Downstream Impacts of Water Pollution in the Upper Citarum River, West Java, Indonesia

Economic Assessment of Interventions to Improve Water Quality

October 2013

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Acknowledgments

The report is based on the Asian Development Bank's Technical Assistance undertaken for the benefit of the Ministry of Public Works, Directorate General of Water Resources in Indonesia, financed by the Kingdom of the Netherlands under the project "Institutional Strengthening for Integrated Water Resources Management in the 6 Ci's[3] River Basin Territory (package B)". It is a summary report of "Water quality in Citarum River. Planning interventions to improve river water quality in upper Citarum river (November 2012)." The ADB project officers for the technical assistance are Thomas Panella and Helena Lawira, who are responsible for the pre-publication review. The Technical Assistance was implemented by DHV, a company under the Royal Haskoning DHV group of companies, and the project team consisted of Aart van Nes, Indra Firmansyah, and Sjoerd Kerstens in cooperation with Deltares (in particular Wil van der Krogt) and Mitra Lingkungan Dutaconsult (MLD). Sjoerd Kerstens wrote the main report. The Ministry of Public Works, Directorate General of Water Resources, has worked with DHV to implement the Technical Assistance by providing valuable input and guidance.

In parallel, DHV worked with the World Bank's Water and Sanitation Program (WSP) to conduct economic analysis of the interventions. Guy Hutton designed the economic analysis and oversaw data gathering, and wrote the economic sections of the report. Isabel Blackett was the task team leader and Almud Weitz, Enrico Rahadi Djonoputro, and Deviariandy Setiawan provided inputs to the study. Peer reviewers were Michael Peter Steen Jacobsen, Paulus Van Hofwegen, and Ilham Abla. The economics work was funded through WSP's Multi-Donor Trust Fund for WSP East Asia and the Pacific, supported by the Government of Australia.

[3] 6 Ci's means 6 rivers in the provinces of Banten, DKI Jakarta and West Java. Citarum is one of the rivers originating in West Java.

Executive Summary

The Economics of Sanitation Initiative (ESI) of the World Bank's Water and Sanitation Program (WSP) commenced in East Asia and the Pacific region in 2006 to generate and disseminate economic evidence on sanitation. A Phase 1 study in five countries of the region, including Indonesia, assessed the economic costs of inadequate sanitation to raise the profile of sanitation nationally. A Phase 2 study compared the costs with the benefits of a range of sanitation intervention options in five physical locations in Indonesia, to assist decision makers in their choice of sanitation technology and delivery method. Since the demonstrated successes of ESI in the East Asia and Pacific region, ESI has become a global flagship program of WSP. However, some economic benefits have not been fully evaluated in monetary terms because of methodological difficulties in valuing nonmarket impacts, the paucity of underlying data sets, and the difficulties inherent in attributing observed impacts to poor sanitation. Among these hard-to-measure benefits are the impacts of poor sanitation on water resources. Hence, the purpose of this study was to develop and pilot test a specific methodology for valuing a wider range of impacts related to water resource pollution in Indonesia.

The Citarum River is of vital importance for water supply to both the Bandung metropolitan area, where almost 10 million people reside, and the greater Jakarta region, which houses 25 million people. However, over the past 20 years, water quality in the upper Citarum River has been decreasing dramatically, and essential parameters are far outside mandatory limits with more than nine times for biological oxygen demand and more than 5,000 times for fecal coliform in some locations (Royal Haskoning DHV 2012). This report describes the origin of the pollution, its effect on water quality, and the economic losses resulting from the deteriorating water quality. This report also identifies feasible interventions for improving water quality and predicts the effect of these measures on water quality. The implementation costs and economic benefits of the interventions indicate a favorable benefit-cost ratio of greater than two, meaning Rp2 of economic return for each Rupiah spent.

Analysis of the sources of water pollution indicates that 64% of biological oxygen demand in the Citarum River is produced by domestic and municipal activities, compared with 36% from industrial or agricultural activities combined. The significant number of people lacking access to improved sanitation in the upper Citarum River basin explains the relatively high contribution of domestic and municipal activities: 60% in rural areas and 35% in urban areas. The available improved sanitation facilities comprise mainly of "septic tanks," or *cubluks*,[1] installed at the household level, whereas centralized sewerage systems are available to only 5% of the population in the upper Citarum River basin. Most of the larger-scale industries have some form of wastewater treatment plant, but treatment efficacy is known to be low, and for smaller industries, the availability and performance of wastewater treatment plants are worse.

If effective interventions are not taken, water quality will further deteriorate in the upper Citarum River, resulting in an increased threat to public health and affecting the general welfare of the population. On the other hand, with improved water quality, financial benefits can be realized, related to reduced costs of drinking water production, increased yields from fish farming, enhanced real estate and associated opportunities for tourism, and biodiversity. The corresponding financial benefits of improved water quality amount to a total of Rp2.1 trillion (US$226 million) annually.[2] Further benefits can be gained by introducing additional measures that aim to recover resources from wastewater and solid waste. Examples are production of biogas (energy), production of compost, recovery of plastics and papers of solid waste, and promotion of effluent reuse by industries. These additional measures increase the benefits by Rp500 billion (US$54 million) annually.

[1] These are brick or block-lined, open bottomed tanks, meaning they are effectively leach pits because of the lack of openings in the side walls.

[2] An exchange rate of Rp9,440 per United States Dollar (US$) was used.

Improvement of water quality to mandatory standards is feasible. This requires interventions in both domestic-municipal levels (by increasing access to improved basic sanitation and sewerage or wastewater management) and addressing industrial pollution. Implementation requires systematic planning, with long-term actions on multiple fronts, comprising establishment and improvement of institutions, allocation of adequate funds, and the construction, operation, and maintenance of sanitation facilities to isolate and/or treat wastewater. The following table provides the estimated costs and benefits for treating both domestic and industrial wastewater, including resource recycling and reuse. These are values that would pertain in 2030, after the required interventions have been scaled up, presented in 2010 prices. The annualized benefits outweigh the annualized costs by a factor of 2.3. The major share of costs are for improving access to domestic sanitation and wastewater treatment (Rp13.7 trillion, or US$1.5 billion) compared with industrial interventions (Rp1.6 trillion, or US$172 million) over a 20-year period. Hence, the sanitation interventions not only improve the water quality but also are economically attractive. Moreover, some benefits have been excluded because they could not easily be monetized, so the ratio of benefits to costs could be significantly greater.

The roadmap required to bring about improved water quality in the upper Citarum River comprises several steps, starting with the simple ones and leaving the more complicated ones for the future. The recommended approach starts with setting up the local organizations to manage sanitation development, including implementation of relatively simple interventions such as promotion and incentives for effective septic tanks, community-based wastewater treatment systems, and improved solid waste collection, transport, and disposal. It is also recommended to address pollution caused by larger industries at an early stage. However, reducing industrial pollution requires both more effective enforcement of present regulation and improvements to the legal framework. More complicated and larger infrastructure, such as off-site wastewater treatment systems, solid waste infrastructure (sanitary landfills), and resource recovery facilities, require more time to successfully implement and are recommended for the medium to long term. The introduction and support of resource recovery through government and private sector actions are highly recommended because of its economic attractiveness and preservation of scarce resources. It is therefore recommended to start planning for resource recovery infrastructure at an early stage.

Variable	Domestic wastewater treatment and industrial wastewater treatment and reuse	
	Rp (billion)	US$ (million)
Investment cost (over 20 years)	15,794	1,670
Annualized costs, including recurrent costs	1,164	129
Annual benefits	2,631	280
Benefit-cost ratio	2.3	2.3

Note: Values refer to when interventions are scaled up in the year 2030, presented in 2010 prices. Rp9,440 = US$1.

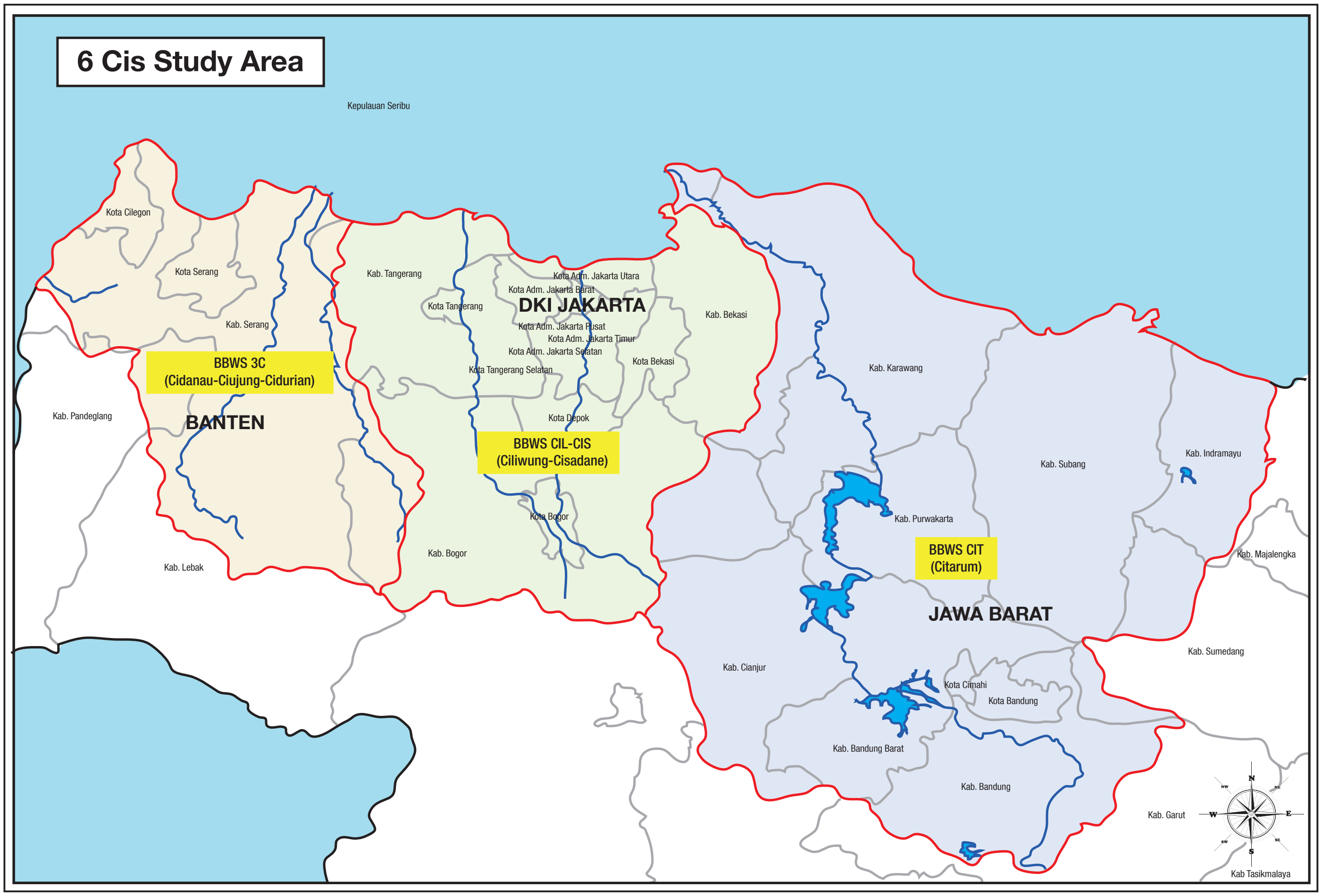
Abbreviations

BMA	*Baku Mutu Air* (Water supply standard)
BOD	Biological Oxygen Demand
BPLHD	*Badan Pengendalian Lingkungan Hidup Daerah* (Regional Control Agency of the Living Environment)
BWRP	Basin Water Resources Project, component of the Java Irrigation and Water Resources Management Project (JIWMP) under World Bank assistance (1995-2004)
COD	Chemical Oxygen Demand
ESDM	*Energi dan Sumber Daya Mineral* (Ministry of Energy and Mineral Resources); the same name is used for the provincial agency for Energy and Mineral Resources
IPLT	*Instalasi Pengolahan Lumpur Tinja* (sludge treatment installation)
MLD	Mitra Lingkungan Duta Consult
PSDA	*Pengelolaan Sumber Daya Air* (Water Resources Management, under Ministry of Public Works); the same name is used for the provincial agency for Water Resources Management
PUSAIR	*Pusat Penelitian Pengembangan Sumber Daya Air* (Research and Development Center for Water Resources); under the Ministry of Public Works; located in Bandung
US$	United States Dollar
USDP	Urban Sanitation Development Program (funded by the Royal Netherlands Embassy)
WWTP	Wastewater treatment plant

Contents

I. Introduction

FIGURE 1.1: THE CATCHMENT OF THE CITARUM RIVER IN RELATION TO THE OTHER FIVE "CI" RIVERS



Safe water resources are essential to support a healthy environment. Jakarta, the capital of Indonesia, and its conglomeration houses some 25 million people, and receives presently 40% of its domestic, municipal and industrial water from a cascade of three large reservoirs in the Citarum River, east of Jakarta, envisaged to increase to 75% to replace current over-exploitation of groundwater in Northern Jakarta. Sufficient water is available, but the Bandung metropolitan area, with some 10 million people and many industries located in the upstream catchments of Citarum, causes serious pollution that is the result of domestic, municipal, industrial and agricultural-related wastewater flows.

A wide range of economic and social benefits is associated with improved sanitation and wastewater management. In 2008, a study under the Water and Sanitation Program's

Economics of Sanitation Initiative (ESI) estimated that poor sanitation led to an economic impact of Rp56 trillion (US$ 6 billion) annually in Indonesia, or the equivalent of 2.3% of national GDP (Napitupulu and Hutton, 2008). A second phase of the ESI demonstrated in five field sites across Indonesia that sanitation interventions offer good value for money, including for urban solutions with higher unit investment costs (Winara, Hutton et al, 2011). Benefits included health, water, and access time; also in the Phase I study, tourism and fishery impacts were assessed.

This report is a follow-up to the two previous ESI studies, examining in greater detail the environmental impacts of poor sanitation and associated economic benefits of improving sanitation. The report presents an economic assessment of interventions to improve water quality in the upper Citarum River, thereby not only improving the quality of life of the people in the greater Bandung area, but ultimately of all people downstream depending on this important water source, including Jakarta. The economic assessment draws on previous economic studies conducted under the ESI[4], and analyses conducted by the 6 Ci's Project on the level of water pollution, the origin of pollution, and the impact on water quality of possible interventions. An additional objective of this study was to develop and pilot test a specific methodology for valuing a wide range of economic impacts related to water resource pollution in Indonesia.

[4] The Economics of Sanitation Initiative (ESI) was initiated in the East Asia & the Pacific (EAP) region in 2006 to generate and disseminate economic evidence on sanitation. However, in the studies to date, economic benefits of reducing the pollution of water resources have not been fully evaluated in monetary terms due to methodological difficulties in valuing non-market impacts, the paucity of underlying data sets, and the difficulties inherent in attributing observed impacts to poor sanitation.

II. Methodology

The methodology follows six steps, presented in Figure 2.1, and described in the following sections.The water quality model used was the River Basin Simulation Model (RIBASIM), developed by Deltares (Deltares 2009).

2.1 WATER QUALITY IN THE UPPER CITARUM RIVER

Water quality data in the Citarum River were obtained through the *Badan Pengendalian Lingkungan Hidup Daerah* (BPLHD), the Regional Control Agency of the Living Environment, which measures the water quality on a wide variety of parameters at different locations several times per year. Data from 2001-2009 were used for the following parameters: COD (Chemical Oxygen Demand), BOD (Biological Oxygen Demand), Nitrogen components (NH_3, NO_2 and NO_3), Total Phosphate (PO_4-P) and Fecal and Total Coliforms. In addition, DO (Dissolved Oxygen) and COD profiles were obtained from *Pusat Penelitihan Pengembangan Sumber Daya Air*, the research and development center for water resources of the Ministry of Public Works, based in Bandung. The locations that are monitored by BPLHD are presented in Figure 2.2.

FIGURE 2.1: SEQUENCE OF METHODOLOGY APPLIED TO ESTIMATE ECONOMIC BENEFITS AND EFFICIENCY

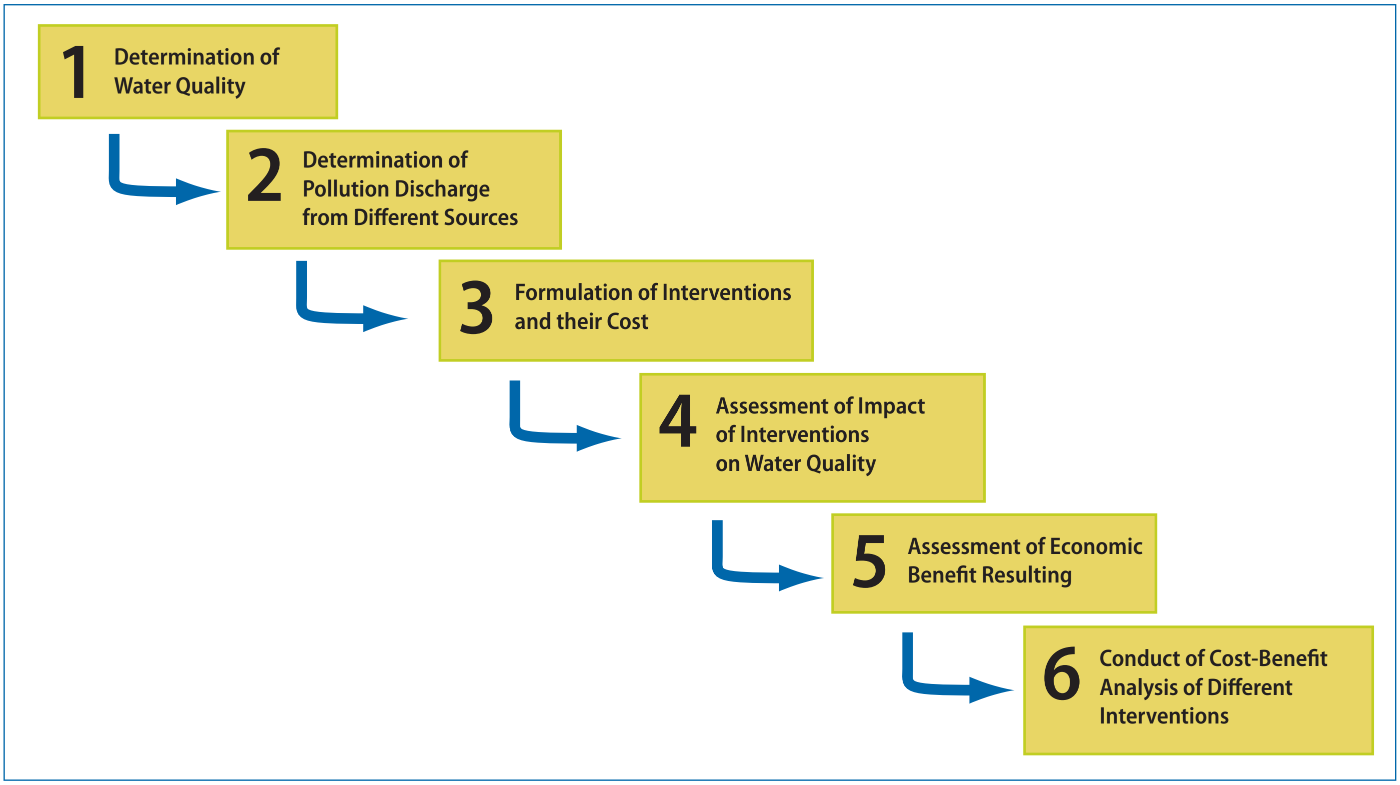
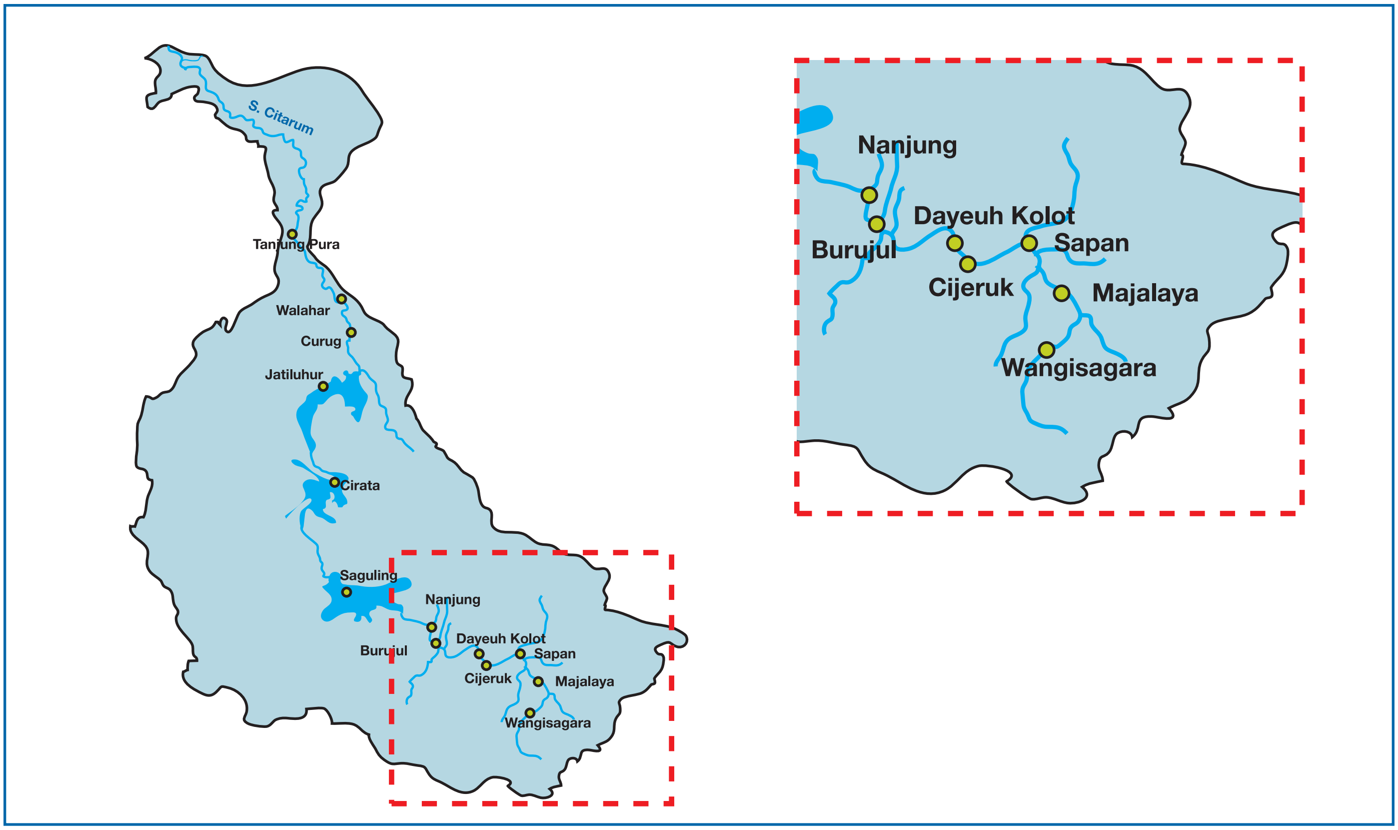


FIGURE 2.2: CITARUM RIVER BASIN AND UPPER CITARUM RIVER BASIN (ENLARGED BOX)



In this study the focal point is the upper Citarum River basin, which is the area draining into Saguling reservoir, but excluding the catchment draining into the Citarum-river downstream of Saguling Dam. Pollution discharges from agricultural, domestic and industrial sources in this area have been assessed, as well as potential investments in this area to reduce the pollution discharges, and the impact of these investments on the water quality of the river stretches in this area. The area covers the cities of Bandung and Cimahi, as well as the districts of Bandung and West Bandung. Most people are living in the cities, while most industries are located in Bandung district.

2.2 POLLUTION DISCHARGE

Wastewater pollution loads were determined from domestic and municipal, industrial and agricultural sources. From domestic and municipal activities, water consumption (and hence discharge) levels were based on guidelines from the Ministry of Public Works, shown in Table 2.1. It is assumed that 80% of intake water is returned to the water system.

For specific pollution loads per person, data from Almy (2008) were used, shown in table 2.2. In the current study, it was assumed that presented data were typical for class 1 (Metropolitan) users. Assuming a similar discharge of pollutants for blackwater (wastewater with fecal contamination from a toilet) per person in areas with different urban statuses, the amount of pollutant discharge via gray water (wastewater from washing and cleaning) was based on the decreasing amount of water used by the defined water consumption categories. In more rural areas, a considerable part of pollutants—assumed to be 60%—will not enter the surface water body because people use pit latrines, plastic bags, or open defecation in fields/forests.

Both water consumption parameters and pollution loads were processed using the 2010 population and expected population development (Scenario C, sustainable growth, and 5% economic growth) in RIBASIM. Data on the population that currently has access to sanitation are based on Napitupulu and Hutton (2008). These data were adjusted depending on specific data availability.

TABLE 2.1: WATER CONSUMPTION PARAMETERS BY TYPE OF URBAN STATUS

Urban status	Description	Unit domestic water demand (liter/capita/day)
Metropolitan	More than 1 million people	190
Large town	500,000–999,999 people	170
Medium town	100,000–499,999 people	150
Small town	20,000–99,999 people	130
Village	3,000–19,999 people	100
Rural	<3,000 people	30

Source: Ministry of Public Works 1989.

TABLE 2.2: POLLUTANTS DISCHARGED TO SURFACE WATER BODIES (GRAMS PER PERSON PER DAY)

Urban status	Parameter				
	COD (g/p/d)	BOD (g/p/d)	TN (g/p/d)	TP (g/p/d)	Total fecal coliform[a] (units/100 mL)
Metropolitan	78.1	39.0	11.7	2.0	1.0E+08
Large town	70.8	35.4	11.1	1.8	1.0E+08
Medium town	60.1	30.0	9.8	1.6	1.0E+08
Small town	50.1	25.0	8.5	1.4	1.0E+08
Village	39.7	19.9	7.3	1.2	1.0E+08
Rural	26.9	13.5	6.0	0.9	1.0E+08

Source: Almy 2008.
Note: TN = total nitrogen; TP = total phosphate; g/p/d = grams per person per day.
[a] No correction factor for fecal coliforms is applied because the presence and impact of these are represented in log scale. Adjustment (like done for the other pollutants) influences the parameter only to a very limited extent.

TABLE 2.3: TYPICAL EFFLUENT CONCENTRATIONS OF INDUSTRIES

Type	Parameter				
	COD (mg/L)	BOD (mg/L)	TN (mg/L)	TP (mg/L)	Total fecal coliforms (units/100 mL)
Food and beverage[a]	5,000	3,000	80	30	0
Paper[b]	4,000	1,500	20	10	0
Pharmaceutical[c]	5,000	1,500	127	25	0
Rubber[c]	7,340	4,400	1,100	220	0
Textile[d]	1,350	450	60	20	0
Others, electronic, and metal[c]	280	168	42	8	0

Note: TN = total nitrogen; TP = total phosphate; mg/L = milligrams per liter; mL - milliliters.
[a] Based on the experience of a consultant for food & beverage (dairy, brewery) in Indonesia.
[b] Based on the experience of a consultant for pulp and paper in the People's Republic of China (20 projects).
[c] BWRP 2000.
[d] Textile industry data were determined based on actual measurements of 21 textile industries in the project area (values from BPLHD) and compared with literature (Ohron et al. 2009).

For industrial activities, the water consumption data of all industries located in the upper Citarum River basin were gathered from the provincial agency for Energy and Mineral Resources (2009) (*Energi dan Sumber Daya Mineral* [Ministry of Energy and Mineral Resources]) for groundwater consumption and from the provincial agency for Water Resources Management (2010) (*Pengelolaan Sumber Daya Air*, under the Ministry of Public Works) for surface water consumption. Industries were categorized based on type of industry and amount of water consumption, and pollution loads were determined by multiplication of effluent flow (for all industries, assumed to be 80% of the demand) and an effluent concentration, shown in table 2.3.

Municipal solid waste accumulating on the Citarum River bank (Photo credit: Aart van Nes)

Agricultural water demand was based on RIBASIM data (2010 and 2030) for technical and nontechnical irrigation. Pollution discharge was based on the Basin Water Resources Planning (2000) study (a component of the Java Irrigation and Water Resources Management Project under World Bank assistance [1995-2004]), shown in table 2.4.

West Java has a considerable number of beef and dairy livestock farms. According to the livestock statistical year book of the ministry of Agriculture about 125,000 dairy cows and 325,000 beef cattle are kept in the whole of West Java. Discussion with representatives of the dairy industry and livestock experts show that typically farmers keep about 2-4 cows per household. Manure is generally collected in stables and dried or composted and applied on the land twice a year as a fertilizer for crop production. Occasionally the manure is collected and digested, producing biogas used for cooking after which the remaining slurry is applied on the land (SNV, 2013). Therefore, in this analysis we have assumed that only run-off of rice and palawija fields, on which collected manure is applied, contributes to pollution discharged to the water bodies.

The impact of municipal solid waste discharged into waterways is from direct water pollution of organic and nutrient loads, blockage of water ways, negative aesthetic impact, and loss of materials that have value, such as organic wastes and plastics. This study ignored the COD, BOD, N, P, and pathogen content of such waste because the water pollution load from municipal solid waste is known to be small compared with that from other sources. However, the required costs to prevent solid waste entering the water bodies, and the associated benefits, are part of the study.

2.3 INTERVENTIONS TO REDUCE POLLUTION

Given the small contribution of agriculture to the overall pollution of water resources[5] and the challenge of finding implementable interventions to reduce pollution, the focus of this study was on interventions to reduce domestic and municipal wastewater, industrial wastewater and solid waste, and interventions to increase the rate of resource recycling.

For domestic and municipal interventions, three types of main system were distinguished, that is, on-site systems, community-based systems, and off-site systems. The features of each of these systems are summarized in table 2.5 and are described in detail elsewhere (Urban Sanitation Development Program 2012). Following the approach developed under the Urban Sanitation Development Project (funded by the Royal Netherlands Embassy), the feasibility for application depends on the combination of residential population density, urban functions as well as groundwater problems.

TABLE 2.4: POLLUTANTS DISCHARGED TO SURFACE WATER BODIES

Crop	Pollutant (g/yield/ha)				
	COD	BOD	TN	TP	Total fecal coliforms
Rice	45	22.5	21.5	6.5	0
Palawija[a]	34	17.0	4.6	0	0

Source: BWRP 2000.
Note: TN = total nitrogen; TP = total phosphate.
[a] Nonrice food crops such as corn (maize) and soy beans.

[5] Overall, agriculture contributes 8% of BOD, 6% of COD, 15% of nitrogen, and 18% of phosphorous (Royal Haskoning DHV 2012).

TABLE 2.5: OVERVIEW AND FEATURES OF APPLICABLE SANITATION OPTIONS IN THE INDONESIAN CONTEXT

Main category	On-site systems	Hybrid: Community-based systems	Off-site systems
Sub-division	- Shared - Individual (Ind.)	- Communal septic tank - IPAL communal - MCK++ with connections	- Medium: decentralized - Centralized
User interface	No running water required	Running water/pour flush toilets preferred	Running (tap) water required
Transport system	No sewer system	Community sewer system	Simplified/sanitary/conventional sewer system
Treatment system	Containment via septic tank	Septic tank/ABR + filter MCK+: digester + ABR + filter	Anaerobic, aerobic or pond systems
Final disposal	Centralized septage treatment system (IPLT)		Sludge treatment at site of WWTP
Sample picture			

Note: MCK = Mandi Cuci Kakus (public bathing, washing and toilet facility); ABR = Anaerobic baffled reactor.

TABLE 2.6: ASSUMED REMOVAL EFFICIENCIES IN WATER TREATMENT SYSTEMS

Removal (percent)	System			
	On-site[a]	Community-based[b]	Off-site 2010[c]	Off-site 2030[d]
COD	30	60	65	85
BOD	40	70	65	90
TN	5	5	80	80
TP	5	5	55	70
Fecal Coliforms	75	95	99.990	99.999

Note: TN = total nitrogen; TP = total phosphate.
[a] Mgana 2003; Tchobanoglous et al. 2004.
[b] Kerstens et al. 2012; Tchobanoglous et al. 2004; Ulrich et al. 2009.
[c] Bojong Soang data (2010).
[d] Author's estimate.

The Urban Sanitation Development Program has developed tools that allow for rapid assessment of required budget and time to install each type of intervention. Figure 2.3 shows the typical prices per person served.[6] The main industries operating along the upper Citarum River include electronics, food & beverage, metal, paper, pharmaceutical, rubber, and textile. To determine the type and costs of industrial wastewater interventions, three types of design for each typical scale were prepared. Designs were based on treating wastewater from (a) textile makers producing batik (with reactive dyes), (b) textile makers producing other types of textile (no reactive dyes), and (c) food & beverage, paper & pulp, and other industries. Note that the design of the wastewater treatment plant (WWTP) treating this type of wastewater is based on the design of a typical dairy industry WWTP.[7]

For each of these types of "uniform" wastewater treatment plant construction, capital expenditure, operational expenditure, and total running costs have been determined based on the quotation of suppliers, contractors, and the author's

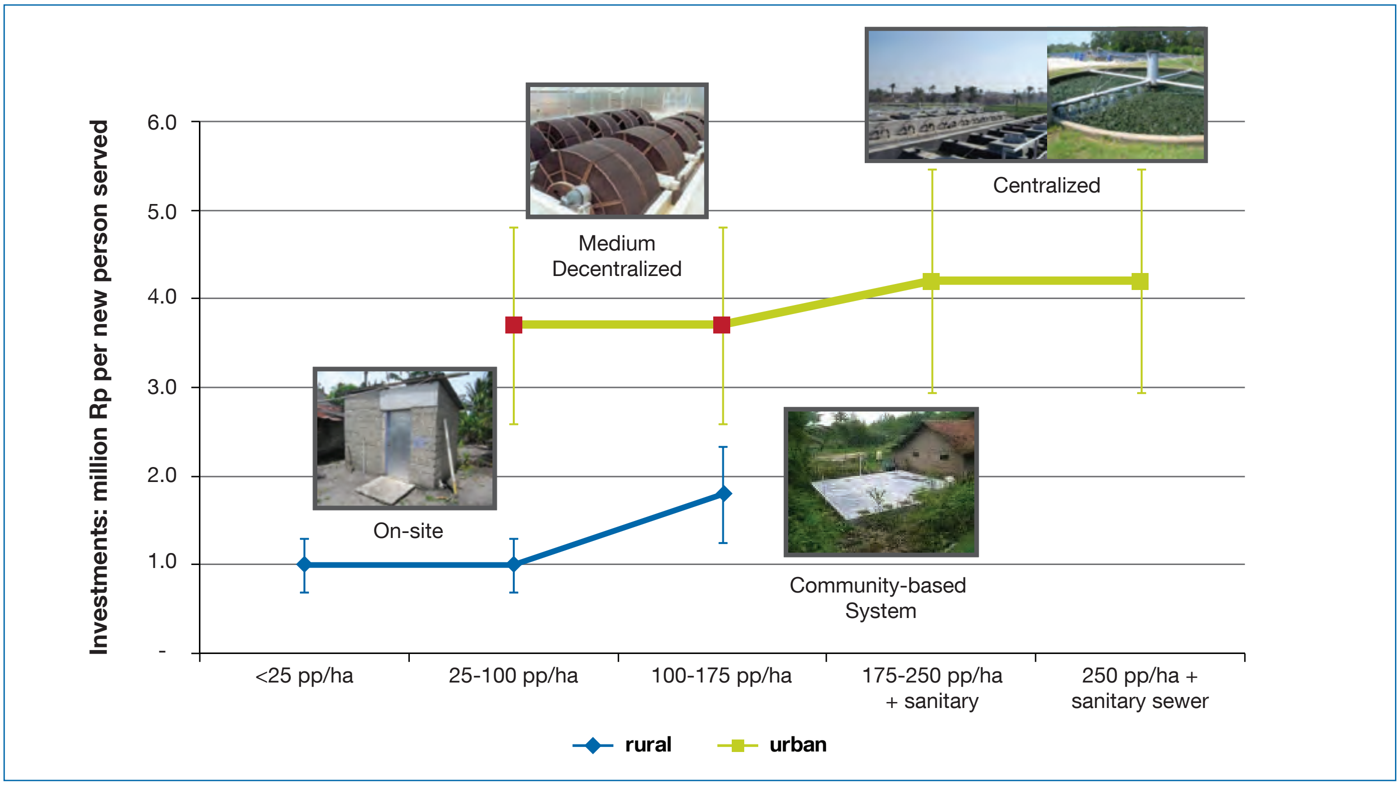
[6] Prices vary for selected types of sewer and treatment systems and land features.
[7] Royal HaskoningDHV has visited several dairy producing industries in Indonesia including Ultra Jaya, Frisian Flag Indonesia and Nestle. The proposed wastewater treatment process flow diagram in the current analysis is based on the typically applied systems by these industries.

estimate. Based on the expected life span of investments, annualized costs are estimated for the year 2030, applying a discount rate of 10%. For cost determination, it is assumed that 70% of the textile industry is typically batik industry (applying system 1) and 30% produces a different type of textile. In addition, it is assumed that 50% of all industries that already have a treatment system need to upgrade their system before 2030. Note that the costs for treatment of chromium (for example, used in leather/tannery industries), phenols (certain types of textile industries), and metals such as fluoride (electronic industries) have not been calculated separately.

In these treatment schemes, the treated effluent is discharged (back) into the surface water. However, the Bandung area is known for its severe subsidence as a result of overabstraction of groundwater, with approximately half of the industries using groundwater. Minimizing groundwater use can reduce land subsidence; however, reliance on surface water will increase only if its quality is improved. In that case, effluent reuse, following a subsequent treatment process, can be considered. "Produced" water is of very high quality, and all water that cannot be reused and is discharged in the system will directly result in improvement of water quality.

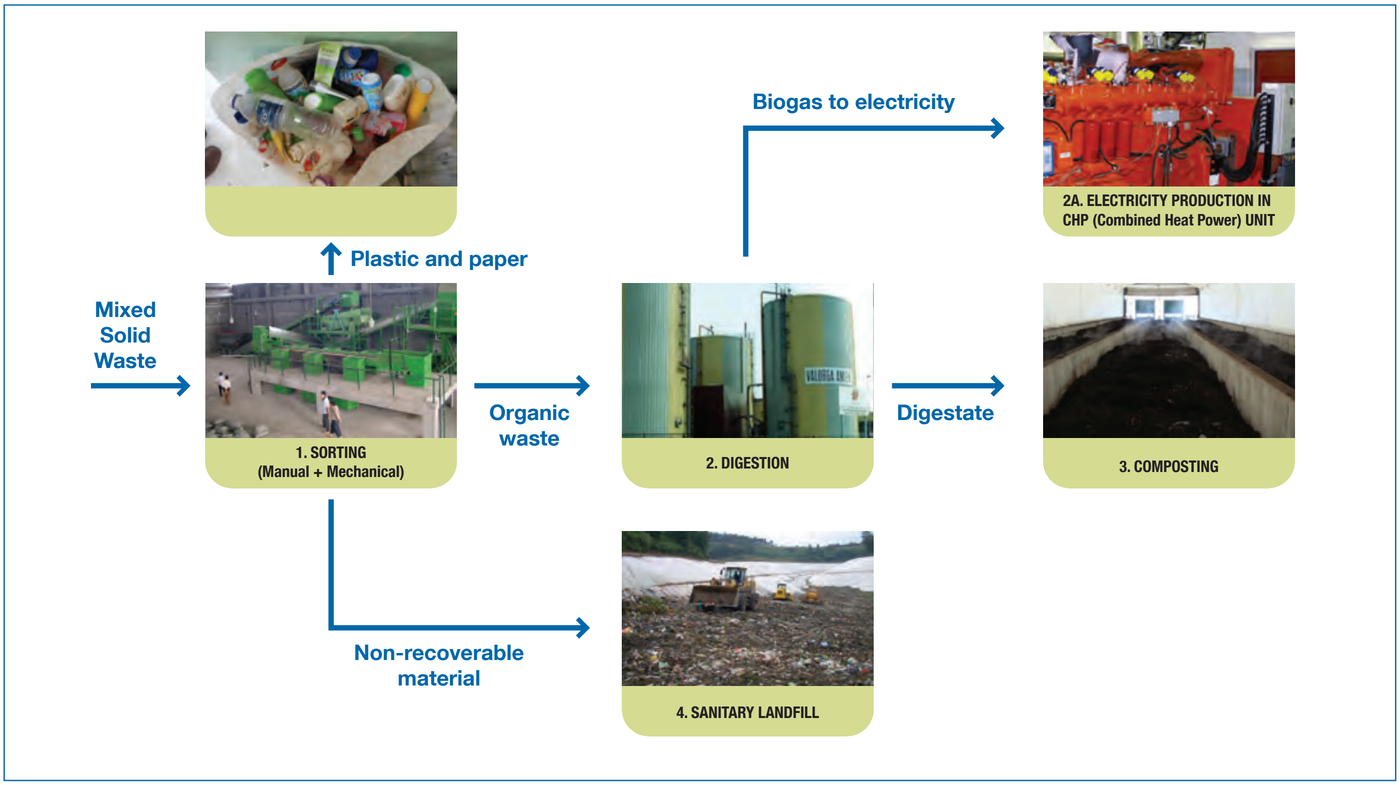
Recycling of municipal solid waste is assumed to be processed at two regional sites for the whole of the upper Citarum River basin, following the 3R principles (reduce, reuse, recycle). At each regional facility, solid waste is first sorted, both manually and mechanically. Plastic, papers, and other recoverable materials are put aside and sold for local market prices. Separated organic waste is first digested, which results in the production of biogas. Biogas contains a high (roughly 65%) methane content that can be converted in a combined heat power unit; the digestate (outgoing mixture) is then composted (possibly with some park and garden waste to add structure), resulting in the production of compost that can be sold. Finally, all matter that cannot be treated biologically or have no direct value are sent to a landfill. Because the major part of organics has been removed, landfill gas treatment and leachate treatment require only limited work. Figure 2.4 illustrates the process.

FIGURE 2.3: TYPICAL COSTS OF WASTEWATER TREATMENT SYSTEMS PER PERSON SERVED, BY URBAN AND RURAL CLASSIFICATION AND POPULATION DENSITY



Key: pp/ha = population per hectare

FIGURE 2.4: SOLID WASTE PROCESSING AND FINAL DISPOSAL



2.4 WATER QUALITY MODELING AND SCENARIOS

RIBASIM was developed for the whole 6 Ci's area. The smallest unit captured in RIBASIM is the water district. A water district is hydrologically defined and is different from an administrative area. It can cover multiple *kelurahan* or *kecamatan*[8] ; moreover, in one *kecamatan*, more than one water district may be present. In this study, nine water districts in the upper Citarum or Bandung catchment were taken into consideration. Figure 2.5 presents the tool that was developed for these water districts. The model is used for simulation of various interventions to analyze the impacts. Pink stars indicate locations with simulations reported on in the current study.

To set priorities, the effect of different interventions needs to be analyzed and compared with each other. For this purpose, six scenarios were developed. Annex 2 provides further detail on these scenarios.

Table 2.7 presents the effluent requirements.

- Scenario 1: Current situation (2010)
- Scenario 2: Reference case for 2030, assuming continuing current trend with no interventions
- Scenario 3: Treat domestic wastewater
- Scenario 4: Treat industrial wastewater, differentiating all industries (4A) or large industries only (4B)
- Scenario 5: Treat domestic and industrial wastewater
- Scenario 6: Treat domestic and industrial wastewater and recycle industrial wastewater.

Table 2.7 presents the requirements for the effluent from individual industries as established by the Environmental Management Board (BPLHD) for 2010 and stricter requirements assumed for 2030, as well as the requirements for the river flows (effluent diluted by river discharges) or Baku Mutu Air (water supply standard; BMA) as specified in general (class II rivers) by the Ministry of Environment in Indonesia.

[8] In Indonesia, a province is composed of cities (*kota*) and regencies (*kabupaten*). These are, in turn, divided in subdistricts (*kecamatan*), which are further divided into administrative villages (*kelurahan* or *desa*).

FIGURE 2.5: RIBASIM AND LOCATIONS WITH SIMULATIONS IN THE UPPER CITARUM

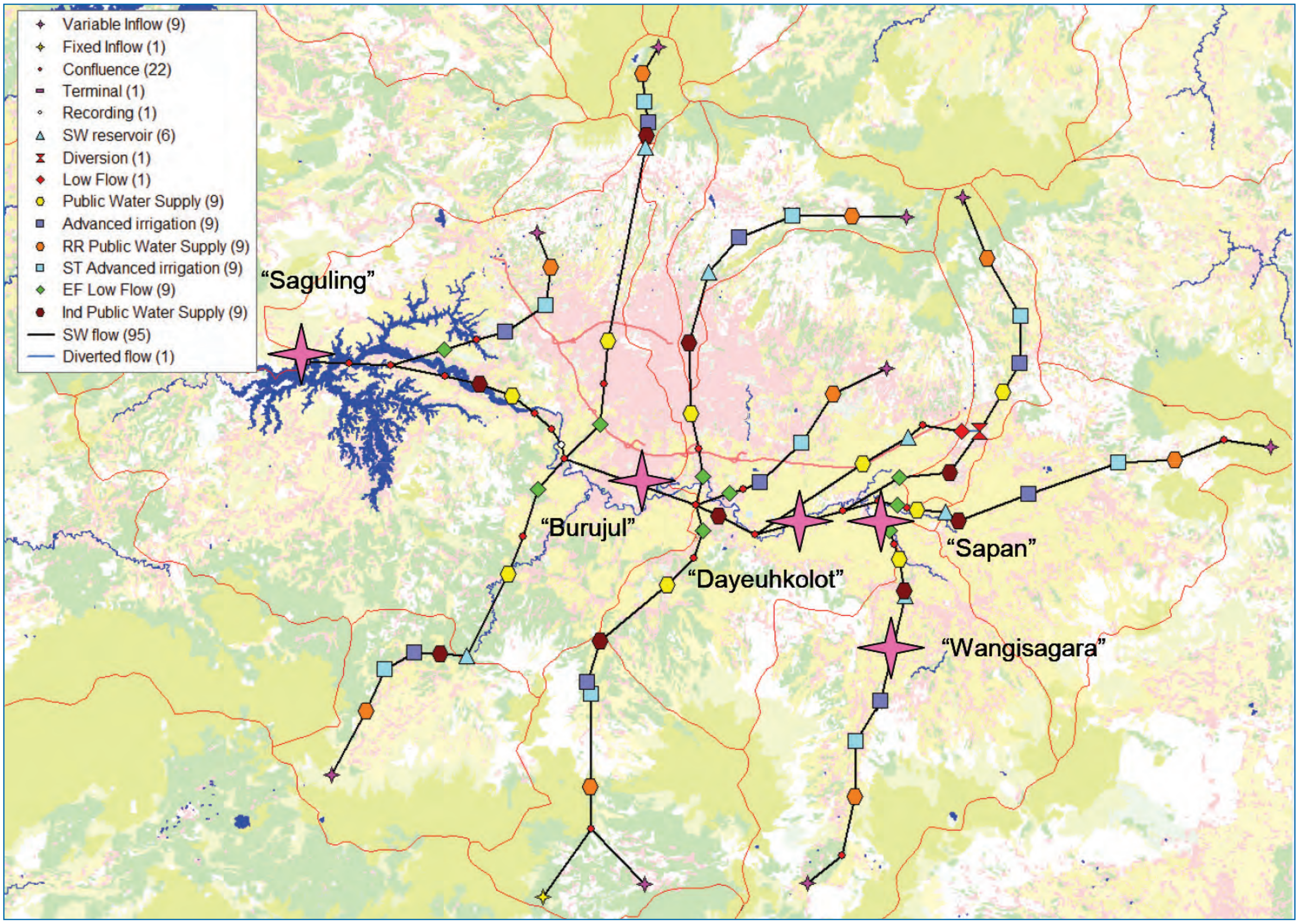


TABLE 2.7: EFFLUENT REQUIREMENT AND CURRENTLY APPLICABLE WATER QUALITY STANDARDS

Parameter	Unit	Effluent requirements			Currently required water quality standard in Citarum River values class II (BMA)[b]
		Domestic	Industrial		
		No. 112 (2003) by Ministry of Environment	BPLHD (2010)[a]	Assumed (2030)	
BOD	mg/L	100	60	20	3
COD	mg/L	-	150	100	25
TSS	mg/L	100	50	50	50
Phosphate	mg/L	-	-	10	0.2
Ammonia	mg/L	-	8	5	-
Total nitrogen	mg/L	-	-	10	-
Sulfide	mg/L	-	0.3	0.3	0.002
Oil and grease	mg/L	10	3	3	1
Phenol	mg/L	-	0.5	0.5	0.001
Chromium	mg/L	-	1.0	1.0	0.05
pH	-	6-9	6-9	6-9	6-9

[a] BPLHD standards refer to the effluent an industrial WWTP has to comply with.
[b] BMA refers to the water quality standards of the receiving water body as per Government Regulation PP 82/2001.

Current legislation for domestic wastewater treatment only requires removal of BOD, TSS, and grease. In comparison with legislation in neighboring countries, the Indonesian requirements are not very stringent. For example, the BOD requirements in the Philippines (No. 35, Series of 1990), Malaysia (PU(A) 398/2000), Viet Nam (TCVN 6772-2000), and the People's Republic of China (GB18918-2002) are 30-80 mg/L, 20-50 mg/L, 30-40 mg/L (levels 1-3), and 10-40 mg/L, respectively. In addition, most of these refer to maximum coliform values in the effluent, whereas no such standard is present in the Indonesian guidelines. The World Health Organization (2006) has defined several standards for reuse in agriculture or aquaculture, which are 103–104 units coliforms/100 mL (depending on the type of application). However, in the water quality standard (Value Class II) of these guidelines, the maximum total and fecal coliform values are, respectively 5,000 and 1,000 units/100 mL. The Indonesian industrial standards are much more stringent than the domestic standards and are comparable with the standards in neighboring countries. In the analysis of this study, removal efficiencies for modeled parameters have been assumed that result in better quality than the domestic requirements (see table 2.6).

Although data on BOD and COD are plentiful,[9] limited data are routinely reported on heavy metals. To fill this gap, Mott MacDonald (2011) conducted surveys, where additional water quality parameters are reported. The study concluded that the heavy metals causing the main potential risks are iron, manganese and nickel. Concerning pesticides, the study concluded that these are not traceable. Another study by DHV in 2011 examined the availability and application of pesticides in the project area (Upper Citarum basin) and concluded these do not pose a serious hazard in this area. Internationally banned pesticides were not found in the shops in the project area. The only pesticide with some hazard is Carbofuran, but it mostly represents a health risk for farmers in the application of the pesticide if personal protection measures are not taken.

With reference to the assumed benefits of treating the wastewater, it is expected that all anticipated benefits regarding access time, water treatment costs, environment, and reuse costs will be achieved if water quality is improved accordingly (see next section). With respect to public health improvements, a major benefit is already expected by moving from unimproved or open defecation to improved sanitation. This will drastically reduce the chance of direct contamination for humans. In addition, note that the modeled fecal coliforms value (1,000 units/100 mL) will not be reached in the upper Citarum River, where values will be approximately 100 times higher. However, it must be noted that in the analysis, the kinetic die-off[10] of pathogens is not included, whereas this is likely to happen as a result of exposure to sunlight. The Indonesian drinking water regulation (no. 492) for 2010 requires the complete removal of all coliforms, which will further limit direct contamination of water obtained from the Upper Citarum River. Please note that the usual practice in Indonesia is to boil the drinking water to remove fecal contamination, which the cost is borne by every household

2.5 BENEFIT ESTIMATION

Following the methodology for cost-benefit assessment developed under the Economics of Sanitation Initiative (Winara et al. 2011), for this study, in the Citarum River basin, the range of impacts of poor river water quality were assessed to decide which were the most important and quantifiable for valuation in monetary terms. Because the aim of this study was to assess the efficiency of sanitation interventions, the study compared the estimated costs with the estimated economic benefits of the sanitation and wastewater management interventions under the six scenarios. The annual equivalent costs and benefits are both estimated for the year 2030, when the interventions have been scaled up and are operating at their planned level. Because it is difficult to estimate benefits separately for municipal and industrial water management, these were assessed as one group in scenario 5 and were then attributed to each subcomponent (scenarios 3 and 4) based on the pollution reduction (biochemical oxygen demand and *Escherichia coli*) arising from each intervention. In scenario 6, the benefits of reusing the various products of wastewater and solid waste were calculated.

[9] As reported by PJT II, the agency responsible for water management of the Jatiluhur reservoir and the Citarum River.

[10] Pathogens die off because of sunlight and heat.

TABLE 2.8: BENEFITS OF IMPROVED SANITATION AND WASTEWATER MANAGEMENT

Benefit	Monetized benefits	Other benefits (described)
Scenario 5		
Health	Averted fecal-oral disease from improved on-site sanitation and wastewater management - Individual (Ind.)	Reduced cases of food poisoning from consumption of fish infected by algal blooms or heavy metal
	Averted health impacts of less exposure during flooding events	
Access time	Value of time savings from reduced travel time and/or queuing for meeting sanitation needs	Increased convenience associated with having a nearby and available toilet
Water	Reduced water treatment costs to households and industries	Increased business investment due to availability of cheap, clean water
	Improved fish yields from farming in downstream lakes	Reduced frequency and costs of flood events due to preventing further land subsidence from excessive groundwater extraction[a]
Environment	Reduced frequency of river and reservoir dredging due to sludge extraction before wastewater release	Improved quality of life for riverside communities
		Conservation: preserved biodiversity
	Rise in land prices due to improved aesthetics of riverside and lakeside real estate	Tourism opportunities due to improved aesthetics of riverside and lakeside locations
Scenario 6		
Reuse	Compost reuse from sludge and organic municipal solid waste	
	Biogas generation from wastewater and organic municipal solid waste	
	Recycling of municipal solid waste (plastics, papers)	
	Effluent reuse for industries	
	Averted maintenance costs of hydroelectric facilities becoming clogged with solid waste	

[a] The assumption is that surface water can be sourced more easily and cheaply for municipal and industrial uses, hence reducing reliance on groundwater.

Table 2.8 shows which benefits were monetized and which were described or quantified but could not be monetized. The estimation methodology is described for each impact. For benefits valued in monetary terms, algorithms were created detailing the physical benefits and their unit value (see Annex 3). An exchange rate of Rp9,440 per United States dollar (US$) was used.

Health. Improved on-site sanitation is a part and precondition of reduced discharge of human excreta to the environment. The health benefits of improved on-site sanitation were estimated based on the number of households expected to gain sanitation access from 2010 until 2030, under a coverage increase from 54-86%.[11] Total health costs include health care costs, health-related losses in productivity (mainly adults), and premature mortality. These costs were estimated by multiplying the average disease reduction of 36% from baseline by the average annual health cost per five-member family from unimproved sanitation of Rp3.16 million (US$334), taken from the ESI study in the nearby Tangerang District (Winara et al. 2011). These costs are made up of health care costs (Rp2.2 million, or US$231), health-related productivity losses (Rp782,000, or US$83), and mortality (Rp182,000, or US$19). Added to the benefits of basic (on-site) sanitation are the incremental benefits of reducing environmental exposure to pathogens through improved waste-

[11] Ninety percent in urban areas and 80% in rural areas.

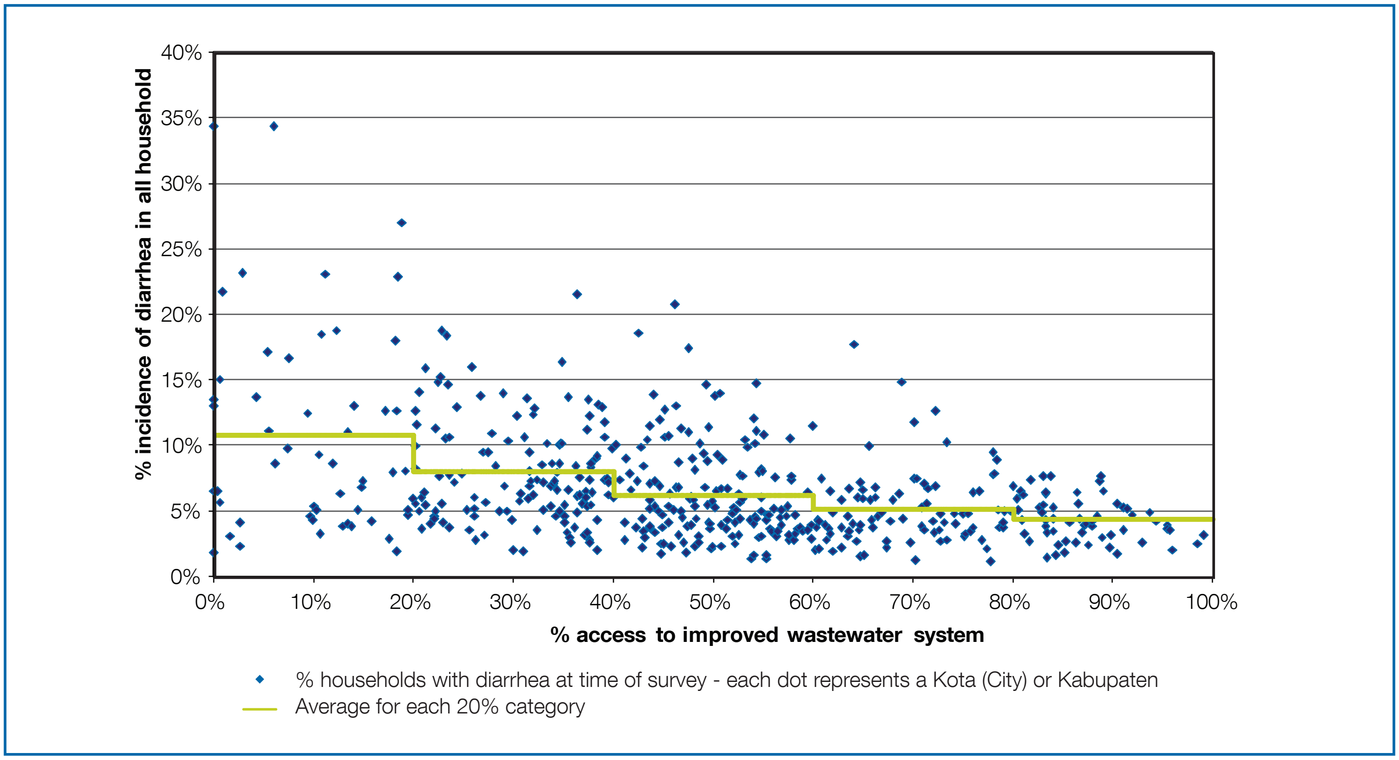
water management,[12] leading to a further disease reduction of 20% age points (that is, total disease reduction of 56%). Target coverage for wastewater management options was 70% of households, from a baseline of 6%.

Figure 2.6 shows a clear decreasing trend of occurrences of diarrhea with improved access to sanitation, demonstrated using SUSENAS data (BPS 2010). The occurrence of diarrhea in cities and districts with less than 20% access to improved sanitation is almost three times higher than those with over 80% of improved access to sanitation.

For communities who suffer flooding and exposure to contaminated water, there will be health benefits of improved river water quality. This is limited to communities that experience flooding. The number of additional health cases was estimated by comparing reported health cases (infectious diseases and skin complaints) during a period of several flooding events (January-March 2009) to the same period in a nonflood year (January-March 2010). This figure was adjusted to reflect an average year of flooding and was scaled to reflect all the flooded communities in the Citarum River basin. This method gave an estimated 15,000 averted cases per year. The economic value was estimated by multiplying the average number of additional cases per year by the unit cost of inpatient and outpatient services, including productivity losses.

Access time. When using a latrine in the home or plot instead of outside, time is saved. ESI in Indonesia showed significant time savings for different household members across five sites, based on over 1,000 interviewed households. In the Tangerang site, which most closely reflects the Bandung area, an average of 115 minutes per household was gained per day,[13] giving an annual value of Rp953,000 (US$101) per household. Only the time of adults and school-aged children was included, valued at 30 and 15% of the hourly rate implied by the GDP per capita, respectively. This figure was applied to the access gain of 32% of households for the period from 2010 until 2030 (54% coverage to 86% coverage of access to own latrine).

FIGURE 2.6: OCCURRENCE OF DIARRHEA AND ACCESS TO SANITATION



Source: BPS 2010.

[12] This includes septage sludge (septic sludge to be regularly removed from septic tanks) management.
[13] This was based on an average of three minutes per trip (journey and waiting time) for off-plot sanitation options in rural areas and eight minutes in urban areas.

Water. Improved river and lake water quality will have a range of benefits for households and the local communities as well as the wider economy. Some effects are indirect but are potentially very significant. One benefit that can be easily quantified is the impact of river water quality on the costs of water treatment for use by households, businesses and industries. Because of the decreasing groundwater levels and the related issue of land subsidence, water supplies will have to increasingly rely on surface water. Currently, the cost of water treatment using surface water sources is Rp1,270 per cubic meter. The unit production costs of using polluted surface water are higher than those of clean surface water. This is the result of less investment and corresponding capital expenditure (for example, fewer treatment steps) as well as lower operational costs (less energy and chemicals required). Hence, under scenario 5, it is estimated that water supply from surface water can be provided with an average production cost of Rp600 per cubic meter, including both capital and operating costs. This saving is multiplied by the estimated annual consumption of water from surface water sources of 207 million cubic meters for municipal consumers and 70 million cubic meters for industrial consumers in the year 2030. Under this scenario, 54% of water is still sourced from groundwater in 2030.

A second impact of improved water quality is that fish stocks and production in rivers and lakes will be increased. Although it is difficult to estimate wild capture because of lack of data, the production information on farmed fish in the Citarum River is more accurate. In recent years, the volume of farmed fish has reduced by 5,000 metric tons per year.[14] This is thought to have two main causes: deterioration of overall water quality flowing into the Saguling reservoir (leading to lower DO levels) and overuse of fish feed,[15] which causes fish kills. This latter impact is ignored in this study because it is outside the control of sanitation interventions. It is conservatively estimated that by 2030, the fish capture could increase by 8,000 metric tons per year, resulting solely from improving the DO levels. The increasing levels of DO from the modeled interventions are assumed to account for one-third in this expected annual gain of farmed fish in the Citarum basin. Current market prices of fish of Rp15,000 per kilo are used. This calculation ignores the contribution of the polluted Citarum River to the water quality in the Jakarta Bay area and reductions in fish catch and impacts on livelihoods (Arifin 2004).

A further linked benefit of improved surface water quality is that, over time, water suppliers will rely less on groundwater sources. In Bandung, as in other locations in Java, there is serious land subsidence in some locations.[16] Residential and other real estate in and around Bandung has subsided by as much as 0.7 meters in the last decade, leading to more common and more severe flooding events, infrastructure damage, and corresponding decrease in land prices. Studies have estimated how much these areas will continue to subside under a business-as-usual scenario. The Master Plan for the Citarum River Territory (DHV et al. 2012) indicates that alternative surface water sources have to be identified to the extent of approximately 10-15 cubic meters per second. Reuse of water from domestic and industrial sources will contribute only 20%, or approximately two to three cubic meters per second, and alternative sources have to be found, such as pumping from the Saguling reservoir or interbasin transfer from the south of Bandung basin. However, realistically, groundwater will continue to be extracted, although it is expected that its rate will reduce over time.[17]

Environment. In future years, a reduction in untreated wastewater release and dumping of fecal and septage sludge into rivers will lead to a slower rate of sedimentation in the Citarum River. Less sediment means that less regular dredging is needed. Sediment from erosion flowing into Saguling is estimated at 1.3 million cubic meters per year (6 Ci's Project). However, untreated municipal wastewater is likely to

[14] Based on interviews and data from the Fisheries Office.

[15] During cooler weather spells, the change in water currents brings to the surface deoxygenated water caused by overuse of fish feed. This, in turn, leads to suffocation of the fish, causing mass fish kills, which are often reported in the local press.

[16] Land subsidence is caused mainly by extracting water from deep aquifers, which are insufficiently replenished in the wet season. This phenomenon is prevalent where many industries, big malls, housing estates, and hotels extract excessive deep groundwater. Outside these areas, the groundwater basin still has potential to provide extra deep groundwater.

[17] This is an assumption, but it is likely as the problem becomes more serious and politicized, and also, with falling groundwater levels, it becomes more expensive to extract.

account for only a small proportion of total sediment, compared with other land-based sources such as run-off from agricultural land and due to deforestation. It is estimated that 10% of sediment is from municipal and industrial sources, or approximately 0.13 million cubic meters per year.[18] With the cost of dredging estimated at Rp37,760 per ton of sediment,[19] the total annual cost averted is estimated.

A second major potential environmental benefit is the impact on the price of riverside land. At present, riverside land is not well developed because of the poor water quality and flood risk. One of the reasons why riverside property cannot be developed and used is that protection is needed for the river from being further polluted. However, pollution occurs because wastewater management and regulation are not practiced. Under scenario 5, it is expected that the riverside would be a place where inhabitants, small businesses, and tourist facilities could be situated. It is expected that the government might allow riverside construction if the reasons for the current rules (risk of water pollution from riverside properties) no longer apply because wastewater management practices have improved. Hence, with significantly improved river water quality, the price of land could increase for both land acquisition and final selling of developed properties. Currently, agricultural land in the vicinity of Bandung averages Rp107,000 per square meter. The current market suggests that land prices can climb to Rp713,000 per square meter in highly desirable locations. This rate refers to land acquisition. There will be further price increases for property that has been developed.[20] Inclusion of the latter margin will fully reflect the eventual benefits of developed land, including use for tourism. Improved river water quality is assumed to account for 50% of the differential of Rp606,000 per square meter between agricultural land value and prime real estate before development. The resulting value increment of Rp303,000 is multiplied by an estimate for the amount of land developed per year after 2030, which is 50 hectares per year, or 500,000 square meters.[21]

These benefits do not fully reflect the impact on the quality of life of residents who come into regular contact with the river, as well as biodiversity. The current state of contamination of the Citarum River has a massive impact on both aspects, but this is difficult to quantify—although attempts have been made (see results section). Additional field research would be necessary to verify this.

Reuse. The costs of wastewater reuse are estimated in scenario 6, and hence, this section describes how the benefits were estimated. There are various potential markets in products of sanitation and wastewater. These include sludge for fertilizer, biogas for energy, and recovered water for productive uses. In addition, by recovering these resources, the costs of safe disposal of the original waste products are averted. Table 2. 9 shows the parameters used.

Two other economic benefits are expected. By reducing the solid waste disposal in water resources, the expensive damage and management of solid waste in hydropower installations are reduced. Furthermore, application of 3R (reduce, reuse, recycle) prevents waste from being deposed in landfills, which results in averted landfill costs and savings, typically around 50% of the land required.

This study conducted a sensitivity analysis to assess the impact of uncertainty in input parameters on the benefit-cost ratios (BCRs). It should be noted that the study assessed only more pessimistic scenarios—to explore whether economic return would fall below the breakeven point (BCR >1). Because of lack of evidence on ranges for the parameters, lower bounds selected were arbitrary, as follows:

- Disease rates and mortality were reduced to half the baseline value.
- Infrastructure remained functioning for 15 years instead of 20 years.
- Value of time gained was zero for all children and 15% of GDP per capita for adults.

18 Estimated using 40 L of sediment per person per year, 10 million people in Bandung basin, of which 50% are not connected to proper sludge processing.

19 The cost of river dredging is Rp18,880 (US$2) per cubic meter. However, the cost of dredging the Saguling reservoir will be much more because it comes from deeper parts; hence, the costs estimated are conservative. The cost of disposal for a distance of 1 kilometer is assumed to double the dredging cost, hence an all-inclusive cost of Rp37,760.

20 Adjusted downward for the investment made by the property developer.

21 Fifty hectares (ha) per year converted to developed land is justified as follows. Currently, the estimated land area within 100 meters of the Citarum river is 2070 ha (excluding tributaries), distributed as follows: water resources (135 ha), housing and Industry (730 ha), cropland (irrigated ricefield and horticulture) (825 ha), and dry land (380 ha). In a seven-year period, 380 ha were converted from cropland to housing and industry, or roughly 50 ha per year. There is still considerable potential in the future for conversion of riverside land currently used as cropland or dry land, as well as land on the banks of the tributaries.

- Water supply costs (per cubic meter) were reduced by half, hence reducing the size of benefit from improving water quality.
- Value of undeveloped real estate was reduced to half the baseline value.
- Value of recycled resources was reduced to half the baseline value.

TABLE 2.9: DATA SOURCES TO ESTIMATE REUSE VALUES IN SCENARIO 6

Resource	Source	Amount produced	Source of value
Compost (from sludge) and organic solid waste	On-site and community-based wastewater options, centralized wastewater options, and organic solid waste management	• Compost production from sludge from on-site and community-based sludge management systems (IPLT) • Wastewater volume x sludge per cubic meter wastewater based on yield for anaerobic centralized options • Compost production from organic solid waste, assuming 60% as organic waste present (Kool 2010)	Compost value based on nutrient content (Rp400/kg)
Biogas	Centralized sewerage plus organic solid waste	Wastewater volume x energy per cubic meter of wastewater, as well as organic solid waste digestion	Energy value (Rp975/KWh)
Recoverable solid waste products	Increased recycling rate of plastic and paper	Amount produced per household per year x number of households x % waste recycled	Current price for recycled plastic and paper (Rp2,000/kg)[a]
Recovered water	Industrial wastewater treated	Water recovery per cubic meter of wastewater x total wastewater produced x percentage of industries practicing wastewater recovery	Cost of groundwater extraction (Rp600/m^3)

Note: x indicates multiplication. IPLT = *Instalasi Pengolahan Lumpur Tinja* (sludge treatment installation).
[a] In September 2012, a mission to Banjarmasin was conducted, which showed the following prices for recovered waste products: plastic bottle = Rp2,400/kg; white plastic bottle = Rp3,400/kg; other plastic bottle = Rp1,800/kg; aqua bottles = Rp4,000/kg; cardboard = Rp1,100/kg; thick paper = Rp500/kg; glass bottle = Rp400/kg.

III. Results

3.1 WATER QUALITY

Water quality deteriorates substantially while passing through the upper Citarum River basin. Figure 3.1 presents the average values for the different locations between 2001 and 2009. In Bandung City, COD, BOD, and E. Coli concentrations are alarmingly high. Indeed, all major parameters require attention and most of the time do not comply with applicable standards. Organic pollutants (COD and BOD) are exceeding the limits typically by a factor of three to ten. These high levels will result in oxygen depletion and anaerobic conditions of the water body, which results in loss of biodiversity, foul smells, and black water. Nutrients (nitrogen and phosphorus) are high, and measures should be taken to reduce these to minimize eutrophication and subsequent algal blooms and mentioned effects such as fish-kills. Coliform values exceed the limit by a large margin.

Figure 3.2 presents the DO (mg/L) and COD (mg/L) values throughout the whole Citarum River basin for 1990, 2000, and 2010 (Yusuf 2011). These cross-tabulations indicate a clear inverse relationship between two parameters. High COD is associated with low DO, and vice versa.

FIGURE 3.1: AVERAGE WATER QUALITY DATA AT INDICATED LOCATIONS (2001–2009)

6. Burujul (2001-2009)

BOD	24.7	mg/l
COD	59.7	mg/l
PO_4 - P	0.7	mg/l - P
$NH_3 + N0_{3,2}$	5.4	mg/l -N
Fec. CF	1.3×10^6	U/100ml

7. Nanjung (2001-2009)

BOD	27.3	mg/l
COD	70.1	mg/l
PO_4 - P	0.8	mg/l - P
$NH_3 + N0_{3,2}$	5.6	mg/l -N
Fec. CF	1.3×10^6	U/100ml

5. Dayeuh Kolot (2001-2009)

BOD	24.2	mg/l
COD	60.2	mg/l
PO_4 - P	0.6	mg/l - P
$NH_3 + N0_{3,2}$	4.6	mg/l -N
Fec. CF	3.5×10^5	U/100ml

4. Cijeruk (2001-2009)

BOD	26.0	mg/l
COD	64.4	mg/l
PO_4 - P	0.5	mg/l - P
$NH_3 + N0_{3,2}$	4.1	mg/l -N
Fec. CF	1.4×10^7	U/100ml

1. Wangisagara (2001-2009)

BOD	2.9	mg/l
COD	10.1	mg/l
PO_4 - P	0.2	mg/l - P
$NH_3 + N0_{3,2}$	0.8	mg/l -N
Fec. CF	5.8×10^5	U/100ml

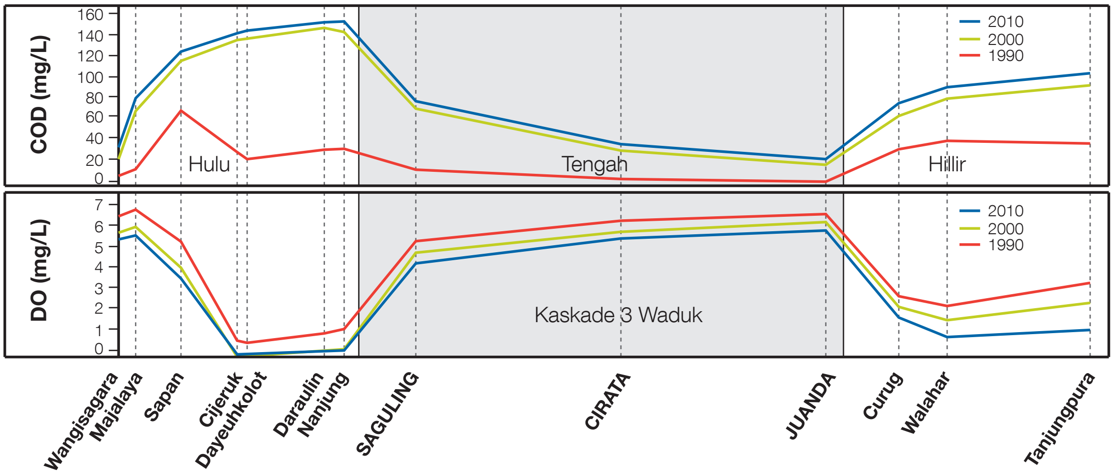
2. Majalaya (2001-2009)

BOD	7.7	mg/l
COD	19.7	mg/l
PO_4 - P	0.3	mg/l - P
$NH_3 + N0_{3,2}$	1.8	mg/l -N
Fec. CF	5.3×10^5	U/100ml

3. Sapan (2001-2009)

BOD	27.8	mg/l
COD	78.8	mg/l
PO_4 - P	0.6	mg/l - P
$NH_3 + N0_{3,2}$	4.2	mg/l -N
Fec. CF	1.5×10^6	U/100ml

FIGURE 3.2: COD AND DO PROFILES IN THE CITARUM RIVER BASIN



Source: Yusuf 2011.

TABLE 3.1: CURRENT WATER DEMAND OF DOMESTIC-MUNICIPAL AND INDUSTRIAL USERS PER WATER SOURCE

User	Source					
	Surface water		Groundwater		Total	
	m³/d	m³/s	m³/d	m³/s	m³/d	m³/s
Domestic-municipal	125,500[a]	1.45	827,100[b]	9.57	952,600	11.0
Industrial	111,300	1.29	101,900[c]	1.18	213,200	2.5
Total	**236,800**	**2.74**	**929,000**	**10.75**	**1,165,800**	**13.5**[d]

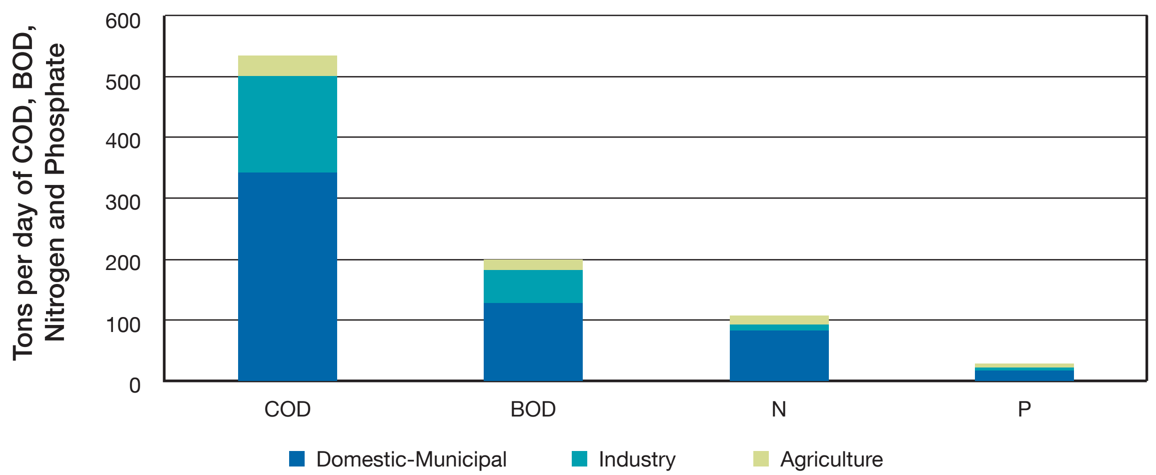
[a] Estimated based on urban water demand of population living in various types of urban area and served by PDAM. The actual water abstraction is about 30% higher as a result of losses in the distribution network.
[b] Estimated based on population not covered by PDAM with water needs of 30 L/capita/d.
[c] It is estimated that this is only a fraction of the actual water extracted by industries. Including illegal water intake by industries, this value might be higher by a factor of three.
[d] Taking the previous two points in consideration, the water extracted from the system amounts to 16.5 m³/s.

3.2 SOURCES OF WATER POLLUTION

The major share of organic pollutants is from domestic-municipal sources, whereas for heavy metals, it is from industrial sources. Table 3.1 shows current water use between domestic-municipal and industrial users, by water source. The data show that the major part of withdrawal for these two users is for domestic-municipal use, at over 80%. There is variation per city or district (not shown). Inside the city of Bandung, for instance, the industrial percentage is far lower than in Cimahi City. The major part of industrial water use, on average, is 84% by textile industries.

Textile industries are known for discharge of a wide variety of pollutants if no sufficient treatment is available. Among others, these are phenols and chromium. Studies refer to chromium levels exceeding the World Health Organization's recommended limit by a factor of three (Mott MacDonald 2012). It should be noted that pollution loads for industries are based on formal water consumptions. It is estimated that illegal water use (from deep wells) may be a factor of three higher than reported values, and consequently, the pollution caused by industries might be higher. In this report, the official values are applied.

FIGURE 3.3: POLLUTANT DISCHARGE PER WATER USE (DOMESTIC-MUNICIPAL, INDUSTRY, AND AGRICULTURE)



3.3 IMPACT OF INTERVENTIONS

If no interventions are implemented (i.e. scenario 2), pollution will increase by approximately 50% from 2010 to 2030. Intervention will reduce pollution, but the impacts will vary by scenario. Reducing domestic and municipal pollution (scenario 3) will have a larger impact than reducing industrial pollution (scenarios 4A and 4B). Interventions in both pollutant sources (scenarios 5 and 6) can bring pollution below the mandatory levels (BMA as shown in table 2.7). Figures 3.4 to 3.7 show the impact of implementing interventions as defined in the different scenarios for discharge of, respectively, COD, BOD, nitrogen, and phosphorus.

The additional pollutant removal from industrial wastewater in scenario 6 is minimal compared with that in scenario 5. However, in scenario 6, approximately 120,000 m^3/d less is extracted from the water source, which corresponds with the total current amount of groundwater extraction. On the total water balance as simulated by RIBASIM, this effect is, again, minimum because in scenarios 1–5, 80% of industrial water use is returned to the water system. Gains are predominantly found in (1) less groundwater abstraction, which results in less subsidence, and (2) more reliable water supply for industries.

The pollution discharge and water demands of domestic-municipal and industrial activities are assumed to be constant over a year, whereas agricultural pollution discharge and water demands depend on the amount of area being irrigated. Variations in concentrations are the result of variation in rainfall, which results in different "dilution" factors of more concentrated waste flows from domestic-municipal and industrial activities. High levels of COD correspond with the dry season, and low levels, with the rainy season.

Based on the calculated water quality in each location and the proposed investment planning, the development of the water quality in Saguling was modeled over the coming 30 years. In this model, the point at 20 years presents scenario 2 (for no intervention scenario), shown in figure 3.8, and scenario 6 for intervention scenario, shown in figure 3.9. It can be seen that without intervention, all concentrations of pollutants will continue to increase to levels as high as 3 times the acceptable levels. If interventions are implemented, the concentrations will initially continue to increase but will eventually drop. After 20 years, the COD concentrations are within the limits as expected and will, based on follow-up actions, continue to decrease. The dashed red line shows the period for which quantified measures (investment as well as operations and maintenance costs) are described in this report.

The results show that implementation of both domestic-municipal and industrial interventions can lead to improvement in water quality in the Citarum River to the required values. It must be noted that in RIBASIM, no biodegradation effects are included. To a large extent, this is valid, because the time in the basin is limited. However, for all parameters, additional reduction is expected, which will result in further improvement in water quality.

FIGURE 3.4: COD DISCHARGE PER SCENARIO

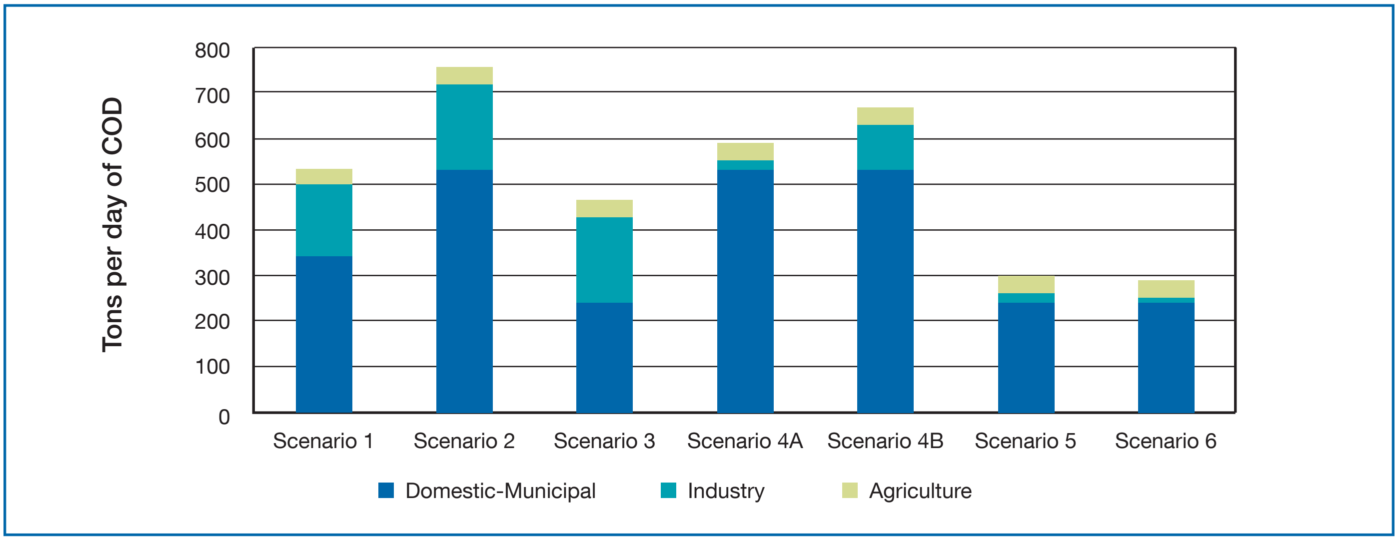


FIGURE 3.5: BOD DISCHARGE PER SCENARIO

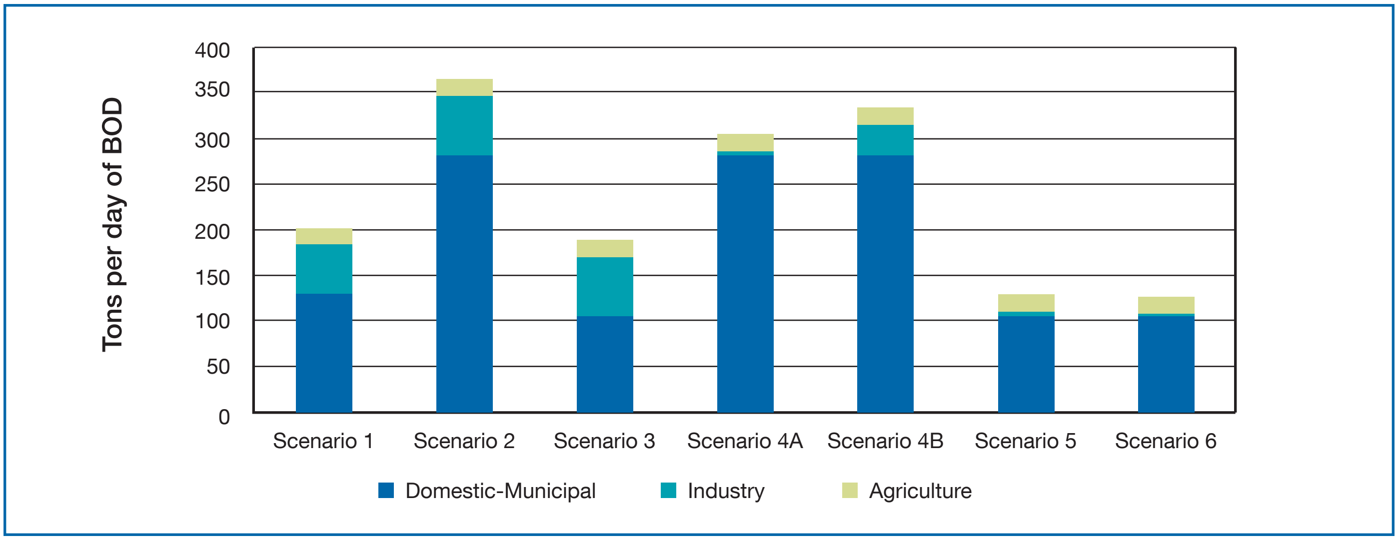


FIGURE 3.6: NITROGEN DISCHARGE PER SCENARIO

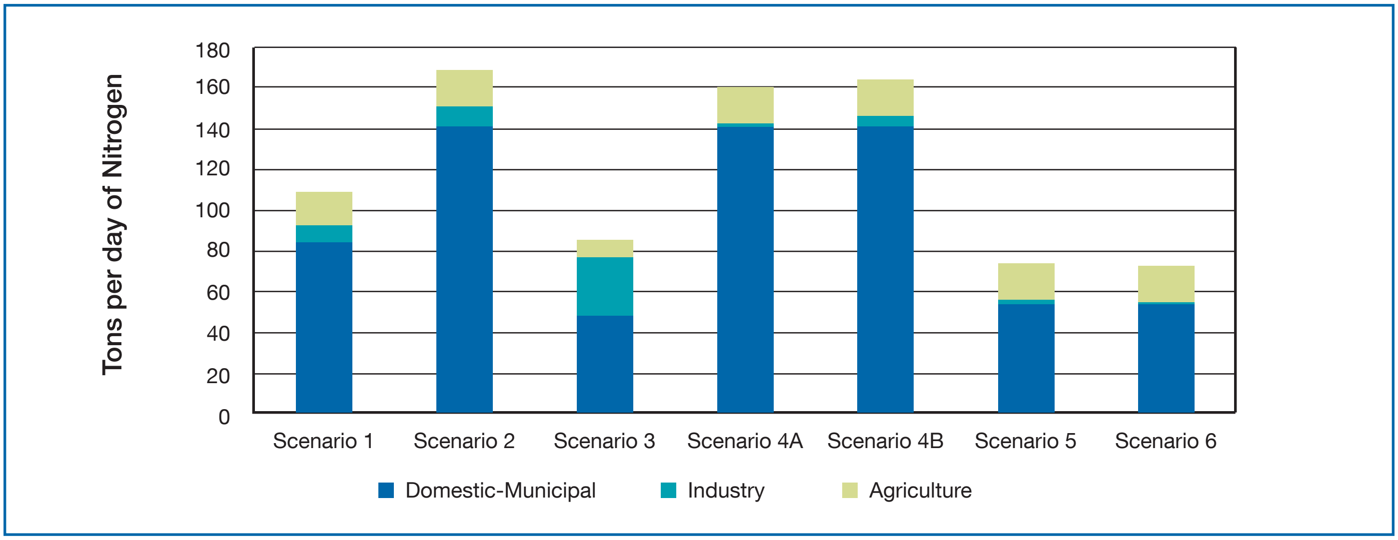


FIGURE 3.7: PHOSPHOROUS DISCHARGE PER SCENARIO

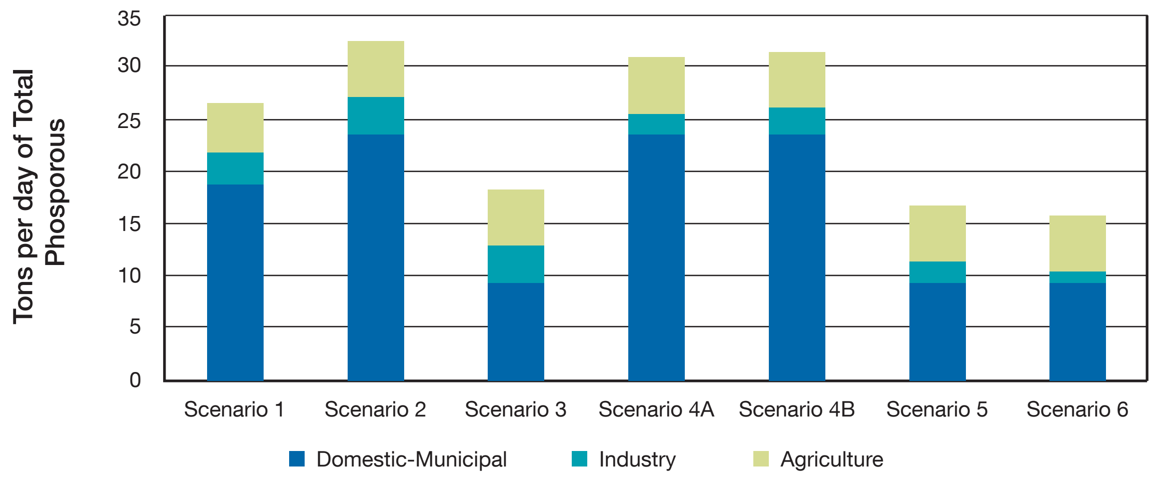
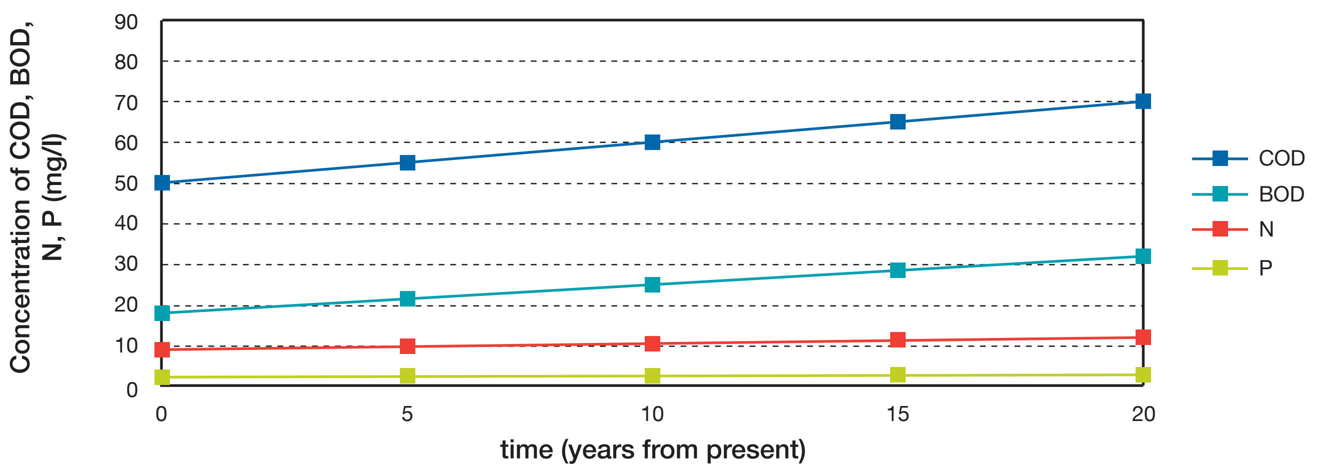
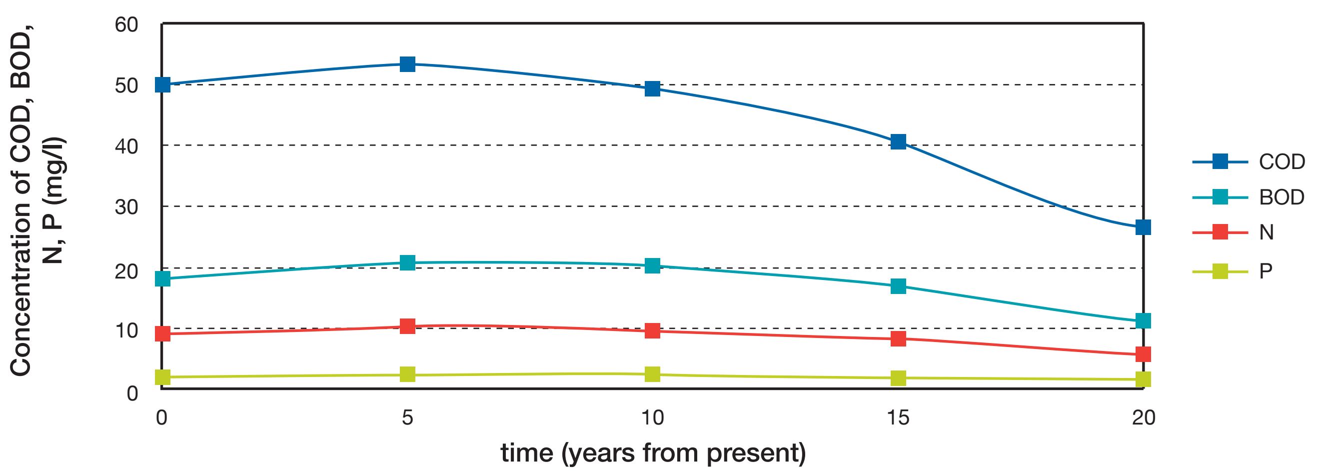


FIGURE 3.8: DEVELOPMENT OF POLLUTANTS AT SAGULING IF NO INTERVENTION TAKES PLACE



Note: Currently required water quality standard in the Citarum River (values class II): COD = 20; BOD = 3; P = 0.2. See table 2.7.

FIGURE 3.9: DEVELOPMENT OF POLLUTANTS AT SAGULING IF INTERVENTIONS ARE IMPLEMENTED



Note: Currently required water quality standard in the Citarum River (values class II): COD = 20; BOD = 3; P = 0.2. See table 2.7.

3.4 COSTS OF INTERVENTIONS

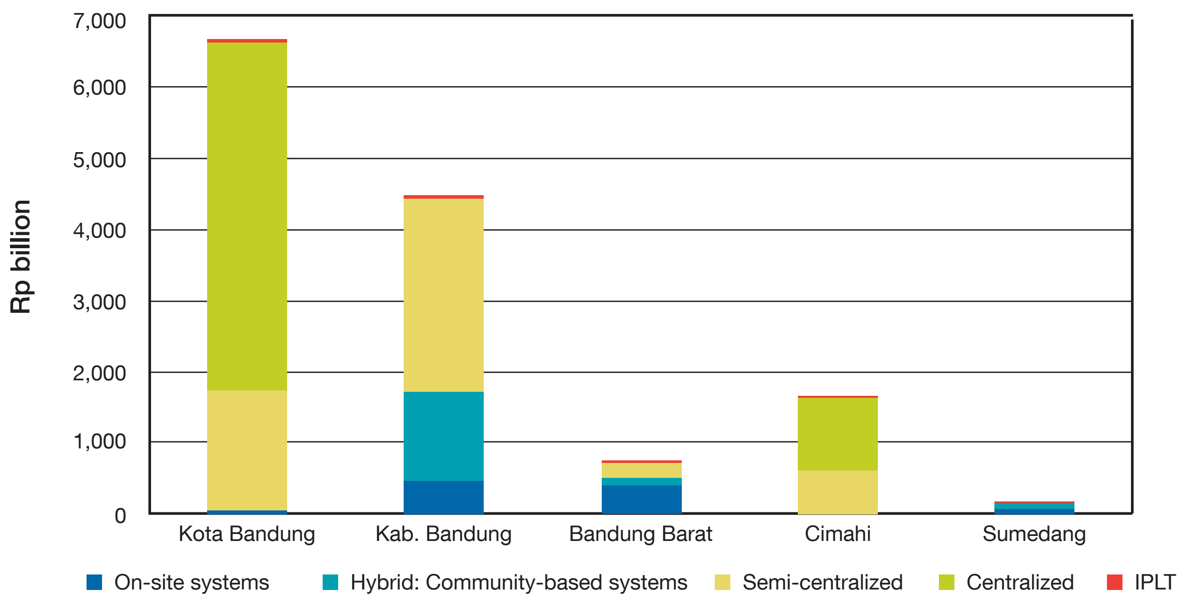
The interventions over a 20-year period require Rp20 trillion[22] (US$2.11 billion). The types of domestic-municipal interventions applied depend on the typical features of the area, with significant variations by district. Figure 3.10 shows how the total required investments over 20 years of approximately Rp14 trillion (US$1.48 billion) per type of wastewater treatment system are divided to reach the stated levels of access and corresponding levels in water quality per city and district.

The expected investments for municipal solid waste infrastructure to prevent disposal of solid waste in the waterways are approximately Rp0.75 trillion. This includes the costs for the collection, transfer, and transport system as well as costs for landfill. Following the policy of the government of Indonesia, in which 3R is promoted, additional measures can be taken that aim to recover biogas and compost (from organic waste), as well as plastics and paper. In that case, investment cost will increase to approximately Rp0.8 trillion. Figure 3.11 shows the development of costs (including operations and maintenance as well as benefits) for the municipal solid waste management with the application of 3R in all residential areas in the upper Citarum River basin.

Figure 3.12 shows the required budget per type of industry and size of district (including the reuse option for larger industries). The total required investment (scenario 4A) is Rp1.1 trillion (US$117 million), but for big industries only (scenario 4B), it is Rp0.47 trillion (US$50 million). In scenario 6, effluent reuse is promoted for big- (80%) and medium-sized (50%) industries, costing Rp1.57 trillion (US$166 million).

Table 3.2 presents the overall costs per city and district and per user over different periods. In this analysis, short-term interventions reflect setting up governmental institutions and constructing "simple" infrastructure (septic tanks, community-based systems, and waste collection systems) and interventions to control pollution caused by big industries, which are considered easier to implement. More complex systems (off-site WWTPs and sewer systems and solid waste treatment and landfill facilities) and introduction of resource recovery systems are assumed to take place in the mid- to long-term.

FIGURE 3.10: INVESTMENTS PER TYPE OF WASTEWATER TREATMENT SYSTEM PER CITY AND DISTRICT



Note: IPLT = Instalasi Pengolahan Lumpur Tinja (sludge treatment installation).

[22] This value represents the discounted costs.

FIGURE 3.11: DEVELOPMENT OF MUNICIPAL SOLID WASTE BUDGET UNDER 3R (REDUCE, REUSE, RECYCLE)

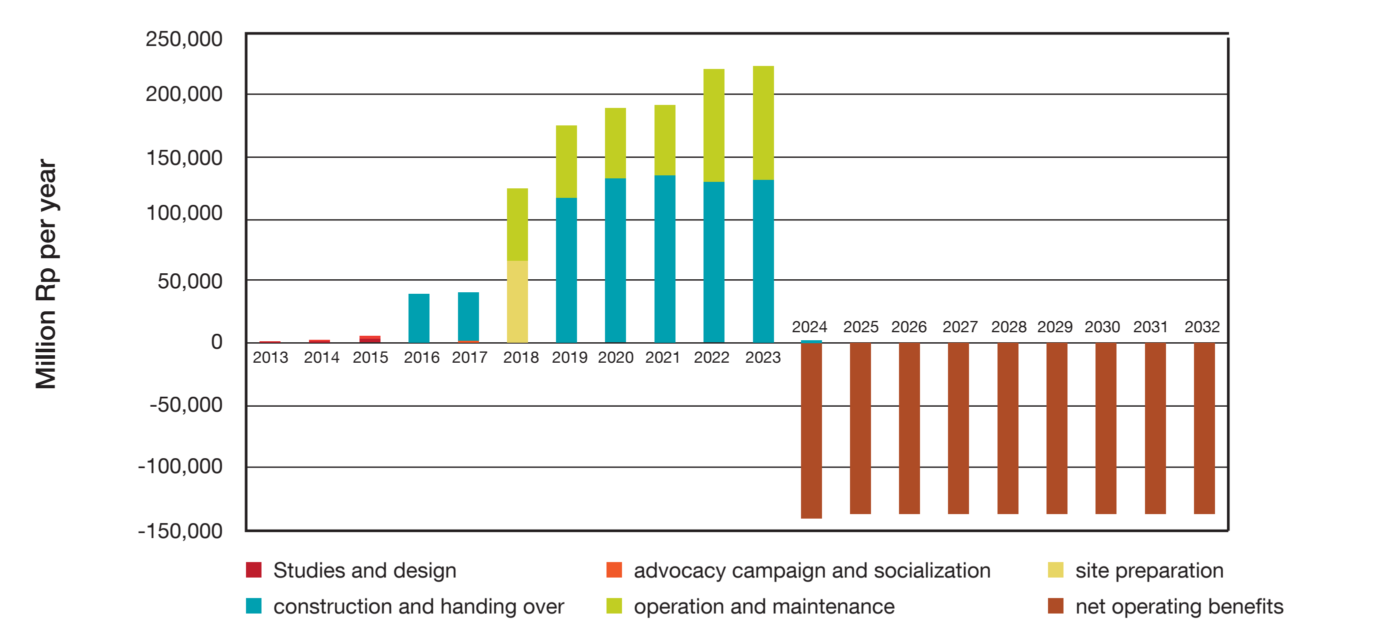
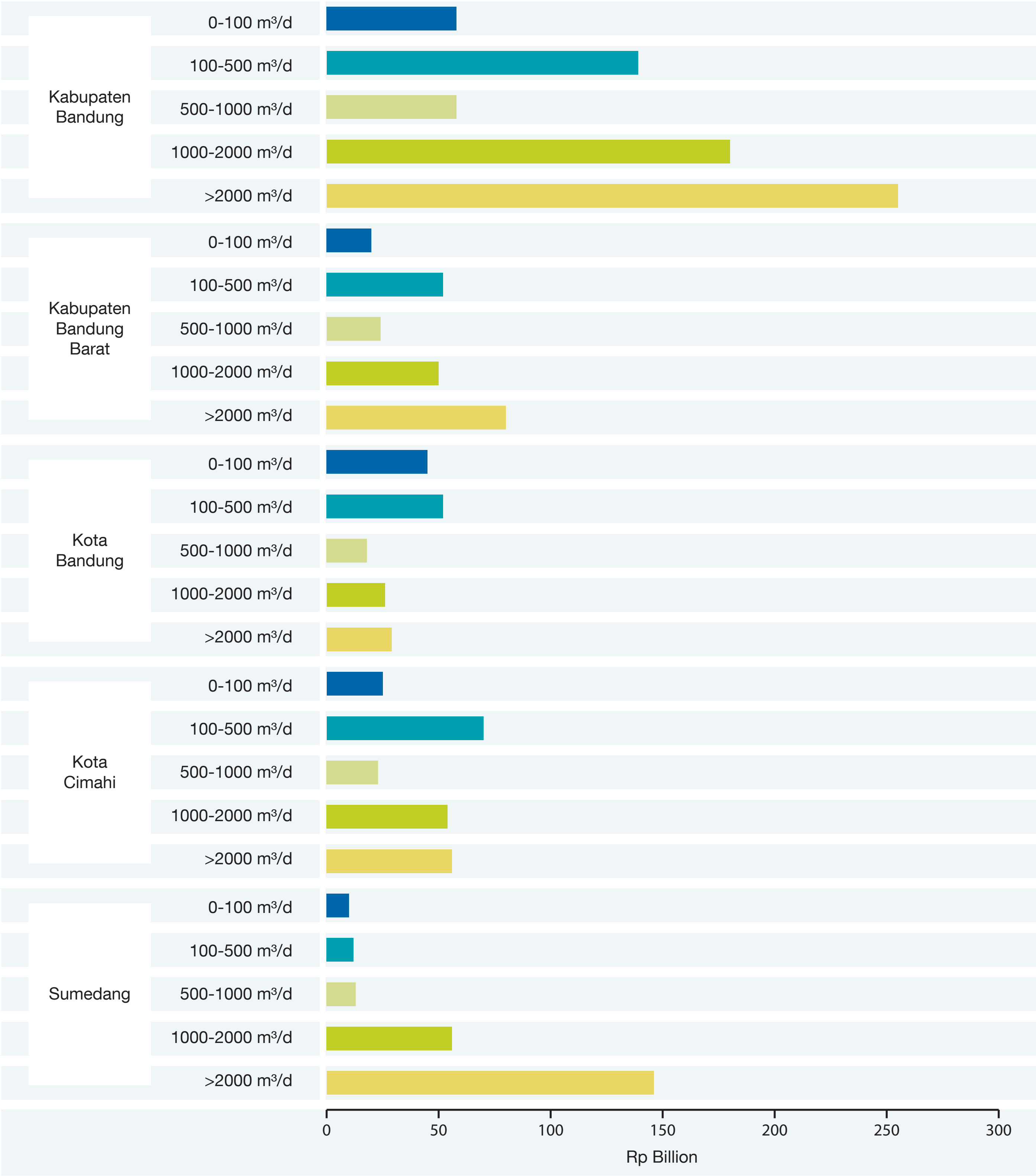


TABLE 3.2: INVESTMENT SCHEME UPPER CITARUM RIVER BASIN

District or city	Sector	Interval (Rp billion)			Grand total (Rp billion)
		Short term	Mid term	Long term	
Bandung District	Domestic MSW	121	158	37	316
	Domestic WWT	1,837	2,348	278	4,463
	Industrial WWT	216	242	215	673
West Bandung District	Domestic MSW	35	40	5	80
	Domestic WWT	391	279	63	732
	Industrial WWT	73	95	62	231
Bandung City	Domestic MSW	112	131	19	262
	Domestic WWT	3,718	2,272	641	6,631
	Industrial WWT	29	114	37	180
Cimahi City	Domestic MSW	25	34	8	67
	Domestic WWT	729	675	233	1,638
	Industrial WWT	54	114	68	236
Sumedang District	Domestic MSW	9	15	6	30
	Domestic WWT	57	67	25	149
	Industrial WWT	122	38	86	246
Total		**7,530**	**6,622**	**1,782**	**15,935**

Note: Rp9,440 = US$1. MSW = municipal solid waste; WWT = wastewater treatment.

FIGURE 3.12: BUDGET REQUIRED PER CONSUMPTION LEVEL AND DISTRICT



3.5 ECONOMIC BENEFITS OF IMPROVED WATER QUALITY

The total quantified economic benefits are estimated at Rp2.6 trillion per year (US$279 million/year). This equates with 0.89% of GDP for the Bandung area at 2011 prices.[23] Forty-five percent of the quantified benefits are from health gains; 21%, from time gains; 19%, from reuse; 9%, from reduced treatment costs; and 6%, from land value increases. Table 3.3 provides the breakdowns.

Table 3.4 shows the attribution of the economic gains to the different intervention breakdowns, and the sections following the table present a more detailed analysis of each of the impacts outlined in table 3.4. The intervention with the greatest economic impact is basic sanitation and treatment of municipal wastewater (scenario 3), attributable to the large volumes of waste and the significant associated health and time benefits. The economic value associated with this intervention is Rp2 trillion (US$214 million). The exclusion of health impacts from scenario 4 partly caused the lower value for treatment of industrial wastewater, whereas, in fact, there may be some health benefits to the population. In addition, the overall gains in scenario 5 are allocated based on the proportion of biochemical oxygen demand. Scenario 6—including the value of resource reuse—adds a further Rp0.5 trillion (US$54 million) to the value of scenario 5.

TABLE 3.3: OVERALL ECONOMIC BENEFITS OF INTERVENTIONS (SCENARIO 6)

Impact	Rp (billion)	US$ (million)	%
Health	1,195	126.6	45
Welfare (access time)	546	57.8	21
Reduced treatment cost	225	23.8	9
Sedimentation	5	0.5	0
Land value	151	16.0	6
Reuse	507	53.7	19
Dam maintenance	1	0.1	0
Total	**2,631**	**278.7**	**100**

Note: Values in 2010 prices, for the year 2030.

TABLE 3.4: OVERALL ANNUAL ECONOMIC BENEFITS, ALLOCATED ACROSS INTERVENTION SCENARIOS

Impact (Rp billion)	Scenario 3	Scenario 4	Scenario 5[a]	Scenario 6	Total[b]
Health	1,195	0	1,195	0	1,195
Welfare (access time)	546	0	546	0	546
Reduced treatment cost	167	59	225	0	225
Sedimentation	3	1	5	0	5
Land value	107	45	151	0	151
Reuse	0	0	0	507	507
Dam maintenance	0	0	0	1	1
Total	**2,018**	**105**	**2,123**	**508**	**2,631**

Note: Values in 2010 prices, for the year 2030.
[a] Scenarios 3 and 4 sum to scenario 5. Scenarios 3 and 4 are estimated from apportioning the combined benefits based on E. coli (for health benefits) and BOD (for water and land benefits).
[b] Total=scenarios 5 and 6.

[23] Using the average Indonesian GDP per capita of US$3,500 in 2011.

The estimated health benefits are largely from reductions in fecal-oral diseases from improvements in both on-site excreta management and off-site wastewater and sewage management (table 3.5). The economic benefit of increasing on-site sanitation access to 80% of the rural population and 90% of urban population is Rp651 billion (US$68.9 million). Improved off-site wastewater management, which has a smaller disease risk reduction but a higher targeted population than the on-site option does, has an economic benefit of Rp543 billion (US$57.4 million). Reduced disease due to irregular flooding events is considerably smaller at Rp3 billion (US$0.3 million).

In addition, there are health impacts that were not quantified in this study. There exists a considerable international literature on the health impacts of consuming fish that are raised in or exposed to polluted water from municipal and industrial discharges (Alabaster 1986), especially the impacts of mercury on pregnant women (NRC 2000; Rasmussen et al. 2005). Other health risks occur when fish are exposed to algal blooms and other heavy metal such as cadmium. However, the health impacts for individuals consuming contaminated fish in the Citarum River basin could not be estimated because of the lack of local data on key variables.[24] It is expected that the socioeconomic costs of a single case can be considerable because of the long-term and debilitating nature of associated diseases. On the other hand, it is expected that the number of cases would be relatively small.

The population groups affected by these health impacts are those without improved sanitation and those who are exposed to river pollution such as fishermen and families who use surface water for domestic water needs. These population groups tend to be poor. The priority groups to target would be those whose current (unimproved) sanitation option leads to the greatest environmental pollution.

Access time for sanitation facilities is a hidden cost and has been little researched. However, for new latrine users, convenience and time savings are among the top five reasons for having a latrine in the home area (Winara et al. 2011). Convenient latrine access is especially important for those household members who spend most of the day at home: for women caring for small children, for people with special needs (sick people, people with a disability), and for evening or nighttime use, especially for girls and women. ESI in Indonesia asked household members how much time they spent accessing off-plot options while at home, whether using shared facilities or practicing open defecation. The results showed that household members (in an average household of five members) in the Tangerang District used as much as 115 minutes per day (Winara et al. 2011). Translated to the population of Bandung, for an additional 32% of the population in 2030 having access to own latrine facility, this would mean an annual gain of Rp546 billion (US$58 million). This estimate is relatively conservative because it excludes travel needs for urination purposes, and time is valued at 30% of the GDP per capita, which, for the working population, is well below the income that would be earned with the time savings. However, given that it is not clear how the time savings would be used, the monetary value reflects more closely economic (welfare) rather than expected financial gains.

Table 3.6 shows the benefits from reduced water treatment cost. A large share of these benefits will accrue to the PDAM and the users of PDAM water, who will pay a lower cost for their piped water supply. Benefits are expected to be Rp139 billion (US$14.7 million) in cost savings to PDAM water users, whereas industries are expected to benefit Rp46 billion (US$4.9 million) annually. The value of farmed fish yields is expected to be in excess of Rp40 billion (US$4.2 million).

TABLE 3.5: ANNUAL HEALTH BENEFITS, DISAGGREGATED BY TYPE

Health impact	Rp (billion)	US$ (million)	%
On-site sanitation	651	68.9	54.4
Off-site wastewater management	542	57.4	45.4
Flooding events	3	0.3	0.2
Total	**1,196**	**126.6**	**100.0**

[24] These include levels of contamination of fish, rates of toxic poisoning and birth defects, associated socioeconomic costs, and the links of the health impacts with actual consumption of contaminated fish.

TABLE 3.6: ANNUAL BENEFITS FROM REDUCED WATER TREATMENT COST, DISAGGREGATED BY TYPE

Water impact	Rp (billion)	US$ (million)	%
Municipal water treatment	139	14.7	61.6
Industrial water treatment	46	4.9	20.6
Farmed fish yields	40	4.2	17.8
Total	**225**	**23.8**	**100.0**

TABLE 3.7: ANNUAL ENVIRONMENTAL BENEFITS DISAGGREGATED BY TYPE

Environmental impact	Rp (billion)	US$ (million)	%
Sediment dredging	5	0.5	3.1
Land value	151	16.0	96.9
Total	**156**	**16.5**	**100.0**

A potential important economic benefit that was not quantified in this study is the reduced land subsidence, which is closely linked to the excessive extraction of groundwater. Furthermore, the benefit from reduced flooding caused by less land subsidence and less sediment in the river might need to be added as well. In the Citarum River basin, flooding is occurring with increasing frequency as land areas bordering the Citarum River are subsiding at faster rates than the river itself. Land subsidence is a direct cause of excessive groundwater extraction by industries, municipality, farmers, and households. There is evidence of land subsidence being significant (seven centimeters per year), and measurements have been made (Deltares and MLD 2011). Currently, it is estimated that 1.1 million people live in a flood-prone area of the Citarum River. An Asian Development Bank (2011) study for Java puts economic damages at US$800 million per year (damage costs to houses and crop impacts) (TA 7364). If allocated to the Citarum River basin using the proportion of population at risk, the study resulted in an estimate of US$90 million flood damages in Citarum. By putting a stop to groundwater extraction, or by replenishing groundwater with treated wastewater, land subsidence would cease. However, groundwater will continue to be used if an alternative is not available. The current levels of river pollution are too high for this to be a realistic alternative. The river water has to be less polluted and better distributed throughout a network, to provide an alternative.

Population groups affected are those living in low-lying areas, who tend to be poor and who lack options to move or adapt. Higher-income groups can afford to modify their houses by raising the floor level or moving to a better location. However, flooding of community areas still occurs frequently.

Table 3.7 shows the environmental benefits that were quantified in this study, with (a) the avoided sediment dredging at Rp5 billion (US$0.5 million) per year and (b) increases in land value based on annual land sales at Rp151 billion (US$16 million).

In addition to these quantified estimates, there are other benefits not estimated in this study. One important benefit is the quality of life of local residents of improved river water quality, which has been shown in international studies to be potentially significant. For example, a study from the People's Republic of China in the 1990s shows the various cited uses of improved river water quality for residents, including the pleasures of walking (54%), relaxing and enjoying the scenery (45%), enjoying while traveling (35%), letting children play in or around the river (21%), swimming (20%), fishing (18%), boating or canoeing (17%), and watching wildlife (11%) (Day and Mourato 1998). A recent World Bank paper reports an economic valuation study conducted in Yunnan, the People's Republic of China, which estimated the total value of a real investment project to improve the water quality of Lake Puzhehei by one grade level (Wang et al. 2011). The study conservatively estimated that, on average, a household located in Qiubei County is willing to pay about CNY30 (US$4.5) per month continuously for five years for water quality improvement, equivalent roughly to 3%

of household income. Another study from India showed that the average willingness to pay to improve the water quality of the Pavana River (Pune City) was estimated at Rs17.6 (US$0.4) per family per month.

Table 3.8 shows the annual economic values associated with reuse options, including compost production from organic solid waste processing and improved sludge management of Rp22 billion (US$2.3 million), biogas production of Rp224 billion (US$23.7), solid waste reuse of Rp236 billion (US$25 million), and industrial wastewater reuse of Rp26 billion. It is also expected that improved solid waste management would avert the current costs of Rp1 billion (US$0.1 million) to evacuate the waste to avoid equipment damage in the hydroelectric facility.

3.6 COST-BENEFIT ASSESSMENT

The cost-benefit assessment compares the annualized costs of the interventions with the annualized benefits of the interventions in the year 2030. Overall, implementing scenarios 5 and 6 together produces a BCR of 2.0. This means that there is an economic return of at least Rp2 for every Rupiah invested. The actual value will be greater than this because several benefits were omitted from the calculations because of data limitations. Scenario 5 has a BCR of 4.9, whereas the incremental BCR of adding scenario 6 is 2.3. When scenario 5 is split into scenarios 3 and 4, it appears that scenario 4 has a lower ratio, at 0.6. However, this is because the main benefit—health gain—has not been included as a quantified benefit of industrial waste management.

If the infrastructure is expected to last for 40 years[25] instead of 20 years, the BCRs increase to 3.4 (for scenarios 5+6). Taken separately, the BCR increases significantly for both scenario 5 (to a BCR of 3.1) and scenario 6 (to a BCR of 5.7) because of the important proportion of capital cost in annualized costs (table 3.9).

Table 3.10 shows the impacts of changes in the input values of key parameters. Only more pessimistic scenarios are explored, to assess how close the BCR comes to the threshold value of one, where net benefits become net costs. For scenarios 3, 5, and 6, none of the changes in assumption result in a BCR of less than 1.44. Hence, the conclusions of interventions being economically viable are not changed when each assumption is examined in turn. The two most critical variables are when the health benefits are reduced by half and when the opportunity cost of time (that is, implicit value of time) is reduced by half for adults and to a value of zero for children. Even when these input values change, the BCR for the overall intervention (scenarios 5 and 6) does not reduce beyond a value of 1.75 from a baseline of 2.25. However, if several input values were simultaneously changed, it is likely that the BCRs would reduce toward one and even cross the threshold. However, this was not explored further because there are no data that indicate the probability of multiple pessimistic values occurring.

TABLE 3.8: ANNUAL RESOURCE REUSE BENEFITS, DISAGGREGATED BY TYPE

Reuse benefits	Rp (billion)	US$ (million)	%
Compost production	22	2.3	4.2
Biogas production	224	23.7	44.1
Solid waste reuse	236	25.0	46.4
Wastewater reuse (industrial)	26	2.7	5.0
Dam maintenance	1	0.1	0.2
Total	**508**	**53.8**	**100.0**

[25] Forty years was selected as an alternative period because sewer systems can last 40 years or considerably longer. This is balanced by probably shorter maximum lengths of life of wastewater treatment plants and landfills of 20 to 40 years.

TABLE 3.9: BENEFIT-COST ESTIMATION

Benefit	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Total (scenarios 5+6)
Total annualized costs	**888**	**172**	**1,060**	**105**	**1,164**
Investment cost[a]	14,111	1,071	15,182	611	15,794
Annualized investment costs (20 years)	706	54	759	31	790
Annual recurrent costs	182	118	300	74	374
Total annual benefits	**2,018**	**105**	**2,123**	**508**	**2,631**
BCR	**2.3**	**0.6**	**2.0**	**4.9**	**2.3**
BCR with 40-year duration of capital stock	3.8	0.7	3.1	5.7	3.4

Note: All values in Rp billion in 2010 prices, for the year 2030.
[a] Total investment costs have been discounted.

TABLE 3.10: RESULTS OF THE SENSITIVITY ANALYSIS

Parameter	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Total (scenarios 5+6)
Baseline	2.27	0.61	2.00	4.86	2.26
Health costs halved[a]	1.60	0.61	1.44	4.86	1.75
Capital stock 15 years[b]	1.80	0.55	1.62	4.43	1.84
Lower bound time value[c]	1.64	0.61	1.47	4.86	1.78
Water supply costs reduced by half	2.19	0.47	1.92	4.86	2.18
Undeveloped real estate valued at half baseline	2.19	0.44	1.91	4.86	2.17
Recycled resources value reduced by half	2.27	0.61	2.00	2.56	2.05

[a] Disease rates and mortality were reduced to half the baseline value.
[b] Infrastructure remained functioning for 15 years instead of 20 years.
[c] Value of time gained was zero for all children and 15% of GDP per capita for adults.

IV. Conclusion

Water quality in most locations in the upper Citarum River basin is poor, and pollution levels far exceed the maximum allowable levels. Water quality has been deteriorating in the past 20 years and is likely to continue to do so if no considerable effort is made to reverse it. Furthermore, there is a clear deterioration in water quality on all parameters going from upstream areas to downstream areas. Domestic-municipal activities produce at least two-thirds of pollution, followed by industrial and agricultural-irrigation activities.

Improving the water quality in the upper Citarum River basin (and with that of downstream areas as well) to levels in line with the standard values class II (BMA) is possible but requires interventions in both domestic-municipal and industrial sectors. Focusing on one of these segments alone will most probably not result in reaching the desired quality improvements. Corresponding costs for domestic-municipal and industrial wastewater interventions are approximately Rp14 trillion and Rp1.6 trillion, respectively, over a period of 20 years. Further, an approximate investment of Rp0.8 trillion for municipal solid waste infrastructure is expected.

This study shows that there is a wide range of benefits associated with cleaning up the Citarum River. These benefits are significant compared with the intervention costs, giving very favorable BCRs. Benefit-cost ratios exceeding two means that the benefits of implementing sanitation facilities outweigh the total costs by more than a factor of two. Most economic benefits are gained because of improving public health. Resource reuse is an important component in making the river cleanup economically attractive. The range of economic beneficiaries suggests that sufficient financing can be obtained for the river cleanup program. However, given the large investment costs, government and external partners play an important role in advocating for proposed interventions and providing support for upfront financing needs. Involvement of private sector to facilitate resource recovery should be promoted.

Initial interventions should be based on what is achievable and realistic in the short and medium terms. Preparation of city sanitation strategies is key for making budgets available for wastewater and municipal solid waste budgets. For industrial interventions, the focus should be on the bigger industries to start with, after which the smaller industries should be addressed.

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