assess the importance of water quality protection about different types of water bodies in the different water environment function zone.

Table 7-6-1 the importance evaluation table of the possible different water types of water (environment) functional areas

Water types	Utmost important	Moderately important	General important
The source water	√		
water quality in class II or class I	√		
Ecological flow is difficult to guarantee		√	
not achieve the aims and demands of functional area		√	
Other water types			√

The most important control units in table are delimited as water environment red line areas, including source water, water quality maintaining in class I and class II. The moderately important control units are delimited as water environment yellow line areas, including water quality does not meet the requirements of the target of function zone caused by man-made pollution, the river is more difficult to maintain the ecological flow. The general important control units are delimited as water environment green line areas, including the rest of land and water control unit which do not belong to the most important and moderately important control unit.

Figure 7-6-1 Map of the importance assessment result of water source protection in Guangzhou

7.7 Module 5F: Assess priorities for the protection of coastal areas

The fragility assessment method of riparian

Reference domestic and abroad empirical data of riparian vegetation protection width, and consider the riparian water environment function zone, water quality objectives and soil erosion, make fragility assessment of riparian in the city.

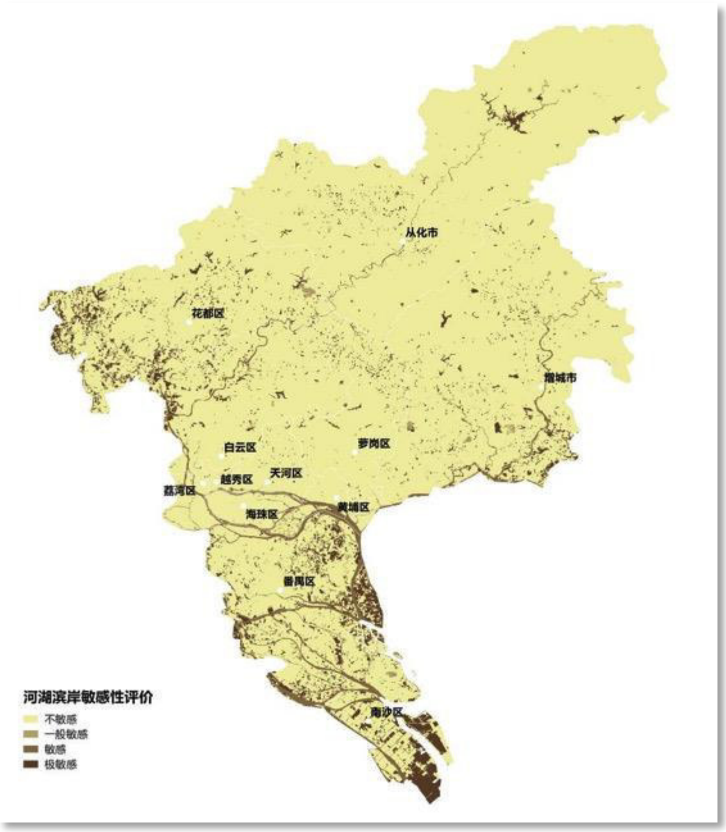


Figure 7-7-1 Map of the fragility assessment result of rivers in Guangzhou

The fragility assessment method of coastal hazards

In the intense erosion coastal areas, sea level rise and storm surge strongly affected zone, comprehensively overlay the width of the erosion for many years, sea level rise affected zone width and storm surge affected zone width. Take the largest width among the three as the fragile coastal areas of the city.

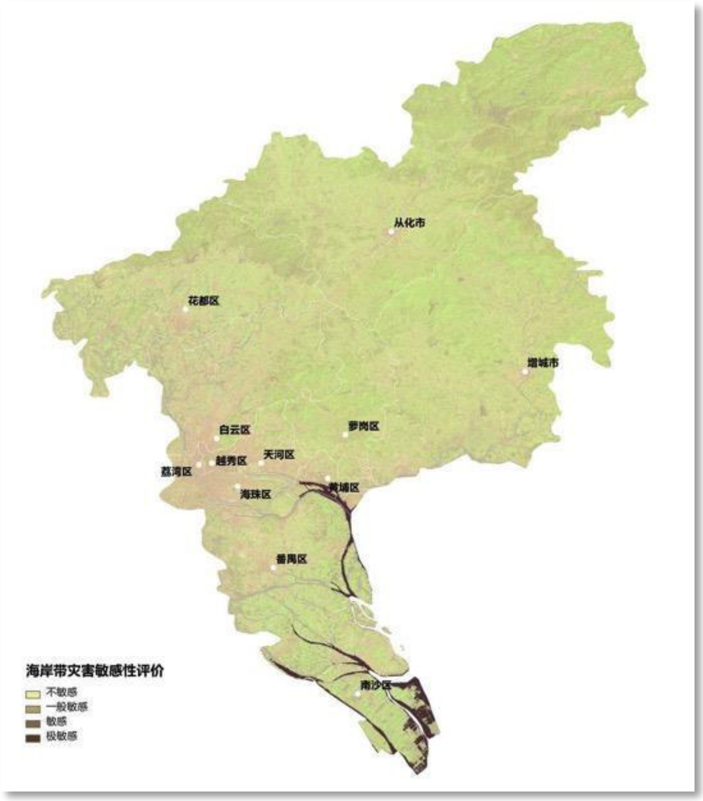
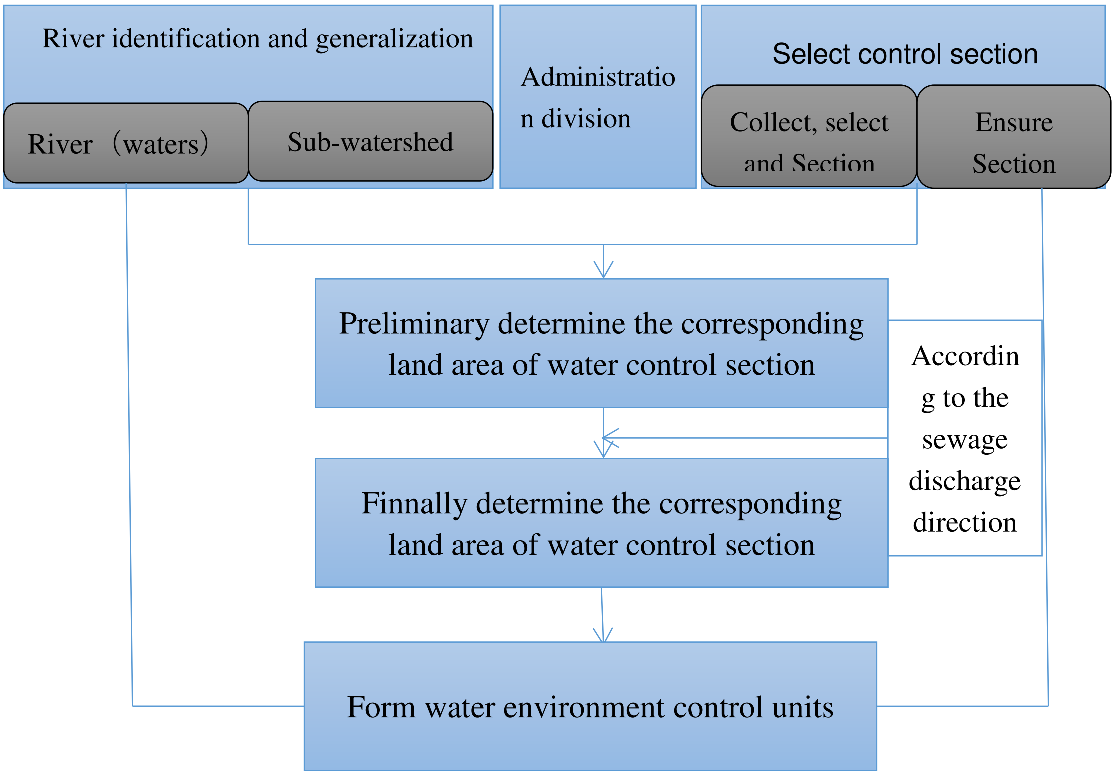


Figure 7-7-2 Map of the fragility assessment result of coastal hazards in Guangzhou

7.8 Module 5G: Indicative water quality protection zoning and mapping

Analytical levels and scope should be firstly determined in analysis of water environment system. In the pilot exploration of master environmental planning, "control unit", popular and mature in China, was mainly used as basis, based on analysis on features of natural catchment, water system gathering and relationship of pollutant transmission, to establish the conceptual map of water system; by combining DEM data, in accordance with the principles of goal-oriented, full covering of whole region, administrative districts at all levels should be responsible for water quality in area under administration, combining water area and land, determining land boundary with water boundary, etc., the control system by goals of areas of watershed-control- control unit" was established as the basic framework for water environment control. Based on this, the vulnerable areas of water environment and important biodiversity conservation areas should be systematically analysed for space management of water environment.

The thinking for analysing water environment system is that based on control unit of water environment, conduct the evaluation of vulnerability of water environment system, sensitivity of aquatic organisms and importance of function of water sources, and specifically conduct regionalized management of water environment system. Clearing the relationship analysis of the

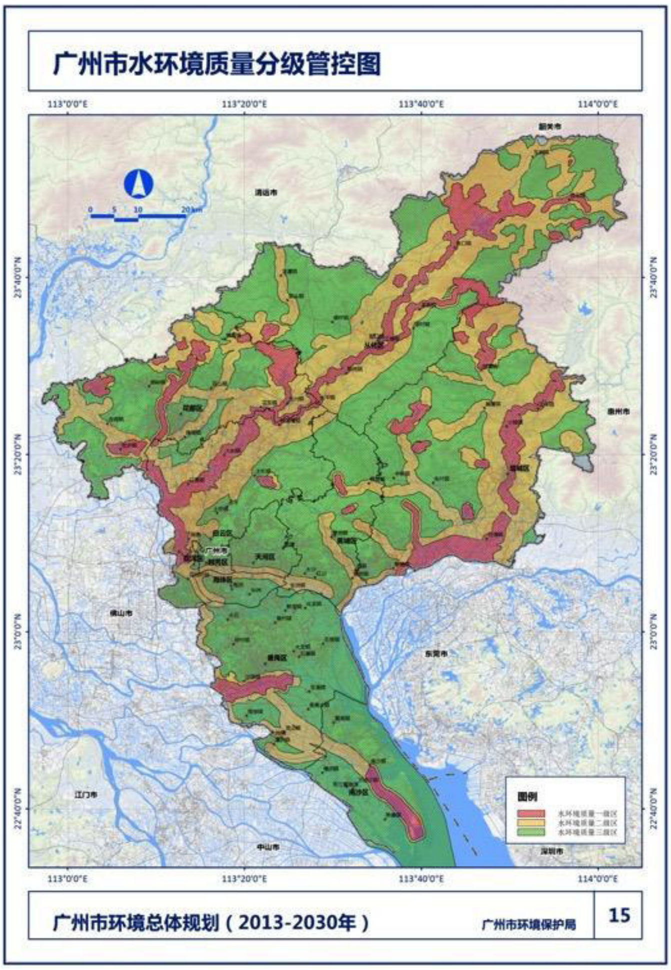


runoff yield and concentration of water environmental system and the delimiting of control unit are the basis for conducting environmental space control, which affects the scientificity and accuracy of analysis of water environment system. There are relatively mature technical methods for evaluation of sensitivity of aquatic organisms, importance of function of water sources in the analysis of water environment system, but the technological evaluation method for vulnerability evaluation is not perfect. Through the practical exploration in "Planning for Water Pollution in Key Watersheds", "Water Pollution Prevention and Control Planning for Haihe River Basin" and Fuzhou and Yichang and other cities, the Institute of Environmental Planning has gradually explored a suit of relatively complete technology for delimiting of control unit and evaluation of vulnerability of water environment.

Figure 7-8-1 Flow Chart for Delimiting Control Unit of Water Environment

One is the technology for delimiting of control unit. For the delimiting of control unit, the integrity of water cycle system should be kept, and determine the convergence scope in land area based on the natural convergence characteristics, with socio-economic development, main problems of water environment, characteristics of water pollution, regional pollution control key points and directions and other aspects comprehensively considered to form a control zone that combines water and land areas. Technical methods combining top-down and bottom-up should be adopted in the delimiting process, and determine the land boundary by water boundary in combining water and land areas. The control unit scope should be preliminarily determined by overlaying the administrative region and Class III area of water resources. Based on spatial heterogeneity, the highest level of zoning should be conducted according to the principles of minimum difference within regions, maximum difference with in regions and regional conjugate, then zoning should be conducted downward level by level. Based on spatial similarity of water environment characteristics, in accordance with the principles of regional relative consistency and conjugate, amalgamation should be done from bottom to top level by level. Basic data for use includes location, the size, the function, the water quality, the planning dominant function, the functional goals, the starting section and end section and other information.

The other one is the evaluation technology for vulnerability of water environment system. Method combining qualitative and quantitative should be adopted, and main factors affecting the process vulnerability such as hydrological characteristics, rivers, water exchange conditions of waters should be analyzed one by one (influence of salty tide, tidal, etc., should also be taken into consideration for coastal cities), to incorporate the areas with obvious decreasing flow, flow



speed and narrowing riverbed, which result in difficult diffusion of pollutant, weak water change, as well as obvious decreasing diffusion speed of water pollutant and lowering water environmental capacity, into the red line system of water environment. On technical methods, combining the urban water quality characteristics, featured pollutant indicators such as NH_3-N, permanganate index, dissolved oxygen, etc., should be adopted as sensitivity index for water health condition. The hydrodynamic water quality model should be adopted by taking into consideration the applicability, data availability and sophistication of the model. Usually, it is suggested to adopt two-dimensional hydrodynamic model for evaluation.

Figure 7-8-2 Map of Grade Control of Water Environmental Space in Guangzhou

The spatial grade control measures of water environment

Based on the importance, sensitivity and fragility assessment of water environment, by GIS spatial overlay technology, the city is divided into the water environment red line areas, yellow line areas and green line areas three region, making grade management. The spatial control measures are as follows:

Red line areas are required to strictly protect drinking water source first class protection areas and second class protection areas according to relevant laws and regulations. Prohibit setting outfall in the water environment red line areas. Prohibit new construction, reconstruction, expansion of the pollutants emission construction projects (projects which have been completed should be ordered to remove or turn off). Prohibit contaminating drinking water activities. Stop construction project approval, and strengthen water pollution prevention and control, and develop appropriate industrial layout adjustment planning, and gradually reduce industrial point source pollution which has a great impact on the water environment. Develop and implement strict environmental protection planning of drinking water source protection areas, and establish warning signs. For drinking water sources, rare and endangered species' water habitats and other important and sensitive area, prohibit the development activities which do not meet the requirement of environment function, and strengthen the restoration and maintenance of ecological functions.

Yellow line areas as a buffer zone of red line areas, are required to implement strict approval standards, establish a comprehensive system of water environment monitoring network, and effectively protect the water environment safety. Implement total control and total replacement measures, and gradually reduce emissions of water pollutants. Improve the urban drainage system planning, and strengthen pollution prevention and control, and effectively reduce the impact of domestic, industrial and agricultural pollution on water environment. Maintain and gradually increase the capacity of the water environment, and water environment quality improve.

Green line areas are required to actively promote water environmental quality to reach the standards accordance with the related economic and social development planning and environmental protection planning. Make sure that the total amount of water pollutants and economic development in harmony. Set a reasonable drainage channels, and earnestly make water environment planning and actively carry out ecological restoration in green line areas.

7.9 Example

7.9.1 Evaluation of Environmental Capacity in Fuzhou

(1) Computation on water environmental capacity:

Runoff volume method needs not much data for calculating idea water environmental capacity, and is capable of calculating the environmental capacity of whole water system in one shot, and more convenient and high efficient than cross-section method.

(2) Comparative analysis on water environmental capacity and pollution emission:

The ratios of master pollutant discharge and water environmental capacity for all sub-watersheds are calculated for judging the differences on bearing conditions. Evaluation standards: bearing rate of water environment= pollution discharge/water environmental capacity; for areas with bearing rate over 1.5, they are called saturated area, for that in 0.8-1.5, basically balanced area, and that smaller than 0.8, surplus area.

(3) Change the calculation results into management means:

--change into guidelines for industrial regulation

For overloaded control unit, new pollution discharge should be strictly restricted, "replacing small units with large ones", "substitute with material of less pollution" and "reducing pollution by replacing project with half pollution" should be implemented.

--change into the targets for total amount control of pollutant

Control targets determined: the overloaded part of pollution discharge in overload area should be cut 50% by 2020, and the discharge amount in overload units and basically balanced units should be controlled within 90% of water environmental capacity, and discharge amount in other units should not increase in principle.

Table 7-9-1 Targets for Discharge Amount Control of Water Pollutant in All Watersheds in Fuzhou (Expected)

Watershed	Current values in 2012（t/a）		Control targets for 2020（t/a）		Control targets for 2030（t/a）	
	COD	Ammonia nitrogen	COD	Ammonia nitrogen	COD	Ammonia nitrogen
Minjiang River	54924	7559	48043	5060	46286	4439
AoJiang River	1551	467	1137	261	1137	119
Longjiang River	6668	1434	3310	717	3000	600
Dahangxi River	2706	354	1617	163	1587	89
Qibuxi River	1048	144	733	81	733	49
Area for discharge in sea	——	——	35733	5686	31373	4771

(4) Evaluation and Application for water resources capacity in Fuzhou

Based on conceptual model of carrying capacity of water resources, Fuzhou has established a multi-objective indicator system for carrying capacity of water resources, which combines the indicator evaluation and analytic hierarchy process to calculate the index of carrying capacity of water resources in many years for all districts and counties in Fuzhou, with water resources distribution advices proposed.

8 Technical Modules in Step 6: Prepare an Indicative Zoning Map for Air Quality Protection

8.1 Purpose of this Guideline

The urban environmental problems generated from a lack of comprehensive consideration of environmental quality in the industrial layout, urban spatial layout and other activities. Environmental systems lack the necessary space to maintain environmental quality and ecological health which leads "the conflicts of environmental space". To solve these conflicts needs the environmental spatial planning. Urgently it needs environmental spatial planning and developments environmental spatial control methodology. From the urban water environment, atmospheric environment, ecological environment, based on the elements' current situation, divide control unit, and evaluate the importance, the sensitivity and the fragility of each environmental elements, and delimit environmental and ecological protection red line and strictly protected space boundaries.

Clear and space matched environmental spatial control can not only ensure the operability of the implementation process, but also provide guidelines for the space convergence with Urban Master Planning and Land Use Planning, improving land development space, building structural integrity, function and stability of ecological environmental security pattern.

Objectives in Measuring, Mapping and Analyzing Atmospheric Air Quality

Evaluate the environmental carrying capacity of atmospheric and clear the upper limit line of economic development and pollutant emission. Study the regional pattern of air environmental carrying capacity, analysis the spatial differences of regional environmental carrying capacity and nature environment capacity, to make sure the main pollutants emission intensity and the total amount. Study on the control strategy of social and economic development based on environmental carrying capacity, guide the develop intensity and scale adapt to sptial pattern of the environment capacity, establish the development pattern of economic and social match with the constraint of environmental capacity.

Measuring progress towards objectives

The overriding goal of protecting non-urban land from urban development, urban sprawl and overdevelopment will only be achieved under conditions of sustainable urban development. Peoples Governments at all levels will need measurable and staged objectives, to guide urban management personnel and resource consumers to develop to directions beneficial for urban environmental development.

Indexes are proposed to quantify and integrate progress towards objectives. Four sets of indexes are proposed: ecological pattern category, environmental carrying category, environmental quality category and environment public service category, and each category includes several indexes. The relevant air quality indexes are shown in Table 01.

In the table, the bottom line index refers to the environmental bottom line that should be guaranteed in urban development process. Medium and long-term index systems are recommended. These can be adjusted as appropriate to local conditions.

Table 8-1-1 Medium and Long-term Target Index System Recommended for UREMP: Air quality indexes

Field	No.	Index	Base year	Recent target year	Long-term target year	Bottom-line/ binding force
Safe and stable ecological pattern	2	Atmospheric environment class I zone area proportion (%)				
Environmental resources with sustainable utilization	12	Proportion of above-scale industrial enterprise and key commercial enterprises implementing clean production (%)				
Healthy and safe environmental quality	14	$PM_{2.5}$ annual average concentration (ug/m3)				
Fair and sharing environment public services	20	Days with qualified air quality				

8.2 Module 6A: Assess priorities for microclimate protection areas

The Gather Fragility Assessment Method

Identify urban pollutants easy gathering areas. The method is that set up the same intensity constant emissions source in each grid, and simulate and calculate in the meteorological conditions in different seasons. Select SO2, PM2.5, O3 and other primary/secondary pollutants. Depending on the spatial distribution of pollutant concentrations, determine urban pollutants easy gathering areas. Atmospheric environment fragile areas are generally located in small atmospheric environment capacity, weak innate self-purification capacity (such as valleys, basins, etc.) and serious air pollution areas.

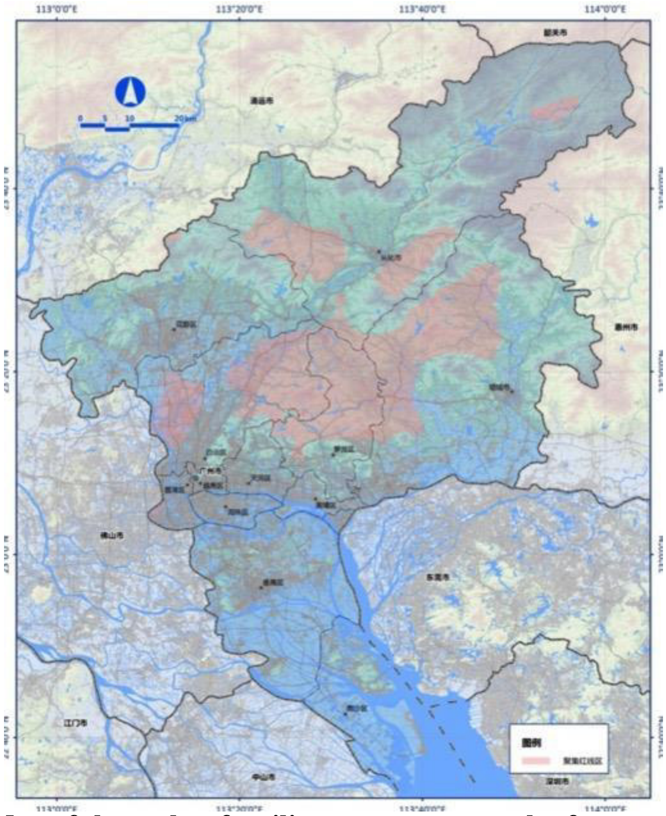


Figure 8-2-1 Map of the gather fragility assessment result of atmospheric environment in Guangzhou

8.3 Module 6B: Develop a regional atmospheric flow model

Simulating the Atmospheric System

It is recommended that the Mesoscale WRF + CALMET meteorological model is adopted. Terrain elevation data is combined for respectively stimulating three-dimensional meteorological fields in provincial areas, urban rural areas and key blocks. On the basis, CMAQ and other air quality models are applied to simulate air pollution transboundary transport, proliferation and transformation among cities. CALPUFF and other air quality models are applied to simulate air pollution dispersion and transformation in the city and among key blocks.

1) Data Preparation

Basic data includes society, economy, population, energy consumption data, monitoring site air quality data, Wupu dynamic updating data or environmental statistic data, etc. in recent 5 years.

Meteorological data includes ground meteorological observation and upper-air observation data in recent 5 years, ground observation data includes hourly wind direction, wind speed, air pressure, temperature, humidity, precipitation data, etc.

Spatial data includes population distribution, terrain elevation, land use, administrative division, etc.

Recommended model software includes ArcGIS, mesoscale meteorological model (MM5, WRF, CALMET, etc.), and air quality model (CMAQ, CAMx, CALPUFF).

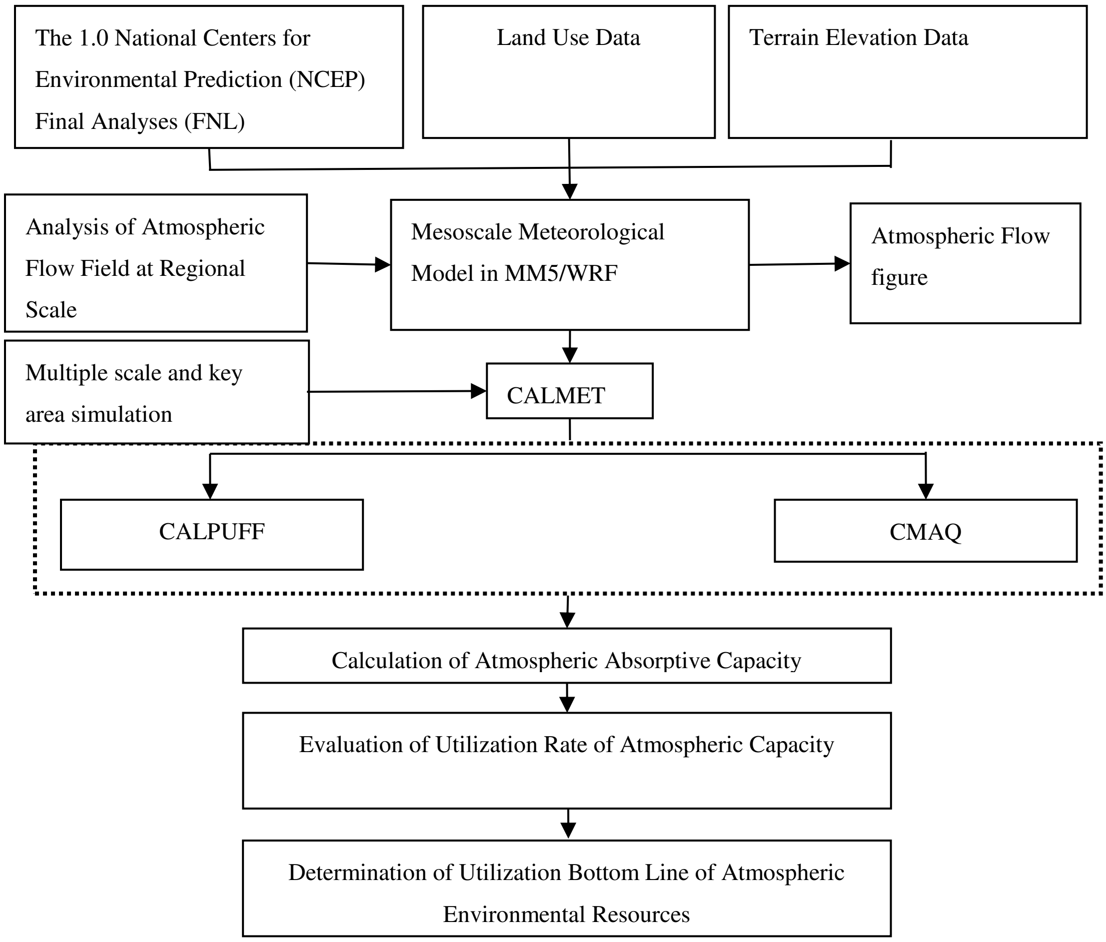


Figure 8-3-1 Proposed Technique for Determining Air Quality Bottom Line

2) Grid Space Unit Division

The studied area is divided into a number of regular (uniformly-spaced grid) or irregular (according to provincial, city and county administrative region division) space units. 3km × 3km grid settings and urban internal key blocks should be adopted in whole urban area dimension. 1km × 1 km grid settings should be adopted for grid division.

3) System Simulation

High frequency meteorological field simulation technology is utilized to simulate flow field characteristics of regional dimensions, urban and rural dimensions and urban internal small dimension typically in January, April, July and October.

Mesoscale meteorological model WRF is adopted for combining urban terrain elevation data and urban monitoring site whole-year hourly meteorological data (wind speed, wind speed, total cloud, temperature, humidity, air pressure and precipitation). 3D dynamic meteorological wind field of regional 3km resolution is stimulated, upwind, diffusion channel, static wind and other typical meteorological characteristic areas are recognized. On the basis of WRF stimulation results, urban region terrain data are combined. CALMET model is utilized for stimulating air fields of 1km resolution on medium and small scales. Atmospheric pollution diffusion characteristics are refined and atmospheric pollution diffusion and transmission routes on urban area and key block scales are made clear.

Atmospheric Environment Situation Analysis and Problem Identification

First, grasp the urban atmospheric environment meteorology characteristics, including weather conditions, pollution dispersion characteristics; second, research urban and surrounding areas atmospheric pollution emissions; third, grasp the urban atmospheric environmental quality, such as the concentrations of SO2, NOx, O3, PM2.5.

8.4 Example

8.4.1 Method for Atmospheric System Analysis

We have conducted practice and exploration on the above-mentioned ideas in pilot cities, and will continuously explore in selection of specific models and methods, selection of evaluation pollutant, determination of evaluation precision and grading parameters. We believe that, for selection of specific models and methods, selection of evaluation pollutant, determination of evaluation precision and grading parameters and other concrete content, they can be determined by comprehensively taking into consideration the factors such as availability of data, the precision of the data, urban scale and current air quality, etc. In general, it is recommended to combine the using of CALPUFF/CMAQ rather than single CALPUFF for analytical technology of atmospheric environment system; resolution should be deepened from 3km*3km to 1km*1km; and analytical object should be expanded from sole SO2 to NOX and PM2.5 and O3.

Table 8-4-1 Concrete Method for atmospheric System Analysis and Delineation of Spatial Control

	Fuzhou	Yichang	Guangzhou	Weihai
Selection of air model	CALPUFF	CALPUFF	CMAQ	CALPUFF/CMAQ
Evaluation method	Concentration vulnerability, layout sensitivity and receptor importance	Concentration vulnerability, layout sensitivity and receptor importance	Concentration vulnerability, layout sensitivity and receptor importance	Concentration vulnerability, layout sensitivity and receptor importance
Evaluation accuracy	Concentration vulnerability, (3 km * 3 km), layout sensitivity (3 km * 3 km)	Concentration vulnerability, (3 km * 3 km), layout sensitivity (3 km * 3 km)	Concentration vulnerability, (1 km * 1 km), layout sensitivity (3 km * 3 km)	Concentration vulnerability, (1 km * 1 km), layout sensitivity (3 km * 3 km)
Evaluation object	SO2	SO2	NOX、PM2.5、O3	SO2

8.5 Module 6C: Develop a regional pollution source model

The Receptor Importance Assessment Method

Based on the atmospheric environment function areas and population aggregation, the densely populated areas and the first class atmospheric environment function areas (nature reserves and forest parks) are delimited as the red line areas, which are the key control units of atmospheric environment management. Among them, the densely populated areas are regional centre, county built-up areas, key industrial parks.

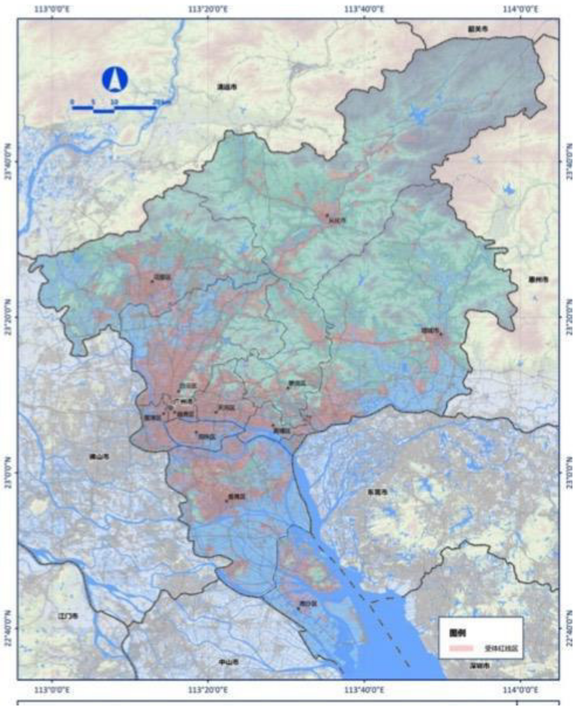


Figure 8-5-1 Map of the receptor importance assessment result of atmospheric environment in Guangzhou

The Source Sensitivity Assessment Method

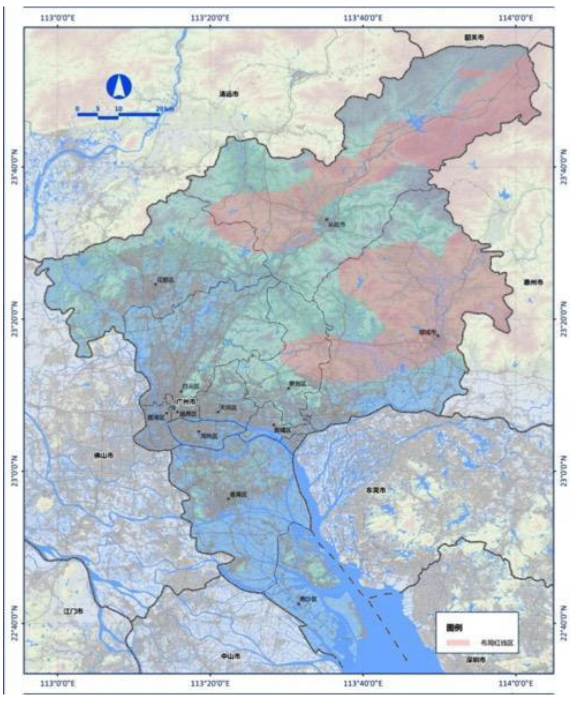
The urban atmospheric environment source sensitivity assessment method are as follows:

First, identify the upwind or air duct areas in the city, which are the source emissions regions having a large impact on the entire area.

Second, select representative pollutants according to the major pollutants type of the city. For example, SO2, O3, PM2.5 can be considered as representative pollutants. Then according to the size of the city and research needs, choose the appropriate grid size, such as the resolution of 9km × 9km, 3km × 3km, 1km × 1km.

Third, set up the same virtual emission sources in each grid. Use the same weather conditions to simulate, and calculate concentration of pollutants caused by each grid. Compare and determine the source sensitivity.

Figure 8-5-2 Source sensitivity assessment result of atmospheric environment



Module 6D: Develop a regional atmospheric absorptive model

Calculating Atmospheric Absorptive Capacity

1) Data Preparation

Basic data includes source emission list, pollution source location map, meteorologic condition, capacity measurement region area, urban atmospheric environmental function zoning map, all function zoning area, etc. The recommended modeling software includes CMAQ, MM5, SMOKE, etc.

2) Capacity Calculation Method

Firstly, the appropriate month is selected as representative of different seasons with atmospheric circulation characteristics according to city meteorological characteristics. CMAQ model can be utilized for stimulating pollutant concentrations of sulfur dioxide, nitrogen oxides, respirable particulate matter, etc., grid concentration distribution data are obtained. Then, actual monitoring data should be adopted as reference for assessing and estimating simulation error on simulation results.

Secondly, air quality compliance rate is calculated according to national air quality standards. The pollutant emissions under the condition of compliance rate can be regarded as pollutant atmospheric environmental capacity under the condition of compliance rate. In concrete operation, compliance rate of different pollutants corresponding to national class II standard should be regarded as benchmark plan. Therefore, the relationship between emission strength and compliance rate can be obtained, and source emission strength is regarded as atmospheric environmental capacity under corresponding compliance rate. Formula obtained by the above fitting can be utilized for further calculating pollutant atmospheric environmental capacity on the basis of targeted compliance rate in the future.

Concretely selected pollutants include sulfur dioxide, nitrogen oxides, respirable particulate matter, etc. Recommended technical methods for calculation include AP value method, multi-source mode method, ADMS diffusion model simulation method, etc.

3) Example: Method for Calculating Atmospheric Environment Capacity

Many methods can be used for calculating atmospheric environmental capacity. In order to better calculate the environmental capacity of main pollutant in atmospheric environment, we have conducted comparative analysis by selecting different air quality simulation models and flow field simulation models in different cities.

Table 8-6-1 Method for Calculating Atmospheric Environment Capacity

	Fuzhou	Yichang	Guangzhou	Weihai
Selection of air model	CALPUFF	CALPUFF	CMAQ	CALPUFF/CMAQ
Selection of meteorological model	WRF	WRF	MM5/WRF	WRF
Calculation method for capacity and carrying capacity	Use WRF-modified A-value method to calculate capacity and bearing rate of SO2, NOX and PM10	Use WRF-modified A-value method to calculate capacity and bearing rate of SO2, NOX and PM10	Use multi-source simulation method in CMAQ model to calculate capacity and bearing rate of NOX and PM2.5	Use WRF-modified A-value method to calculate capacity and bearing rate of SO2, NOX and PM10; use multi-source simulation method of CMAQ model to calculate capacity and bearing rate of PM2.5

Through practice, we believe that WRF-modified A-value method and multi-source simulation method of CMAQ model are all relatively mature and advanced technical approaches at present, and they are recommended to be used.

4) Analysis of Air Pollution Load

The load calculation formula of atmospheric environment is:

C_a (1)

In the formula, R_a refers to air pollution load, P_a refers to air pollutant emission, and C_a refers to atmospheric absorption capacity.

Atmospheric environment pollution loads of different regions are obtained on the basis of calculation result and pollution source emission status of atmospheric environmental capacity. Then, all assessment units are divided into serious over-load area with pollutant emission seriously beyond atmospheric environmental capacity, general over-load area with pollutant emission seriously beyond certain limitation of atmospheric environmental capacity, balance area with basically equivalent pollutant emission and atmospheric environmental capacity, and balance area with pollution emission condition still within the atmospheric environmental capacity scope. Meanwhile, key overload pollutants can be screened.

Table 8-6-2 Atmospheric Pollution Load Assessment Grade

Grade	Characterization status	Load	Grade description
I	Ideal, low load	≤50%	Very large development space
II	Good, lower load	50%-80%	Large development space
III	General, medium load	80%-100%	General development space
IV	Early-warning, higher load	100%-150%	Small development space
V	Critical, high load	≥150%	Very small development space

5) Atmospheric Environment Load Regulation Plan

Key overload pollutants can be screened according to atmospheric environment carrying capacity pattern of planned city. Regulation bottom lines of atmospheric environment load-carry duty at different stages are made clear. Upper limits of main atmospheric pollutant emissions are formulated, and regulation requirements of city key waste gas emission industry layout and industry structure are proposed in the future.

- Grade I (low load) shows that urban atmospheric environment is in the ideal state, and less emissions of air pollutants should be achieved.
- Grade II (lower load) shows that load levels of all urban atmospheric environment factors are in good state, enterprise compliance emission should be strictly required in the regions, and load level should be monitored and analyzed.
- Air quality condition in grade III (medium load) region should be in general level with general atmospheric environment load level, which has been in early full-load status. The regions should be monitored for realizing continuously lowering total pollutant emission, and pollution development to serious direction should be prevented.
- Most atmospheric environment element load levels in grade IV (high load) area reach critical state or some of atmospheric environment indexes are in serious overload level. Environment access should be improved in the region. Total amount reduction control should be implemented for atmospheric pollutant emissions in overload category. Total emission of overload pollutants should be gradually lowered, and they should reach environmental quality standards before deadline.
- Grade V (critically high load) refers that main indexes of urban environment are in the crisis state of serious overloading with serious atmospheric environmental pollution. More stringent atmospheric pollutant emission standards and total amount control indicators should be implemented in the regions. Total emissions of various pollutants can be reduced and controlled, and atmospheric pollutant emissions can be greatly reduced. Environment load level can be reduced to normal state gradually in stage within regulated time.

8.6 Example

8.6.1 Evaluation of Atmospheric Capacity in Fuzhou

The spatial pattern of environmental capacity of SO_2, NOx and Primary Particulate Matter of districts and counties in Fuzhou have been calculated respectively. Based on the environmental capacity, current pollutant discharge and estimated pollutant discharge, the spatial pressure of atmospheric environment at different regions were determined. Based on three basic principles, such as: atmospheric environmental quality of all districts and counties should not be degraded, emissions in month with bad weather conditions should not be overloaded and the air environmental quality is continuously improving, the constraint goals for pollutant emission in atmospheric environment were determined.

1) Measurement and calculation on atmospheric environmental capacity

Taking annual average concentrations of the three pollutants reaching class I standard and Class II standard as constraint conditions, the 1km ventilation coefficient was calculated based on WRF-CALMET model; A-value method was adopted for calculating the maximum allowable emissions of SO2, NOx and primary particulate matter in 4 typical months of January, April, July, October and the whole year, with the spatial pattern of environmental capacity of the three air pollutants in districts and counties analyzed.

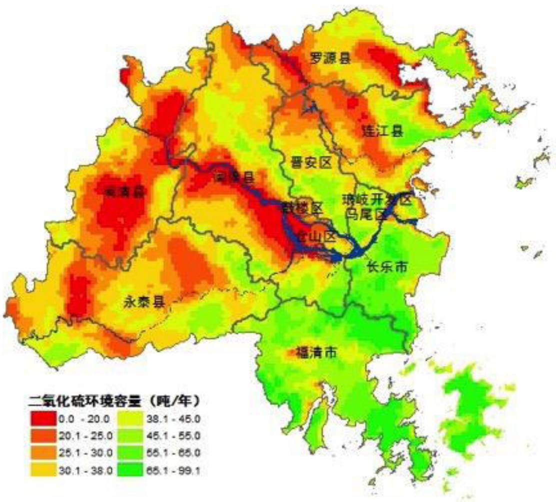


Figure 8-7-1 SO_2 water environmental capacity

2) Change the calculation results into management means

Change into the goals for controlling pollutant: based on three basic principles, such as: atmospheric environmental quality of all districts and counties should not be degraded, emissions in month with bad weather conditions should not be overloaded and the air environmental quality is continuously improving, the minimum requirement line for utilization of atmospheric environment was determined (seen in the following table).

Table 8-7-1 Spatial distribution of environmental capacity of sulphur dioxide in Fuzhou

Region	Control targets for 2020		Control targets for 2030	
	SO2	NOx	SO2	NOx
Municipal District	0.17	0.21	0.17	0.21

Fuqing	0.93	2.58	0.9	2.58
Changle	2.31	1.63	2.3	1.36
MinHou	0.18	0.05	1.6	0.5
Lianjiang	0.72	1.53	0.72	1.27
Luoyuan	1.56	0.54	1.56	0.54
Minqing	1.35	1.63	1.35	1.36
Yongtai	0.01	0.003	Does not increase	Does not increase

8.7 Module 6E: Indicative air quality protection zoning and mapping

The Spatial Grade Control Measures of Atmospheric Environment

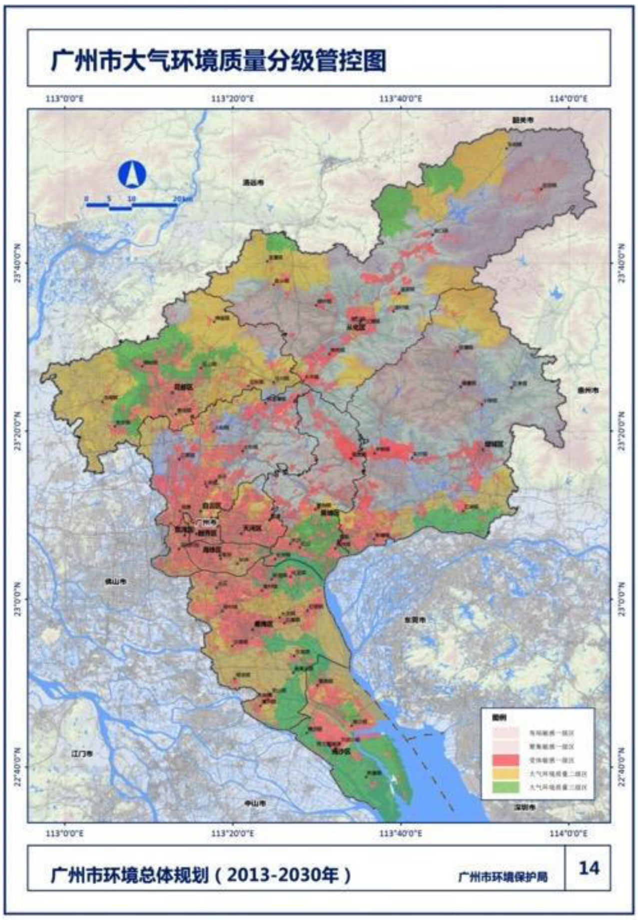


Figure 8-8-1 Map of Grade Control of Atmospheric Environmental Space in Guangzhou

According to the importance, sensitivity and fragility assessment of atmospheric environment, through GIS spatial overlay technology, the city is divided into atmospheric environment red line areas, yellow line areas and green line areas three regions, and implement the spatial grade control. The spatial grade control measures are as follows.

Highly sensitive and fragile areas in the red line areas are required to prohibit new construction, reconstruction and expansion of coal, steel, building materials, coke, nonferrous metals, petrochemical, chemical and other high-pollution industrial projects. Ban on new chemical projects involving poisonous gas emissions, and implement the most stringent emission standards. The receptors important areas in the red line areas should prohibit the use of high-polluting fuel which is required by environmental protection administration departments. Use natural gas, liquefied petroleum gas, electricity or other clean energy. Prohibit new coal-fired facilities and activities, and strictly restrict construction of new atmospheric pollutants industrial enterprises. The existing large emissions industrial enterprises gradually transform, or relocate, or eliminate to progressively realize the region ‘zero coal fired’.

Yellow line areas are mainly concentrated in the red line areas periphery. The new petrochemical, nonferrous metals, chemical industry and coal-fired boilers in the yellow line areas must meet the requirements in air pollutants emission standards.

Green line areas are the key region of urban development and construction. Under the condition of meeting the requirement of total control and emission standard, implement moderate development. The new petrochemical, nonferrous metals, chemicals and other heavily polluting projects and coal-fired boilers must meet the air pollutant emission standards in particular emission limit requirements.

8.8 Example

8.8.1 Practical Case of Atmospheric Environmental Space Control in Yichang

1) 3D simulation of wind field in full region and analysis on airflow field

Wind field of Yichang was simulated at the resolution of 3 km; combining with the terrain data of Yichang, the features of atmospheric flow field in Yichang weresimulated at the resolution of 1 km, with wind directions and wind speed emphasized.

2) Analysis on layout sensitivity

The CALPUFF model was used for quantitative simulation the sensitivity of spatial layout of pollution source, identifying the districts with higher affected scope and degree under equal pollution emission.

3) Analysis on concentration vulnerability

The CALPUFF model was used for quantitative simulation of the transmission and concentration characteristics of air pollutant and identifying the easily concentrated areas.

4) Analysis on importance of receptors

Functional zones of atmospheric environment, existing built-up area has relatively large influence to people's health.

5) Map of Grade Control of Atmospheric Environmental Space in Yichang

Through the above-mentioned processes, based on the spatial difference on layout sensitivity, concentration vulnerability and importance of receptors of atmospheric environmental system, the whole administrative area of Yichang was divided into red line area, yellow line area and green line area of atmospheric environment quality to conduct space control of atmospheric environment.

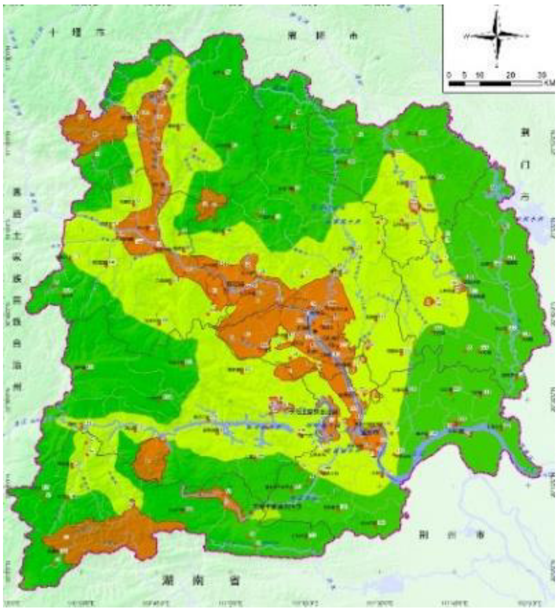


Figure 8-9-1 Map of Grade Control of Atmospheric Environmental Space in Yichang

9 Technical Modules in Step 7: Prepare an Indicative Zoning Map for Ecosystems Restoration

The next three pages consist of extracts from the publication South Australia, Department of Environment and Natural Resources, Habitat Restoration Planning Guide for Natural Resource Managers, 2011.

9.1 Purpose of this Guideline

Habitat loss and urban and rural ecological degradation is the most important cause of species decline and extinction. For the purpose of this guide, 'urban and rural ecosystem restoration' can be defined as: 'the assisted recovery of degraded urban and rural ecosystem'. 'Habitat restoration' focuses on providing suitable environments and resources for target species or groups of species that are currently in decline due to past habitat clearance or degradation.

Objectives

Landscape-scale restoration goals should ideally be developed to clarify what in the landscape is currently inadequate to meet the needs of the species of interest. Landscape-scale goals should then inform site-scale goals.

Ecosystem restoration goals should be identified that are specific, measurable, agreed upon, realistic and time-bound.

Stakeholder consultation is important for identifying and agreeing upon restoration goals. The ideal 'goal state' (composition and structure) for restored habitat should be identified from an understanding of the target species requirements, what their healthy habitats look like, how ecological communities function and how they may change over time. Ideally, planners need to not only have a clear vision of what the habitat should look like but where it will best be located to fulfil species needs across the wider landscape.

Identifying restoration goals and desired habitat states is an iterative process which begins with understanding the past, current and possible future states of the system being worked on (at the landscape scale and at the site scale). A site assessment should identify the current state of the site and the level of management intervention that is needed to shift the species composition and structure towards the goal state. Goals may need to be redefined if the actions required to meet the goal state are too difficult or require resources beyond those available.

Outcomes of restoration actions, such as revegetation, are often not certain at sites with variable starting conditions and an erratic climate (e.g. unreliable rainfall). Restoration at such sites (particularly where they are large-scale) may be directed through trialling different management approaches. Restoration planners may set up scientific trials in an adaptive management framework so that project managers can learn from outcomes and help direct implementation in later stages.

Timeframes for restoration projects often relate to budget timeframes set by funding bodies, but ecological development generally occurs over a much longer timeframe. Implementation may occur in several different 'phases' or stages over time. The time taken for habitat to be restored to the goal state will affect how goal statements are written and how monitoring of outcomes is designed and scheduled.

9.2 Module 7A: Identify and map potential for habitat and biodiversity regeneration

Habitat and biodiversity inventory

It will be useful for restoration planners to compile a ‘habitat and biodiversity inventory’. This inventory is a compilation of key habitat features (‘keystone structures’) and resources required by the target species or species group for them to successfully complete a lifecycle and maintain a viable population. Such an inventory can be devised and used as a checklist in the site assessment process to evaluate an area’s suitability for the restoration goals and help identify which key species or other elements are needed in a restored community to improve the adequacy of habitat in the project area. This assessment process will iteratively help set realistic goals and milestones and help direct restoration actions and monitoring.

Examples of factors that make up the goal state that may be important to define in a habitat inventory may include:

1) minimum patch size and connectivity requirements
2) specialised food resources
3) preferences for particular vegetation densities or structures (e.g. woodland with shrubby understorey; open grassy woodland; open grassland; or a particular successional stage of disturbed habitat)
4) special niches for feeding or shelter (e.g. leaf litter, fallen timber, ground cover, bark on trees)
5) types of resting spots and breeding sites utilised (standing dead trees, low hanging limbs, hollows in tree limbs or logs, rocks)
6) requirements for water
7) Tolerance to disturbance.

Habitat types, structures and compositions are influenced by the physical elements at a site such as soil fertility, topography, geology and hydrology. Restoration planners should be aware that the composition and structural formations of restored habitats should differ within sites according to changes in the physical environment. The density of vegetation (both horizontally and vertically) can influence how plants grow and which fauna can make use of the vegetation. Different fauna species are associated with dense vegetation compared to open vegetation.

Regeneration potential evaluation

A key determinant of restoration action will be the ability of the native vegetation at the site to naturally regenerate if threats are removed and whether the resultant species composition is likely to meet the restoration goal. The regeneration potential mainly lies in:

- ✓ the health and diversity of the native seed bank at the site
- ✓ The proximity to remnant vegetation from which propagates may disperse into the site.

The threats to regeneration include:

- ✓ the competition exerted by weeds or mature native plant species
- ✓ presence of grazers
- ✓ lack of a germination trigger (e.g. fire)
- ✓ How historical influences may have changed the site's physical properties.

- ✓ Investigating the soil seed bank

The primary factors determining whether a native soil seed bank might be present at the site include:

- ✓ the extent of native vegetation clearance
- ✓ time since clearance
- ✓ level of direct soil disturbance (e.g. cultivation) in recent decades
- ✓ Disturbance (e.g. fire or flooding) regime experienced in recent decades.

For example, there will most likely be a native soil seed bank present if a site has some remnant vegetation remaining in good health, the soil has never been cultivated (which destroys many soil-stored seeds) and the site has not been burnt by a fire regime that precludes seed production.

Seeds stored aerially in wooden capsules can be visually observed in the canopy of trees and shrubs, but soil seed banks require germination to reveal their true composition. When site history is not known and the site is patchily degraded, an examination of the current soil seed bank status may be helpful to determine the regeneration potential.

Possible trials that may reveal the species composition and responsiveness of the soil seed bank include:

- ✓ excluding grazers
- ✓ removing weed competition
- ✓ burning representative parts of the site to stimulate germination using 'burn boxes' (box-like structures of primarily non-flammable material designed to enable discrete burns to be implemented over an area with minimal threat of fire escape)
- ✓ scalping off top soil, place in shallow trays in controlled laboratory or nursery conditions to promote germination and identify resultant seedlings
- ✓ Applying smoke water products to stimulate germination.

Gaining this assessment information as early in the restoration process as possible will increase the opportunity for success and avoid the unnecessary expense of revegetation where natural regeneration processes can be used instead. Allow for at least 'one average' seasonal cycle to pass (may be several years in some regions) to facilitate germination from the soil seed bank and see the response. Set up monitoring plots and/or photo points.

As this process is expensive and time consuming it is relevant primarily for large-scale sites with long-term project timeframes.

Qualitative vs. quantitative data collection: Initial site assessments may be brief visual overviews that give a qualitative indication of the level of degradation and suitability of a site for restoration. Detailed secondary site assessments can be coordinated with development of a monitoring and evaluation program to collect baseline data. The two processes are closely linked. Integrating them at the start will ensure that the right data are collected, and in a way that can be interpreted and evaluated in an ongoing monitoring program.

To increase the collective knowledge base and accelerate levels of understanding about the condition of natural assets, investigate where assessment data collection can contribute to wider datasets where possible.

Mapping

Aerial photography is now commonly used to gain an overview of the features at a site. Observation through stereo-pairs[2] of aerial photographs can help give an even better understanding of topography, landform, presence of vegetation and man-made features for very large-scale sites prior to field work.

Global positioning system (GPS) technology can contribute to detailed collection of accurate field data during site assessment and can be used with geographic information systems (GIS) to map boundaries and calculate the area for units of particular management interest. Manually marking transition zones or 'fuzzy boundaries' on transparent aerial overlay or aerial printout can also be useful in the early stages of site assessment.

9.3 Module 7B: Identify and map potential for water bodies and riparian restoration

Driver / Purpose

In urban areas many waterways (rivers, streams, wetlands, lakeshores, and beaches) have disappeared under concrete, and elsewhere are channeled, diverted and/or degraded. Experience has shown that all of these cases are candidates for remediation, rehabilitation and restoration. They can then form parts of networks and corridors that extend into the areas that are given the highest levels of environmental protection through environmental zoning, and thus should be mapped as part of the wider land analysis.

Objectives

The objective of this module is to assess and map the disappeared waterways which have potential for remediation, rehabilitation and restoration, as input to the overall analysis of ecosystems restoration. Specifically, the objectives of Module 8B are as follows.

- To document and map the modified waterways which have potential for remediation, rehabilitation and restoration in the UREMP area.
- To provide comprehensive and credible input to planning decisions about the directions and nature of urban development and the distribution of ecosystems restoration in the UREMP area, so that high-value waterways are fully protected from urban development, urban sprawl and overdevelopment.

Outputs

Potential for water bodies and riparian restoration mainly depends on riverside belt sensitivity, coastal zone protection function importance, etc. Different impact factors can be selected for emphasized analysis according to different local natural and geographical conditions. Where, water and soil erosion sensitivity, riverside belt sensitivity, coastal zone sensitivity, etc. should be assessed according to 'National Ecological Protection Red Line - Ecological Function Red Line Delineation Technical Guide (Trial)' (Huan Fa [2014] No. 10). Coastal zone protection function importance evaluation mainly relates to coastal erosion, storm surge prevention, mangroves and coral reefs and other important terrestrial and marine life distribution and breeding area, as well as other important for maintenance of the local ecological environment security coastal zone, tidal flats and offshore areas.

1. The sensitivity assessment method for rivers

Reference domestic and abroad empirical data of riparian vegetation protection width, and consider the riparian water environment function zone, water quality objectives and soil erosion, make sensitivity assessment of riparian in the city.

$$H = f(a, b)$$

[2] May be available from the Department of Environment and Natural Resources

H refers to the minimum breadth of vegetation considering water quality objectives and soil erosion; a refers to the classification of water quality objectives; b refers to the classification of the soil erosion.

2. The sensitivity assessment method of coastal hazards

In the intense erosion coastal areas, sea level rise and storm surge strongly affected zone, comprehensively overlay the width of the erosion for many years, sea level rise affected zone width and storm surge affected zone width. Take the largest width among the three as the fragile coastal areas of the city.

$$\mathrm{f(x)} = \max\{a, b, c\}$$

f(x) refers to the influence scope of the coastal zone disaster; a refers to width of coastal erosion sensitive area; b refers to width of zone affected by sea rising; c refers to width of storm surge water affected zone

3. Assess the importance of coastal zone protection function

The assessment of the importance of coastal zone protection function mainly evaluates the coastal zone and tidal flats and offshore area of typhoon, ocean waves and storms, protection of coastal erosion, etc. And mangroves and coral reefs and other important terrestrial and Marine life distribution and breeding area and related biodiversity protection. Evaluation method and index can refer to the state oceanic administration of the Marine functional zoning of China report

(1) the coast erosion area refers to areas which are vulnerable to the corrosion of waves and currently have obvious (corrosion speed > 0.4 m/a) erosion, and have serious impact on the residents living along the river, arable land, construction of urban industrial and must take measures to prevent the corrosion area.

(2) the storm surge area refers to typhoon, storm surges caused by high winds and continuous wind, easy to cause the levee breaches, seawater intrusion in coastal towns and to shore, industry, ports, large tracts of arable land, shrimp ponds, yantian and residents' life, need to protect the area.

(3) The important Marine biodiversity protection area: mangrove ecosystem area, coral reef ecosystems concentrated distribution area, coastal tidal flats wetlands of important migratory species breeding during winter and summer, national and provincial protection of animal and plant species distribution area

(4) significant natural relics and natural landscape area: Marine geological structures with major scientific and cultural value, fossil distribution area, volcanoes, hot springs and other natural relic distribution area, natural zonality representative significance and scientific value of the coastal area

(5) Marine resources protection area: areas where national and local government forbid fishing perennially or in a phase, areas where the international fisheries forbid fishing, need to protect the important economic fish, shrimp, shellfish, spawning, breeding and larvae on water distribution.

(6) the coastal forest shelter belt zone: forest shelter belt already built, and to reduce the harm, improve the environment of storm surge, must build the forest; Forest belt width should be more than 30 m, length is more than 10 km.

(7) Groundwater resources reserve: obvious ground subsidence, water level decline has reached under 2 m, flooding has affected large tracts of arable land and the people's living environment, on the coast has formed a large funnel bottom area (1000 km2).

4. Assess and map-based on the above analyses – the relative value of potential for water

bodies and riparian restoration

Based on the above analyses, GIS technology is adopted for analyzing individual impact factors. The impact factors are overlaid and integrated according to certain rule, thereby obtaining integrated potential distribution map. Potential for water bodies and riparian restoration levels are assessed and zoned, and these areas can be divided into different levels.

Outcome

The Step 7 map (Indicative Zoning Map for Ecosystems Restoration) and the ultimate Step 8 UREMP instrument (showing the red line, yellow line and green line protection zones) are informed by potential for water bodies and riparian restoration in this module.

9.4 Module 7C: Identify and map potential for urban greening and open space

This section is an extract from the publication Ives, C et al. *Planning for green open space in urbanising landscapes*. RMIT University, 2014.

Map design and spatial analysis of urban greening and open space

Map design considerations included the need to balance competing objectives between spatial accuracy and collecting accurate data. For example:

- ✓ In order to get a good spatial accuracy in the responses, the map needed be large and provide ample information and reference points to allow survey participants to easily orient themselves and identify relevant green open spaces.
- ✓ To encourage a good response rate by not deterring or overwhelming participants it was important to keep the map clear and easy to read.
- ✓ The value stickers had to be small for spatial accuracy but large enough that survey participants could easily peel and place the stickers on the map
- ✓ Printing scanning and general user friendliness restricted the size of the maps to A1.

Following receipt of the completed surveys and maps, the location of sticker dots were digitised into a Geographic Information System (GIS). Each sticker dot was assigned to a respondent's survey ID and the value attribute was recorded. Invalid survey points (points that did not adhere to the survey instructions) were digitised but omitted from analysis. This task was completed by a qualified GIS technician. In addition to generating a digital spatial point dataset of mapped values, some processing and editing of other data layers was necessary to enable later analysis. These are outlined below.

Refining polygon geometry

Whilst the original park layers where adequate for visualising the Green Open Spaces in the maps sent to Survey Participants, the polygons in the original layers were not appropriate for analysis. The park polygons were edited to more accurately represent open green spaces while preserving the size and geometry of areas of continuous character. Park polygons that shared a boundary and the same park character were merged into a single park polygon using the Dissolve tool. The layer was manually inspected using a combination of Google Earth, satellite imagery, and a local street directory as validation data. Further edits were made according to the following rules/principles:

- ✓ Where an obvious change in physical character was apparent from satellite imagery the polygon was split and the character edited
- ✓ Polygon boundaries were edited to and reflect their true size.

- ✓ Adjoining local council parks were merged if all of the following criteria were satisfied; maximum 30m separation, vegetation coverage, land use unchanged and not interrupted by any roads or linear features other than streams and paths.
- ✓ Omitted green open spaces were added if they were identified as a park in one of the validation references and the area was accessible to the public
- ✓ For National Parks, tracks and unsealed roads were not deemed to interrupt a person's use or appreciation of the area. Therefore, where these features altered the park shape, the polygon was edited so the park area and perimeter reflected the park geometry without being distorted by other features.

The XY coordinates of each open space polygon centroid was calculated to aid in proximity calculations later on. In addition, the minimum distance of each park boundary to a water body was calculated.

Respondent home address

The address or nearest street corner of the each respondent (from questionnaire response) was digitised in a separate point feature class. The SurveyID field was stored with the "Home" point and the X and Y coordinates of the Home Point objects were added as fields in the attribute table (using the Add XY tool in ArcGIS). ArcGIS tools were used to relate these locations to other relevant information:

- ✓ The distance (as the crow flies) to the nearest park to their home residence, generated by the ArcGIS tool "Near". This was calculated as:

$$Distance\ from\ Home\ to\ Park\ Cent_m =$$

$$\sqrt{((\text{Home\_Xm} - \text{Park\_Center\_Xm})^2 + (\text{Home\_Ym} - \text{Park\_Center\_Ym})^2)}$$

- ✓ The percentage of vegetation cover within a 100m radius of respondents' home residence calculated using the vegetation layer and the "Spatial Join" tool.

Park Management Categories

To ensure consistency, we reclassified the categories parks were assigned to because the two LGAs that supplied park data did not use the same classification system within their local planning documents.

Parks from council data layers were reclassified as:

- ✓ Sportsfield – an area designated for sports (i.e. ovals, golf courses, etc.)
- ✓ General – the park was dominated by a designated community function (i.e. children's parks, landscaped green open spaces)
- ✓ Natural – an area that has generally naturally occurring vegetation. Area is devoid of obvious evidence of human interference with vegetation and landscape except for grass length management (mowing). This category also included National and State Parks.

Mapping point attribute densities

To display the digitised data, 'heat maps' for each value attribute were produced as follows:

- ✓ A base polygon layer consisting of 100m2 polygons that spanned the extent of the Suburb scale was created using ArcMap
- ✓ Survey Point layers were generated for each value attribute type.

- ✓ Each Value Attribute Point layer was spatially joined to the base layer. Each Spatial Join generates a "Join_Count" field which is the amount of points that intersect the 100m square polygon
- ✓ The resulting density maps were then visualised according to the density of points in each 100m2 grid.

Statistical Analyses

A range of statistical methods was employed to analyse data from the survey and spatial mapping responses. All analysis was conducted using the R statistical environment. Details of the main analyses are outlined below:

Relationships among ordinal Likert scale survey responses and between other survey responses were tested via Spearman Rank Correlation analysis. Pearson correlation tests were performed between continuous variables. Differences between categorical factors (e.g. housing status) were analysed via Chi-squared tests. Survey responses from Parts 1 and 5 of the survey (general open space values and socio-demographics) were also related to the abundance of mapped value dots via correlation analyses.

To simplify the range of green space values and identify general themes in how people relate to green spaces, a factor analysis was conducted on responses from Part 1 of the survey instrument. First, a scree plot of the data was generated from a principal components analysis to determine the number of distinct factors. The factor analysis was then conducted using the "factanal" function in the "stats" package in R using varimax rotation.

Relating the abundance of mapped value dots in parks to landscape and environmental variables required a statistical method that accounted for the fact that a high proportion of the parks in the study regions did not contain any dots. Since the response variable (dots in parks) was count data, zero-inflated Poisson modelling was adopted for this analysis. These analyses were conducted using the 'zeroinfl' function in the 'pscl' package in R. Before conducting the analysis, all predictor variables were standardised by subtracting the mean of the dataset from each value and dividing by the standard deviation.

To analyse the effect of distance from home on the assignment of value dots, it was necessary to account for the configuration of parks in each suburb in order for the true effect to be ascertained. To this end, a null model of park values was generated by randomly assigning 6 'dots' to parks in each suburb for each respondent's home address. The resulting output represented a random distribution of park distances from home addresses which could then be compared to the real mapped data. Histograms were produced for each value attribute for both the null models and real datasets. The differences in the bin values of each histogram were then plotted as a way of representing the true effect of distance from home on park values.

The compatibility between mapped values was calculated by comparing dot abundances in park polygons. A value compatibility score between value attributes V1 and V2 in a park was calculated as follows:

$$\text{Value compatibility score } (V_1, V_2) = 1 - |\,(V_1 - V_2) / (V_1 + V_2)\,|$$

This gives a compatibility score (ratio) between the pair of value dots. The mean score for each value pair was calculated by averaging over all parks. A matrix of pairwise value comparisons was generated by repeating for every value pair.

9.5 Module 7D: Identify and map potential for brownfield remediation

Driver / Purpose

The remediation of brownfield sites is a contribution to environmental protection in its own right, in that contaminants are reduced, and land is made available for development as an alternative to converting non-urban land to urban. It may be more beneficial, in that brownfield sites can become part of green networks and corridors, they can be used to restore biodiversity or to produce food and fibre, and in this way they may strengthen the case for the land including the old brownfield site to be given high levels of environmental protection.

Objectives

The objective of this module is to assess and map the brownfield which have potential for remediation, as input to the overall analysis of ecosystems restoration. Specifically, the objectives of Module 8D are as follows.

- To document and map the brownfield which have potential for remediation in the UREMP area.
- To provide comprehensive and credible input to planning decisions about the directions and nature of urban development and the distribution of ecosystems restoration in the UREMP area, so that high-value brownfield are fully protected from urban development, urban sprawl and overdevelopment.

Outputs

Brown (Brownfield sites) are those areas which may have potential environmental hazards in the process of redevelopment and reuse. Contaminated land assessment and environmental pollution control is the precondition of brownfield redevelopment. Therefore, in order to identify and map potential for brownfield remediation, soil environmental quality evaluation should be done firstly, to identify the brown area, on this basis, the brownfield remediation policy suggestions can be put forward.

1. Identify the status quo of brownfield in the planning area

Make investigation about brownfield pollution condition, find out the type, range, degree and the space distribution of brownfield, and analyze pollution causes. Especially focus on polluting enterprises, industrial legacy or surrounding the abandoned site, focus on solid waste disposal site, oil field, and mining area, the main vegetable base, sewage irrigation area, large traffic mainline, etc.,and determine the brownfield’s basic situation.

2. Assess pollution risk of brownfield

Integrated use land survey data of soil environment in environmental protection, agriculture and other related departments, and assess soil environmental quality of brownfield. The specific calculation formula is:

$$P_{ip} = {}^{C_i}\!/_{S_{ip}}$$

P_{ip}: pollution index of pollutant i in soil; C_i: measured concentration of pollutant i in soil; S_{ip}: Assessment standard of pollutant i. soil environmental quality can be classified into five degrees according to the number of P_{ip}.

Table 9-5-1 The classification of soil environmental quality

Classification	P_{ip}	Pollution assessment
1	$P_{ip} \leq 1$	No Pollution
2	$1 < P_{ip} \leq 2$	Mild Pollution
3	$2 < P_{ip} \leq 3$	Medium Pollution
4	$3 < P_{ip} \leq 5$	High Pollution

5	$P_{ip}>5$	Extreme Pollution

3. Analyze potential and risk of the brownfield redevelopment

According to the results of soil pollution assessment, soil environment can be divided into three types. Among them, the first area includes no-pollution area; Mild pollution, medium pollution and high pollution are divided into the second area; Extreme pollution is divided into the third area. Brownfield development focused on the second and third area.

Brownfield development potential is the most important reason to attract brownfields development, but there are also many risks in the process of redevelopment. To reduce the risk of loss, you must first identify and determine the risk factors of the existence of brownfield redevelopment, including law, policy, economy, technology, management and other aspects of the risk factors.

4. Assess and map–based on the above analyses – the relative value of brownfield remediation

Based on the above analyses, GIS technology is adopted for analyzing brownfield remediation. Then, provide different development strategies for different areas.

Outcome

The Step 7 map (Indicative Zoning Map for Ecosystems Restoration) and the ultimate Step 8 UREMP instrument (showing the red line, yellow line and green line protection zones) are informed by potential for brownfield remediation in this module.

9.6 Module 7E: Indicative environmental restoration zoning and mapping

This section is an extract from the publication: Clewell, A et al, *Guidelines for Developing and Managing Ecological Restoration Projects*, Society for Ecological Restoration International, 2005.

The final step in an analysis is to map indicative environmental restoration zoning on the results of the analysis.

- ✓ Identify the project site location and its boundaries. Delineate project boundaries and portray them as maps, preferably generated on a small-scale aerial photograph and also on soil and topographic maps that show the watershed and other aspects of the surrounding landscape. Use of GPS (Global Positioning System), land survey, or other measurement devices as appropriate is encouraged.

- ✓ Identify ownership. Give the name and address of the landowner(s). If an organization or institution owns or manages all or part of the site, give the names and titles of key personnel. Note the auspices under which the project will be conducted—public works, environmental stewardship, mitigation, etc. If there is more than one owner, make sure that all are in agreement with the goals and methods proposed for the restoration program.

- ✓ Identify the need for ecological restoration. Tell what happened at the site that precipitated the need for restoration. Describe the improvements that are anticipated following restoration. Benefits may be ecological, economic, cultural, aesthetic, educational, and scientific. Ecological benefits may amplify biodiversity; improve food chain support, etc. Economic benefits are natural services (also called social services) and products that ecosystems contribute towards human wellbeing and economic sustainability. Ecosystems in this regard are recognized and valued as natural capital.

✓ Cultural improvements may include social performance and rituals, passive recreation, and spiritual renewal. Aesthetic benefits pertain to the intrinsic natural beauty of native ecosystems. Educational benefits accrue from advances in environmental literacy that students gain from participating in, or learning about, ecological restoration. Scientific benefits accrue when a restoration project site is used for demonstration of ecological principles and concepts or as an experimental area.

✓ Identify the kind of ecosystem to be restored. Name and briefly describe the kind of ecosystem that was degraded, damaged, or destroyed, for example, tropical dry forest, vernal pool, semiarid steppe, shola (India), chalk meadow (Europe), cypress swamp (USA), etc. Other descriptors should be added to facilitate communication with those who may not be familiar with the natural landscapes in the bioregion. These descriptors should include the names of a few characteristic or conspicuous species and should indicate community structure (desert, grassland, savannah, woodland, forest, etc.), life form (herbaceous perennial, succulent, shrub, evergreen tree, etc.), predominant taxonomic categories (coniferous, graminaceous, etc.), moisture conditions (hydric, xeric, etc.), salinity conditions (freshwater, brackish, saline, etc.), and geomorphologic context (montane, alluvial, estuarine, etc.). Reference to readily accessible published descriptions can augment or replace some of these descriptors.

✓ Identify restoration goals. Goals are the ideal states and conditions that an ecological restoration effort attempts to achieve. Written expressions of goals provide the basis for all restoration activities, and later they become the basis for project evaluation. We cannot overemphasize the importance of expressing each and every project goal with a succinct and carefully crafted statement. All ecological restoration projects share a common suite of ecological goals that consist of recovering ecosystem integrity, health, and the potential for long-term sustainability. They are listed as the attributes of restored ecosystems in Section 3 of the SER International Primer. They deserve to be restated for each restoration project. Otherwise, they can be underappreciated or overlooked by authorities and other interested parties who are not well versed in ecological restoration. A project may have additional ecological goals, such as to provide habitat for particular species or to reassemble particular biotic communities.

9.7 Examples

9.7.1 Grassland Ecological Protection Scheme

1) Returning grazing land to grassland

The process of changing grazing land back to grassland includes two measures: forbidden grazing and rest grazing. In ecologically fragile natural grasslands with vegetation cover below 50% or in areas that are more than 4500 m above sea level, grazing should be forbidden. Moderately degraded grasslands with vegetation cover between 50 and 70%, and slightly degraded grasslands with vegetation cover between 70 and 80%, can be ecologically recovered by rest grazing.

In Baotou city, the area of grazing land that will be restored to grassland from 2006 to 2020 is planned to be 1.2 million hm^2 (see Table 8-1 and Fig. 8-1). Of these, the forbidden grazing area comprises 325 thousand hm^2, of which the reseeding area is 98 hm^2, and the rest grazing area comprises 875 thousand hm^2, of which the reseeding area is 262 hm^2. In the eco-city plan, during the short-term stage, the aim is to curb northern grassland degradation. During the medium-term stage, i.e., by 2015, the goal is to recover desertified and degraded grasslands. For a comprehensive recovery of grasslands, along with a coordinated development of grassland ecology and animal husbandry, the target is the long-term stage of the plan, i.e., by 2020.

Table 9-7-1 Area, in thousand hm2, of returning grazing land to grassland in Baotou

Area of returning grazing land to grassland in Baotou		**1200**	
Forbidden grazing	By Reseeding	Rest grazing	By Reseeding
325	98	875	262

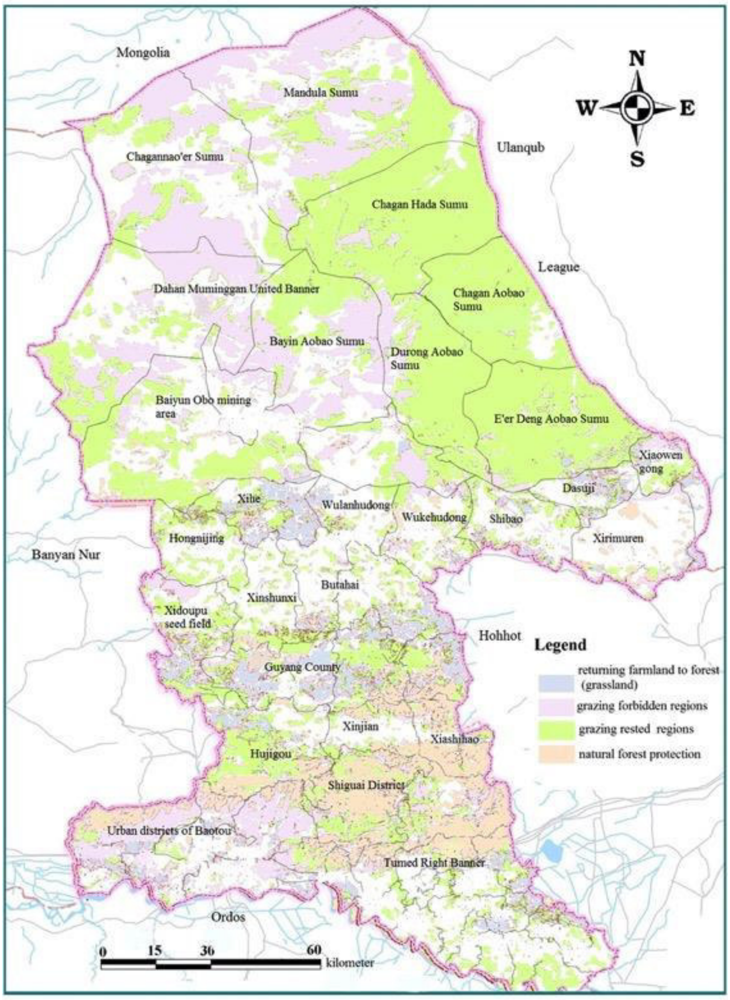


Figure 9-7-1 Baotou's ecological protection projects

The first step in the process of project implementation is to compile a work design based on regional requirements and distribute the tasks into three levels: villages, families and meadows. The next step is to use global position system (GPS) to pinpoint meadow position by longitude and latitude, and compile each village's operation map. To coordinate the electronic management system, technical measures should be standardized. At the family level?

2) Natural Forest Protection Project

Baotou City launched its first natural forest protection project in 2000. After several years' efforts, the Jiufengshan natural forest protection region in the northern part of the city has developed into a green barrier that protects Baotou's ecological environment. The area of this protected region is 130 thousand hm^2 and encompasses five districts, 44 villages, and nine national forest farms. If the current project construction zones are taken into consideration, the actual area is 170 thousand hm^2. However, because Baotou is located in arid and semiarid regions, forest development is under tremendous stress. Moreover, the afforestation-driven ecological restoration idea is being questioned by many people. For these reasons, the construction area for natural forest protection is planned to be within 300 thousand hm^2. Implementation measures include the abolition of natural forest harvesting, effective management of natural and other forests, active development of high-yield timber, and the strengthening of the forest cover of barren mountains and land. The total area of afforestation from 2006-2020 is planned to be 80 thousand hm^2.

3) Returning farmland to grassland (forest)

The key regions of farmland that will be returned to grassland/forest include sloping farmlands with gradients over 15° and farmlands suffering from desertification and/or degradation. Specifically, sloping farmlands with gradients over 25° and severely desertified farmlands will be returned to grassland/forest by 2010; they cover 67 thousand hm^2. Sloping farmlands with gradients over 15° and severely degraded farmlands with poor water and nutrient conditions will be returned to grassland/forest by 2020, and cover an area of 120 thousand hm^2. However, Baotou is not suitable for large area forestation given its arid and semiarid climate. Therefore, the south mountainous region, the shady slopes of mountains, and the banks of rivers will be planted with forests while farmlands will be mainly restored to grasslands. Combined with Natural Forest Protection Project mentioned above, a small portion of the farmlands could be returned to forests using artificial or natural afforestation methods.

4) Ecological Migration Project

Theoretically, ecological pressure that is caused by overpopulation can be resolved by transferring population from ecologically degraded regions to the outside. The resulting principle of ecological migration aims to rationally distribute ecological pressure in larger space. To achieve this in Bautou, we propose the movement of people who live in villages with poor ecological condition, scarce water resources, and severe desertification to regions with improved traffic and water resource conditions. The target population for ecological migration includes 15 thousand people from Damao district and 10 thousand people from Guyang district. Three different arrangements will be in place for these people: Firstly, the construction of new ecological migrant villages around an already developed town - activities such as drylot feeding and vegetable growing will be encouraged to provide the residents with agricultural and sideline products. Secondly, movement of the ecological migrants to regions with good water and nutrient conditions, where efficient ecological agriculture and husbandry practices can be developed. Thirdly, encouraging them to work in the towns – this will not only increase their employment chances but will also alleviate the ecological pressure on the land.

9.7.2 Grassland Ecological Construction Scheme

1) Desertification Grassland and Wandering Dune Comprehensive Treatment

The severely desertified area of Baotou is 19008 km^2 while the moderately or above wind erosion desertification area is 12746 km^2; these are mainly located in north and central Baotou's agricultural pastoral ecotone and north Baotou's grazing region. The current plan mainly aims at overgrazing-induced desertification. Also, since the desertification area of Baotou is too large, it is not economically feasible to treat the entire area. Therefore, this plan emphasizes the treatment of desertified land in Damao and Guyang districts. Chief treatment measures include forbidden grazing, returning grazing land to grassland, and restoring farmland to grassland. The total treatment area is planned to be 1620 km^2, which consists of 90 km^2 of wandering dunes and 1530 km^2 of desertified grasslands (Fig. 8-2).

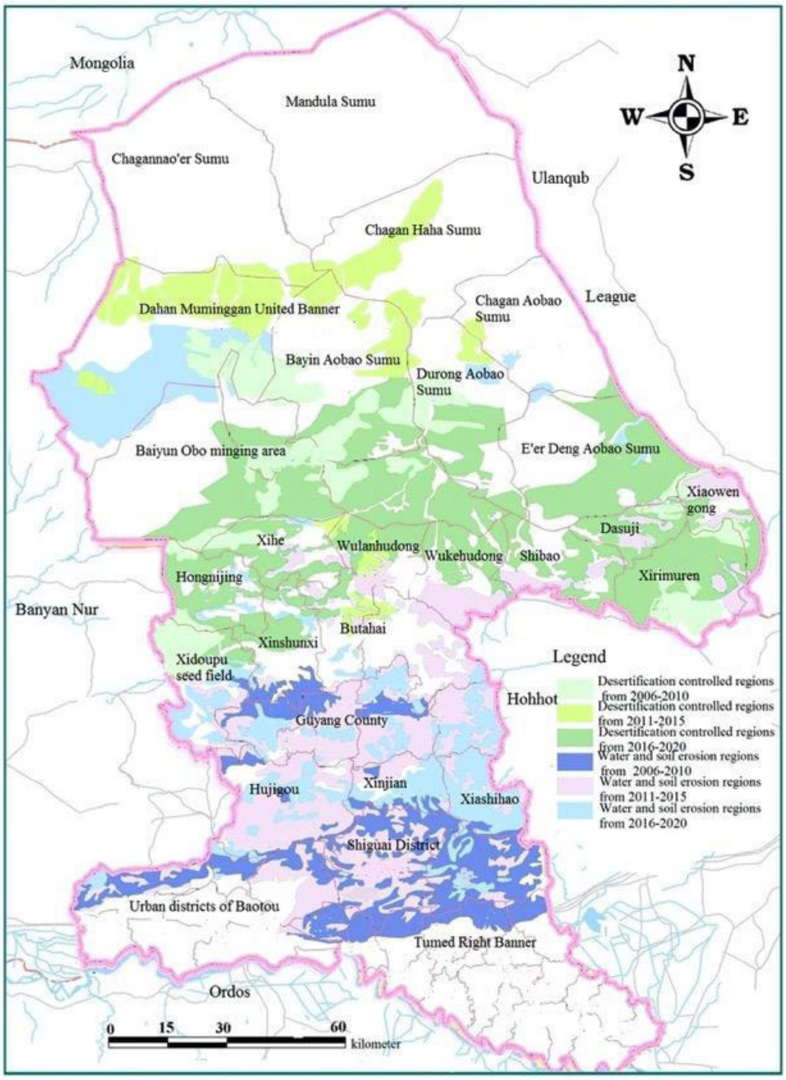


Figure 9-7-2 Ecological restoration and management projects in Baotou City

Given the rate of development of Baotou in recent years as well as the projected rate of future development, it is imperative to utilize desertified grassland in an ecological manner and improve land quality. Rational use, which in itself is a kind of scientific management, and improvement of desertified grassland is a complex problem that cannot be solved by a single approach. For fixed and semifixed desert grasslands, building fences and reseeding appropriate plants, growing these plants into pioneering species, fixing the desert grassland, and then developing a stable vegetation community, will have a strong sand stabilization effect. For wandering dunes, stabilization of sand should be engineered by building fences and grass square sand barriers, by planting shrubs in the sand barrier, and by reseeding local pastures. This stabilization will in turn help in the recovery of a vegetation canopy.

2) Comprehensive Treatment of Water Loss and Soil Erosion

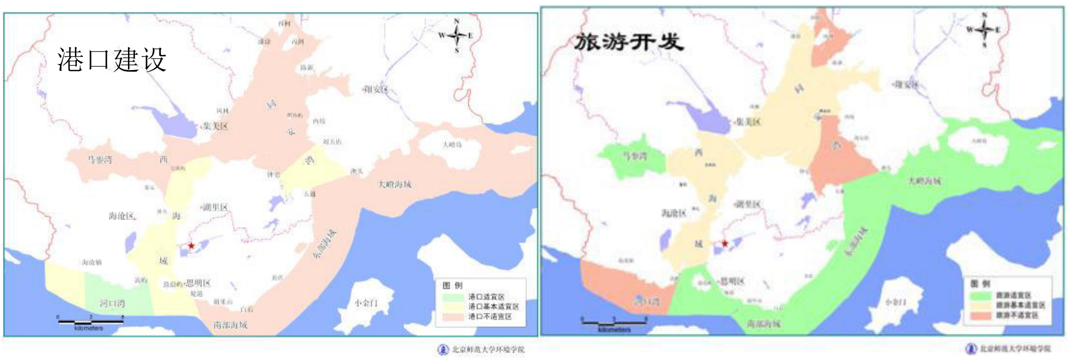
The area of water loss and soil erosion in Baotou is 8402 km^2, accounting for 30.26% of the total area of Baotou city. In particular, the area of severe water loss and soil erosion is 5500 km^2, mainly in the medium and low hills of Jiuyuan and Guyang districts. The primary measures to treat the water loss and soil erosion area are outlined in the Natural Forest Protection Project, Returning Grazing Land to Grassland Project, and Returning Farmland to Grassland (Forest) Project. By 2010, in the short-term stage of the eco-city plan, the treatment area of water loss and soil erosion is planned to be 3534 km^2; this is 42.06% of the total deteriorated area. In the medium-term stage, the treatment area is planned to be 5000 km^2, i.e., 59.5% of the total deteriorated area will be treated by 2015. Finally, the treated area will reach 80% by 2020, in the long-term stage of the eco-city plan. This will be achieved by adopting comprehensive treatment measures, which are a combination of biological and engineering measures. For example, on barren slopes and abandoned farmlands with a gradient above 25°, grass will be artificially grown, and quality of natural grasslands will be improved. On barren mountains and slopes with a gradient between 10 and 25°, trees will be planted for water and soil conservation - shrubs if the soil layer is thin, tall forests or mixed forests of trees and shrubs if the soil is thick. On thick fertile soil layers with a gradient between 5 and 10°, economic forests that cooperate with cave-shaped soil preparation will be planted. On sloping fertile lands with a gradient below 5°, basic farmlands will be developed. Additional measures include the planting of 'shelter' forests around farmlands, grasslands and on the sides of roads, construction of roads in traffic inconvenient districts, and digging of wells in districts where there is no direct irrigation source.

9.7.3 Ocean ecological construction and environment protection planning

For the purpose of establishing a healthy and live marine ecosystem, Xiamen's oceanic ecological planning will focus on coastal tourism industry development, marine environmental protection, and the restoration of destroyed marine ecosystem.

Based on the advantage of its geographical location and resource characteristics, Xiamen should be positioned as a tourism center and also a coastal tourist city. In the future, Xiamen will be transformed from a sight-seeing tourism city into a multi-functional city supplying travel, relaxation, tours, holiday, and business. The awareness of environmental protection should be also be strengthened in the development of the tourist resources. The coastal tourism industry planning efforts will emphasize the protection of our natural environment as well as cultural and historic heritage. Promoting the ecological and cultural tourism industries can help Xiamen to balance relations between economic development and environmental protection, also helping to achieve sustainable development in the long run. Xiamen has rich tourism resources allowing for the integration of culture, tourism, and other related industries. We will strive to promote Xiamen's tourism industrialization.

Xiamen’s sea pollution mainly comes from the land, so initial efforts will focus on controlling the emissions from land-sources. A large amount of these pollutants come from non-point sources; therefore, apart from the infrastructure construction, we aim to adjust the industry structure and improve the existing marine functional regionalization. Meanwhile, focus will also be given to the protection of marine biodiversity in Xiamen. The marine ecosystem of Xiamen is now adversely affected by economic development. As such, the government should propose resolutions to include the adjustment of industrial structures and ecological restoration in impaired marine ecosystems such as the western sea area, Majian Bay, and the coastal wetlands.



(a) (b)

(c)

Figure 9-7-3 Ecological suitability analysis diagram of ocean development in Xiamen (a) port construction; (b) tourism development; (c) mariculture

1) Ocean resources development and utilization planning

Leisure fishery had become a highlight of marine tourism as well as a new industry of island economy in Xiamen. As such, focus should shift from traditional aquaculture to leisure fishery. The key area of Xiamen's marine industry is tourism and port shipping. Efforts will be made to foster the marine high-tech industry and optimize the coastal industrial base. The following measures should be considered for the development of the coastal tourism industry:

1. Establish business ideas, promote the integration of tourism industry, and develop a number of powerful enterprises

2. Highlight the development of leisure and ecological tourism products

3. Pay attention to the development of Jinmen city

4. Construct ecological protection park, e.g. wetland park and urban park

The Xiamen port can be regarded as the shipping center for the Fujian province, south Jiangxi, and east Guangdong. We should integrate Xiamen's port shipping resources and continue to strengthen its infrastructure development. The fishery industry of Xiamen is high-quality and it is also a fry cultivation and supply base. We should improve the aquaculture fry industry, promote the intensive land-based, pollution-free aquaculture industry, and optimize the aquaculture structure while vigorously developing the leisure fishery. We will strive to strengthen the establishment of the ocean technology innovation system, the construction of ocean high-tech industry parks, and implementation of high-tech marine projects.

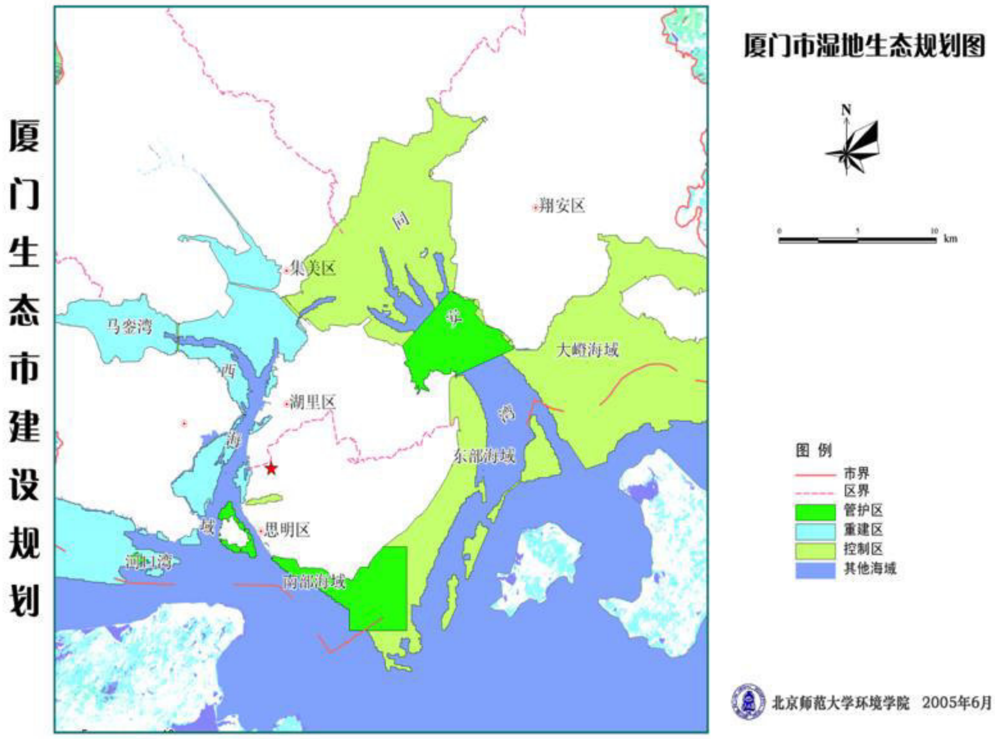


Figure 9-7-4 Wetland ecological plan in Xiamen

2) Ocean environmental protection planning

●Marine pollution control

Xiamen's ocean pollutants are mainly derived from non-point source pollutants on land. Therefore, apart from some basic measures such as infrastructure construction, the industry structure should be adjusted, allowing for the formulation of large-scale, offshore functional divisions and plan comprehensive marine environment protection. In the eastern ocean area, it is important to reduce the pollutants migrating with farmland runoff. Control measures such as the reuse of livestock and poultry manure, the mode of ecological farming, and organic fertilizer projects should be considered. In the estuary areas, we should stress the control of rural domestic refuse while improving the water supply and drainage systems in rural areas. In the western sea area, we should control the pollution sources in the cities and the tail water from the urban sewage treatment plants. For the southern marine area, the regulatory authorities should collect and dispose of urban domestic sewage, while intercepting polluted water from Xiagangbifengwu. Through the comprehensive coordination of major issues with the concept of ecological compensation, the concept of basin comprehensive renovation should be implemented so as to protect the ecological environment, and achieve the sustainable development of water resources in the JiuLongJiang basin.

●Islands exploitation and protection

There are 17 uninhabited islands and 27 key rocks scattered in Xiamen's sea area. Xiamen will work towards a policy of "putting prevention first, while enhancing management and minimizing exploitation". This means that we will establish special marine natural reserves, protect the cultural heritage on the island, and plant more trees to protect and rebuild the island landscape. The authorities will also implement coastline erosion protection and implement island vegetation restoration.

●Marine biodiversity protection

There is a concern that the ecological restoration of Xiamen's natural reserves is not an optimistic goal. The following measures should be considered to improve the chances of restoration:

1. Promote public participation and natural reserve management
2. Reform the management system while intensifying coordination ability
3. Improve the existent protection legislation
4. Intensify publicity and education while improving scientific monitoring
5. Formulate policies regarding sustainable use of natural resources

In order to protect Xiamen's marine biology resources, strict measures should be taken to limit the constructions of coastal engineering projects. We will work to adjust the fishery structure and control fishing intensities, while adopting a logical strategy for fishing. It is also important to release fish fries into the sea, which can help to restore the damaged marine ecosystem more effectively. Xiamen is vulnerable to invasive species invasion such as Spartina alterniflora, Loisel invasion, and Mytilopsis sallei Reeluz invasion. Some guidelines should be issued concerning activities which could lead to the introduction of invasive species. Establishing risk assessments and early warning mechanisms are also very necessary.

3) The damaged Marine ecological system restoration and construction planning

Maluan Bay is the most seriously damaged area in Xiamen's marine ecological system. In this bay, the blind expansion of aquaculture and intensive breeding practices have led to significant organic pollution. Our objective is to support the development of the Maluan region, restore the ecological service function required by its regional development, and maintain the health of the marine ecosystem.

Table 9-7-2 Maluan Bay ecosystem restoration indicator

Restoration rate（unit）	Status value	Target value	
		2010	2020
Sea area（km^2）	4.5	>8	>10
Water quality	IV or V	III	III
phytoplankton（$\times10^3$cell/L）	1620, eutrophic	<800	<500
Bentonic organism biodiversity index H'	2.87	>3	>3
Sediment sulfide(mg/kg)	>1000	<600	<300

The main priorities of coastal wetland restoration and construction efforts include: constructing coastal wetland reserve, prohibiting illegal reclamation, conserving the region's biodiversity, and reducing the high-concentrated pollutants emission.

Table 9-7-3 Coastal wetland ecosystem restoration indicators

Restoration index（unit）	Status value	Target value		
		2010	2015	2020
The restoration of damaged mangrove（hm^2）	4.5	>8	>9	>10
Tide volume of semi-closed gulf（$\times10^8m^3$）	5.5	6.5	7.2	7.6
The water high-quality rate of bathing place（%）	46.3	60	70	80

The detailed plan for restoration includes two parts: habitat and marine organism restoration. We should implement the mud-cleaning project, forbidden "fishing project", and "source cut & pollution control project". In terms of marine organism restoration, we should regulate exotic species, construct large scale mangrove plantation, and restore the structure and function of the aquatic ecosystem.

10 Technical Module in Step 8: Integrated Environmental Protection Zoning

10.1 Module 8A: Environmental protection zoning

The objective of this module is to produce a summary environmental protection zoning map delineating environmental protection zones (red line), restricted development zones (yellow line) and development zones (green line) based on the maps and data produced in Steps 3 to 7. The method includes an overlay and evaluation of all data and maps produced in the concluding zoning maps that have so far built up the UREMP Atlas.

The UREMP environmental protection zones, red line, yellow line and green line are compiled on layers of comprehensive analyses, each leading to many more than just three sets of controls.

Any one Step – for instance, Step 4: Prepare an Indicative Zoning Map for Green Land – generates many layers of analysis – in this case, forests, agriculture, mineral resources, etc – which might distinguish between different kinds of forest lands, or different environmental impacts of agriculture, or different environmental sensitivities. The resulting indicative zones for Green Land will show a range of assessments concerning the environmental value of distinct areas of land, and a range of potential policy responses (no development of any kind, certain kinds of positive development, encouragement of rehabilitation, long term protection for future purposes, etc).

Each of Steps 3, 4, 5, 6, and 7 will generate an indicative zoning map of this kind, with a range of assessments and policy responses depending on a number of spatial and non-spatial factors.

To give another example, Step 5: Prepare an Indicative Zoning Map for Water Quality Protection. There will be layers of analysis – rivers, lakes, wetlands, coasts, water source protection, flood mitigation, etc – identifying the attributes and values of specific land or water environments according to their condition and their potential roles as protected areas. These will be merged into indicative zones for water quality protection, managing locations in a variety of ways according to their value for particular purposes.

This is a complex but essential process. It results in five indicative zoning maps generated by Steps 3, 4, 5, 6, and 7. By overlaying the five maps, areas with exceptional value, and areas with high values for a number of sectors, and areas with potential to provide essential ecosystem services, become candidates for the red line environmental protection zone. The reasons for including each specific spatial unit, water location, and air quality cell in the red line zone might be quite different. In short, land, water and air locations in the red line zone are not all the same. They are all to be given the highest level of protection from development, but for possibly diverse reasons.

Protecting these red line locations will generally require that environmental controls are reflected in land use master plans and urban master plans, and that development control policies are reflected in the various policies and practices of the agencies responsible for water resource management, forestry management and agricultural land management. In negotiating such coordinated planning, the UREMP planners will need more than the colour on the map. They will need to document, explain and provide evidence for the decision to place any specific spatial unit in the red line zone.

ADB

Technical Assistance Consultant's Report

Project Number: 47061-001
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People's Republic of China: Institutionalization of Urban-Rural Environmental Master Planning to Guide Environmentally Sustainable Urbanization in the People's Republic of China

(Financed by the Technical Assistance Special Fund and Urban Environmental Infrastructure Fund)

Report 2: Technical Guidelines

(Pages 71–141)

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For the Ministry of Environmental Protection

While areas of land and water in the yellow line zone do not justify the blanket ban on development provided by the red line environmental protection zone, they are protected in specific ways depending on their attributes and the impact that various kinds of development would have on their environmental values and functions.

Accordingly, the yellow line zone is differentiated, with different policy implications in different areas. In some parts of the yellow line zone, low-impact urban development is compatible with environmental protection; in other parts, forms of green development such as farming or recreation are compatible, and may be beneficial; in yet other parts, the construction of certain kinds of infrastructure may have little impact, or may be beneficial. Implementing these polices will require negotiations with those responsible for land use master planning, urban master planning, water resource management, forestry management and agricultural land management.

10.1.1 The problem of boundaries: defining a single layer of spatial units

The summary environmental protection zoning map produced in Module 8 is divided into a patchwork of separate land and water parcels according to the value of each location and the management responses required to protect and enhance that value. Through the investigations and decisions made in Modules 3, 4, 5, 6 and 7, the whole of the UREMP Area is divided and subdivided into distinct locations, or spatial units.

The boundaries of the spatial units for ecosystems and landscapes will be determined largely by the extent of natural systems: ecosystems may be fragmented, and may be in patches; landscape units may be determined by land cover and land use, some with natural boundaries, some with boundaries made, for instance, by following the edges of fields or roads or power lines. The boundaries of the spatial units for Green Land will often differ from these. The boundaries of the spatial units for water will reflect the water environment. Spatial units for air may be cells in a broad grid.

In Module 8, all of these spatial units must be overlaid, compared and merged into a single set of boundaries for the final redline map. In some places, subsets and subareas will be required, creating new, smaller spatial units, to reflect the different kinds of controls and polices (responses) that are needed to protect the environmental values of those places. In other places, the nature of the controls and policies may allow the planners to define larger spatial units that incorporate the spatial units relating to two or more factors, since the same management response applies across the group of spatial units.

This task will be iterative, since refining the data and refining the management responses for various factors will lead to revisions and amendments. In the end, however, a single layer of spatial units is likely to be needed. This is a task that needs to involve the whole UREMP team, since decisions are being made about values, ranking, priorities and regulations. It also should involve representatives of any neighbouring UREMP teams or alternatively representatives of neighbouring provinces and local governments, since natural systems exist (and need protection) on both sides of all UREMP boundaries.

10.1.2 The problem of zoning: reducing multiple assessment to a single zone

Any particular place in the UREMP Area may be in the red line zone for ecosystems, the yellow line for land, the green line for water, and in one or other of those zones for air and for restoration. There may be individual places with many combinations of those zones for the different factors. The challenge for the UREMP planners is to integrate those differing zones for the final, comprehensive environmental protection zoning map.

Using the new, integrated spatial units prepared as just described, the multiple zones derived for each factor must be transformed into a single red, yellow or red line zone.

A common ranking used in environmental assessments is a rank based on a scale of 1 (poor) to 5 (good), as in Table xx and Table 2.3. In the process of transforming multiple zoning outcomes into a single zone this practice has serious dangers.

- It gives the process an erroneous appearance of precision or objectivity, when the rankings are actually relative values based on expert judgements.
- It often leads to a mechanical process of summing the numbers to produce a combined score. This is a bad error, for the numbers indicate rank (they are ordinal numbers) and are not a measure of value (they are not cardinal numbers). The best way to avoid this error is to use a scale such as E (poor) to A (good); or any ranking that does not encourage rankings to be added together, such as --, -, ±, +, ++; or ⇊, ↓, ⇅, ↑, ⇈.
- The rankings for each factor are not comparable. A rank of 'B' for the ecosystem is not same as a rank of 'B' for land, or water, or air, or restoration. These ranks are already based on multiple considerations and express – for each factor – a relative value for signify q2cance or sensitivity or vulnerability or rarity or combinations of these, and require different responses.

For all of these reasons, the value of any particular spatial unit cannot be measured by a simple addition or combination or ranks.

The value of any particular spatial unit must be based on a considered assessment of its overall significance and value in the widest context. The reason and significance of the rank for each factor has to be considered, and then the relative value of the specific spatial unit has to assessed in the context of its total significance in the UREMP Area and beyond. This task will be iterative, since refining the value or management response for one spatial unit may lead to revisions and amendments of other spatial units. In this way, the entire UREMP team must agree on an overall relative value for each and every spatial unit.

10.1.3 The problem of controls and policies: knowing why each area is significant

The coloured map produced in Module 8 determines if each location is in the environmental protection zone (red line), the restricted development zone (yellow line) or the development zone (green line). This could suggest that the only response required to pressures and impacts is to prevent, restrict or allow development on each spatial unit.

In fact, not all places in the red line zone are the same, and the implications for places in the yellow line zone are even more varied. The appropriate response for some places in the yellow line zone may be no development of any kind. Or it may be that certain kinds of development has the potential to deliver offsets, or protection, or restoration. Or it may be that at this place certain kinds of urban development have less impact than anywhere else.

Therefore, the coloured map must be seen as the top layer of a spatial database with many layers. For each specific spatial unit, the final environmental protection zoning map is the index to the information on that spatial unit: the value of that place for ecosystem services, for land use, for water, for air, and for the potential for restoration.

The final environmental protection zoning map gives access to the reasons for allocating the land to that zone, and it gives access to the specific controls and policies recommended for the place. Thus, the UREMP Atlas contains all maps produced in the preparation of the UREMP Plan, the reasons for assessments, and the responses that are required to protect the values of the place.

10.1.4 The problem of implementation: harmonising land use, urban, resource and environmental planning

Creating the comprehensive environmental protection zoning map and database in Module 8 is the definitive step in the URMP process, but it is only the beginning.

The zoning map and database enables the UREMP partners to document, explain and provide evidence for the decision to place any specific spatial unit in any particular zone. It therefore provides the UREMP partners with the information they need to enter into negotiations with governments, departments and agencies to have the controls and polices incorporated into planning instruments, implemented in development control for all relevant development proposals, and applied in land use master planning, urban master planning, water resource management, forestry management and agricultural land management.

10.2 Examples

10.2.1 Determination of environmental protection partition (Fuzhou)

Fuzhou has delimitated ecological environmental protection partition, ambient air quality partition, water environment quality partition, environmental risk prevention partition. Two control levels, as red line area and yellow line area, are delimitated in each factor/domain.

Features of Fuzhou environmental protection: First, ecosystem integrity, it has a good ecological environment quality, but recently faced with large-scale development and construction, the importance of ecological environment maintenance, especially the environmental protection of rural-urban fringe area is highlighted; Second, water culture is deeply rooted, the overall urban water quality is good, but the water quality of urban inland river is poor without obvious improvement for many years, therefore to improve the urban river water quality is imminent; Third, the ambient air is good, yet with increasingly intensive high-rise buildings along the Minjiang River, as well as the increased proportion of heavy industry in eastern coastal areas, the future maintenance of the environmental quality of ambient air will have spacial and structural problems. Combined with urban development and environmental protection features of Fuzhou, the judgment matrix for comparison between the importance of single factor is set to determine the weight of each factor as follows:

Table 10-2-1 Value Assignment for Importance of Single Factor in Fuzhou

	Weight of red line	Weight of yellow line
Ecological environmental protection partition	0.43	0.39
Ambient air quality district	0.18	0.22
Water environment quality partition	0.30	0.37
Environmental risk prevention partition	0.09	0.02
Total	1	1

Upon the above weights, an overlay analysis on single factor/domain is made to correct the red line area boundaries under the principle of remaining intact administrative boundaries, natural geographical attributes undestroyed, and intact humanity things as far as possible. For example, correct natural mountain protection range upon terrain data, try as much as possible to incorporate entire red line area into a unified administrative tenure in accordance with administrative divisions, try not to artificially increase the fragmentation of comprehensive ecological protection red line area, finally Fuzhou comprehensive environmental protection partition map is obtained.

10.2.2 Construction of grid management system on environmental protection (Changji Industrial Innovation Development Demonstration Area)

The grid management of Changji Industrial Innovation Development Demonstration Area adopts the I-III management mode "municipal (management committee) - (district or county) - town (street) - standard grid", taking town (street) as the minimum unit with highest administrator to be responsible person for the environment management of standard grid. Environmental standard grid establishes grade-by-grade refined standard grid in accordace with its own ecological environment features.

Grade I: administrative scope covering Changchun (partially) and Jilin (partially), the district environmental agency, being responsible for environmental management within its area, will guide the establishment and operation of subordinate grid, will inspect and report environmental violations like pollution or environmental security risks of enterprises within its administrative scope.

Grade II: Towns and streets within the demonstration area, it is responsible for environmental management within its area and will guide the establishment and operation of standard grid

Grade III: establish standard 1km standard grid within the urban area. Grid management is implemented on single factor/domain environment partition, air pollution control, water environment management, ecological environment improvement, industrial corporate governance, environmental risk prevention and control. Grid supervisor will implement full-time monitoring and management on unit assigned to him/her.

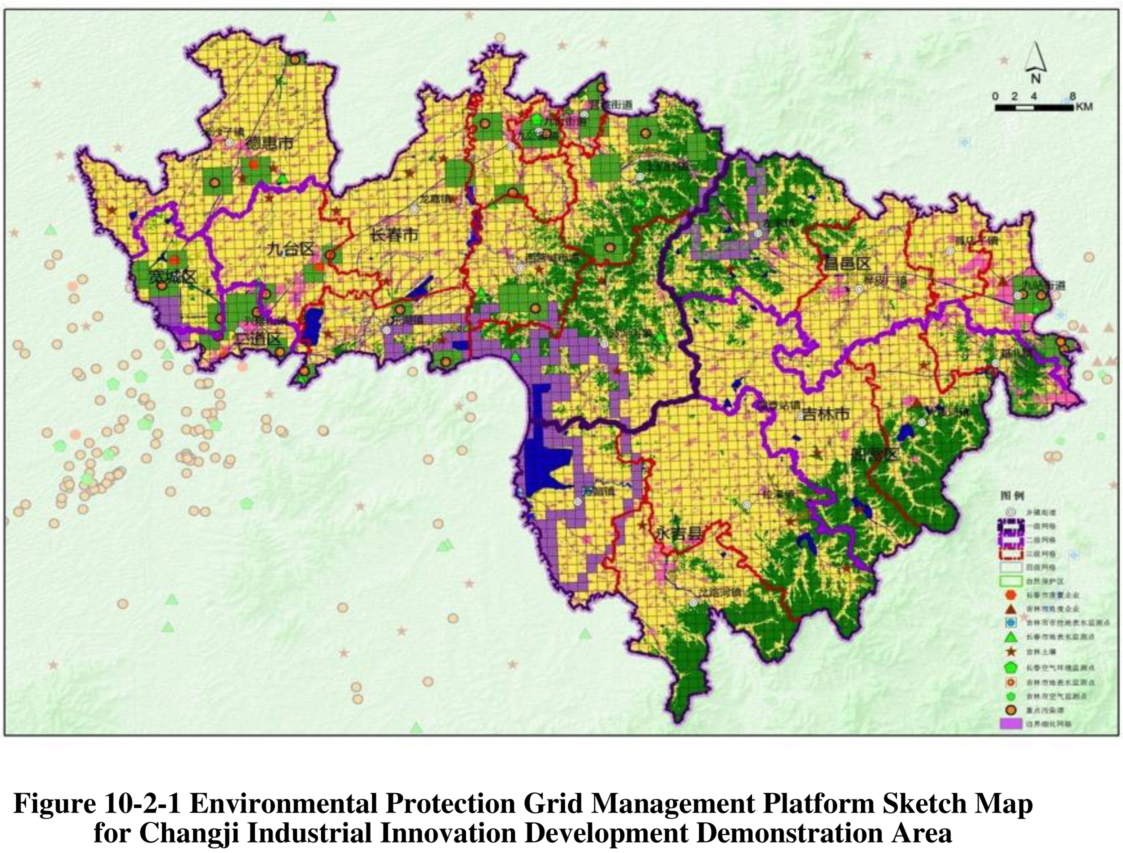

Figure 10-2-1 Environmental Protection Grid Management Platform Sketch Map for Changji Industrial Innovation Development Demonstration Area

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