CHAPTER 4

WATER FOR DEVELOPMENT PLANNING INDEX

4.1 Introduction

The development of water for development planning index (WDPI) based on a combination of integrated urban water management (IUWM) and pressure-state-response (PSR) frameworks to make decision over further development planning incorporates all the aspects of urban water systems. In framework, seven broad categories of indicators have been considered which include twenty sub-indicators to measure the relevant indicator. Formulation of WDPI has been established for an urban development planning.

4.2 Water for Development Planning Index (WDPI): Indicator Identification

Water is a renewable resource, so its sustainable use is possible. Water sustainability could be defined as regular supply of clean water for human uses and for other livings. It does not specify exactly how much water we have, nor does it imply the unrestrained, infinite availability of water. Rather, it refers to the sufficient availability of water into the foreseeable future. Indicator is a key term which bridges the final objectives and relevant criteria to achieve the objectives. An indicator quantifies and aggregates data that can be measured and monitored to determine whether the change is taking place. But in order to understand the process of change, the indicator needs to help decision-makers to understand why change is taking place (FAO, 2012). Assessment of sustainability in urban water systems identified indicators under environmental, social, economic and technical criteria (EU, 2003; UN, 2007; Popawala et al., 2011; Leeuwen et al., 2012; Ulian et al., 2017). In broader prospect, many sustainability indicator frameworks have been presented (Table 1). All these indicator frameworks do not include each component of urban water systems. It is claimed that there will never be a perfect set of indicators for IUWM. Most common reason of failings of indicator system is selection of unsuitable or unavailable data sources (Pires et al., 2014). Anderson (2000) claimed that water conservation and water recycling measures are the key elements in integrated urban water planning. However, relevant indicators are need to be organized to assess status of water supply and receiving water as well as societal responses such as an adequate protection and their relative importance, depending on local and regional factors (Lundin, 1999).

Leeuwen et al. (2012) considered, twenty-four indicators which are sub-divided into eight broader categories i.e. water security, water quality, drinking water, sanitation, infrastructure, climate robustness, biodiversity & attractiveness and governance for assessment of water sustainability in city setup. WATERINCORE project (2012) implemented under the transnational program of European Territorial Cooperation and identified twenty-nine common indicators based on DPSIR framework which focused on water preservation and avoidance of water stress. It includes total annual water consumption, produced urban wastewater, percentage of population served by WWTP, reused wastewater, population served by water supply network, ecological status of surface waters, chemical status of surface waters, quantity of ground waters, chemical status of ground waters, bathing water quality and cost recovery.

Water availability is constrained by natural processes, whereas water allocations within city boundary is also depend upon the infrastructure necessary to deliver water for domestic and other use, and also for collection of storm water and wastewater. The impacts of human activities on water quality and quantity are anthropogenic in nature. Hence, to measure sustainability with the objective of new development planning there is a need to know the thrust on the existing system, present condition of the existing system and possible options to improve the system. Therefore, the indicators need to be categorized on the basis of above mentioned factors. There are some sub-indicators associated with each indicator. However, indicators are associated with any of the criteria of pressure, state and response included in WDPI evaluation. Table 4.1 shows the indicator with their respective sub-indicators. The purpose of its selection and relevant description of the sub-indicator is given in Table 4.2.

1. Water security is the top issue in urban water cycle as water quality degradation, ground water depletion as well as wastewater directly or indirectly polluting the fresh water resources. Hence, this indicator is considered under pressure effect. There are four sub-indicator includes:

i) Urbanization rate (Ulian, 2017): Rate of urbanization, describes the projected average rate of change of the size of the urban population over the given period of time.

ii) Water withdrawal (Lundin & Morrison, 2002; Okeola, 2012): Water withdrawal is the percentage of water that is extracted from ground sources to volume of water available in ground water reserve. The extraction of ground water may be estimated using storativity within defined area.

iii) Fresh water scarcity (OECD, 2004): Ratio of total water footprint to total renewable water resources (recharge and reuse). Water footprint defined as water produced within the boundary for all services including products manufactured to transport outside the region.

iv) Pollution risk vulnerability: Pollution risk vulnerability is defined as pressures due to threat of pollution intense anthropogenic activities. Intrinsic vulnerability of a surface water body can be defined as the ease with which pollution introduced into the existing system.

2. Investment Scope is availability and requirement of funds for water projects and infrastructure maintenance.

i) Economic pressure (IMF, 2013): Economic pressure is the ratio of funds required to available for water projects and infrastructure maintenance.

3. Water quality of water bodies (Ulian, 2017) is always an important indicator as it affects directly human health and environment. There is direct recharge or discharge may take from aquifer to surface water and vice-versa which may pollute each other depending on its respective quality. So, there are two sub-indicators:

i) Ground water quality

ii) Surface water quality

*4. **Water quantity*** indicator ensures the sufficiency of available water within closed boundary. This includes:

i) Adequacy: It refers to providing water services to public in the urban region and measured by percentage of city population with water production.

ii) Reliability (Xiaoquin, 2009; Okeola, 2012): It is defined as ratio of per capita water produced and the per capita domestic water consumption.

iii) Extra Consumption: It is defined as ratio of per capita water demand and per capita actual water produced within the city.

5. Infrastructure: urban areas have many different infrastructures for fresh water production, drinking water supply, wastewater collection and treatment and storm water drainage. Storm water could be used as an alternative source of water (UNEP, 2008). Coverage area is a measure to present condition of infrastructure (Okeola, 2012). Water supply, wastewater collection and storm water coverage area have been considered separately. The following measures may reduce both wastage and operating costs (ADB, 2010). These measures are:

i) Water supply coverage area: It refers to percentage coverage of infrastructure available to total urban area for distribution to serve population.

ii) Wastewater collection coverage area: It is the percentage coverage of wastewater collection facilities available in the given region.

ii) Separation of wastewater & storm water (Bahri et al., 2011): It is defined as available infrastructures that facilitate the separation of for wastewater to storm water.

6. Reuse, recycle and recharge is the essential component of urban water cycle. Water balancing modeling expected to maximize reuse of water and minimize fresh water extraction (Lundin & Morrison, 2002; Barton et al., 2009). Reuse of treated wastewater may help the cities to improve, human and environmental health, while supporting economic activities (Brown, 2009). For the purpose, local reuse, recycle potential must be known. Water available for reuse, runoff storage, recharge potential other than natural processes and the economic efficiency for these options are required.

i) Percentage of wastewater available for reuse: This measure ensures the treatability of wastewater and its availability for reuse to various stakeholders.

ii) Surface runoff storing capacity: It is defined as the infrastructure available to store runoff water in the surface water bodies except rivers within the city.

iii) Reuse potential of city: It refers to total reuse potential from various water demands within or nearby city boundary.

iv) Economic efficiency: It is measured by ratio of the total cost of water produced to total cost of treated water (recycled).

v) Resource recovery (Makropoloulos, 2008): It is defined as willingness to pay by stakeholders and total cost recovery through by-product resource.

vi) Recharge potential of the city: It can be estimated by percentage of impervious surface in city and the constructed structure to improve recharge potentials.

7. Governance is a socio-political issue (Fleming, 2008). Good governance is a necessary for the development of all people within the framework of national and international legislation and regulations (Brown, 2009; European Green City Index, 2009). Governance means that explicit choices to be made in the trade-offs under policies. These are given below:

i). Management and action plan: Management means services provided by the government agency. Action plan refers to policy matters which have to be implemented in the existing system to improve the urban water services and projects.

ii). People's acceptability (Xiaoquin, 2009): Public perception influences decision-making and limits what is possible to implement, especially when it comes to water reuse. Sometimes, economically rational reuse options are not viable, for example because of the perception that faecal material may still be present in potentially insufficiently treated wastewater. Hence, it is important to consider which uses are safe, appropriate and acceptable with which type of water.

iii). Public participation: as the role of citizen involvement and behavioral change in achieving healthy urban communities and environments is one of the key elements (Brown, 2009; European green city index, 2009; Okeola, 2012). Involving citizens in decision-making at all levels promotes engagement and ownership. This includes decisions as to what types of sanitation facilities are desirable and acceptable, and how they can be securely funded and maintained in the future.

Table 4.1: Previous frameworks and indicators covered under urban water cycle

Sr. No.	Frameworks of sustainable indicator	Indicators covered related to Urban Water Cycle	Source
1.	European Common Indicators	water supply, water bodies, production to consumption and disposal	European Commission (2003)
2.	OECD Key Environmental Indicators	municipal waste generation intensities, wastewater treatment connection rates, intensity of use of water resources	OECD (2004)
3.	Global City Indicators	water consumption, system leakages, wastewater system treatment, water efficiency and treatment policy	Global Cities Institute (2007)
4.	European Green City Index	residential water supplies per property, Water utilities services, public participation	European Green City Index (2009)
5.	Sustainable Cities Index	water consumption per capita, water system leakages, water quality policy, water sustainability policy, share of waste water treated, public participation	Australian Conservation Foundation (2010)
6.	Asian Green City Index	water access rate, domestic water consumption, wastewater treatment rate, domestic treatment rate, public water supply coverage, total water consumption	Asian Green City Index (2011)
7.	China Urban Sustainability Index	urban density, wastewater treatment, public water supply, water efficiency	Urban China Initiatives, Li et al., (2014)
8.	Community Sustainability Indicators	population density, water uses, water supply by source, waste generation per capita	Sustainability City Report (Issaquah, WA, USA), (2016)

Table 4.2: Indicators and relevant sub-indicators with their description categorized for WDPI development

Indicator	Sub-Indicator	References	Purpose	Description
Water Security	Urbanization rate	Ulian, 2017	Measure of population increase	% of population increase per annum under urban boundary
	Water withdrawal	Lundin& Morrison (2002) Okeola(2012)	Sustainable development of City, Region	% of water that is extracted from ground sources to volume of water available in ground water reserve
	Fresh water scarcity	OECD(2004)	Measure of water providing	Ratio of total water footprint to total renewable water resources (recharge + reuse)
	Pollution risk vulnerability		Measure of water pollution extent	Percentage of wastewater collection and its treatment
Investment Scope	Economic pressure	IMF(2013)	Measure of economic pressure	Ratio of funds required to available for water projects and infrastructure maintenance
Water Quality	Surface water quality	Ulian(2017)	Requirement for environmental and public health	Assessment of the water quality preferably based on standard
	Ground water quality	Ulian(2017)	Requirement for public health	Assessment of the water quality preferably based on standard
Water Quantity	Adequacy		Requirement for human livelihood & health	% of city population with water production
	Reliability	Xiaoquin(2009) Okeola(2012)	Use efficiency	Water produced per capita / domestic water consumption (per/capita)
	Extra consumption		Present water consumption	Water demand per capita /Water produced per capita
Infrastructure	Water supply coverage area		Measure of service coverage	% of infrastructure for water treatment and distribution
	Wastewater collection coverage area		Measure of service coverage	% of infrastructure for wastewater collection
	Separation of wastewater and storm water	Bahri et al.(2011)	Measure of uses of resources	% of separation of infrastructures for wastewater to storm water collection
	Percentage of treated		Measure of reclaimed water quantity available	Availability of treated waste water quantity within city, region

	wastewater availability			
	Surface runoff storing capacity		Measure of green water storage potential	Infrastructure available to store storm water within city, region
	Reuse potential of city, region		Measure of reuse potential	Total reuse potential from various requirement of city, region
Reuse, Recycle & Recharge	Economic efficiency		Measure of recycle cost	Total cost of water produced / Total cost of treated water (recycled)
	Resource recovery	Makropoloulos(2008)	Measure of recovery cost	Willingness to pay and total resource recovery cost
	Recharge potential		Measure of recharge through green water	% of impervious surface in city, region
	Management and action plan		Measure of participatory, adaptive coordinated and integrated management	Measures of local and regional commitments to adaptive, malfunction, infrastructure and design for IUWM
Governance	Public participation	Xiaoquin(2009)	Measure of local community strength and willingness	Proportion of individuals who volunteer for group or organization as a measure of local community strength and willingness of residents to engage in the activities for which they are not remunerated
	People's acceptability	Brown(2009) Okeola, 2012	Measure of local acceptance of policy	Degree of acceptance of local people to water services and policy

4.3 Framework of Water for Development Planning Index (WDPI)

A framework is being proposed using combination of integrated urban water management (IUWM) and pressure-response-state (PSR) frameworks. Integrated Urban Water Management (IUWM) framework facilitates planning, designing, and managing urban water systems. It is a flexible process that responds to change and enables stakeholders to predict the impacts of interventions. Growing competition, conflicts, shortages, waste and degradation of water resources make it imperative to rethink conventional concepts – to shift from an approach that attempts to manage different aspects of the urban water cycle in isolation to an integrated approach supported by all stakeholders (GWP, 2013). Mitchell et al.(2001) noted that several components i.e. water usage, reuse of wastewater, storm water and change in water storage within the system are need to be integrated in urban water cycle. Usually, fresh water is being used in domestic demands for drinking, cooking, flushing of wastes etc., horticulture, industrial, construction or other such purposes. Whereas, recycling and reuse of treated wastewater are also important part of the sanitation cycle and it may be used as alternate source of water supply. Anderson (2006) observed that the new planning requirements significantly increase the opportunities to integrate recycled water into urban water supply systems to increase the available supplies and also to minimize environmental impact.

Anderson et al. (2001) noted reclaimed water is currently one of the top priorities in sustainable water resource utilization which is one of the goals of IUWM. However, identification of reuse potential of any urban area is challenging as it depends on seasonal demand variation, habits of people, number of open drains available for flushing, area for irrigation, horticulture and availability of wetlands near river courses. It has been identified that management of raw water, treated wastewater and storm water is much challenging due to several criteria viz. environmental, economic and social and their respective indicators which affect the cost for delivering acceptable quality of water supply to cities for multiple uses. It is also argued that water management solutions for new residential developments should be based on sustainability considerations due to their far reaching social, economic and environmental implications (Makropoulos, 2008). Thus, water required for new developments may consider reuse, recycle and recharge easily which will reduce thrush on the existing supply system. In this context, there is need to reclassify the sustainability criteria, the relevant indicators and their corresponding sub-indicators.

Rees (2006) defined goals of IUWM at different scales i.e. household/community, municipality/ city utility, basin, regional and national or international. At municipality level it includes conserve andre-allocate supplies, improve health and basic needs, increase investment and source protection or quality protection. Conserve and re-allocate supplies covers supply network maintenance and planned reuse at urban scale. Health improvement observed by preventing waste infiltration into water supply, facilitating community-level provision, targeted subsidies and education of water hygiene. Increase in investment includes cost based tariffs, better revenue collection, improved operation efficiency and curbing illegal connections. Source protection or quality protection includes ground water extraction control, leak control, land zoning and industrial and domestic waste pollution control.

European Environment Agency (1999) developed DPSIR framework (Drivers–Pressure–State–Impact–Response) which is useful in describing the relationships between the origins and consequences of environmental problems, but in order to understand their dynamics it is also useful to focus on the links between DPSIR elements. DPSIR framework that human activities exert 'pressures' on the environment, as a result of production or consumption processes, which can be divided into three main types: (i) excessive use of environmental resources, (ii) changes in land use, and (iii) emissions (of chemicals, waste, radiation, noise) to air, water and soil (Kristensen, 2004).The ‘state’ of the environment is affected i.e. the quality of the various environmental compartments (air, water, soil, etc.) in relation to the function of these compartments. Water quality (rivers, lakes, seas, coastal zones, groundwater etc.) and human health are major components in water sector. A 'response' by society or policy makers is the result of an undesired impact and can affect any part of the chain between driving forces and impacts.

The goals of IUWM are defined by many authors but could not be covered the extent of its real impact. This enforces to adopt modified approach for IUWM framework. DPSIR framework and PSR framework (OECD, 1998) may be considered to meet the objectives of IUWM. The improved model will result in estimation of water for development planning which ultimate goal is holistic use of urban water (Table 4.3).

Table 4.3: Need of modification in existing framework based on PSR framework and final expected goals

Goals of IUWM Framework at Municipality Level (Rees, 2006)	**Issues need to be addressed (Giordano and Shah, 2014;Pires et al., 2014)**	**Suggested Modification(s)**	**Final Goals Expected of present study**
1). Conserve supplies and reallocate supplies 2). Improve health and basic needs 3). Increase Investment 4). Source protection or quality protection	1). Identification of context rather than universal sustainability criteria 2). Non-availability of suitable data sources	1). Integration of PSR to IUWM framework 2). Finding of new measures/indicators 3). Development of WDP framework for urban water management system	Water for Development Planning Index (WDPI) evaluation

As every city has its own social, financial and environmental setting in which water managers have to operate. Trend and Pressure Framework (TPF) were introduced to revise the City Blueprint indicators (Coop & Leeuwen, 2015). In this study an attempt is being made to introduce 'state' and 'response' to define WDP for urban water management system. Final goals will evaluate water for development planning index (WDPI) based on pressure-state-response (PSR) which helps to evaluate the available water for further development around city (Fig.4.1).

A framework is proposed for water for development planning index (WDPI) for calculating the sustainable development index which is inspired with PSR framework taking pressure, state and response component. The framework consists six indicators i.e. water security, water quality, water quantity, infrastructure, reuse recycle recharge and governance (Fig.4.2).

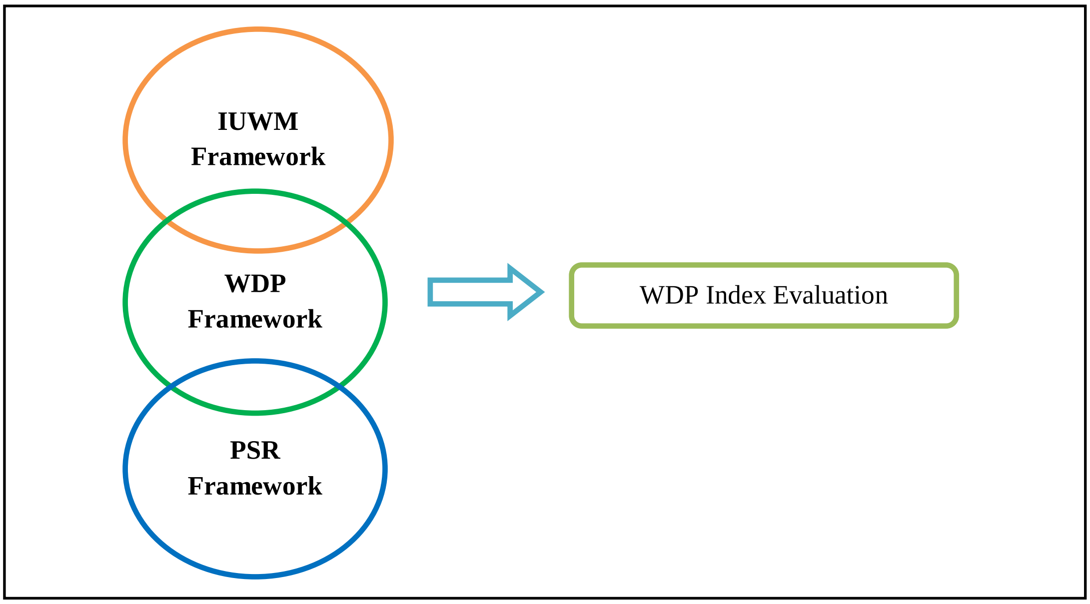

Fig.4.1: Interaction among IUWM, WDP and PSR framework to evaluate WDPI

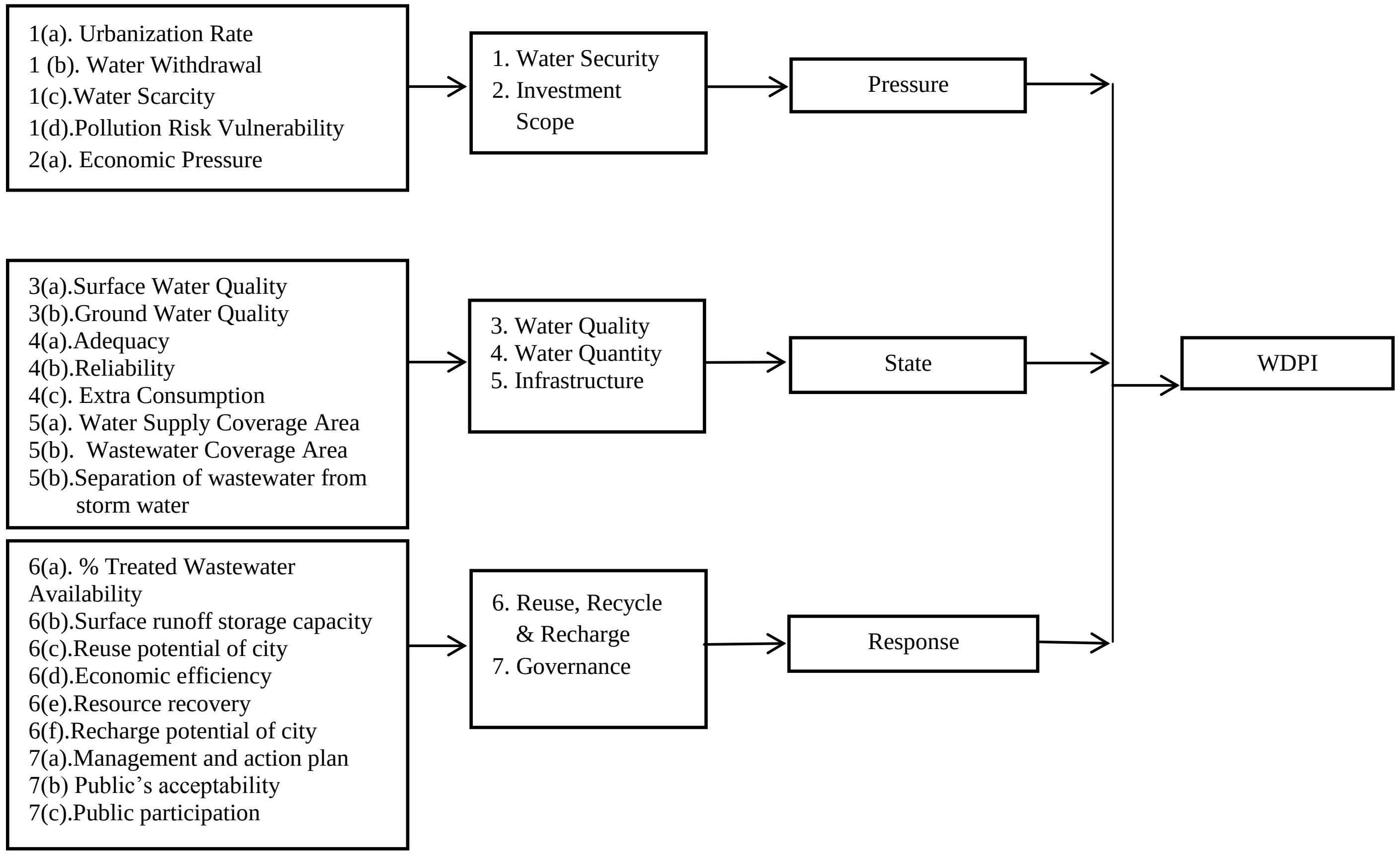

Fig.4.2: Framework of Water for Development Planning Index (WDPI)

Table 4.4: Weight Assignment to Indicators, Relevant Sub-indicators and PSR for WDPI Evaluation.

WDPI	**Objective (PR/ST/RE)**	**Indicator (I)**	**Sub-Indicator (SI)**	**Weight Within Each Category (w)**	**Weight within Objective (W)**	**Weight of Objective (W_P/ W_S/W_R)**
Water for Development Planning Index (WDPI)	Pressure	Water Security	Urbanization rate	0.20	0.80	0.23
			Water withdrawal	0.40		
			Fresh water scarcity	0.30		
			Pollution risk vulnerability	0.10		
		Investment Scope	Economic pressure	1	0.20	
	State	Water Quality	Surface water quality	0.50	0.25	0.37
			Ground water quality	0.50		
		Water Quantity	Adequacy	0.40	0.375	
			Reliability	0.40		
			Consumption	0.20		
		Infrastructure	Water Supply Coverage Area	0.35	0.375	
			Wastewater Collection Coverage Area	0.35		
			Separation of wastewater and storm water	0.30		
	Response	Reuse, Recycle & Recharge	% Availability of treated wastewater for reuse	0.10	0.67	0.40
			Surface runoff storing capacity	0.20		
			Reuse potential of city, region	0.20		
			Economic efficiency	0.05		
			Resource recovery	0.15		
			Groundwater Recharge potential	0.20		
		Governance	Management and action plan	0.40	0.33	
			Public participation	0.40		
			People's acceptability	0.20		

4.4 Formulation of WDPI using Pressure-State-Response (PSR) Framework

In urban water supply management, the exploitation of fresh water resources and the generation of wastewater create Pressure (PR) on the environment. The pressures in turn affect the State (ST) of the water supply and demand environment. This refers to the quality of the various environmental media (water) and their consequent ability to support the demands placed on them (for example, supporting human and non-human life, supplying resources, etc.).The Response (RE) demonstrates the efforts of the governance (e.g. decision makers) and society (public participation, perception etc.) to solve the problems identified by the assessed impacts, e.g. policy measures, and planning actions. Using this concept, a single index, Water for Development PlanningIndex (WDPI) may be calculated (eqn. 3) in line with Alternative Evaluation Index (AEI) (Chung & Lee, 2009). In present framework pressure-state-response has been considered as objective function (OF). Indicator (I) value is calculated through the defined sub-indicators (SI) values and its corresponding weight value (w) (eqn. 1). Based on indicator value (I) and weight (W) assigned to it, OF is calculated (eqn. 2). Weight assignment of the indicators is based-on scheme followed by Environmental Performance Index (EPI). Weights of each sub-indicator have been decided by conducting a desk-based survey with technical field experts.

$Ij = \sum_{i=1}^{n} SIi \text{ x wi}$ (eqn. 1)

$OF = \sum_{j=1}^{m} \text{Wjx } Ij$ (eqn. 2)

Where, SI = sub-indicator value w = weight of sub-indicator

I = indicator value W = weight of indicator

$WDPI = W_P \text{ x } PR + W_S \text{ x } ST + W_R \text{ x } RE$ (eqn.3)

Where, PR = Pressure W_P = weight factor of pressure

SR = State W_S = weight factor of state

RE = Response W_R = weight factor of response

$W_P + W_S + W_R = 1$

WDPI has been evaluated at a scale of 0-10 which consists of three objectives pressure, state and response. Pressure-State-Response (PSR) has the same scale of measure as WDPI. Based on WDPI the performance has been categorized as given in Table 4.5.

Table 4.5: WDPI value range to classify category of status

WDPI Value	**Category**
0-3	Poor
3-5	Critical
5-8	Fair
8-10	Excellent

A computer based graphical user interface (GUI) has been developed using Visual Studio 2008 and mySQL database software and visual basic programming language (details given in chapter 5). The sub-indicators have been derived through primary/secondary field data. Further, the measures of the sub-indicators have been normalized to a single scale 0-10.