Brigham Young University
BYU ScholarsArchive

Theses and Dissertations

2019-06-01

Management of Global Reservoir Sedimentation: Evaluating RESCON 2 for Sediment Management Alternatives

Christopher Jacob Garcia
Brigham Young University

Follow this and additional works at: https://scholarsarchive.byu.edu/etd

BYU ScholarsArchive Citation

Garcia, Christopher Jacob, "Management of Global Reservoir Sedimentation: Evaluating RESCON 2 for Sediment Management Alternatives" (2019). *Theses and Dissertations*. 7505.
https://scholarsarchive.byu.edu/etd/7505

This Thesis is brought to you for free and open access by BYU ScholarsArchive. It has been accepted for inclusion in Theses and Dissertations by an authorized administrator of BYU ScholarsArchive. For more information, please contact scholarsarchive@byu.edu, ellen_amatangelo@byu.edu.

www.manaraa.com

Management of Global Reservoir Sedimentation: Evaluating RESCON 2 for Sediment Management Alternatives

Christopher Jacob Garcia

A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Science

Rollin H. Hotchkiss, Chair
Daniel P. Ames
E. James Nelson

Department of Civil and Environmental Engineering

Brigham Young University

Copyright © 2019 Christopher Jacob Garcia

All Rights Reserved

للاستشارات المنارة

www.manaraa.com

ABSTRACT

Management of Global Reservoir Sedimentation: Evaluating RESCON 2 for Sediment Management Alternatives

Christopher Jacob Garcia
Department of Civil and Environmental Engineering, BYU
Master of Science

Reservoir sedimentation occurs as dams impound streams and rivers, preventing the delivery of sediments downstream. Globally, reservoirs lose approximately 40 million acre-ft of storage to sediments each year. Several methods for managing reservoir sedimentation have been developed to help extend project life. In 2017, the World Bank sponsored RESservoir CONservation (RESCON) 2, a pre-feasibility program aimed to help users select sediment management practices to consider for more detailed studies.

There are two main objectives to this research: 1) perform a sensitivity analysis to understand which parameters require greater precision and which can be roughly approximated, and 2) evaluate RESCON 2 suggested practices to assess the model's accuracy and consistency for providing the optimal solution. Comparisons of the actual sediment management practice will be made with RESCON's results and applicable zones from the Sediment Management Options Diagram (SMOD). Brief descriptions of the SMOD and RESCON 2 will be provided. RESCON-required inputs will be summarized, and some key entries will be presented. Additionally, innovations taken in Japan to modify and retrofit exiting reservoirs with sediment management capabilities will be explored.

The sensitivity analysis proves the unit benefit of reservoir yield parameter to be highly sensitive, and users should invest time into determining this value. The sensitivity analysis also illustrates certain processes in RESCON, such as automatically determining the implementation schedule of flushing or a sustainable solution for dredging operations, have great influence over the respective method's analysis. Approximations can be used if these options were selected.

Twenty reservoirs from around the world were modeled in RESCON 2, with storage capacities ranging between 152 acre-ft and 31.9 million acre-ft. All sediment management alternatives whose NPV lied within 30% of the highest alternative were deemed practicable for the reservoir. Of the twenty models analyzed in RESCON 2, ten did not practice sediment management. Analyzing only those reservoirs where sediment management is being employed, RESCON predicted the correct or used practice eight out of ten times.

Recommendations to improve RESCON include 1) an HSRS operations and maintenance parameter, 2) expanding the unit benefit of reservoir yield parameter into several terms to more explicitly state applicable revenue sources, and 3) creating a list of RESCON model builds, updates, and bug treatments and an option for users to report bugs or other problems.

Keywords: reservoir sedimentation, sediment management, RESCON, reservoir conservation

www.manaraa.com

ACKNOWLEDGEMENTS

I would like to first thank my mentor, Dr. Rollin Hotchkiss, for his invaluable feedback and guidance throughout my research; for providing me opportunities to travel abroad and experience firsthand the brilliance of our colleagues and their work; and for exemplifying professionalism as both a teacher and friend.

As part of my graduate committee, I would like to thank Dr. Dan Ames and Dr. Jim Nelson for their feedback and critique. Additionally, I would like to thank them for their years of help and assistance throughout my undergraduate and graduate experience at BYU.

I would also like to thank George Annandale, Paul Boyd, and Nikolaos Efthymiou for providing information to help me better understand, execute, and analyze RESCON, and Razieh Anari for helping me run sensitivity analyses on RESCON.

Lastly, I would like to thank my wife, Missy, and our family members and friends. Whether cooking and providing me meals, staying overnight with me at the hospital, or helping me relax with games and other fun activities, their time and love has helped me beyond expression. Thank you!

المنارة للاستشارات

www.manaraa.com

TABLE OF CONTENTS

المنارة للاستشارات

www.manaraa.com

المنارة للاستشارات
www.manaraa.com

www.manaraa.com

LIST OF TABLES

للاستشارات

www.manaraa.com

LIST OF FIGURES

www.manaraa.com

1 INTRODUCTION

Reservoir sedimentation is the process by which reservoirs lose their storage capacity to sediments over time, and occurs as dams impound streams and rivers, changing the natural flow regime and preventing sediment delivery downstream. The worldwide annual storage loss due to sedimentation is between 0.5- and 1%, accounting for some 40 million acre-ft (50 km3) (Mahmood 1987; Basson 2009). This problem is compounded by the fact that the "worldwide annual loss of storage to sedimentation is higher than the increase of capacity by construction of new reservoirs." In order to preserve and restore storage capacity, both for existing and future reservoirs, "mitigation measures are urgently needed" (Schleiss et al. 2016).

When reservoir sedimentation was beginning to receive attention, few methods for managing inflowing sediments existed. In the 1930s, engineer and consultant J.C. Stevens urged people to conduct an "intensive study and an intelligent research that will ultimately effect a practical solution" (Nordin 1991). Later, in the 1970s, the ASCE Sedimentation Engineering manual stated, "In an age that has progressed from the first automobile to a landing on the moon in much less than a 100-year span, it is possible that in time either the reservoirs of today will no longer be needed or that more effective methods of retaining their capacity will be developed" (Vanoni 1975). Since Stevens' time and that landmark statement from the ASCE, several sediment management alternatives have been developed, and more effective means will

www.manaraa.com

eventually surface. Consequently, over time, the dilemma has shifted from how to manage sediments to which method to choose.

In response to the need to actively manage sediments in reservoirs, and with the advance of technology and a greater understanding of sedimentation characteristics, in 2017 the World Bank sponsored REServoir CONservation (RESCON) 2, an Excel-based program currently in its beta development stages but expected to be finished over the next two years (Efthymiou, personal communication, 2019). RESCON can analyze up to nine alternatives and attempts to help users and analysts select practices to consider for more detailed studies. Upon inputting required information into and running the program, a pre-feasibility analysis is provided comparing the nine alternatives side-by-side. This analysis identifies practicable solutions for the reservoir, whether each method is sustainable or non-sustainable, its net present value, and the long-term reservoir storage capacity and reservoir lifetime. There are two main objectives for this research: 1) perform a sensitivity analysis on RESCON 2 input parameters to determine which variables need more accurate data and which can be roughly approximated; and 2) evaluate RESCON 2 suggested alternatives to assess the model's accuracy and consistency for providing the optimal solution.

www.manaraa.com

2 RESERVOIR SEDIMENTATION

Reservoir sedimentation occurs in every reservoir, but the fill rate varies significantly depending on its geographic region. Figure 2-1 illustrates the global pattern of suspended sediment yield in tonnes/km^2/year. Locations receiving the highest sediment delivery are the western Americas, southeast Africa, southern Europe, and southeast Asia. Ironically, these erosion-prone regions correlate with locations having high dam density. Figure 2-2 shows the number of dams per million sq. km on the basis of the GRanD database. Dams are defined as having more than 0.1 km^3 storage capacity, however, smaller reservoirs were included if data were available (Lehner et al. 2011). Figure 2-3 transposes Figure 2-1 on top of Figure 2-2 to demonstrate the relationship between sediment yield and dam density. The fact that many of the world’s reservoirs lie within these areas is one reason why storage loss and storage preservation is a topic of increased focus and concern.

2.1 Local Impacts of Dams

All rivers carry sediment from upstream to downstream and ultimately into either lakes or oceans. When a dam is constructed, it alters the natural flow regime of the river and prevents the delivery of sediments to the downstream river. A list of repercussions resulting from dam construction are presented in Table 2-1, both up- and downstream of the reservoir, as well as within. Impacts are distinguished by primary, secondary, and tertiary impacts. Other sediment-

www.manaraa.com

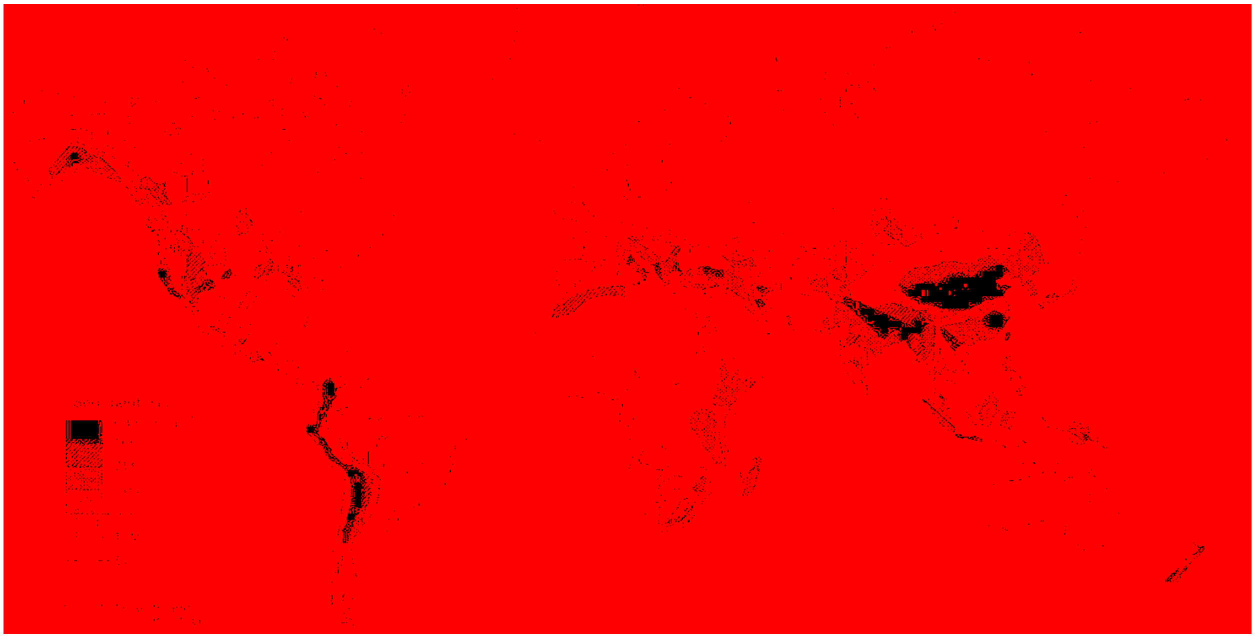

Figure 2-1: Global pattern of suspended sediment yield (Walling and Webb 1983)

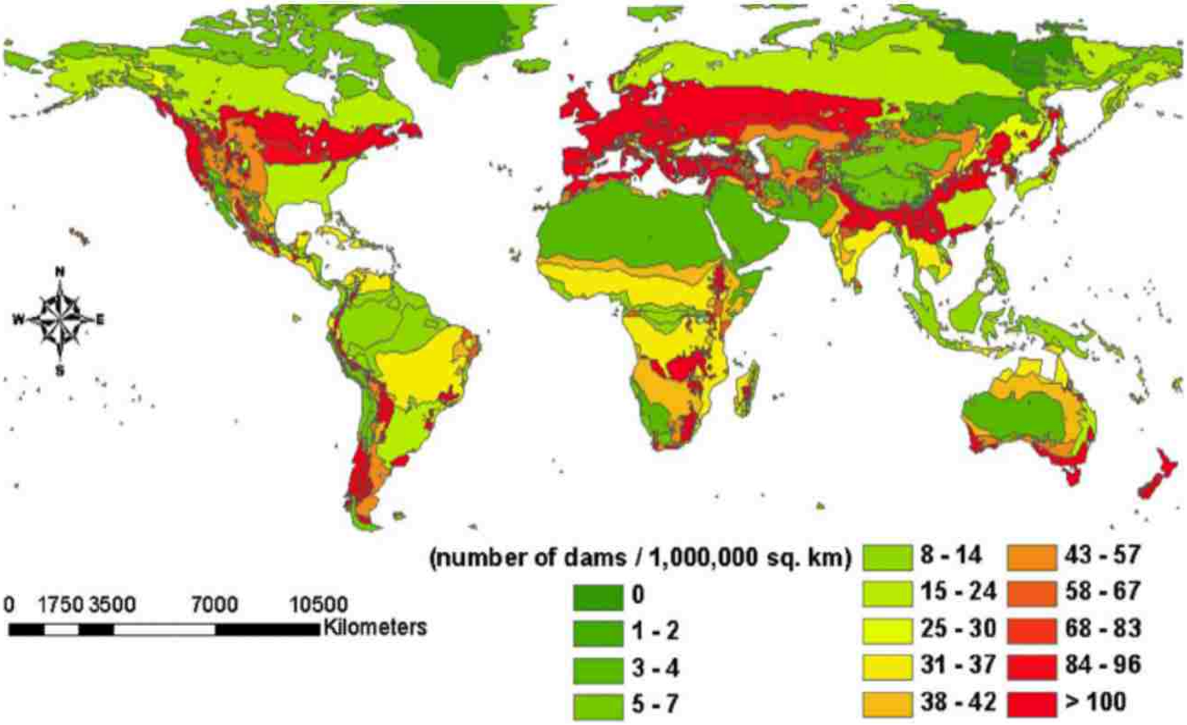

Figure 2-2: Dam density (Hossain et al. 2012)

المنارة للاستشارات
www.manaraa.com

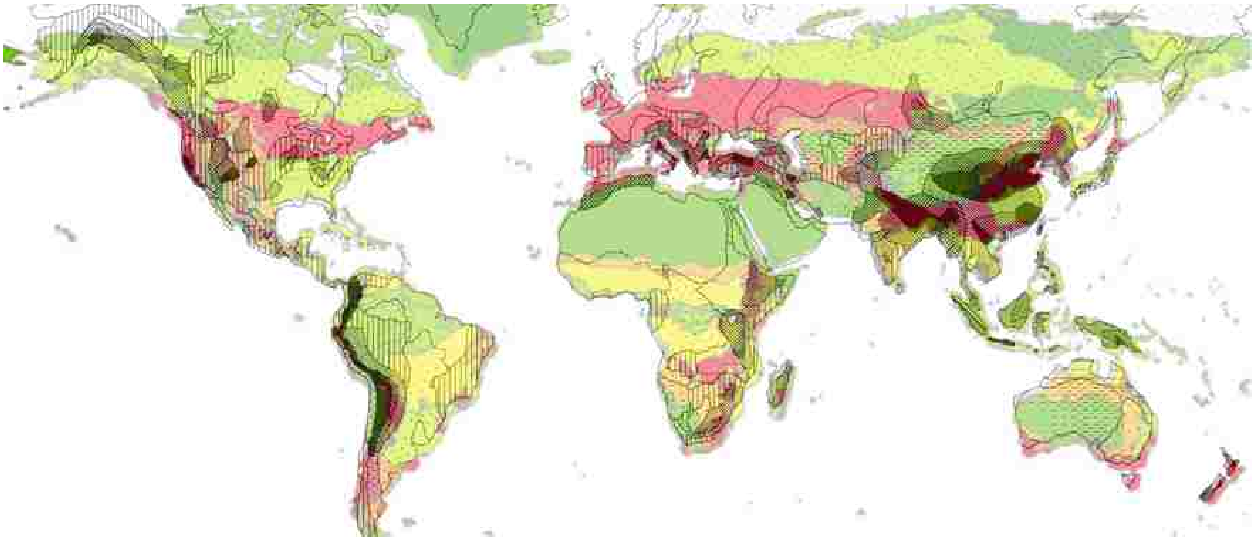

Figure 2-3: Comparing dam density with erosion-prone areas

related consequences include coastal and shoreline erosion for beaches (Kondolf 1997; Pilkey et al. 1992; Slagel and Griggs 2006), sediment abrasion on turbines (Auel et al. 2016), and the plugging of dam outlet works (Randle et al. 2017). Greater detail about sedimentation consequences is provided in Palmieri et al. (1998), Morris and Fan (1997), and Annandale (2006).

2.2 Deposition Characteristics

Flowing waters possess a certain amount of sediment-carrying capacity or power. This power dissipates when water enters the reservoir, leaving the majority of sediments to accumulate at the reservoir headwaters and form a delta, while finer materials propagate toward the upstream face of the dam. Figure 2-4 illustrates this phenomenon in a general sense, and Figure 2-5 and Figure 2-6 provide an example from Lake Mead Reservoir, USA, impounded by Hoover Dam. Near the headwaters of Lake Mead, sediment deposition is between 250- and

المنارة للاستشارات
www.manaraa.com

300-ft thick. The next several miles contain between 50- and 75-ft of deposited material. The tributary feeding into Lake Mead—the Virgin River—has between 0- and 10-ft of deposition.

Table 2-1: Sediment-Related Consequences of Dam Construction (Hotchkiss and Bollman 1996)

Primary Impact	Secondary Impact	Tertiary Impact
Upstream deposition	Tributary aggradation Increased groundwater levels Decreased navigational clearance Increased flood frequency Deposition at diversions Altered geomorphology Uncontrolled wetland creation	Increased soil moisture in root zone Flooded homes
Downstream scour	Armoring of bed bank instability Tributary degradation Undercut diversions Increased bridge scour Lower groundwater levels Decreased turbidity Geomorphic changes	Change in habitat Loss of riparian vegetation Agricultural impacts Aquatic habitat changes
Reservoir deposition	Reduction in all benefits Reduced useful life Degraded water quality	Decreased dissolved oxygen Interstitial deposition Contaminant concentration

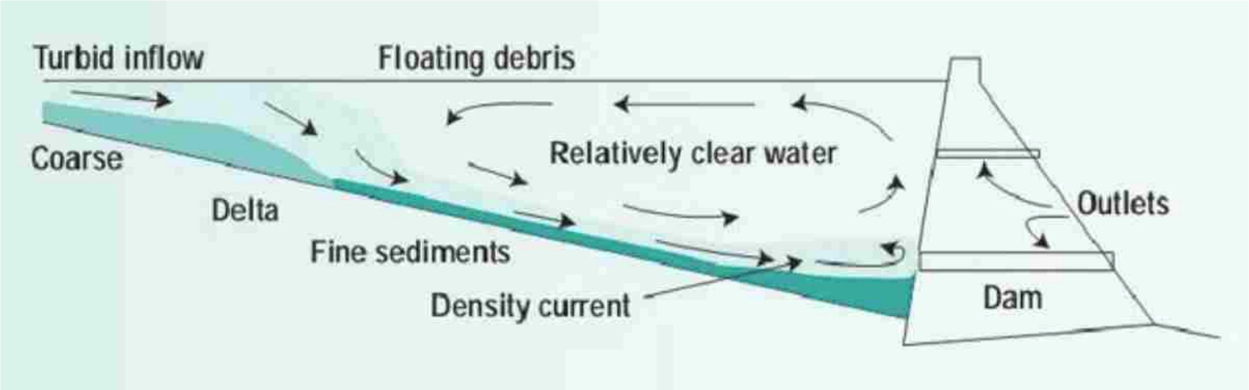

Figure 2-4: Reservoir sediment deposition schematics (Ketelsen et al. 2013)

www.manaraa.com

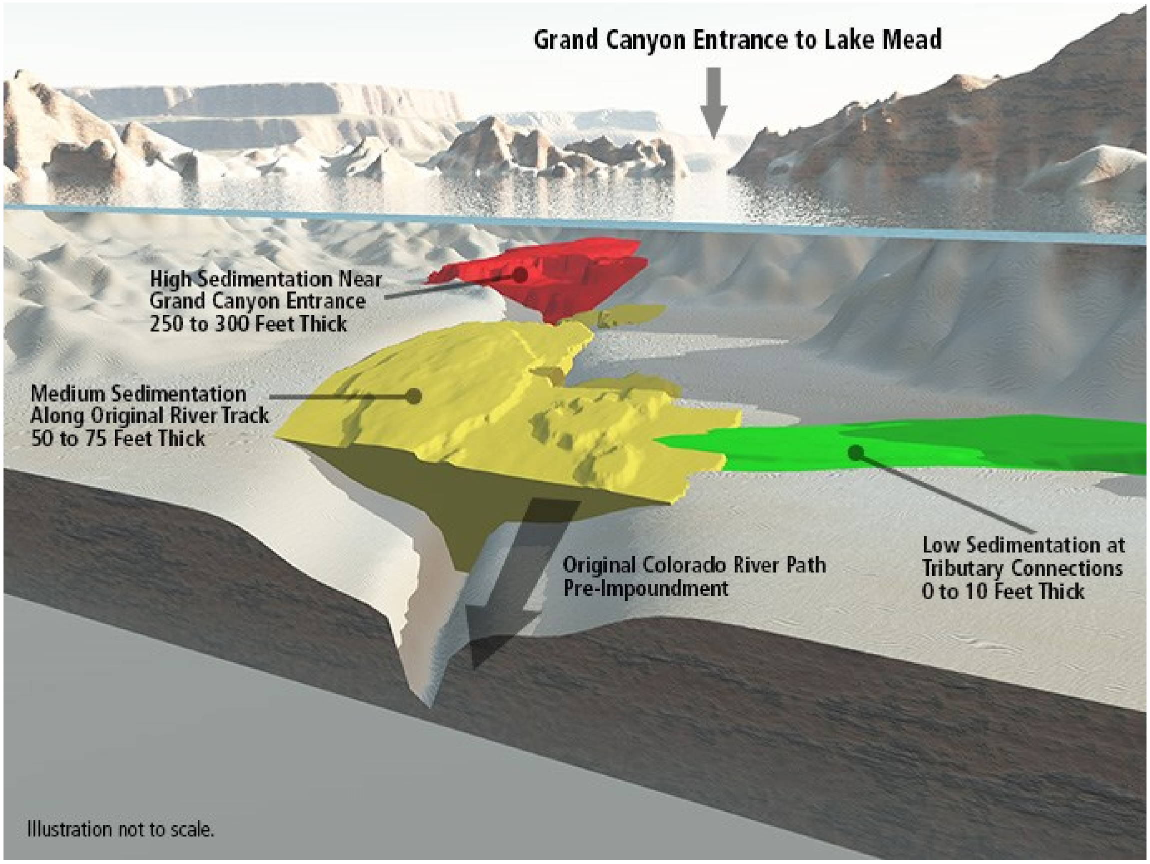

Figure 2-5: Sediment deposition in Lake Mead (NPS 2015)

www.manaraa.com

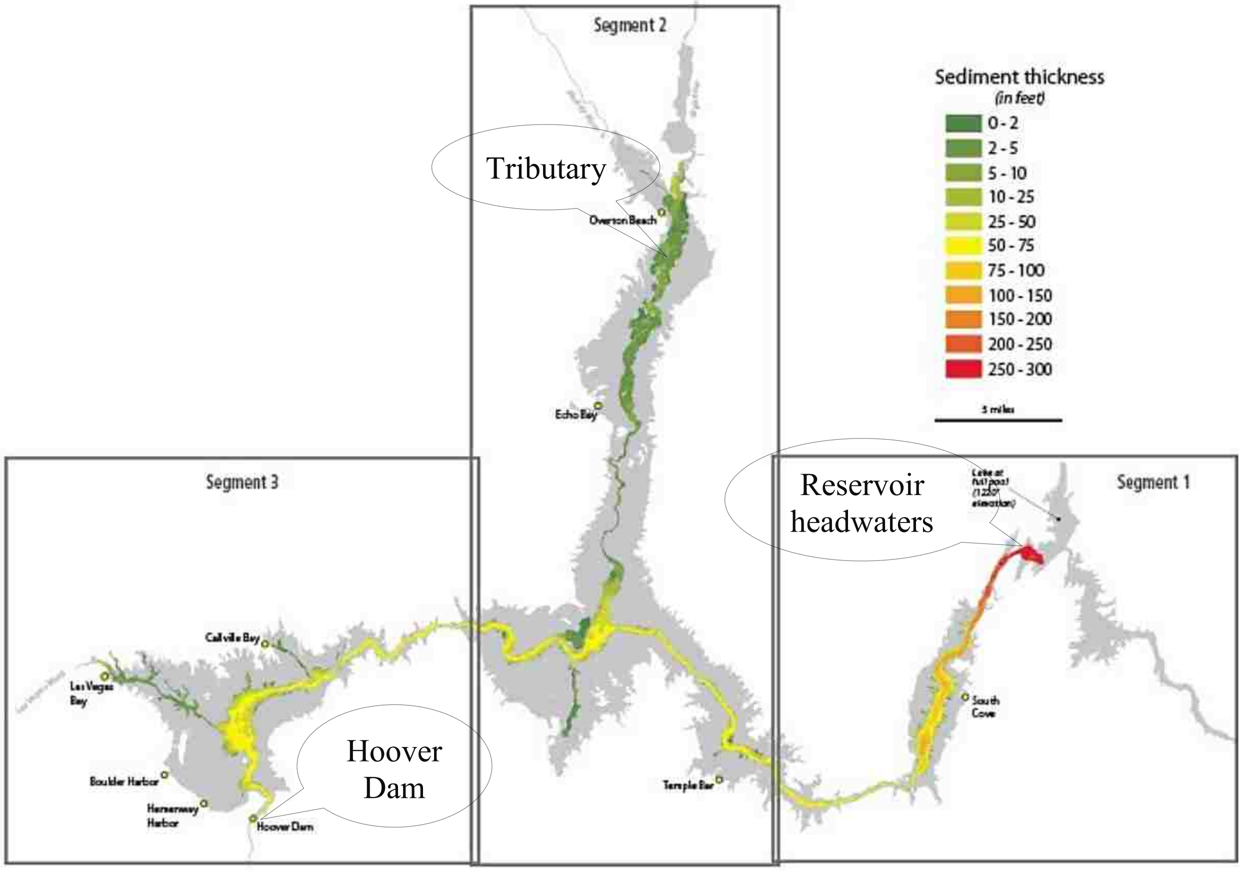

Figure 2-6: Sedimentation in Lake Mead (NPS 2015)

2.3 Consequences for Future Generations

Annandale (2013) described reservoirs as either an exhaustible or renewable resource, either of which is decided by how the dam is designed and operated. For instance, reservoir storage space is considered an exhaustible resource if the rate of consumption (i.e., capacity loss to sedimentation) exceeds the rate of replenishment, or the rate at which storage capacity can be restored or added to. “Similarly,” Annandale states, “if a decision were made to manage reservoir sedimentation by preventing or minimizing storage loss, the characterization of the storage space changes from exhaustible to renewable.”

www.manaraa.com

Intergenerational equity is defined as meeting and satisfying the needs of present generations without compromising the ability of future generations to meet theirs (Summers and Smith 2013). Sedimentation will eventually make reservoirs obsolete and place future generations with less desirable locations to construct new dams. Some estimates postulate that as much as one-quarter of all dams will lose their storage capacity to sedimentation within the next 50 years (Schleiss et al. 2016). Conscious decisions made toward mitigating the effects of reservoir sedimentation will ultimately determine if reservoirs will be classified as exhaustible or renewable; if it will meet only present needs or be perpetuated to benefit others.

المنارة للاستشارات
www.manaraa.com

3 RESERVOIR SEDIMENT MANAGEMENT

Many of the adverse effects experienced via reservoir sedimentation can be mitigated through appropriate countermeasures. The two most useful approaches for considering sediment management alternatives are the RESCON program and using a graph called the Sediment Management Options Diagram (SMOD). Each will be explained. Additionally, innovations taken in Japan to manage sedimentation will be explored.

3.1 Sediment Management Alternatives

There are several methods for managing sedimentation in reservoirs. Table 3-1 outlines the nine most commonly used alternatives, with descriptions taken from the RESCON 2 manual (Efthymiou et al. 2017). For a more descriptive analysis of the various alternatives, see Kondolf et al. (2014).

3.1.1 Effects of Sediment Management

Through the appropriate selection, implementation, and operation of reservoir sedimentation countermeasures, many adverse effects can be controlled and even resolved. Auel et al. (2016) showed three cases in Japan where sediment management helped prolong the useful of the Asahi, Nunobiki, and Dashidaira Reservoirs by 440-, 1,200-, and 180-years, respectively. Kondolf (1997) demonstrated how artificial sediment replenishment to the Rhine River helped to

للاستشارات المنارة

www.manaraa.com

prevent further channel incision below the Barrage Iffezheim Dam in France and Germany, and in other locations was implemented to restore spawning habitats for fish. However, not every response to sediment management will be positive. As Coker et al. (2009) commented, “No solution to the sedimentation problem will be without compromise of competing values.” Quadroni et al. (2016) recorded local ecological impacts following a flushing operation from the Madesimo Reservoir in Northern Italy. Among other reactions, it was noted that the benthic community closer to the reservoir did not recover to its pre-flushing condition 1-year after the flushing operation. Analyzing and understanding all aspects of reservoir sedimentation and sediment management will minimize negative consequences and maximize desired outcomes.

Table 3-1: Summary of Sediment Management Alternatives Used in RESCON 2

Sediment Management Practice	**Description**
No Action	No sediment management plan implemented
Catchment Management	Reduce the sediment inflow into the reservoir
Sluicing	The reservoir volume is partially reduced during the flood season, increasing the flow velocity
Sediment Bypass Tunnel	The diversion of sediment-laden flows before the transported sediment load is deposited within the reservoir
Density-Current Venting	The turbidity transported in reservoirs by means of density currents
Flushing	Remobilization of deposited sediments by increasing the flow velocity in the reservoir
HSRS*	Energy for the dredging operation is supplied by the hydrostatic head at the dam
Dredging	Removes sediment by pumping water entrained sediment from the reservoir bed
Trucking	The removal of accumulated sediment from a drained reservoir using heavy equipment

* Hydrosuction sediment-removal systems

المنارة للاستشارات
www.manaraa.com

3.2 RESCON: A Brief History

Originally published in 2003, RESCON was created with the purpose of providing users with a rapid assessment and pre-feasibility analysis of sediment management alternatives (Palmieri et al. 2003). As understanding of the different alternatives developed and future effects of climate change improved, the World Bank was prompted to update the RESCON model. Commenting on the objective of the new RESCON 2 model, Annandale et al. (2017) noted it was “to assess the technical viability and economic optimality of reservoir sedimentation management alternatives at policy and pre-feasibility level,” and clearly stated it was “not intended for feasibility and design phases of projects.”

The original RESCON only included assessments of flushing, hydrosuction-sediment removal systems (HSRS), dredging, and trucking. Since then, sediment routing and inflow reduction practices have been added (see Table 3-2). In addition to new sediment management strategies, RESCON 2 improved on its economic analysis and added an additional feature assessing climate change effects on reservoir sustainability (Annandale et al. 2017). The economic analysis can consider various implementation schedules for sediment management strategies and optimizes timing or recurrence to produce the highest net present value (NPV). The climate change assessment is comprised of multiple steps which are documented in the RESCON 2 user manual. To summarize, RESCON analyzes possible future climate scenarios and selects a set that “spans the full range of climate futures,” and evaluates the different sediment management strategies under these potential conditions (Efthymiou et al. 2017).

www.manaraa.com

Table 3-2: RESCON vs RESCON 2 Sediment Management Options

Original RESCON	RESCON 2
Flushing	Flushing
Trucking	Trucking
Dredging	Dredging
HSRS	HSRS
No Action	Bypass Tunnel
-	Sluicing
-	Density-Current Venting
-	Catchment Management
-	No Action

3.2.1 RESCON 2 Input Parameters

Table 3-3 illustrates the six input worksheets within RESCON 2, the number of inputs for each worksheet, and some key entries found therein. In total, there are 233 input parameters in RESCON 2. However, note the sediment management page does not require all 80 inputs to run, as not all sediment management options need to be analyzed. Also, some values can be empirically estimated using functions built into the program, such as the mean annual sediment inflow and the unit cost of dredging.

Table 3-3: RESCON Required Inputs

Page Name	Number of Inputs	Key Entries
Project Definition	9	Required reliability of water supply
Environmental Safeguard	97	Allowable environmental and social damage
Reservoir Geometry	12	Storage capacity (live and dead), pool and bed elevations
Hydrology and Sediment	26	Mean annual runoff and sediment inflows
Economic Parameters	9	Unit cost of construction, discount rate, unit value of reservoir yield, maximum duration of financial analysis
Sediment Management	80*	Allowable loss, year of implementation, frequency of events
Total:	233	

*Maximum of 80, but fewer can be used if not analyzing all practices

www.manaraa.com

3.3 RESCON 2 Limitations

The RESCON 2 user manual lists the main limitations to the program (Efthymiou et al. 2017, pp. 5-6). Among these are its empirical-based approach and incomplete evaluation of environmental influences. RESCON 2 uses empirical equations for trapping efficiency combined with a time step to successively fill the reservoir with sediment. The trapping efficiency is updated with the new volume and the process repeats itself. In this way, an empirically based sediment front fills the reservoir. The problem with this method is it is not site specific. The annual sediment and water inflows, storage (dead and active) capacities, and certain other variables are site specific, however, RESCON treats reservoirs as linear and is unable to simulate multiple branches, and water and sediment inflow to the reservoir is treated as entering at the headwaters. Additionally, the calculation of water yield is based on an empirical method, which does not account for the operational rules of the reservoir. With regards to RESCON's environmental analysis, the manual states: "Despite scientific progress in environmental science, no generic cause-effect relationships exist between changes in sediment flows and environmental quality that can be incorporated in a pre-feasibility level mathematical model such as RESCON" (pp. 137-138).

3.4 Sediment Management Options Diagram

There has been some debate as to the origins of the SMOD. It has traditionally been referred to as the "Basson Diagram" (see Palmieri et al. 1998; Aras 2009); however, Dr. Basson stated he used work previously done by Chinese researchers to develop his graph, and agreed the name "Sediment Management Options Diagram" would be an appropriate title for the chart (Basson, personal communication, 2018).

www.manaraa.com

The SMOD relates water and sediment inflows to storage capacity in a graphical format (Figure 3-1). The x-axis represents the reservoir storage capacity divided by the mean annual inflow. This ratio is indicative of the hydraulic retention time (HRT), or the amount of time water remains in the reservoir before passing downstream. A low HRT value would mean water can fill the reservoir many times each year. The y-axis is the storage capacity divided by the mean annual sediment inflow and can be interpreted as the reservoir's life expectancy (Auel et al. 2016). This ratio does not perfectly represent the lifetime of a reservoir, as reservoirs tend to fill more slowly over time as storage capacity is lost (Morris and Fan 1997). Thus, the SMOD is a somewhat simplistic approach to consider sediment management strategies, but, like RESCON, it is meant to be used at the pre-feasibility stage and provides useful feedback and information.

In practice, the x- and y-coordinates of an existing or future dam is plotted on the SMOD to determine which sediment management alternatives might merit more investigation. Experience has shown that the various alternatives are effective for only a limited range of x- and y-values, as demonstrated in Figure 3-1.

3.5 Innovations in Japan

During June 2018, a trip was taken to tour several Japanese dams and observe local sedimentation problems and actions taken to mitigate their effects. Dr. Tetsuya Sumi and Dr. Sameh Kantoush, along with Dr. Sumi's graduate student, Koshiba Takahiro, kindly provided and guided many visits, with stops at the Kurobe, Koshibu, Dashidaira, Yamasubaru, Saigo, and Ouchubaru Dams. The latter three are part of a cascading series of dams located in the Miyazaki Prefecture (Figure 3-2), lying along the Mimikawa (Mimi) River (Figure 3-3).

المنارة للاستشارات
www.manaraa.com

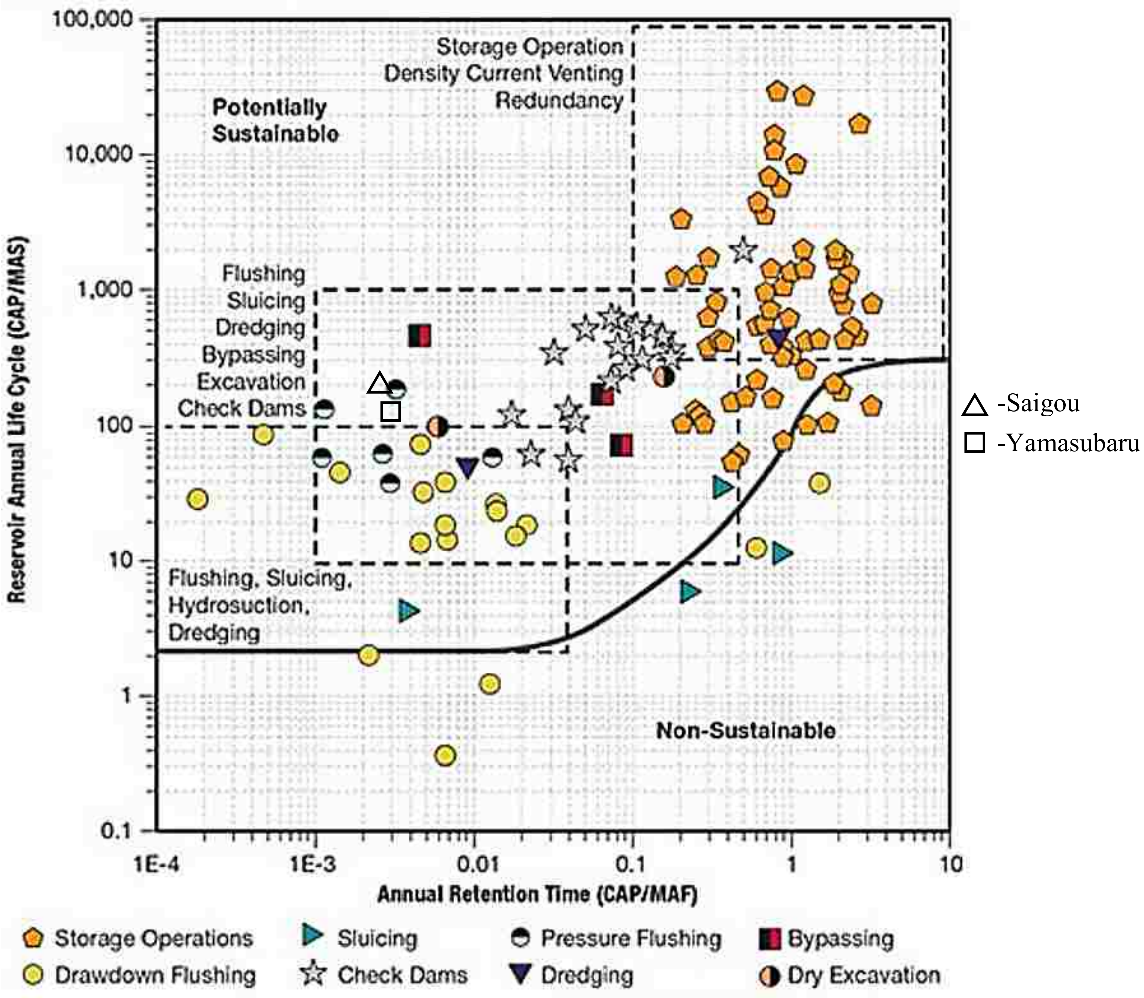

Figure 3-1: Categorization of reservoir sedimentation countermeasures (Schellenberge et al. 2017, adapted from Annandale 2013)

المنارة للاستشارات
www.manaraa.com

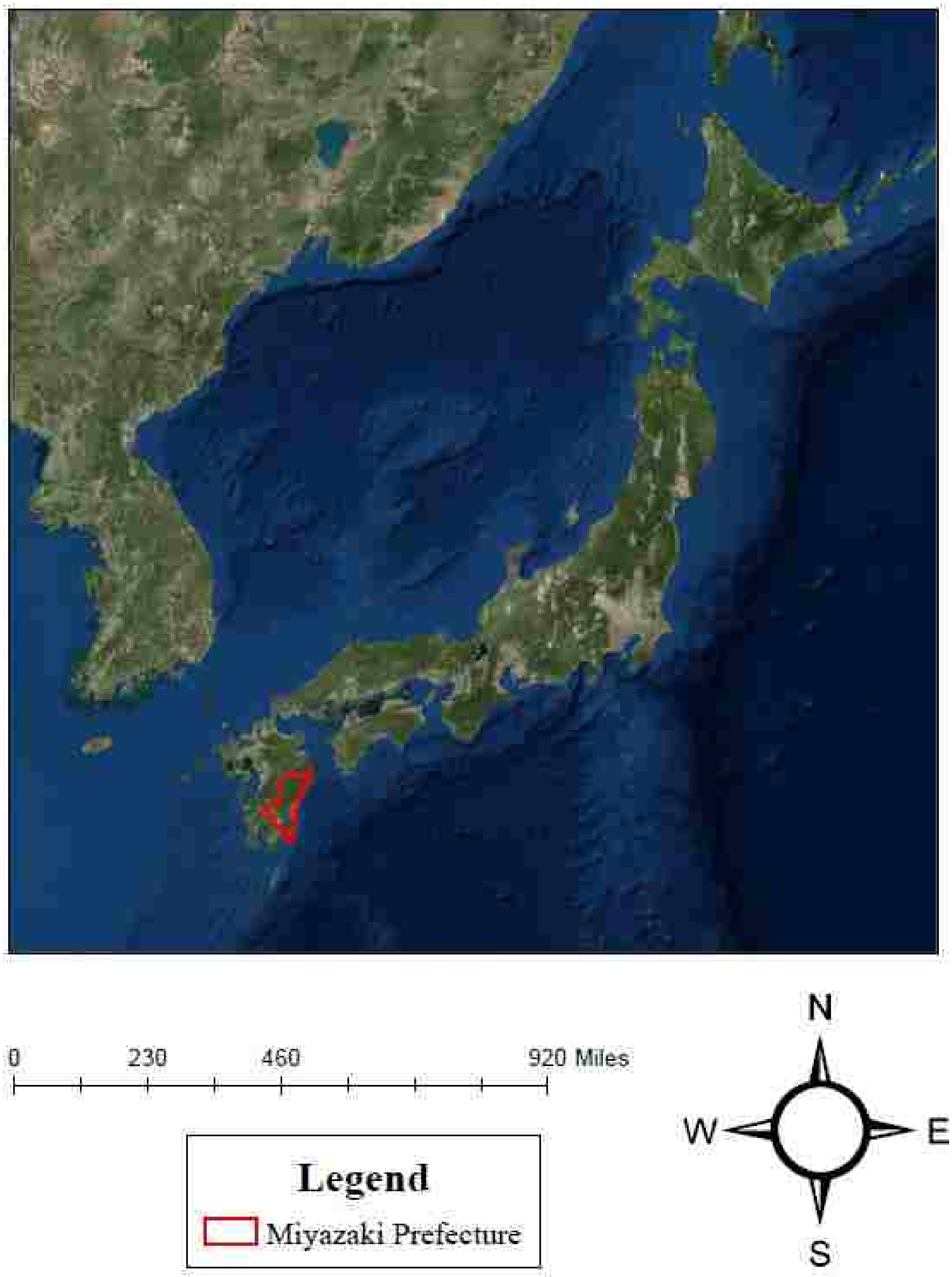

Figure 3-2: Map of Miyazaki Prefecture, Japan

المنارة للاستشارات
www.manaraa.com

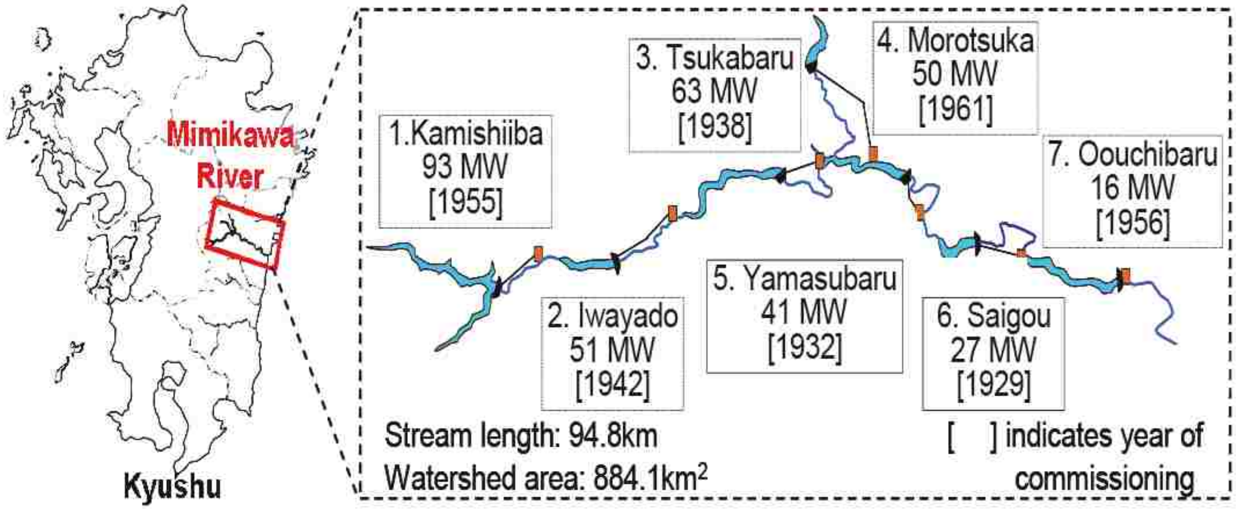

Figure 3-3: Mimi River basin (Sumi et al. 2015)

In September 2005, Typhoon 0514 (Nabi) devastated the Mimi River basin with more than 500 landslides and 50 inches (1,300 mm) of rain over a three-day period, causing severe damage to surrounding urban areas and flooding rivers and reservoirs with sediments and other large debris. Figure 3-4 shows one landslide, approximately a quarter of a mile wide (400-m), occurring just downstream of the Tsukabaru Dam.

Figure 3-4: Slope failure downstream of the Tsukabaru Dam (Sumi et al. 2015)

المنارة للاستشارات
www.manaraa.com

In response to the effects caused by Typhoon Nabi, Sumi et al. (2015) commented:

> *"In October 2011, Miyazaki Prefecture, the river administrator, compiled the 'Mimikawa River Basin Integrated Sediment Flow Management Plan' which is showing the current status of the complex Mimikawa River sediment problems and possible approaches to solve these problems while balancing flood control, water usage and environmental conservation. As part of the Management Plan, the Kyushu Electric Power Company, KEPCO, which is responsible for dam installation is aiming to restore the original sediment flow which has been trapped by dam reservoirs up until now, and has drawn up a plan for sediment sluicing operation at Yamasubaru, Saigou and Oouchibaru Dams."*

The sediment sluicing operation mentioned involved retrofitting the Yamasubaru and Saigou Dams with larger and lower sluice gates. Figure 3-5 illustrates the change in operation from a side view. The "Existing Operation" dam shows sediments forming a delta-like deposit toward the reservoir headwaters, as explained in Section 2.2. Lowering the gates decreases the water depth in the reservoir, allowing the dam to function more as a run-of-river dam, providing easier passage of sediments downstream to the river and increasing flood control and protection.

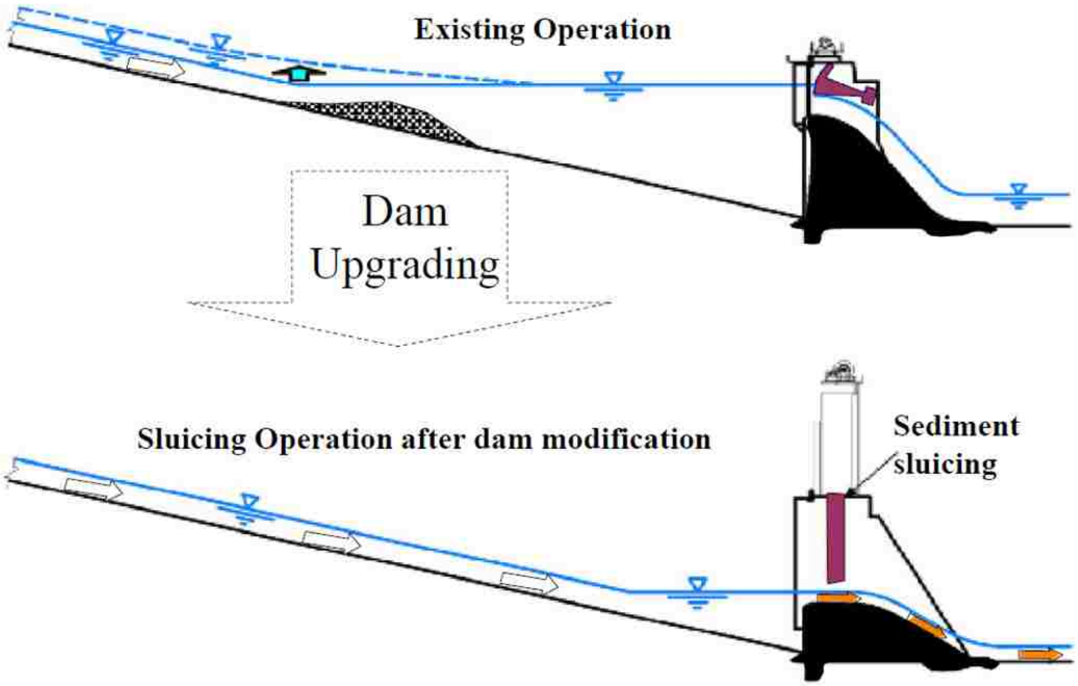

Figure 3-5: New sediment sluicing operation (Sumi and Kantoush 2016)

www.manaraa.com

Figure 3-6 shows the current states and artistic renditions of the Yamasubaru and Saigou Dams following their modifications. Two of the center gates at Yamasubaru will be merged into one and lowered by approximately 30.5-ft (9.3-m). At Saigou, the four middle gates will be merged into two gates and lowered by approximately 14-ft (4.3-m) Retrofitting these dams was projected to be complete by 2022 and June 2018, respectively.

Figure 3-6: Dam retrofitting for Yamasubaru and Saigou Dams (Sumi et al. 2015)

Sumi and Kantoush (2016) performed an analysis on Yamasubaru Dam demonstrating the change in riverbed elevation upstream of the reservoir with and without sediment sluicing over a 33-year period (Figure 3-7). Their results indicated the riverbed would increase by as much as 14.8-ft (4.5-m), with an average increase of about 6.6-ft (2-m) projecting 6-km upstream, if no maintenance were performed to manage inflowing sediments. Under sluicing

www.manaraa.com

operations, the riverbed would essentially remain unchanged, with some aggradation in the stream bed immediately upstream from the dam and degradation in other locations.

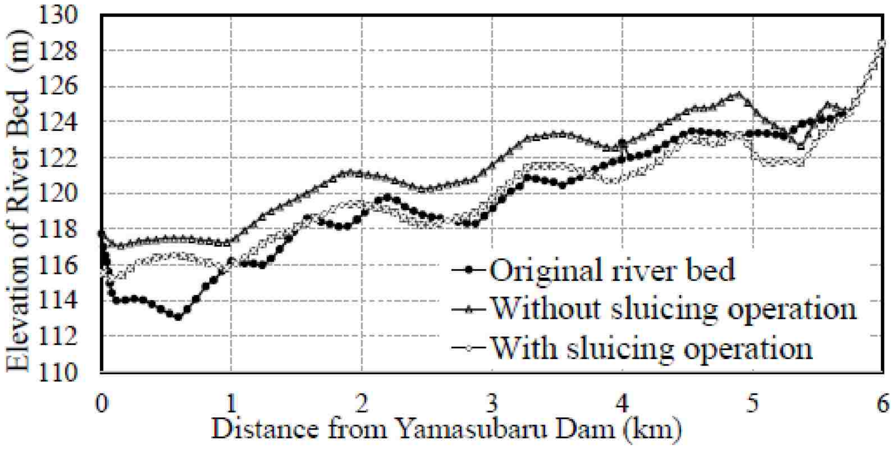

Figure 3-7: Results of riverbed fluctuation analysis (Sumi and Kantoush 2016)

The fact that these dams have been/are being retrofitted is extraordinary. Sumi and Kantoush (2016) remarked this would be the "first time … an existing dam [in Japan] will be retrofitted by the addition of a new sluicing function after 80 years of commissioning." This is a novel step for sediment management both in Japan as well as globally, as many of the existing and soon-to-be built dams are planned and designed without consideration of sediment management (Kondolf et al. 2014). Economically justifying modifications had to overcome 1) initial costs of implementation and 2) loss of revenues from generating hydroelectricity while installing the new sluice gates. However, by remodifying these dams, storage capacity will be preserved, providing for more and longer production of hydroelectricity over time (De Miranda and Mauad 2014) and better flood control capabilities (Pattanapanchai et al. 2002).

www.manaraa.com

4 METHODOLOGY

4.1 Compiling RESCON 2 Models

Gathering data to compose a RESCON 2 model required extensive work to connect with outside sources. Table 4-1 lists all RESCON-analyzed reservoirs and sources used to develop or obtain the model. Some models came preconfigured in RESCON 2, others had to be converted from the original RESCON model into RESCON 2, while others were created from only data. This also is shown in Table 4-1 under “Original Model Type.”

4.1.1 Conversion from Original RESCON Models into RESCON 2

When developing a RESCON 2 model from the original RESCON, default values for certain parameters were used. RESCON 2 contains several more variables than the original model, so insufficient data were encountered in every transfer. In general, the parameters not included in the original RESCON models and their assumed values in RESCON 2 are listed below in Table 4-2. However, as a pre-feasibility program, the goal of RESCON 2 is to provide a rapid assessment of sediment management strategies to consider and evaluate under detailed analyses. Acquiring requisite data for each model proved difficult as certain information is not posted or publicly available. As more accurate data becomes available, these can be modified to increase evaluations of RESCON 2; but, at least in this way, an initial investigation of RESCON 2 and its probability of suggesting the ideal alternative could be assessed.

www.manaraa.com

Table 4-1: Reservoirs Analyzed in RESCON 2

Reservoir	Source	Original Model Type
Abdel Karim	Annandale, G.W. (2017)	RESCON 2
Baira	Annandale, G.W. (2019)	RESCON
Banja	Adhikari, S. (2017)	RESCON 2
Bin El Quidine	Annandale, G.W. (2017)	RESCON 2
Çubuk	Aras, T. (2009)	RESCON
El Canadá	Zamora, J. (2018)	Data
Gavins Point	Boyd, P. (2019)	RESCON, data
Gebidem	Annandale, G.W. (2019)	RESCON
Ichari	Annandale, G.W. (2019)	RESCON
Iron Gate	Annandale, G.W. (2017)	RESCON 2
Kali Gandaki	Annandale, G.W. (2017)	RESCON 2
Kulekhani	Shrestha, H.S. (2012)	RESCON
Millsite	Hotchkiss, R.H. (2018)	Data
Mohammed V	Annandale, G.W. (2017)	RESCON 2
Sanmenxia	Annandale, G.W. (2019); Wu, B. (2018)	RESCON
Sefid-Rud	Annandale, G.W. (2019)	RESCON
Sidi Driss	Annandale et al. (2017)	RESCON
Tarbela	Annandale, G.W. (2017)	RESCON 2
Three Gorges	Annandale, G.W. (2019)	RESCON
Upper Karnali	Annandale, G.W. (2017)	RESCON 2

المنارة للاستشارات
www.manaraa.com

Table 4-2: Default Values Used in Converting RECON Models Into RESCON 2

RESCON 2 Parameter	Units	Description	Assigned Value		
ncomp	-	Number of reservoir compartments	5		
ExceedT	%	Percentage of time exceeded	30	60	90
ExceedMAR	%	Percentage of mean annual water inflow	40	20	3
ExceedMAS	%	Percentage of mean annual sediment inflow	25	5	3
T_b	%	Duration of bedload transport (% of annual time)	5		
Distribution	-	Distribution of annual inflows	Lognormal		
-	-	Application of declining discount rate?	No		
CycleNS	Years	Time interval between flushing events during the 1st phase (Reservoir storage > sustainable long term reservoir capacity)	1		
CycleS	Years	Time interval between flushing events during the 2nd phase (Reservoir storage < sustainable long term reservoir capacity)	1		
Cycle1DR	Years	Duration of phase (No dredging)	1		
Cycle2DR	Years	Cycle length in phase 2 (Dredging operation)	1		
Year HSRSstart	Years	Time of HSRS installation	1		
Cycle1TR	Years	Implementation year (for trucking operation)	1		
Cycle2TR	Years	Frequency of trucking operation	1		

4.2 RESCON 2 Models Within the Sediment Management Options Diagram

Each RESCON-analyzed reservoir in this study was plotted on the SMOD. Data for each reservoir is located in Table 4-3. The SMOD of Figure 4-1 has been divided into option zones based on field experience (Annandale 2013; see Figure 3-1). Reservoirs lying within or near box 1 were assumed to use either flushing, sluicing, HSRS, or dredging; box 2 to use sediment bypass tunnels, flushing, sluicing, dredging, density currents, trucking, or check dams; and box 3 to use density currents, catchment management or no action.

المنارة للاستشارات
www.manaraa.com

Table 4-3: SMOD Data for Modeled Reservoirs

Reservoir	**CAP** (million m^3)	**CAP/MAR** (years)	**CAP/MAS** (years)
Abdel Karim	11.3	0.24	68
Baira	2.4	0.0024	11
Banja	403	0.27	221
Bin El Quidine	1,508	1.4	285
Çubuk	7.1	0.25	118
El Canadá	0.187	0.00047	3.7
Gavins Point	580	0.020	129
Gebidem	9	0.021	24
Ichari	11.6	0.0022	7
Iron Gate	100	0.067	33
Kali Gandaki	7.7	0.00094	0.25
Kulekhani	85.3	0.62	113
Millsite	22.2	0.091	243
Mohammed V	726	0.97	75
Sanmenxia	9,640	0.22	6
Sefid-Rud	1,760	0.35	47
Sidi Driss	7.2	0.058	30
Tarbela	14,350	0.19	98
Three Gorges	39,300	0.090	98
Upper Karnali	17.9	0.0011	0.8

المنارة للاستشارات
www.manaraa.com

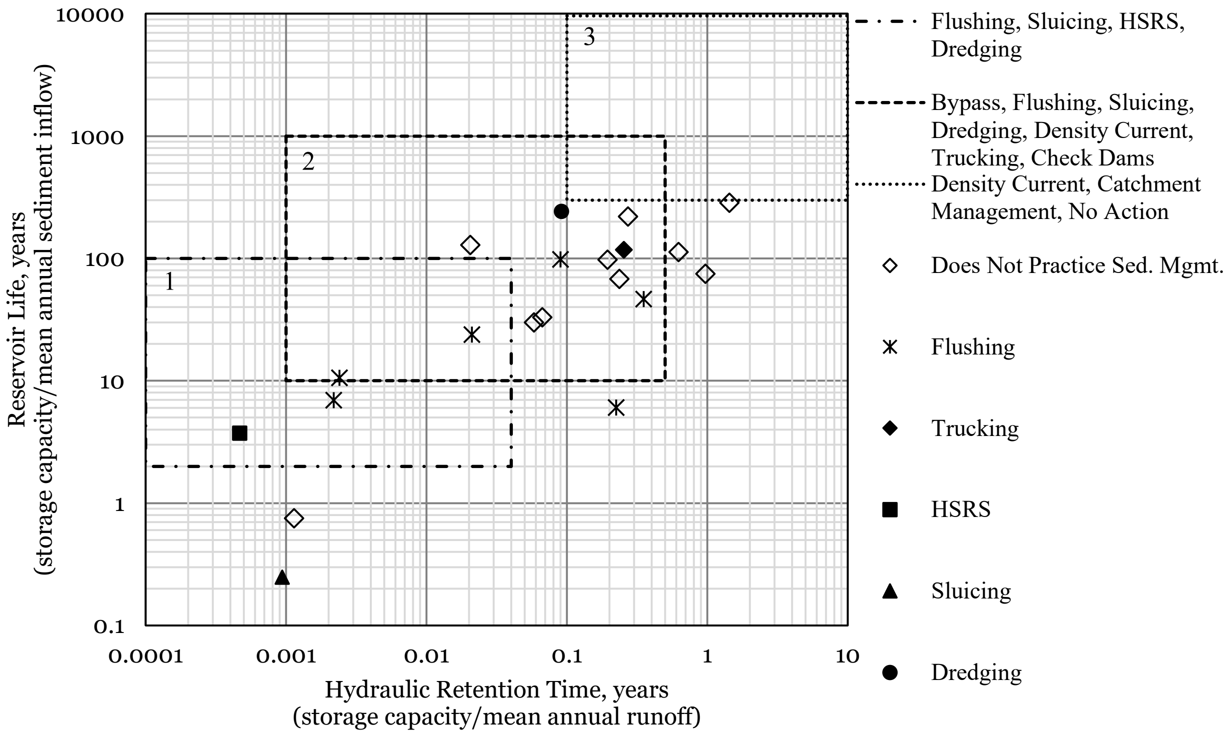

Figure 4-1: SMOD with zones of applicability and RESCON-analyzed reservoirs

4.2.1 Reading and Interpreting the SMOD

In Section 3.3, it was noted the x- and y-axes of the SMOD are used in practice to determine feasible sediment management alternatives depending on where the reservoir lies on the graph. To illustrate how reservoir lifetime and HRT can help determine appropriate solutions, two examples will be explored. The first will look at the Ichari Dam, and the second Bin el Ouidane Dam.

The Ichari Dam is a concrete gravity dam located on the Tons River in Uttarakhand, India, has an HRT of 0.0022 years and a life expectancy of about 7 years. With a low life expectancy and capability of filling the reservoir hundreds of times each year, sediment

www.manaraa.com

countermeasures such as flushing, which can use more water than other methods, may be used without compromising water storage, assuming that adequate low-level outlets exist in the dam.

The Bin el Ouidane Dam is an arch dam located on the El Abid River in the Azilal Province, Morocco. It has an HRT of 1.44 years and life expectancy of 285 years—quite distinct and different from the Ichari Dam. It has an average annual runoff of more than 1 billion m^3, but its large capacity indicates the need to preserve water. Flushing generally requires a complete drawdown of the reservoir, emptying any water storage to remove deposited sediments. If flushing were to occur here, it would eliminate more than an entire year's worth of water storage. Flushing would probably be unrealistic in this scenario, and it would be more appropriate to consider water-conserving strategies such as catchment management, density current venting, or no action.

4.3 Evaluating RESCON 2 Results

There were two main objectives for this research: perform a sensitivity analysis on RESCON 2 input parameters to determine which variables need more accurate data and which can be roughly approximated; and 2) evaluate RESCON 2 suggested alternatives to assess the model's accuracy and consistency for providing the optimal solution. Climate change effects were not included as part of this analysis. To address the first, several parameters were tested in the Tarbela Reservoir model. A couple were taken from Table 4-2 to understand default parameters (i.e., how effective was using a default value to assess RESCON). Other parameters were selected because either RESCON does not offer empirical approximations to assist when determining appropriate values or it was unclear what effect these terms would have on the overall computation and analysis of the various sediment management alternatives.

المنارة للاستشارات
www.manaraa.com

For the second purpose, an economical range was selected for each reservoir, and all practices that lied within that range were considered potential alternatives meriting further investigation. To illustrate how practices were deemed acceptable based on its economic appraisal, an example of RESCON's comparison was taken from the Tarbela Reservoir and shown below in Table 4-4. All results that lied within 30% of the highest NPV alternative were considered potential alternatives. Dredging returned the highest NPV at roughly 298 billion USD, and sluicing, flushing, and trucking were all within 30% (i.e., >208 billion USD) of its value.

Table 4-4: RESCON 2 Comparison of Results for Tarbela Reservoir

Sediment Management Strategy			Aggregate Net Present Value	Long Term Reservoir Gross Storage Capacity	Reservoir Lifetime
Technique	**Sustainability**	**Action in case of storage elimination**	**[Billion US$]**	**[Million m^3]**	**[Years]**
No Action	Sustainable		--	0	224
	Non Sustainable	Decommissioning	187.2		
		Run-Of-River	187.3		
Catchment Management	Sustainable		--	0	236
	Non Sustainable	Decommissioning	191.2		
		Run-Of-River	191.3		
Sluicing	Sustainable		--	192.3	>217
	Non Sustainable	Decommissioning	--		
		Run-Of-River	249.4		
By-Pass	Sustainable		--	0	284
	Non Sustainable	Decommissioning	176.2		
		Run-Of-River	176.2		
Density Current Venting	Sustainable		--	0	196
	Non Sustainable	Decommissioning	75.4		
		Run-Of-River	75.4		
Flushing	Sustainable		267.3	1,472	>300
	Non Sustainable	Decommissioning	--		
		Run-Of-River	--		
HSRS	Sustainable		--	N/A	N/A
	Non Sustainable	Decommissioning	--		
		Run-Of-River	--		
Dredging	Sustainable		297.6	9,856	>300
	Non Sustainable	Decommissioning	--		
		Run-Of-River	--		
Trucking	Sustainable		247.9	7,409	>300
	Non Sustainable	Decommissioning	--		
		Run-Of-River	--		

المنارة للاستشارات
www.manaraa.com

5 RESULTS

5.1 Sensitivity Test

A sensitivity analysis was performed on the Tarbela Reservoir model. The tested parameters, their initial and changed values, and effects seen on the various practices are listed below in

Table 5-1. Under the "Result" section, values between 1 and 4 were assigned depending on how much change was observed. Results with a value of 1 were considered highly sensitive, with an observed change greater than 50%; 2 indicates a sensitive change between 20- and 49%; 3 is a slightly sensitive change between 5- and 19%; and 4 indicates a negligible difference with 0-4% variation. HSRS was not considered technically feasible by RESCON 2 for Tarbela.

Table 5-1: Sensitivity Testing in Tarbela Reservoir Model (1-highly sensitive, 2-sensitive, 3-slightly sensitive, 4-negligible difference)

Parameter (Description)	Units	Original Value	Changed Value	Practice	Result		
					NPV	Long Term Storage	Lifetime
Cv (coefficient of variation of annual run-off volume)	%	12	24	No Action	2	4	4
				Catchment Management	2	4	4
				Sluicing	2	4	4
				Bypass	2	4	4
				Density Current	2	4	4
				Flushing	2	4	4
				Dredging	2	4	4
				Trucking	2	4	4

www.manaraa.com

Table 5-1 Continued

Parameter (Description)	Units	Original Value	Changed Value	Practice	Result		
					NPV	Long Term Storage	Lifetime
Cv (coefficient of variation of annual run-off volume)	%	12	6	No Action	3	4	4
				Catchment Management	3	4	4
				Sluicing	3	4	4
				Bypass	3	4	4
				Density Current	3	4	4
				Flushing	3	4	4
				Dredging	3	4	4
				Trucking	3	4	4
ExceedMAR (Percentage of mean annual water inflow)	%	58	88	No Action	4	4	4
				Catchment Management	4	4	4
				Sluicing	4	2	4
				Bypass	3	4	1
				Density Current	4	4	3
				Flushing	4	4	4
				Dredging	4	4	4
				Trucking	4	4	4
			38	No Action	4	4	4
				Catchment Management	4	4	4
				Sluicing	4	3	4
				Bypass	3	4	3
				Density Current	4	4	3
				Flushing	4	4	4
				Dredging	4	4	4
				Trucking	4	4	4
P1 (Unit benefit of reservoir yield) MD	$\$/m^3$	0.1	10	Dredging	1	4	4
				Dredging	1	4	4
				Dredging	1	4	4
				Bypass	1	4	4
				Density Current	1	4	4
				Flushing	1	4	4
				Dredging	1	4	4
				Trucking	1	4	4

المنارة للاستشارات
www.manaraa.com

Table 5-1 Continued

Parameter (Description)	Units	Original Value	Changed Value	Practice	Result		
					NPV	Long Term Storage	Lifetime
P1 (Unit benefit of reservoir yield) MD	$/m^3	0.1	0.02	No Action	1	4	4
				Catchment Management	1	4	4
				Sluicing	1	4	4
				Bypass	1	4	4
				Density Current	1	4	4
				Flushing	1	4	4
				Dredging	1	4	4
				Trucking	1	4	4
Tf (Duration of flushing after complete drawdown)	Days	30	60	Flushing	4	4	4
			10	Flushing	3	4	4
Cycle2DR (Duration of phase 2, Dredging operation)	Years	10	20	Dredging	4	3	4
			2	Dredging	4	3	4
MD (Amount of sediment removed per dredging event)	Million m^3	100	150	Dredging	4	4	4
			50	Dredging	4	4	4

5.2 Comparison of Results

Figure 5-1, Figure 5-2, and Table 5-2 display the comparative results between RESCON 2, the SMOD, and the currently employed practice at the reservoir. Figure 5-1 and Table 5-2

المنارة للاستشارات

www.manaraa.com

display the results from all twenty dams. Figure 5-2 displays only the results from reservoirs practicing some form of sediment management (i.e., anything but no action). In Figure 5-1 and Figure 5-2, the term "agree" refers to the sediment management practice in use at the reservoir. Looking at all twenty cases, RESCON and the actual practice agreed thirteen times, while the SMOD agreed with the actual practice twelve times. In four instances was neither model able to correctly predict the currently employed alternative. Considering only those reservoirs that practice sediment management, ten of the twenty models were applicable, and RESCON and the actual practice agreed eight out of ten times, while the SMOD and actual practice agreed in all ten cases.

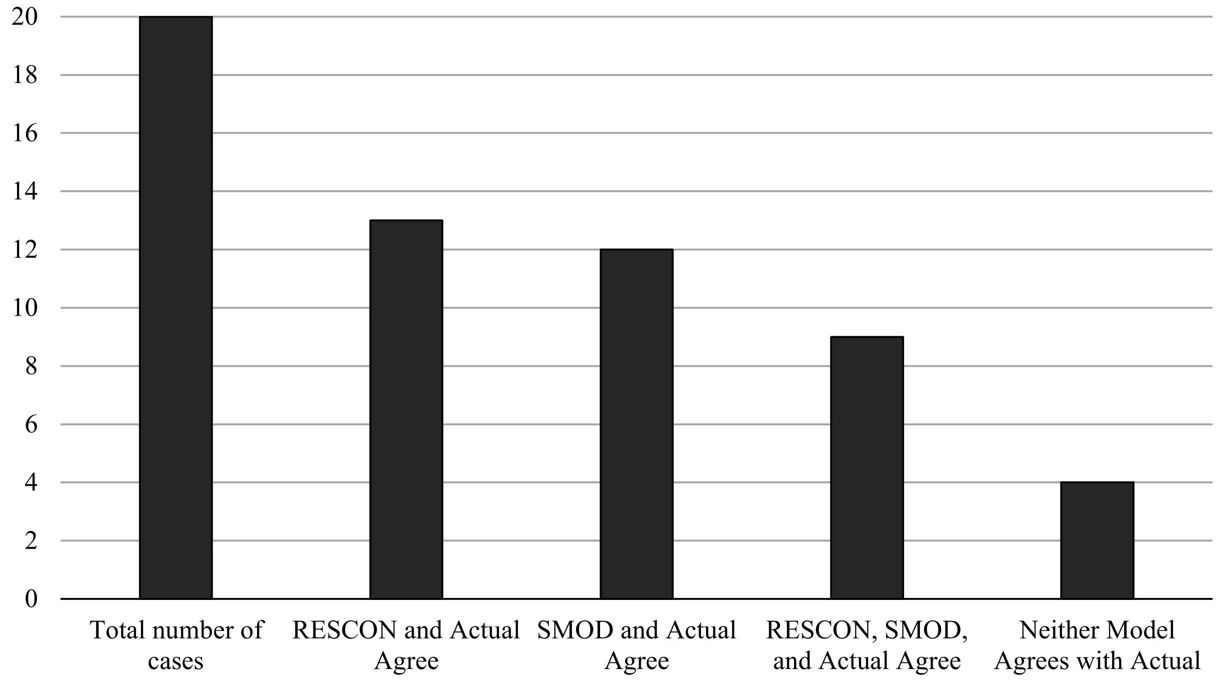

Figure 5-1: Comparison of predicted alternatives, all cases

www.manaraa.com

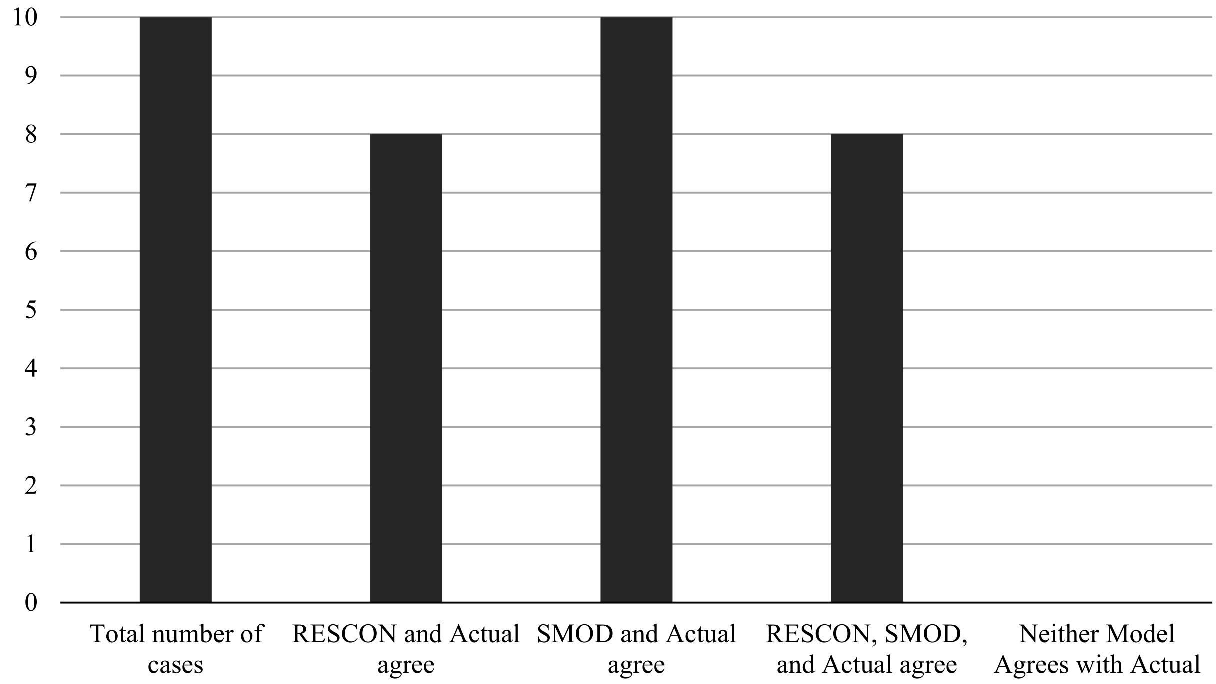

Figure 5-2: Comparison of predicted alternatives, only reservoirs practicing sediment management considered

www.manaraa.com

Table 5-2. Actual Practice vs Acceptable RESCON Practices and SMOD Zone Predictions

Reservoir	Practice	Acceptable RESCON Practices	Applicable SMOD Zones
Baira	Flushing	No Action, Flushing, HSRS	Flushing, Sluicing, HSRS, Dredging, SBT, Density Current, Trucking, Check Dams
Çubuk	Trucking	No Action, Flushing, HSRS, Dredging, Trucking	Bypass Tunnel, Flushing, Sluicing, Dredging, Density Current, Trucking, Check Dams
El Canadá	HSRS	Dredging, No Action	Flushing, Sluicing, HSRS, Dredging
Gebidem	Flushing	No Action, Flushing, HSRS	Flushing, Sluicing, HSRS, Dredging, SBT, Density Current, Trucking, Check Dams
Ichari	Flushing	Flushing	Flushing, Sluicing, HSRS, Dredging
Kali Gandaki	Sluicing	Sluicing	Flushing, Sluicing, HSRS, Dredging
Millsite	Dredging	No Action, Bypass Tunnel, HSRS	Bypass Tunnel, Flushing, Sluicing, Dredging, Density Current, Trucking, Check Dams, Catchment Management, No Action
Sanmenxia	Flushing	Flushing	Flushing, Sluicing, HSRS, Dredging, SBT, Density Current, Trucking, Check Dams
Sefid-Rud	Flushing	Flushing, Dredging	Bypass Tunnel, Flushing, Sluicing, Dredging, Density Current, Trucking, Check Dams
Three Gorges	Flushing	No Action, Flushing, HSRS, Dredging	Bypass Tunnel, Flushing, Sluicing, Dredging, Density Current, Trucking, Check Dams
Abdel Karim	No Action	No Action, Catchment Management, Sluicing, Flushing, Dredging	Bypass Tunnel, Flushing, Sluicing, Dredging, Density Current, Trucking, Check Dams
Banja	No Action	Dredging	Bypass Tunnel, Flushing, Sluicing, Dredging, Density Current, Trucking, Check Dams, Catchment Management, No Action
Bin El Quidine	No Action	No Action, Catchment Management, Sluicing, Bypass Tunnel, Density Current, Dredging	Density Current, Catchment Management, No Action
Gavins Point	No Action	No Action, Flushing, HSRS, Dredging, Trucking	Bypass Tunnel, Flushing, Sluicing, Dredging, Density Current, Trucking, Check Dams
Iron Gate	No Action	No Action, HSRS, Trucking	Bypass Tunnel, Flushing, Sluicing, Dredging, Density Current, Trucking, Check Dams
Kulekhani*	No Action	HSRS	Bypass Tunnel, Flushing, Sluicing, Dredging, Density Current, Trucking, Check Dams
Mohammed V	No Action	No Action, Catchment Management, Sluicing	Bypass Tunnel, Flushing, Sluicing, Dredging, Density Current, Trucking, Check Dams
Sidi Driss*	No Action	Sluicing	Bypass Tunnel, Flushing, Sluicing, Dredging, Density Current, Trucking, Check Dams
Tarbela	No Action	Sluicing, Flushing, Dredging, Trucking	Bypass Tunnel, Flushing, Sluicing, Dredging, Density Current, Trucking, Check Dams
Upper Karnali	No Action	Bypass Tunnel, Flushing	Flushing, Sluicing, HSRS, Dredging

* Models not had in possession but results were obtained via sources outlined in Table 4-1. Thus, other results may be considered practical under "RESCON Acceptable Alternatives".

المنارة للاستشارات
www.manaraa.com

6 DISCUSSION

The following discussion will give emphasis to reservoirs using sediment management, though some of the content may be applicable to reservoirs currently taking no action.

6.1 Implications from Sensitivity Analysis

The Cv parameter expresses the variability of annual flows and is determined by dividing the mean annual water inflow with the standard deviation of incoming flows (Efthymiou et al. 2017). The higher its value implies greater dispersion around the mean annual flow. Increasing this parameter resulted in 20- to 49% lower NPVs for all sediment management strategies, and decreasing this parameter increased NPVs by 5-19%. If insufficient data were available to determine the Cv, and users had to judge between under- or overestimating this parameter, a lower value would likely result in a more moderate change compared to the actual value and its results.

The percentage of mean annual water inflow (ExceedMAR) specifies the intra-annual distribution of water inflow (Efthymiou et al. 2017). For example, a 58% exceedance probability represents a relatively normal inflow that is exceeded 58% of all days in the flow record. Increasing the exceedance probability to 88% indicates a low-flow level, while decreasing the probability to 38% indicates a high-flow. Overall, changing this parameter had negligible influence on sediment management strategies, except for sluicing and sediment bypass tunnel.

www.manaraa.com

When increased to 88%, sluicing and bypass tunnel were both significantly impacted. However, decreasing this value had, at most, a 19% effect on any sediment management strategy. If users had to judge between selecting a higher or lower initial value for this parameter, a lower value is likely to produce a closer response to the actual exceedance probability.

The unit benefit of reservoir yield (P1) resulted in highly significant changes for every alternative's NPV. However, the first test changed the parameter's original value by one order of magnitude and second by half an order (i.e., dividing by 5). To better understand how sensitive this parameter was to change, another test was performed changing the original value from 0.1- to 0.2-\$/m^3. All NPVs were still significantly impacted, with percent differences ranging between 100- and 122%. This suggests users should invest time into accurately determining the value of this parameter.

The other three analyses (i.e., duration of flushing after complete drawdown, dredging operation phase, and amount of sediment removed per dredging event) were tempered by other inputs in RESCON. For flushing, RESCON 2 has the option to determine the implementation schedule of flushing through economic optimization, and dredging has a similar option to automatically determine a sustainable solution. These processes seem to have a greater influence over their respective strategy than any of the three inputs analyzed. This implies users do not need to have specific or very accurate data for these parameters, which is symptomatic of a pre-feasibility program. However, another test was performed for dredging marking "no" to the automatic sustainable solution option and changing the value of removed sediment per event from 100 Mm^3 to 50- and 150 Mm^3, as was done in the initial analysis. This is illustrated in Table 6-1, and the results are shown in Table 6-2. The same designation of 1, 2, 3, and 4 to the observed changes are used here as they were in Section 5.1. Notably, reservoir lifetime remains

www.manaraa.com

unaffected regardless of the amount dredged; storage capacity, on the other hand, is significantly impacted in all cases; and NPV varies.

Table 6-1: Sensitivity Testing on Automatic Calculation Process

RESCON Parameter	**Original Value**	**Sensitivity Analysis Tests**		
Shall a sustainable solution be determined automatically?	Yes	No		
Amount of sediment removed per dredging event (million m^3)	100	100	50	150

Table 6-2: Amount of Sediment Dredged Sensitivity Analysis (1-highly sensitive, 2-sensitive, 3-slightly sensitive, 4-negligible difference)

	NPV			**Long Term Storage**			**Reservoir Lifetime**		
Amount of sediment dredged (Mm^3)	100	50	150	100	50	150	100	50	150
Results	2	4	4	1	1	2	4	4	4

The option to automatically determine a sustainable solution requires a certain amount or percentage of storage capacity be retained throughout the duration of financial analysis. In the “Economic Parameters” worksheet of RESCON, users input a percentage to define the threshold for non-sustainability. For Tarbela, this was 95%—or, in other words, if the reservoir lost 95% of its initial storage capacity it would be considered non-sustainable. RESCON also prompts users to define the maximum duration of financial analysis, which was 300 years in this case. Using these two inputs, and when the automatic solution is used, RESCON adjusts the amount of dredged material to maintain at least 5% of the storage capacity over 300 years.

www.manaraa.com

Analyzing the results when the automatic solution process is turned off, RESCON uses the amount of dredged material per event and mean annual sediment inflow to determine reservoir lifetime. Under this scenario, the reservoir lifetimes appear unaffected, as illustrated in Table 6-2. This is both true and wrong at the same time. The lifetimes under each scenario (i.e., 100-, 50-, and 150 Mm^3) were over 300 years, but the fact the reservoir lifetimes were above the defined period of financial analysis does not mean reservoir lifetimes were altogether unaffected. When changing the duration of financial analysis from 300- to 10,000 years, reservoir lifetimes vary between 350- to more than 10,000-years. Thus, it is best to mark “no” to the automatically determined sustainable solution when either accurate data is available or users are desirous to obtain rough estimates of NPV, reservoir lifetime, and long term storage capacity. It is recommended to mark “yes” when users are lacking information to portray this value and are hoping to gain some idea of what amount of dredged material would provide a sustainable solution.

6.2 Cases Not Captured

There were four cases where RESCON and the SMOD differed from the current practice at the reservoirs, namely, the Kulekhani, Sidi Driss, Tarbela, and Upper Karnali Reservoirs. Each of these reservoirs do not practice sediment management, however, it’s undetermined if the reservoir operators and decision makers made a conscious decision to employ no management technique or if there is just nothing being done. This is the main reason for focusing on reservoirs currently practicing sediment management. For instance, none of these reservoirs have a lifetime expectancy greater than 113 years, with the Sidi Driss and Upper Karnali Reservoirs having an expected life of 30 and 0.75 years, respectively. Obviously, this is undesirable and certainly not

www.manaraa.com

sustainable. When analyzed in RESCON 2 and the SMOD, practices are recommended which differ from taking no action.

When considering only the reservoirs that practice sediment management, all ten cases matched appropriate SMOD zones. RESCON 2 did not predict the correct alternatives for the Millsite and El Canadá Reservoirs.

When analyzed in RESCON 2, the NPV of the actually used practice at Millsite Reservoir (dredging) was approximately 36% lower than the highest NPV alternative (no action). Figure 6-1 shows the SMOD with only Millsite. It lies near the border of zone 3, where density current, catchment management, and no action are reasonable practices. Hotchkiss (2019) confirmed irrigators using water from Millsite Reservoir are being impacted by deposition even now. This would factor into sediment management analyses in a detailed study, but RESCON 2 does not currently have a financial, agricultural repercussion resulting from sedimentation.

6.3 RESCON 2 Simulated Values and Real Values

The acceptable alternatives for Gebidem Reservoir in RESCON would be no action, flushing, and HSRS. At Gebidem, flushing is used quite successfully and a sediment balance has nearly been achieved—that is, outgoing sediments are equal to incoming sediments (Chamoun et al. 2016; Meile et al. 2014; Emamgholizadeh et al. 2006). The reservoir life is perpetuated almost indefinitely, yet RESCON suggests the lifetime of Gebidem under a flushing regime would last about 90 years, clearly shorter than the actual lifetime. Actual data for the other reservoirs are not currently available, so a complete comparison of RESCON-vs-real values cannot be compiled. Nonetheless, at least in the case of Gebidem, there is significant disparity between calculated and real values.

www.manaraa.com

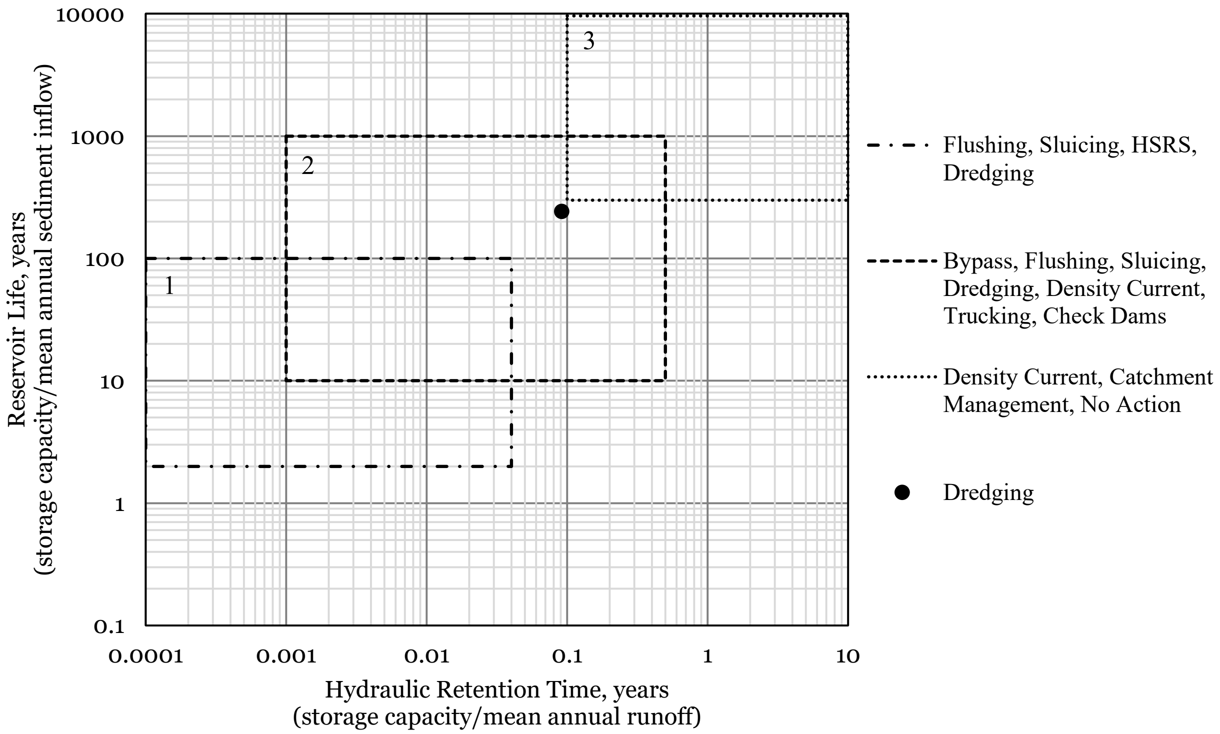

Figure 6-1: SMOD with only Millsite Reservoir

6.4 Assessing RESCON 2 as a Pre-Feasibility Program

While RESCON matched eight of the ten reservoirs with its analysis to the current practice, all ten reservoirs practicing sediment management correlated with appropriate SMOD zones. A reasonable question may then be asked, “If the SMOD requires only three parameters and RESCON 2 requires 233, why bother using RESCON?” This question is further strengthened by recalling RESCON does not account for agricultural repercussions from sedimentation and the disparity between the computed and actual lifetime of Gebidem Reservoir under a flushing regime.

Although RESCON 2 may not yield information revealed in a detailed analysis, the rapid assessment and feedback provided by the program are valuable and informative at the conceptual stage of projects. All of the major sediment management techniques thus far developed can be

المنارة للاستشارات
www.manaraa.com

evaluated from both an economic and sustainable development perspective. The SMOD zones contained the actually used practice in all ten cases but, unlike RESCON, it provides no economic analysis, is not able to adjust for climate change, does not consider the presence or absence of low-level outlets, nor does it attempt to organize the various alternatives, in the sense that some options are likely to be better than others. RESCON 2 can help bridge the gap between potential alternatives (based on SMOD zones) and knowing which practices to begin investigating (based on financial appraisals, etc.).

المنارة للاستشارات

www.manaraa.com

7 RECOMMENDATIONS

As RESCON 2 progresses from a beta to fully developed program, a few concerns if addressed will increase the efficacy of the program and clarity of parameters. Also, using other tools and models can help create a more complete picture of effects from reservoir sedimentation and management strategies and account for model insufficiencies in RESCON.

7.1 HSRS Operation and Maintenance

Under the “Sediment Management” worksheet, there is no input for HSRS operation and maintenance (O&M) costs. RESCON assumes negligible costs are associated with HSRS O&M (Personal communication, Efthymiou 2019), and while they are typically lower than conventional dredging, they aren’t necessarily insignificant. In one case, Zamora (2018) outlined and compared O&M costs for HSRS against conventional dredging at the El Canadá hydropower plant and found HSRS to cost 75% more over a nine-year period. Thus, it is recommended that an HSRS O&M parameter be added to the program. However, if no such improvement is made, there are at least two possibilities to account for HSRS O&M costs.

First, users could determine the lifetime of the reservoir using HSRS, estimate the annual O&M costs, multiply annual O&M costs by the expected lifetime, and add this number to the initial investment required to install HSRS. The second option is to add HSRS O&M costs to the total O&M costs of the reservoir under the “Input (Economic Parameters)” worksheet of the

المنارة للاستشارات
www.manaraa.com

program. This latter alternative is discouraged because adjusting total reservoir O&M costs would affect all sediment management alternatives, not just HSRS. Thus, at least two separate runs would be needed: one to analyze every other sediment management option, and a second for HSRS.

7.2 Unit Benefit of Reservoir Yield

The “unit benefit of reservoir yield” parameter attempts to account for revenues associated with multiple reservoir purposes, including drinking water and irrigation supply, flood control, and hydropower generation (Efthymiou et al. 2017). This single value plays a significant role in calculating NPVs for all sediment management alternatives. As a pre-feasibility analysis, users are not required to perform a detailed study to gain accurate measurements of each of the revenue sources to depict this parameter. Instead, the RESCON 2 user manual provides several sources for estimating this value, yet none of these references are currently listed or found in the manual. Additionally, the manual refers to this parameter as “unit benefit of water yield.” Using the same term in both the program and manual would likely decrease confusion about this variable.

Because this parameter controls all estimates of NPV, it may be beneficial to expand it into multiple variables which this parameter is meant to consider. For instance, Table 7-1 gives specific revenue sources that more clearly indicate which factors apply and potential units for each respective field.

المنارة للاستشارات
www.manaraa.com

Table 7-1: Potential Expansion of Unit Benefit of Reservoir Yield

Current Parameter	Recommended Parameters	Unit
Unit benefit of reservoir yield	Hydroelectric generation	\$/kWh
	Agricultural use	$\$/m^3$
	Municipality use	$\$/m^3$
	Industrial use	$\$/m^3$
	Flood control	\$/year
	Recreational benefits	\$/year

7.3 Bugs and Treatments

Sensitivity tests indicated the flushing O&M parameter is not factored into the NPV calculation. For instance, the Tarbela reservoir was run with two very different O&M costs: $0 and $1,000,000,000. The aggregate NPV remained the same for both cases. This phenomenon was confirmed in other models as well. Additionally, there is a cap on how much sediment RESCON 2 can handle. For example, the Sanmenxia Reservoir, which is known for having extremely high sedimentation rates (Wang et al. 2005), could not be simulated without reducing the mean annual sediment inflow by nearly 40%. It was confirmed and assurance was given that these were, in fact, bugs in the program and would be treated in later versions of RESCON 2 (Personal communication, Efthymiou 2019). In lieu of this, it may be helpful to include a list of all RESCON 2 versions with build numbers and bug treatments. This would help users know if they have the most up-to-date version of the program and if their problem has been resolved with new builds. Some options for performing this would be GitHub, an open source data management tool, GitLab, BitBucket, SourceForge, and/or Launchpad. Similarly, having a system for users to report bugs or suggest recommendations could be helpful to further enhance RESCON's efficacy.

المنارة للاستشارات

www.manaraa.com

7.4 Using the SMOD with RESCON

In the ten reservoirs analyzed and practicing sediment management, the SMOD zones contained each of the various practices implemented at each respective reservoir. To minimize the number of alternatives assessed in RESCON, it is recommended to use the SMOD as an initial assessment of sediment management alternatives. Then, effort could be spent on obtaining information for those methods, thus reducing the time needed for developing a model in and running RESCON.

7.5 Looking Beyond RESCON

RESCON uses an empirical approach for sediment trapping and reservoir capacity, as well as water yield. Using physics-based models can provide details and information not provided by empirical analyses (for instance, see Salloum and Gharagozloo 2014; Kleinhans and Van den Berg 2011). Such models will be based on equations for the conservation of mass (water and sediment) and momentum and will require additional equations for sediment transport competency and losses due to friction and turbulence.

RESCON attempts to account for environmental and ecological impacts, however, other tools for directly assessing these effects have been developed and should be considered. For instance, Glavan et al. (2019) presented a tool for eco-remediation mitigation measures. The main purpose of the tool was "to support decisions and measures taken to correct defined problems and to improve water quality and storage capacity in [a] watershed while minimising[*sic*] sediment transport." The tool focused on user-defined critical source areas within a watershed and showed that sediment inflow could be reduced by up to 30%. As another example, Sanderson et al. (2011) presented a watershed flow evaluation tool used to evaluate

www.manaraa.com

ecological impacts and risks. The tool was implemented in two cases, and successfully assessed risks across an 840,000-acre watershed but was unable to accomplish this in the other, due to active channel change and limited data.

للاستشارات المنارة
www.manaraa.com

8 CONCLUSIONS

Annual global reservoir storage capacity loss due to sedimentation is around 40 million acre-ft (50 km^3). Rates of sedimentation vary, but all dams change the natural flow regimes and can have significant impacts on the local infrastructure, ecology, and environment. Over the last several decades, several sediment management alternatives have been developed to mitigate these impacts and prolong the useful life of reservoirs. More recently, focus has shifted from developing techniques to determining which practices best suit the needs of the reservoir. RESCON 2 is a pre-feasibility tool meant to help and guide users in a rapid assessment of potential solutions to the sediment issues experienced at their dam. This analysis of RESCON 2 Beta found the program correctly predicts the actual practice very often.

Several recommendations are suggested to improve or enhance RESCON's approach to assess sediment management alternatives. In summary, it is recommended to:

1) Include a parameter for HSRS O&M;
2) Use identical terms for the unit benefit of reservoir yield parameter in both the model and user manual, and expand this parameter to more explicitly state what this value is meant to consider;
3) Include sources for estimating the unit benefit of reservoir yield in the user manual's reference list;
4) Incorporate flushing O&M costs to factor into the NPV calculation;
5) Increase the annual sediment inflow capacity to allow for higher sedimentation rates;
6) Provide a list of RESCON model builds and versions to clearly indicate which bugs have been treated using GitHub or other open source data management tools; and

www.manaraa.com

7) Use the SMOD as an initial pre-feasibility tool to determine sediment management practices to then analyze in RESCON.

The primary limitation to this research was the lack of available data necessary to compose RESCON models. As already stated, there are some 200+ variables needed to run the program and limited data is publicly obtainable. Furthermore, of the twenty models analyzed, only ten practiced sediment management, making it difficult to compare RESCON results against the ideal alternatives. Having a larger pool of datasets on reservoirs practicing sediment management would enhance future evaluations of RESCON 2. Additionally, having more models that span a greater set of sediment management practices could improve analyses. The majority of reservoirs used in this study and that practiced sediment management used flushing (60%). By including greater variety in the management type (i.e., reservoirs using bypass tunnels, catchment management, density current venting, etc.), potential strengths and weaknesses of the program could become more apparent.

المنارة للاستشارات
www.manaraa.com

REFERENCES

(NPS) National Park Service. (2015). “Sedimentation of Lake Mead.” Retrieved 8 May, 2019, from https://www.nps.gov/lake/learn/nature/sedimentation-lake-mead.htm.

Adhikari, S. (2017). Evaluating Sediment handling strategies for Banja Reservoir using the RESCON2 model-A comprehensive study of the rapid assessment tool for sustainable sediment management, NTNU.

Annandale, G. (2013). Quenching the Thirst: Sustainable Water Supply and Climate Change. North Charleston, SC, CreateSpace Independent Publishing Platform.

Annandale, G. (2017). Personal Communication.

Annandale, G. W. (2006). "Reservoir sedimentation." Encyclopedia of Hydrological Sciences.

Annandale, G. W. (2019). Personal Communication.

Annandale, G. W., et al. (2016). Extending the Life of Reservoirs, Washington, DC: World Bank.

Annandale, G. W., et al. (2017). RESCON 2: Rapid identification of optimal strategies to mitigate reservoir sedimentation and climate change impacts on water supply reliability. Water Storage and Hydropower Development for Africa, Marrakech, Morocco, The International Journal on Hydropower & Dams.

Aras, T. (2009). Cost Analysis of sediment removal techniques from reservoir, Ms Thesis, Dept. of Civil Engineering, Hydromechanics Laboratory, Middle East Technical Unversity.

Auel, C., et al. (2016). Positive effects of reservoir sedimentation management on reservoir life–examples from Japan. Proceedings of 84th annual meeting of ICOLD, Johannesburg, South Africa.

Basson, G. (2009). Management of siltation in existing and new reservoirs. General Report Q. 89. 23rd Congress of the CIGB-ICOLD, Brasilia, Brazil.

Basson, G., et al. (1998). "Alessandro Palmieri, Farhed Shah, 2 Ariel Dinar1."

المنارة للاستشارات

www.manaraa.com

Basson, G. R. (1996). Hydraulics of Reservoir Sedimentation, University of Stellenbosch. **Doctor of Philosophy**.

Basson, G. R. (2018). Personal Communication.

Boes, R. M. and M. Hagmann (2015). Sedimentation countermeasures—Examples from Switzerland. Proceedings of the First International Workshop on Sediment Bypass Tunnels, Zurich, Switzerland.

Brundtland, G. H., et al. (1987). "Our common future." New York.

Carlisle, D. M., et al. (2011). "Alteration of streamflow magnitudes and potential ecological consequences: a multiregional assessment." Frontiers in Ecology and the Environment **9**(5): 264-270.

Chamoun, S., et al. (2016). "Managing reservoir sedimentation by venting turbidity currents: A review." International Journal of Sediment Research **31**(3): 195-204.

Chin, C. O., et al. (1994). "Streambed armoring." Journal of Hydraulic Engineering **120**(8): 899-918.

Coker, H. E., et al. (2009). "Conversion of a Missouri River Dam and Reservoir to a Sustainable System: Sediment Management 1." JAWRA Journal of the American Water Resources Association **45**(4): 815-827.

De Miranda, R. B. and F. F. Mauad (2014). "Influence of sedimentation on hydroelectric power generation: Case study of a Brazilian reservoir." Journal of Energy Engineering **141**(3): 04014016.

Dendy, F., et al. (1973). "Reservoir sedimentation surveys in the United States." Washington DC American Geophysical Union Geophysical Monograph Series **17**: 349-357.

Dudgeon, D., et al. (2006). "Freshwater biodiversity: importance, threats, status and conservation challenges." Biological reviews **81**(2): 163-182.

Efthymiou, N. (2019). Personal Communication.

Efthymiou, N., et al. (2017). Rapid Assessment Tool for Sustainable Sediment Management: Reservoir Conservation (RESCON 2) Beta Version, The World Bank.

Emamgholizadeh, S., et al. (2006). "Investigation and evaluation of the pressure flushing through storage reservoir." ARPN Journal of Engineering and Applied Sciences **1**(4): 7-16.

George, M. W., et al. (2016). "Reservoir Sustainability and Sediment Management." Journal of Water Resources Planning and Management **143**(3).

www.manaraa.com

Gill, M. A. (1979). "Sedimentation and useful life of reservoirs." Journal of Hydrology **44**(1-2): 89-95.

Glavan, M., et al. (2019). "A tool for the selection and implementation of eco-remediation mitigation measures." Ecological Engineering **130**: 53-66.

Gowans, A., et al. (1999). "Movements of adult Atlantic salmon in relation to a hydroelectric dam and fish ladder." Journal of Fish Biology **54**(4): 713-726.

Hossain, F., et al. (2012). "Climate feedback–based provisions for dam design, operations, and water management in the 21st century." Journal of Hydrologic Engineering **17**(8): 837-850.

Hotchkiss, R. H. (2018). Personal Communication.

Hotchkiss, R. H. (2019). Personal Communication.

Jellyman, P. and J. Harding (2012). "The role of dams in altering freshwater fish communities in New Zealand." New Zealand Journal of Marine and Freshwater Research **46**(4): 475-489.

Ketelsen, T., et al. (2013). Assessing the impact of sedimentation on reservoir life: example from Yali, Viet Nam.

Kimbrel, S., et al. (2014). Paonia Reservoir Sediment Management. AGU Fall Meeting Abstracts.

Kleinhans, M. G. and J. H. Van den Berg (2011). "River channel and bar patterns explained and predicted by an empirical and a physics ‐ based method." Earth Surface Processes and Landforms **36**(6): 721-738.

Kondolf, G. M. (1997). "Hungry Water: Effects of Dams and Gravel Mining on River Channels." Environmental Management **21**(4): 533-551.

Kondolf, G. M., et al. (2014). "Sustainable sediment management in reservoirs and regulated rivers: Experiences from five continents." Earth's Future **2**(5): 256-280.

Lehner, B., et al. (2011). Global reservoir and damg (grand) database. Technical Documentation, Version 1.1**:** Technical Documentation.

Ligon, F. K., et al. (1995). "Downstream ecological effects of dams." BioScience **45**(3): 183-192.

Mahmood, K. (1987). Reservoir sedimentation: impact, extent, and mitigation. Technical paper, International Bank for Reconstruction and Development, Washington, DC (USA).

Malini, B. H. and K. N. Rao (2004). "Coastal erosion and habitat loss along the Godavari delta front- a fallout of dam construction (?)." Current Science **87**(9): 1232-1236.

www.manaraa.com

Meile, T., et al. (2014). "Reservoir sedimentation management at Gebidem Dam (Switzerland)." Reservoir Sedimentation; Schleiss, A., De Cesare, G., Franca, MJ, Pfister, M., Eds: 245-255.

Morris, G. and J. Fan (1997). Reservoir Sedimentation Handbook. Chapter 4: Concepts of Reservoir Limnology, McGraw-Hill.

Murthy, B. (1977). Life of reservoir, Central Board of Irrigation and Power.

Nordin Jr, C. (1991). "JC Stevens and the silt problem—A review." Journal of Sediment Research **3**: 1-18.

Palmieri, A., et al. (2003). "Reservoir conservation volume I: The RESCON approach." Washington, DC: World Bank.

Palmieri, R., et al. (1998). "Reservoir sedimentation and the sustainable management of dams."

Pattanapanchai, M., et al. (2002). Sediment Management In Flood Control Dams. American Agricultural Economics Association Annual Meeting 2002 (New Name 2008: Agricultural and Applied Economics Association), Long Beach, CA.

Pilkey Jr, O. H. and E. R. Thieler (1992). "Erosion of the United States shoreline."

Pilkey, O. H., et al. (1991). "Coastal erosion." Episodes **14**(1): 46-51.

Pringle, C. M., et al. (2000). "Regional Effects of Hydrologic Alterations on Riverine Macrobiota in the New World: Tropical-Temperate Comparisons: The massive scope of large dams and other hydrologic modifications in the temperate New World has resulted in distinct regional trends of biotic impoverishment. While neotropical rivers have fewer dams and limited data upon which to make regional generalizations, they are ecologically vulnerable to increasing hydropower development and biotic patterns are emerging." BioScience **50**(9): 807-823.

Quadroni, S., et al. (2016). "Effects of sediment flushing from a small Alpine reservoir on downstream aquatic fauna." Ecohydrology **9**(7): 1276-1288.

Randle, T. (2018). Personal Communication.

Randle, T., et al. (2017). Frequently Asked Questions about Reservoir Sedimentation and Sustainability, Subcommittee on Sedimentation, National Reservoir Sedimentation and ….

Salloum, M. and P. E. Gharagozloo (2014). "Empirical and physics-based mathematical models of uranium hydride decomposition kinetics with quantified uncertainty." Chemical Engineering Science **116**: 452-464.

Sanderson, J., et al. (2012). "Getting to scale with environmental flow assessment: the watershed flow evaluation tool." River Research and Applications **28**(9): 1369-1377.

المنارة للاستشارات

www.manaraa.com

Schellenberge, G., et al. (2017). "Dealing with Sediment: Effects on Dams and Hydropower Generation." Retrieved 6 June, 2019, from https://www.hydroworld.com/articles/print/volume-25/issue-1/features/dealing-with-sediment-effects-on-dams-and-hydropower-generation.html.

Schleiss, A. and G. De Cesare (2010). "Physical model experiments on reservoir sedimentation." Journal of Hydraulic Research **48**(ARTICLE): 54-57.

Schleiss, A. J., et al. (2016). "Reservoir sedimentation." Journal of Hydraulic Research **54**(6): 595-614.

Shrestha, H. S. (2018). Sedimentation and sediment handling in Himalayan reservoirs.

Slagel, M. J. and G. B. Griggs (2008). "Cumulative losses of sand to the California coast by dam impoundment." Journal of Coastal Research: 571-584.

Sumi, T. and T. Hirose (2009). "Accumulation of sediment in reservoirs." Water Storage, Transport, and Distribution, Encyclopedia of Life Support Systems; Takahasi, Y., Ed: 224-252.

Sumi, T. and S. Kantoush (2016). Sediment Management Option by Sediment Sluicing in the Mimi River, Japan. Proceedings of 12th International Conference on Hydro-Science & Engineering.

Sumi, T., et al. (2015). Retrofitting and change in operation of cascade dams to facilitate sediment sluicing in the Mimikawa River Basin. Proc. 25th congress of ICOLD, Stavanger, Q.

Summers, J. K. and L. M. Smith (2014). "The role of social and intergenerational equity in making changes in human well-being sustainable." Ambio **43**(6): 718-728.

Vanoni, V. A. (1975). "Sedimentation engineering, ASCE manuals and reports on engineering practice—No. 54." American Society of Civil Engineers, New York, NY.

Walling, D. and B. Webb (1996). "Erosion and sediment yield: a global overview." IAHS Publications-Series of Proceedings and Reports-Intern Assoc Hydrological Sciences **236**: 3-20.

Wang, G., et al. (2005). "Sedimentation problems and management strategies of Sanmenxia Reservoir, Yellow River, China." Water resources research **41**(9).

Wilcock, P. R. and B. T. DeTemple (2005). "Persistence of armor layers in gravel - bed streams." Geophysical Research Letters **32**(8).

Wu, B. (2018). Personal Communication.

Zamora, J. (2018). Assessment of Sediment Handling Strategies in the Regulation Pond of El Canadá Hydropower Plant, Guatemala-Processing and analyzing sediment information collected in situ, NTNU.

المنارة للاستشارات

www.manaraa.com

APPENDIX A. RESCON 2 MODELS: SEDIMENT MANAGEMENT PRACTICED

Baira Reservoir

Table A-1: Reservoir Geometry

ID	Parameter	Units	Description	Value
1.1.1	So_gr	[m³]	Original gross storage capacity of the reservoir	2,400,000
1.1.2	So_a	[m³]	Original active storage capacity of the reservoir	2,100,000
1.1.3	So_d	[m³]	Original inactive storage capacity of the reservoir	300,000
1.1.4	Se_gr	[m³]	Existing gross storage capacity of the reservoir	2,040,000
1.1.5	Se_a	[m³]	Existing active storage of the reservoir	1,800,000
1.1.6	Se_d	[m³]	Existing inactive storage of the reservoir	240,000
1.1.7	Wbot	[m]	Representative reservoir bottom width at the dam location	25
1.1.8	--	--	--	--
1.1.9	ELOWL	[masl]	Maximum pool elevation of reservoir	51
1.1.10	ELMWL	[masl]	Minimum operation water level	20
1.1.11	Elbmin	[masl]	Minimum reservoir bed elevation at dam site	0
1.1.12	Lres	[m]	Reservoir length	4,100
1.1.13	ncomp	[-]	Number of reservoir compartments	5

المنارة للاستشارات
www.manaraa.com

Table A-2: Hydrology and Sediment

ID	Parameter	Units	Description	Value
2.1.1.1	MAR	[million m^3/a]	Mean annual reservoir water inflow	1,000
2.1.1.2	Cv	[-]	Coefficient of variation of annual run-off volume	0.50
2.1.1.3	Twater	[°C]	Representative water temperature in the reservoir	10
2.1.2.1	r_d	[tonnes/m^3]	Specific weight of in-situ reservoir sediment (bulk density)	1.25
2.1.2.2	MAS	[million tonnes/a]	Mean annual total (suspended and bedload) sediment inflow mass	0.30
2.1.2.3		[g/l]	Average annual concentration of suspended load	0.270
2.1.2.3	ExceedT	[%]	Percentage of time exceeded	30, 60, 90
	ExceedMAR	[%]	Percentage of mean annual water inflow	40, 20, 3
	ExceedMAS	[%]	Percentage of mean annual sediment inflow	25, 5, 3
2.1.2.4	pcl	[%]	% clay of suspended sediment inflow	--
2.1.2.5	psi	[%]	% silt of suspended sediment inflow	--
2.1.2.6	psa	[%]	% sand of suspended sediment inflow	--
2.1.2.7	ws_cl	[m/s]	Settling velocity of clay particles	--
2.1.2.8	ws_si	[m/s]	Settling velocity of silt particles	--
2.1.2.9	ws_sa	[m/s]	Settling velocity of sand particles	--
2.1.2.10	TE_Method		Trap efficiency method	Brune
2.1.2.11	Brune Curve No	[-]		2
2.1.2.12	p_b	[%]	% bedload of total sediment inflow	10.00
2.1.2.13	T_b	[%]	Duration of bedload transport	5
2.1.3.1	Zpr		Standardized normal nariate at pr*100%	2.33
2.1.3.2	Gd		Gould's correction factor	1.50
2.1.3.3	Sd		Standard deviation of annual run-off	500,000,000
2.1.3.4	Distribution		Distribution of annual inflows	Lognormal

للاستشارات المنارة
www.manaraa.com

Table A-3: Sediment Management – Flushing

ID	Parameter	Units	Description	Value
3.2.1.1	Y	[-]	Indicator of deposits type	300
3.2.1.2	Ans	3 or 1	Sediment removal difficulty	3
3.2.1.3	Qf	[m3/s]	Representative flushing discharge	100
3.2.1.4	Tf	[days]	Duration of flushing after complete drawdown	2
3.2.1.5	Cal_SSfl	[-]	Calibration parameter for Mignot equation	10
3.2.1.6	CLF	[%]	Maximum percent of capacity loss allowable	75
3.2.1.7	s1	[%]	Fraction of run-of-river benefits	90
3.2.1.8	s2	[%]	Fraction of storage benefits	90
3.2.1.9	FI	[US$]	Cost of capital investment	0
3.2.1.10	Elfl_dam	[masl]	Water elevation at dam during flushing	20
3.2.1.12	Shall the implementation strategy of flushing be determined through economic optimization?			No
3.2.1.13	CycleNS	[Years]	Time interval between flushing events during the 1st phase (Reservoir storage > sustainable long term reservoir capacity)	1
3.2.1.14	CycleS	[Years]	Time interval between flushing events during the 2nd phase (Reservoir storage < sustainable long term reservoir capacity)	1
3.2.1.15	OMC_FL	[US$/a]	Annual operation and maintenance costs of flushing	0

Table A-4: Sediment Management - Dredging

ID	Parameter	Units	Description	Value
3.2.2.1	Cw	[%]	Concentration by weight of sediment removed to water removed by traditional dredging	30
3.2.2.2	CLD	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for dredging	75
3.2.2.3	ASD	[%]	Maximum percent of reservoir storage that can be restored during each dredging event	80
3.2.2.4	MD	[m3]	Amount of sediment removed per dredging event	180,000
3.2.2.5	PD	[$/m3]	Unit value of water used in dredging operations	0.005
3.2.2.6	CD	[$/m3]	Unit cost of dredging	5
3.2.2.7	Shall the unit cost of dredging be determined automatically?			Yes
3.2.2.8	Shall the implementation strategy of dredging be determined through economic optimization?			No
3.2.2.9	Cycle1DR	[years]	Duration of phase 1 (No dredging)	1
3.2.2.10	Cycle2DR	[years]	Cycle length in phase 2 (Dredging operation)	1
3.2.2.11	Shall a sustainable solution be determined automatically?			No
3.2.2.12	Where do you want to perform dredging?			Active Storage

المنارة للاستشارات
www.manaraa.com

Table A-5: Sediment Management – HSRS

ID	Parameter	Units	Description	Value
3.2.3.1	Type	1 or 2	Sediment type category to be removed by Hydrosuction Sediment Removal System (HSRS)	1
3.2.3.2	D	[m]	Assume a trial pipe diameter for HSRS	0.46
3.2.3.3	NP	1, 2, or 3	Number of pipes for HSRS	1
3.2.3.4	YA	[%]	Maximum fraction of total yield that is allowed to be used in HSRS operations	10
3.2.3.5	CLH	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for HSRS	75
3.2.3.6	PH	[$/m3]	Unit value of water released downstream of dam in river by HSRS operations	0.005
3.2.3.7	HI	[US$]	Cost of capital investment to install HSRS	0
3.2.3.8	DU	[Years]	The expected life of HSRS	25
3.2.3.9	Shall the implementation strategy of HSRS be determined through economic optimization?			No
3.2.3.10	Year HSRSstart	[Years]	Timing of HSRS installation	1
3.2.3.11	HSRSlimit	[m]	Length limit for implementation of HSRS	4,100

Table A-6: Sediment Management – Trucking

ID	Parameter	Units	Description	Value
3.2.4.1	CLT	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for trucking	75
3.2.4.2	AST	[%]	Maximum percent of reservoir storage that can be restored during each trucking event	80
3.2.4.3	MT	[m3]	Amount of sediment removed per trucking event	180,000
3.2.4.4	CT	[US$/m3]	Unit Cost of trucking	13
3.2.4.5	Shall the implementation strategy of trucking be determined through economic optimization?			No
3.2.4.6	Cycle1TR	[years]	Implementation year	1
3.2.4.7	Cycle2TR	[years]	Frequency of trucking operation	1
3.2.4.8	Shall a sustainable solution be determined automatically?			No
3.2.4.9	Where do you want to perform trucking?			Active Storage
3.2.4.10	sTR	[%]	Fraction of reservoir water yield the year trucking occurs	90

المنارة للاستشارات
www.manaraa.com

Table A-7: Economic Parameters

ID	Parameter	Units	Description	Value
4.1				
4.2	c	[$/m3]	Unit cost of construction per m3 of reservoir capacity	3.04
4.3	C2	[$]	Total cost of reservoir impoundment	0
4.4	r	[%]	Discount rate	5.0
4.5	Mr	[%]	Market interest rate of annual retirement fund	5.9
4.6	P1	[$/m3]	Unit benefit of reservoir yield	0.1
4.7	V	[$]	Decommissioning cost	0
4.8	CL_NS	[%]	Capacity loss for characterization of a reservoir as non sustainable	75
4.9	C1	[$/a]	Total annual operation and maintenance costs	100,000
4.10				
4.11				
4.12				
4.13			Application of declining discount rate?	No
4.14	Ymax	[years]	Maximum duration of financial analysis	300

المنارة للاستشارات
www.manaraa.com

Çubuk Reservoir

Table A-8: Reservoir Geometry

ID	Parameter	Units	Description	Value
1.1.1	So_gr	[m³]	Original gross storage capacity of the reservoir	7,100,000
1.1.2	So_a	[m³]	Original active storage capacity of the reservoir	4,800,000
1.1.3	So_d	[m³]	Original inactive storage capacity of the reservoir	2,300,000
1.1.4	Se_gr	[m³]	Existing gross storage capacity of the reservoir	3,550,000
1.1.5	Se_a	[m³]	Existing active storage of the reservoir	2,400,000
1.1.6	Se_d	[m³]	Existing inactive storage of the reservoir	1,150,000
1.1.7	Wbot	[m]	Representative reservoir bottom width at the dam location	57
1.1.8	--	--	--	--
1.1.9	ELOWL	[masl]	Maximum pool elevation of reservoir	907.6
1.1.10	ELMWL	[masl]	Minimum operation water level	895.0
1.1.11	Elbmin	[masl]	Minimum reservoir bed elevation at dam site	882.6
1.1.12	Lres	[m]	Reservoir length	6.500
1.1.13	ncomp	[-]	Number of reservoir compartments	5

المنارة للاستشارات
www.manaraa.com

Table A-9: Hydrology and Sediment

ID	Parameter	Units	Description	Value
2.1.1.1	MAR	[million m^3/a]	Mean annual reservoir water inflow	28
2.1.1.2	Cv	[-]	Coefficient of variation of annual run-off volume	0.10
2.1.1.3	Twater	[°C]	Representative water temperature in the reservoir	10
2.1.2.1	r_d	[tonnes/m^3]	Specific weight of in-situ reservoir sediment (bulk density)	1.8
2.1.2.2	MAS	[million tonnes/a]	Mean annual total (suspended and bedload) sediment inflow mass	0.08
2.1.2.3		[g/l]	Average annual concentration of suspended load	2.604
2.1.2.3	ExceedT	[%]	Percentage of time exceeded	30, 60, 90
	ExceedMAR	[%]	Percentage of mean annual water inflow	40, 20, 3
	ExceedMAS	[%]	Percentage of mean annual sediment inflow	25, 5, 3
2.1.2.4	pcl	[%]	% clay of suspended sediment inflow	--
2.1.2.5	psi	[%]	% silt of suspended sediment inflow	--
2.1.2.6	psa	[%]	% sand of suspended sediment inflow	--
2.1.2.7	ws_cl	[m/s]	Settling velocity of clay particles	--
2.1.2.8	ws_si	[m/s]	Settling velocity of silt particles	--
2.1.2.9	ws_sa	[m/s]	Settling velocity of sand particles	--
2.1.2.10	TE_Method		Trap efficiency method	Brune
2.1.2.11	Brune Curve No	[-]		3
2.1.2.12	p_b	[%]	% bedload of total sediment inflow	10.00
2.1.2.13	T_b	[%]	Duration of bedload transport	5
2.1.3.1	Zpr		Standardized normal nariate at pr*100%	2.33
2.1.3.2	Gd		Gould's correction factor	1.50
2.1.3.3	Sd		Standard deviation of annual run-off	2,800,000
2.1.3.4	Distribution		Distribution of annual inflows	Lognormal

المنارة للاستشارات
www.manaraa.com

Table A-10: Sediment Management – Flushing

ID	Parameter	Units	Description	Value
3.2.1.1	Y	[-]	Indicator of deposits type	180
3.2.1.2	Ans	3 or 1	Sediment removal difficulty	3
3.2.1.3	Qf	[m3/s]	Representative flushing discharge	27
3.2.1.4	Tf	[days]	Duration of flushing after complete drawdown	5
3.2.1.5	Cal_SSfl	[-]	Calibration parameter for Mignot equation	10
3.2.1.6	CLF	[%]	Maximum percent of capacity loss allowable	99
3.2.1.7	s1	[%]	Fraction of run-of-river benefits	90
3.2.1.8	s2	[%]	Fraction of storage benefits	90
3.2.1.9	FI	[US$]	Cost of capital investment	2,000,000
3.2.1.10	Elfl_dam	[masl]	Water elevation at dam during flushing	895
3.2.1.12	Shall the implementation strategy of flushing be determined through economic optimization?			Yes
3.2.1.13	CycleNS	[Years]	Time interval between flushing events during the 1st phase (Reservoir storage > sustainable long term reservoir capacity)	1
3.2.1.14	CycleS	[Years]	Time interval between flushing events during the 2nd phase (Reservoir storage < sustainable long term reservoir capacity)	1
3.2.1.15	OMC_FL	[US$/a]	Annual operation and maintenance costs of flushing	0

Table A-11: Sediment Management – Dredging

ID	Parameter	Units	Description	Value
3.2.2.1	Cw	[%]	Concentration by weight of sediment removed to water removed by traditional dredging	30
3.2.2.2	CLD	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for dredging	60
3.2.2.3	ASD	[%]	Maximum percent of reservoir storage that can be restored during each dredging event	90
3.2.2.4	MD	[m3]	Amount of sediment removed per dredging event	1,000,000
3.2.2.5	PD	[$/m3]	Unit value of water used in dredging operations	0.001
3.2.2.6	CD	[$/m3]	Unit cost of dredging	15
3.2.2.7	Shall the unit cost of dredging be determined automatically?			No
3.2.2.8	Shall the implementation strategy of dredging be determined through economic optimization?			Yes
3.2.2.9	Cycle1DR	[years]	Duration of phase 1 (No dredging)	1
3.2.2.10	Cycle2DR	[years]	Cycle length in phase 2 (Dredging operation)	1
3.2.2.11	Shall a sustainable solution be determined automatically?			No
3.2.2.12	Where do you want to perform dredging?			Active Storage

المنارة للاستشارات
www.manaraa.com

Table A-12: Sediment Management – HSRS

ID	Parameter	Units	Description	Value
3.2.3.1	Type	1 or 2	Sediment type category to be removed by Hydrosuction Sediment Removal System (HSRS)	1
3.2.3.2	D	[m]	Assume a trial pipe diameter for HSRS	1.2
3.2.3.3	NP	1, 2, or 3	Number of pipes for HSRS	3
3.2.3.4	YA	[%]	Maximum fraction of total yield that is allowed to be used in HSRS operations	10
3.2.3.5	CLH	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for HSRS	60
3.2.3.6	PH	[$/m3]	Unit value of water released downstream of dam in river by HSRS operations	0.001
3.2.3.7	HI	[US$]	Cost of capital investment to install HSRS	1,000,000
3.2.3.8	DU	[Years]	The expected life of HSRS	10
3.2.3.9	Shall the implementation strategy of HSRS be determined through economic optimization?			Yes
3.2.3.10	Year HSRSstart	[Years]	Timing of HSRS installation	1
3.2.3.11	HSRSlimit	[m]	Length limit for implementation of HSRS	6,500

Table A-13: Sediment Management – Trucking

ID	Parameter	Units	Description	Value
3.2.4.1	CLT	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for trucking	60
3.2.4.2	AST	[%]	Maximum percent of reservoir storage that can be restored during each trucking event	90
3.2.4.3	MT	[m3]	Amount of sediment removed per trucking event	3,600,000
3.2.4.4	CT	[US$/m3]	Unit Cost of trucking	4
3.2.4.5	Shall the implementation strategy of trucking be determined through economic optimization?			Yes
3.2.4.6	Cycle1TR	[years]	Implementation year	1
3.2.4.7	Cycle2TR	[years]	Frequency of trucking operation	1
3.2.4.8	Shall a sustainable solution be determined automatically?			No
3.2.4.9	Where do you want to perform trucking?			Active storage
3.2.4.10	sTR	[%]	Fraction of reservoir water yield the year trucking occurs	30

المنارة للاستشارات
www.manaraa.com

Table A-14: Economic Parameters

ID	Parameter	Units	Description	Value
4.1				
4.2	c	[$/m3]	Unit cost of construction per m3 of reservoir capacity	2.46
4.3	C2	[$]	Total cost of reservoir impoundment	0
4.4	r	[%]	Discount rate	10.0
4.5	Mr	[%]	Market interest rate of annual retirement fund	10.0
4.6	P1	[$/m3]	Unit benefit of reservoir yield	0.93
4.7	V	[$]	Decommissioning cost	4,500,000
4.8	CL_NS	[%]	Capacity loss for characterization of a reservoir as non sustainable	99
4.9	C1	[$/a]	Total annual operation and maintenance costs	175,000
4.10				
4.11				
4.12				
4.13			Application of declining discount rate?	No
4.14	Ymax	[years]	Maximum duration of financial analysis	300

المنارة للاستشارات
www.manaraa.com

El Canadá

Table A-15: Reservoir Geometry

ID	Parameter	Units	Description	Value
1.1.1	So_gr	[m³]	Original gross storage capacity of the reservoir	200,000
1.1.2	So_a	[m³]	Original active storage capacity of the reservoir	185,000
1.1.3	So_d	[m³]	Original inactive storage capacity of the reservoir	15,000
1.1.4	Se_gr	[m³]	Existing gross storage capacity of the reservoir	100,000
1.1.5	Se_a	[m³]	Existing active storage of the reservoir	100,000
1.1.6	Se_d	[m³]	Existing inactive storage of the reservoir	0
1.1.7	Wbot	[m]	Representative reservoir bottom width at the dam location	50
1.1.8	--	--	--	--
1.1.9	ELOWL	[masl]	Maximum pool elevation of reservoir	1,417.5
1.1.10	ELMWL	[masl]	Minimum operation water level	1,409.0
1.1.11	Elbmin	[masl]	Minimum reservoir bed elevation at dam site	1,407.0
1.1.12	Lres	[m]	Reservoir length	165
1.1.13	ncomp	[-]	Number of reservoir compartments	3

المنارة للاستشارات
www.manaraa.com

Table A-16: Hydrology and Sediment

ID	Parameter	Units	Description	Value
2.1.1.1	MAR	[million m^3/a]	Mean annual reservoir water inflow	476
2.1.1.2	Cv	[-]	Coefficient of variation of annual run-off volume	0.20
2.1.1.3	Twater	[°C]	Representative water temperature in the reservoir	15
2.1.2.1	r_d	[tonnes/m^3]	Specific weight of in-situ reservoir sediment (bulk density)	1.1
2.1.2.2	MAS	[million tonnes/a]	Mean annual total (suspended and bedload) sediment inflow mass	0.066
2.1.2.3		[g/l]	Average annual concentration of suspended load	0.107
2.1.2.3	ExceedT	[%]	Percentage of time exceeded	30, 60, 90
	ExceedMAR	[%]	Percentage of mean annual water inflow	40, 20, 3
	ExceedMAS	[%]	Percentage of mean annual sediment inflow	25, 5, 3
2.1.2.4	pcl	[%]	% clay of suspended sediment inflow	--
2.1.2.5	psi	[%]	% silt of suspended sediment inflow	--
2.1.2.6	psa	[%]	% sand of suspended sediment inflow	--
2.1.2.7	ws_cl	[m/s]	Settling velocity of clay particles	--
2.1.2.8	ws_si	[m/s]	Settling velocity of silt particles	--
2.1.2.9	ws_sa	[m/s]	Settling velocity of sand particles	--
2.1.2.10	TE_Method		Trap efficiency method	Brune
2.1.2.11	Brune Curve No	[-]		2
2.1.2.12	p_b	[%]	% bedload of total sediment inflow	23
2.1.2.13	T_b	[%]	Duration of bedload transport	10
2.1.3.1	Zpr		Standardized normal nariate at pr*100%	2.33
2.1.3.2	Gd		Gould's correction factor	1.50
2.1.3.3	Sd		Standard deviation of annual run-off	95,200,000
2.1.3.4	Distribution		Distribution of annual inflows	Lognormal

المنارة للاستشارات
www.manaraa.com

Table A-15: Sediment Management – Dredging

ID	Parameter	Units	Description	Value
3.2.2.1	Cw	[%]	Concentration by weight of sediment removed to water removed by traditional dredging	6
3.2.2.2	CLD	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for dredging	100
3.2.2.3	ASD	[%]	Maximum percent of reservoir storage that can be restored during each dredging event	58
3.2.2.4	MD	[m3]	Amount of sediment removed per dredging event	29,000
3.2.2.5	PD	[$/m3]	Unit value of water used in dredging operations	0.04
3.2.2.6	CD	[$/m3]	Unit cost of dredging	2.8
3.2.2.7	Shall the unit cost of dredging be determined automatically?			No
3.2.2.8	Shall the implementation strategy of dredging be determined through economic optimization?			No
3.2.2.9	Cycle1DR	[years]	Duration of phase 1 (No dredging)	1
3.2.2.10	Cycle2DR	[years]	Cycle length in phase 2 (Dredging operation)	1
3.2.2.11	Shall a sustainable solution be determined automatically?			No
3.2.2.12	Where do you want to perform dredging?			Both active and inactive storage

Table A-18: Sediment Management – HSRS

ID	Parameter	Units	Description	Value
3.2.3.1	Type	1 or 2	Sediment type category to be removed by Hydrosuction Sediment Removal System (HSRS)	1
3.2.3.2	D	[m]	Assume a trial pipe diameter for HSRS	0.30
3.2.3.3	NP	1, 2, or 3	Number of pipes for HSRS	1
3.2.3.4	YA	[%]	Maximum fraction of total yield that is allowed to be used in HSRS operations	100
3.2.3.5	CLH	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for HSRS	100
3.2.3.6	PH	[$/m3]	Unit value of water released downstream of dam in river by HSRS operations	0.04
3.2.3.7	HI	[US$]	Cost of capital investment to install HSRS	500,000
3.2.3.8	DU	[Years]	The expected life of HSRS	20
3.2.3.9	Shall the implementation strategy of HSRS be determined through economic optimization?			Yes
3.2.3.10	Year HSRSstart	[Years]	Timing of HSRS installation	1
3.2.3.11	HSRSlimit	[m]	Length limit for implementation of HSRS	165

المنارة للاستشارات
www.manaraa.com

Table A-19: Economic Parameters

ID	Parameter	Units	Description	Value
4.1				
4.2	c	[$/m3]	Unit cost of construction per m3 of reservoir capacity	27.29
4.3	C2	[$]	Total cost of reservoir impoundment	0
4.4	r	[%]	Discount rate	6.0
4.5	Mr	[%]	Market interest rate of annual retirement fund	6.0
4.6	P1	[$/m3]	Unit benefit of reservoir yield	0.2
4.7	V	[$]	Decommissioning cost	0
4.8	CL_NS	[%]	Capacity loss for characterization of a reservoir as non sustainable	100
4.9	C1	[$/a]	Total annual operation and maintenance costs	55,000
4.10				
4.11				
4.12				
4.13			Application of declining discount rate?	No
4.14	Ymax	[years]	Maximum duration of financial analysis	300

المنارة للاستشارات
www.manaraa.com

Gebidem

Table A-20: Reservoir Geometry

ID	Parameter	Units	Description	Value
1.1.1	So_gr	[m³]	Original gross storage capacity of the reservoir	9,000,000
1.1.2	So_a	[m³]	Original active storage capacity of the reservoir	8,600,000
1.1.3	So_d	[m³]	Original inactive storage capacity of the reservoir	400,000
1.1.4	Se_gr	[m³]	Existing gross storage capacity of the reservoir	8,910,000
1.1.5	Se_a	[m³]	Existing active storage of the reservoir	8,570,000
1.1.6	Se_d	[m³]	Existing inactive storage of the reservoir	340,000
1.1.7	Wbot	[m]	Representative reservoir bottom width at the dam location	50
1.1.8	--	--	--	--
1.1.9	ELOWL	[masl]	Maximum pool elevation of reservoir	113
1.1.10	ELMWL	[masl]	Minimum operation water level	20
1.1.11	Elbmin	[masl]	Minimum reservoir bed elevation at dam site	0
1.1.12	Lres	[m]	Reservoir length	1,400
1.1.13	ncomp	[-]	Number of reservoir compartments	5

المنارة للاستشارات
www.manaraa.com

Table A-21: Hydrology and Sediment

ID	Parameter	Units	Description	Value
2.1.1.1	MAR	[million m^3/a]	Mean annual reservoir water inflow	429
2.1.1.2	Cv	[-]	Coefficient of variation of annual run-off volume	0.50
2.1.1.3	Twater	[°C]	Representative water temperature in the reservoir	10
2.1.2.1	r_d	[tonnes/m^3]	Specific weight of in-situ reservoir sediment (bulk density)	1.35
2.1.2.2	MAS	[million tonnes/a]	Mean annual total (suspended and bedload) sediment inflow mass	0.50
2.1.2.3		[g/l]	Average annual concentration of suspended load	1.049
2.1.2.3	ExceedT	[%]	Percentage of time exceeded	30, 60, 90
	ExceedMAR	[%]	Percentage of mean annual water inflow	40, 20, 3
	ExceedMAS	[%]	Percentage of mean annual sediment inflow	25, 5, 3
2.1.2.4	pcl	[%]	% clay of suspended sediment inflow	--
2.1.2.5	psi	[%]	% silt of suspended sediment inflow	--
2.1.2.6	psa	[%]	% sand of suspended sediment inflow	--
2.1.2.7	ws_cl	[m/s]	Settling velocity of clay particles	--
2.1.2.8	ws_si	[m/s]	Settling velocity of silt particles	--
2.1.2.9	ws_sa	[m/s]	Settling velocity of sand particles	--
2.1.2.10	TE_Method		Trap efficiency method	Brune
2.1.2.11	Brune Curve No	[-]		1
2.1.2.12	p_b	[%]	% bedload of total sediment inflow	10
2.1.2.13	T_b	[%]	Duration of bedload transport	5
2.1.3.1	Zpr		Standardized normal nariate at pr*100%	2.33
2.1.3.2	Gd		Gould's correction factor	1.50
2.1.3.3	Sd		Standard deviation of annual run-off	214,500,000
2.1.3.4	Distribution		Distribution of annual inflows	Lognormal

www.manaraa.com

Table A-22: Sediment Management – Flushing

ID	Parameter	Units	Description	Value
3.2.1.1	Y	[-]	Indicator of deposits type	180
3.2.1.2	Ans	3 or 1	Sediment removal difficulty	3
3.2.1.3	Qf	[m3/s]	Representative flushing discharge	20
3.2.1.4	Tf	[days]	Duration of flushing after complete drawdown	2
3.2.1.5	Cal_SSfl	[-]	Calibration parameter for Mignot equation	10
3.2.1.6	CLF	[%]	Maximum percent of capacity loss allowable	99
3.2.1.7	s1	[%]	Fraction of run-of-river benefits	90
3.2.1.8	s2	[%]	Fraction of storage benefits	90
3.2.1.9	FI	[US$]	Cost of capital investment	0
3.2.1.10	Elfl_dam	[masl]	Water elevation at dam during flushing	20
3.2.1.12	Shall the implementation strategy of flushing be determined through economic optimization?			No
3.2.1.13	CycleNS	[Years]	Time interval between flushing events during the 1st phase (Reservoir storage > sustainable long term reservoir capacity)	1
3.2.1.14	CycleS	[Years]	Time interval between flushing events during the 2nd phase (Reservoir storage < sustainable long term reservoir capacity)	1
3.2.1.15	OMC_FL	[US$/a]	Annual operation and maintenance costs of flushing	0

Table A-23: Sediment Management – Dredging

ID	Parameter	Units	Description	Value
3.2.2.1	Cw	[%]	Concentration by weight of sediment removed to water removed by traditional dredging	30
3.2.2.2	CLD	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for dredging	30
3.2.2.3	ASD	[%]	Maximum percent of reservoir storage that can be restored during each dredging event	80
3.2.2.4	MD	[m3]	Amount of sediment removed per dredging event	300,000
3.2.2.5	PD	[$/m3]	Unit value of water used in dredging operations	0.005
3.2.2.6	CD	[$/m3]	Unit cost of dredging	11.29
3.2.2.7	Shall the unit cost of dredging be determined automatically?			No
3.2.2.8	Shall the implementation strategy of dredging be determined through economic optimization?			No
3.2.2.9	Cycle1DR	[years]	Duration of phase 1 (No dredging)	1
3.2.2.10	Cycle2DR	[years]	Cycle length in phase 2 (Dredging operation)	1
3.2.2.11	Shall a sustainable solution be determined automatically?			No
3.2.2.12	Where do you want to perform dredging?			Both active and inactive storage

المنارة للاستشارات
www.manaraa.com

Table A-24: Sediment Management – HSRS

ID	Parameter	Units	Description	Value
3.2.3.1	Type	1 or 2	Sediment type category to be removed by Hydrosuction Sediment Removal System (HSRS)	2
3.2.3.2	D	[m]	Assume a trial pipe diameter for HSRS	0.46
3.2.3.3	NP	1, 2, or 3	Number of pipes for HSRS	1
3.2.3.4	YA	[%]	Maximum fraction of total yield that is allowed to be used in HSRS operations	10
3.2.3.5	CLH	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for HSRS	99
3.2.3.6	PH	[$/m3]	Unit value of water released downstream of dam in river by HSRS operations	0.005
3.2.3.7	HI	[US$]	Cost of capital investment to install HSRS	500,000
3.2.3.8	DU	[Years]	The expected life of HSRS	25
3.2.3.9	Shall the implementation strategy of HSRS be determined through economic optimization?			No
3.2.3.10	Year HSRSstart	[Years]	Timing of HSRS installation	1
3.2.3.11	HSRSlimit	[m]	Length limit for implementation of HSRS	1,400

Table A-25: Sediment Management – Trucking

ID	Parameter	Units	Description	Value
3.2.4.1	CLT	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for trucking	99
3.2.4.2	AST	[%]	Maximum percent of reservoir storage that can be restored during each trucking event	80
3.2.4.3	MT	[m3]	Amount of sediment removed per trucking event	300,000
3.2.4.4	CT	[US$/m3]	Unit Cost of trucking	13.08
3.2.4.5	Shall the implementation strategy of trucking be determined through economic optimization?			No
3.2.4.6	Cycle1TR	[years]	Implementation year	1
3.2.4.7	Cycle2TR	[years]	Frequency of trucking operation	1
3.2.4.8	Shall a sustainable solution be determined automatically?			No
3.2.4.9	Where do you want to perform trucking?			Both active and inactive storage
3.2.4.10	sTR	[%]	Fraction of reservoir water yield the year trucking occurs	80

www.manaraa.com

Table A-26: Economic Parameters

ID	Parameter	Units	Description	Value
4.1				
4.2	c	[$/m3]	Unit cost of construction per m3 of reservoir capacity	2.54
4.3	C2	[$]	Total cost of reservoir impoundment	0
4.4	r	[%]	Discount rate	5.0
4.5	Mr	[%]	Market interest rate of annual retirement fund	5.9
4.6	P1	[$/m3]	Unit benefit of reservoir yield	0.1
4.7	V	[$]	Decommissioning cost	0
4.8	CL_NS	[%]	Capacity loss for characterization of a reservoir as non sustainable	75
4.9	C1	[$/a]	Total annual operation and maintenance costs	210,600
4.10				
4.11				
4.12				
4.13			Application of declining discount rate?	No
4.14	Ymax	[years]	Maximum duration of financial analysis	300

المنارة للاستشارات
www.manaraa.com

Ichari

Table A-27: Reservoir Geometry

ID	Parameter	Units	Description	Value
1.1.1	So_gr	[m³]	Original gross storage capacity of the reservoir	11,550,000
1.1.2	So_a	[m³]	Original active storage capacity of the reservoir	5,500,000
1.1.3	So_d	[m³]	Original inactive storage capacity of the reservoir	6,050,000
1.1.4	Se_gr	[m³]	Existing gross storage capacity of the reservoir	3,925,000
1.1.5	Se_a	[m³]	Existing active storage of the reservoir	2,900,000
1.1.6	Se_d	[m³]	Existing inactive storage of the reservoir	1,025,000
1.1.7	Wbot	[m]	Representative reservoir bottom width at the dam location	60
1.1.8	--	--	--	--
1.1.9	ELOWL	[masl]	Maximum pool elevation of reservoir	37
1.1.10	ELMWL	[masl]	Minimum operation water level	21
1.1.11	Elbmin	[masl]	Minimum reservoir bed elevation at dam site	0
1.1.12	Lres	[m]	Reservoir length	11,000
1.1.13	ncomp	[-]	Number of reservoir compartments	5

المنارة للاستشارات
www.manaraa.com

Table A-28: Hydrology and Sediment

ID	Parameter	Units	Description	Value
2.1.1.1	MAR	[million m^3/a]	Mean annual reservoir water inflow	5,300
2.1.1.2	Cv	[-]	Coefficient of variation of annual run-off volume	0.50
2.1.1.3	Twater	[°C]	Representative water temperature in the reservoir	10
2.1.2.1	r_d	[tonnes/m^3]	Specific weight of in-situ reservoir sediment (bulk density)	1.25
2.1.2.2	MAS	[million tonnes/a]	Mean annual total (suspended and bedload) sediment inflow mass	2.20
2.1.2.3		[g/l]	Average annual concentration of suspended load	0.374
2.1.2.3	ExceedT	[%]	Percentage of time exceeded	30, 60, 90
	ExceedMAR	[%]	Percentage of mean annual water inflow	40, 20, 3
	ExceedMAS	[%]	Percentage of mean annual sediment inflow	25, 5, 3
2.1.2.4	pcl	[%]	% clay of suspended sediment inflow	--
2.1.2.5	psi	[%]	% silt of suspended sediment inflow	--
2.1.2.6	psa	[%]	% sand of suspended sediment inflow	--
2.1.2.7	ws_cl	[m/s]	Settling velocity of clay particles	--
2.1.2.8	ws_si	[m/s]	Settling velocity of silt particles	--
2.1.2.9	ws_sa	[m/s]	Settling velocity of sand particles	--
2.1.2.10	TE_Method		Trap efficiency method	Brune
2.1.2.11	Brune Curve No	[-]		2
2.1.2.12	p_b	[%]	% bedload of total sediment inflow	10
2.1.2.13	T_b	[%]	Duration of bedload transport	5
2.1.3.1	Zpr		Standardized normal nariate at pr*100%	2.33
2.1.3.2	Gd		Gould's correction factor	1.50
2.1.3.3	Sd		Standard deviation of annual run-off	2,650,000,000
2.1.3.4	Distribution		Distribution of annual inflows	Lognormal

المنارة للاستشارات
www.manaraa.com

Table A-29: Sediment Management – Flushing

ID	Parameter	Units	Description	Value
3.2.1.1	Y	[-]	Indicator of deposits type	300
3.2.1.2	Ans	3 or 1	Sediment removal difficulty	3
3.2.1.3	Qf	[m3/s]	Representative flushing discharge	2,200
3.2.1.4	Tf	[days]	Duration of flushing after complete drawdown	1
3.2.1.5	Cal_SSfl	[-]	Calibration parameter for Mignot equation	10
3.2.1.6	CLF	[%]	Maximum percent of capacity loss allowable	75
3.2.1.7	s1	[%]	Fraction of run-of-river benefits	90
3.2.1.8	s2	[%]	Fraction of storage benefits	90
3.2.1.9	FI	[US$]	Cost of capital investment	0
3.2.1.10	Elfl_dam	[masl]	Water elevation at dam during flushing	21
3.2.1.12	Shall the implementation strategy of flushing be determined through economic optimization?			No
3.2.1.13	CycleNS	[Years]	Time interval between flushing events during the 1st phase (Reservoir storage > sustainable long term reservoir capacity)	1
3.2.1.14	CycleS	[Years]	Time interval between flushing events during the 2nd phase (Reservoir storage < sustainable long term reservoir capacity)	1
3.2.1.15	OMC_FL	[US$/a]	Annual operation and maintenance costs of flushing	0

Table A-30: Sediment Management – Dredging

ID	Parameter	Units	Description	Value
3.2.2.1	Cw	[%]	Concentration by weight of sediment removed to water removed by traditional dredging	30
3.2.2.2	CLD	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for dredging	75
3.2.2.3	ASD	[%]	Maximum percent of reservoir storage that can be restored during each dredging event	80
3.2.2.4	MD	[m3]	Amount of sediment removed per dredging event	1,000,000
3.2.2.5	PD	[$/m3]	Unit value of water used in dredging operations	0.005
3.2.2.6	CD	[$/m3]	Unit cost of dredging	5
3.2.2.7	Shall the unit cost of dredging be determined automatically?			Yes
3.2.2.8	Shall the implementation strategy of dredging be determined through economic optimization?			Yes
3.2.2.9	Cycle1DR	[years]	Duration of phase 1 (No dredging)	1
3.2.2.10	Cycle2DR	[years]	Cycle length in phase 2 (Dredging operation)	1
3.2.2.11	Shall a sustainable solution be determined automatically?			No
3.2.2.12	Where do you want to perform dredging?			Active storage

المنارة للاستشارات
www.manaraa.com

Table A-31: Sediment Management – HSRS

ID	Parameter	Units	Description	Value
3.2.3.1	Type	1 or 2	Sediment type category to be removed by Hydrosuction Sediment Removal System (HSRS)	1
3.2.3.2	D	[m]	Assume a trial pipe diameter for HSRS	0.46
3.2.3.3	NP	1, 2, or 3	Number of pipes for HSRS	1
3.2.3.4	YA	[%]	Maximum fraction of total yield that is allowed to be used in HSRS operations	10
3.2.3.5	CLH	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for HSRS	75
3.2.3.6	PH	[$/m3]	Unit value of water released downstream of dam in river by HSRS operations	0.005
3.2.3.7	HI	[US$]	Cost of capital investment to install HSRS	5
3.2.3.8	DU	[Years]	The expected life of HSRS	100
3.2.3.9	Shall the implementation strategy of HSRS be determined through economic optimization?			No
3.2.3.10	Year HSRSstart	[Years]	Timing of HSRS installation	1
3.2.3.11	HSRSlimit	[m]	Length limit for implementation of HSRS	11,000

Table A-32: Sediment Management – Trucking

ID	Parameter	Units	Description	Value
3.2.4.1	CLT	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for trucking	75
3.2.4.2	AST	[%]	Maximum percent of reservoir storage that can be restored during each trucking event	80
3.2.4.3	MT	[m3]	Amount of sediment removed per trucking event	1,000,000
3.2.4.4	CT	[US$/m3]	Unit Cost of trucking	13
3.2.4.5	Shall the implementation strategy of trucking be determined through economic optimization?			Yes
3.2.4.6	Cycle1TR	[years]	Implementation year	1
3.2.4.7	Cycle2TR	[years]	Frequency of trucking operation	1
3.2.4.8	Shall a sustainable solution be determined automatically?			No
3.2.4.9	Where do you want to perform trucking?			Active storage
3.2.4.10	sTR	[%]	Fraction of reservoir water yield the year trucking occurs	90

المنارة للاستشارات
www.manaraa.com

Table A-33: Economic Parameters

ID	Parameter	Units	Description	Value
4.1				
4.2	c	[$/m3]	Unit cost of construction per m3 of reservoir capacity	2.20
4.3	C2	[$]	Total cost of reservoir impoundment	0
4.4	r	[%]	Discount rate	3.0
4.5	Mr	[%]	Market interest rate of annual retirement fund	5.9
4.6	P1	[$/m3]	Unit benefit of reservoir yield	0.1
4.7	V	[$]	Decommissioning cost	0
4.8	CL_NS	[%]	Capacity loss for characterization of a reservoir as non sustainable	75
4.9	C1	[$/a]	Total annual operation and maintenance costs	250,000
4.10				
4.11				
4.12				
4.13			Application of declining discount rate?	No
4.14	Ymax	[years]	Maximum duration of financial analysis	300

www.manaraa.com

Kali Gandaki

Table A-34: Reservoir Geometry

ID	Parameter	Units	Description	Value
1.1.1	So_gr	[m³]	Original gross storage capacity of the reservoir	7,700,000
1.1.2	So_a	[m³]	Original active storage capacity of the reservoir	3,100,000
1.1.3	So_d	[m³]	Original inactive storage capacity of the reservoir	4,600,000
1.1.4	Se_gr	[m³]	Existing gross storage capacity of the reservoir	0
1.1.5	Se_a	[m³]	Existing active storage of the reservoir	0
1.1.6	Se_d	[m³]	Existing inactive storage of the reservoir	0
1.1.7	Wbot	[m]	Representative reservoir bottom width at the dam location	100
1.1.8	--	--	--	--
1.1.9	ELOWL	[masl]	Maximum pool elevation of reservoir	524.0
1.1.10	ELMWL	[masl]	Minimum operation water level	518.0
1.1.11	Elbmin	[masl]	Minimum reservoir bed elevation at dam site	490.0
1.1.12	Lres	[m]	Reservoir length	5,000
1.1.13	ncomp	[-]	Number of reservoir compartments	5

المنارة للاستشارات
www.manaraa.com

Table A-35: Hydrology and Sediment

ID	Parameter	Units	Description	Value
2.1.1.1	MAR	[million m^3/a]	Mean annual reservoir water inflow	8,211
2.1.1.2	Cv	[-]	Coefficient of variation of annual run-off volume	0.40
2.1.1.3	Twater	[°C]	Representative water temperature in the reservoir	15
2.1.2.1	r_d	[tonnes/m^3]	Specific weight of in-situ reservoir sediment (bulk density)	1.5
2.1.2.2	MAS	[million tonnes/a]	Mean annual total (suspended and bedload) sediment inflow mass	41.05
2.1.2.3		[g/l]	Average annual concentration of suspended load	4.949
2.1.2.3	ExceedT	[%]	Percentage of time exceeded	15, 30, 50
	ExceedMAR	[%]	Percentage of mean annual water inflow	50, 24, 12
	ExceedMAS	[%]	Percentage of mean annual sediment inflow	20, 2, 1
2.1.2.4	pcl	[%]	% clay of suspended sediment inflow	--
2.1.2.5	psi	[%]	% silt of suspended sediment inflow	--
2.1.2.6	psa	[%]	% sand of suspended sediment inflow	--
2.1.2.7	ws_cl	[m/s]	Settling velocity of clay particles	--
2.1.2.8	ws_si	[m/s]	Settling velocity of silt particles	--
2.1.2.9	ws_sa	[m/s]	Settling velocity of sand particles	--
2.1.2.10	TE_Method		Trap efficiency method	Churchill
2.1.2.11	Brune Curve No	[-]		1
2.1.2.12	p_b	[%]	% bedload of total sediment inflow	1.00
2.1.2.13	T_b	[%]	Duration of bedload transport	5
2.1.3.1	Zpr		Standardized normal nariate at pr*100%	2.33
2.1.3.2	Gd		Gould's correction factor	1.50
2.1.3.3	Sd		Standard deviation of annual run-off	3,284,400,000
2.1.3.4	Distribution		Distribution of annual inflows	Lognormal

المنارة للاستشارات
www.manaraa.com

Table A-36: Sediment Management – Catchment Management

ID	Parameter	Units	Description	Value
3.1.1	CM_Method	[-]	Catchment management method	De-intensification of land use practices
3.1.2	MASb reduction	[%]	Expected reduction of bedload inflow in reservoir due to catchment management	5
3.1.3	MASs reduction	[%]	Expected reduction of suspended load inflow in reservoir due to catchment management	5
3.1.4	YearMAS reduction Start	[Years]	How many years after its implementation will catchment management affect sediment inflow in reservoir?	1
3.1.5				
3.1.6	C_CM	[US$]	Costs for implementation of catchment management measures	20,000,000
3.1.7	OMC_CM	[US$/a]	Annual operation and maintenance costs of catchment management	200,000
3.1.8	Shall the implementation year of catchment management be determined through economic optimization?			No
3.1.9	Year CMstart	[years]	Implementation year of catchment management	5
3.1.10	CL_CM	[%]	Maximum allowable storage loss before implementation of catchment management	100

www.manaraa.com

Table A-37: Sediment Management – Flushing

ID	Parameter	Units	Description	Value
3.2.1.1	Y	[-]	Indicator of deposits type	180
3.2.1.2	Ans	3 or 1	Sediment removal difficulty	3
3.2.1.3	Qf	[m3/s]	Representative flushing discharge	3,000
3.2.1.4	Tf	[days]	Duration of flushing after complete drawdown	2
3.2.1.5	Cal_SSfl	[-]	Calibration parameter for Mignot equation	1
3.2.1.6	CLF	[%]	Maximum percent of capacity loss allowable	50
3.2.1.7	s1	[%]	Fraction of run-of-river benefits	50
3.2.1.8	s2	[%]	Fraction of storage benefits	50
3.2.1.9	FI	[US$]	Cost of capital investment	0
3.2.1.10	Elfl_dam	[masl]	Water elevation at dam during flushing	505
3.2.1.12	Shall the implementation strategy of flushing be determined through economic optimization?			No
3.2.1.13	CycleNS	[Years]	Time interval between flushing events during the 1st phase (Reservoir storage > sustainable long term reservoir capacity)	2
3.2.1.14	CycleS	[Years]	Time interval between flushing events during the 2nd phase (Reservoir storage < sustainable long term reservoir capacity)	14
3.2.1.15	OMC_FL	[US$/a]	Annual operation and maintenance costs of flushing	0

Table A-38: Sediment Management – Dredging

ID	Parameter	Units	Description	Value
3.2.2.1	Cw	[%]	Concentration by weight of sediment removed to water removed by traditional dredging	30
3.2.2.2	CLD	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for dredging	50
3.2.2.3	ASD	[%]	Maximum percent of reservoir storage that can be restored during each dredging event	50
3.2.2.4	MD	[m3]	Amount of sediment removed per dredging event	2,000,000
3.2.2.5	PD	[$/m3]	Unit value of water used in dredging operations	0.00
3.2.2.6	CD	[$/m3]	Unit cost of dredging	10
3.2.2.7	Shall the unit cost of dredging be determined automatically?			No
3.2.2.8	Shall the implementation strategy of dredging be determined through economic optimization?			No
3.2.2.9	Cycle1DR	[years]	Duration of phase 1 (No dredging)	1
3.2.2.10	Cycle2DR	[years]	Cycle length in phase 2 (Dredging operation)	1
3.2.2.11	Shall a sustainable solution be determined automatically?			Yes
3.2.2.12	Where do you want to perform dredging?			Bot active and inactive storage

المنارة للاستشارات
www.manaraa.com

Table A-39: Sediment Management – HSRS

ID	Parameter	Units	Description	Value
3.2.3.1	Type	1 or 2	Sediment type category to be removed by Hydrosuction Sediment Removal System (HSRS)	2
3.2.3.2	D	[m]	Assume a trial pipe diameter for HSRS	1
3.2.3.3	NP	1, 2, or 3	Number of pipes for HSRS	3
3.2.3.4	YA	[%]	Maximum fraction of total yield that is allowed to be used in HSRS operations	100
3.2.3.5	CLH	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for HSRS	100
3.2.3.6	PH	[$/m3]	Unit value of water released downstream of dam in river by HSRS operations	0.00
3.2.3.7	HI	[US$]	Cost of capital investment to install HSRS	20,000,000
3.2.3.8	DU	[Years]	The expected life of HSRS	20
3.2.3.9	Shall the implementation strategy of HSRS be determined through economic optimization?			No
3.2.3.10	Year HSRSstart	[Years]	Timing of HSRS installation	5
3.2.3.11	HSRSlimit	[m]	Length limit for implementation of HSRS	5,000

Table A-40: Sediment Management – Trucking

ID	Parameter	Units	Description	Value
3.2.4.1	CLT	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for trucking	100
3.2.4.2	AST	[%]	Maximum percent of reservoir storage that can be restored during each trucking event	100
3.2.4.3	MT	[m3]	Amount of sediment removed per trucking event	500,000
3.2.4.4	CT	[US$/m3]	Unit Cost of trucking	12
3.2.4.5	Shall the implementation strategy of trucking be determined through economic optimization?			No
3.2.4.6	Cycle1TR	[years]	Implementation year	1
3.2.4.7	Cycle2TR	[years]	Frequency of trucking operation	1
3.2.4.8	Shall a sustainable solution be determined automatically?			Yes
3.2.4.9	Where do you want to perform trucking?			Both active and inactive storage
3.2.4.10	sTR	[%]	Fraction of reservoir water yield the year trucking occurs	50

www.manaraa.com

Table A-41: Sediment Management – Sediment By-pass

ID	Parameter	Units	Description	Value
3.3.1.1	C_{B-P}	[US$]	Cost for implementation of by-pass structure	0
3.3.1.2	OMC_{B-P}	[US$/a]	Annual operation and maintenance Costs of by-pass structures	0
3.3.1.3	Shall the duration and implementation year be defined through economic optimization?			No
3.3.1.4	$Year_{BP\ Start}$	[years]	Implementation year of by-pass	0
3.3.1.5	T_{BP}	[months]	Duration of sediment by-pass	1.0
3.3.1.6	CL_{B-P}	[%]	Maximum allowable storage loss before implementation of sediment by-pass	100
3.3.1.7	$T_{B-P\ max}$	[months]	Maximum allowable duration of by-pass operation	6
3.3.1.8	BP_Efficiency	[%]	Water by-pass efficiency	80
3.3.1.9	BPbedload_Efficiency	[%]	Bedload by-pass efficiency	100
3.3.1.10	BPsuspendedload_ Efficiency	[%]	Suspended load by-pass efficiency	60
3.3.1.11	BPlimit	[m]	Length limit for feasibility of by-pass structure	5,000

Table A-42: Sediment Management – Sluicing

ID	Parameter	Units	Description	Value
3.3.2.1	EL_{SL}	[masl]	Reservoir pool elevation during sluicing	495
3.3.2.2	C_{SL}	[US$]	Cost for implementation of sluicing structure	0
3.3.2.3	OMC_{SL}	[US$/a]	Annual operation and maintenance costs of sluicing structures	0
3.3.2.4	Shall the duration and implementation year be defined through economic optimization?			No
3.3.2.5	$Year_{SL\ Start}$	[years]	Implementation year of sluicing	1
3.3.2.6	T_{SL}	[months]	Duration of sluicing operation	4.00
3.3.2.7	CL_{SL}	[%]	Maximum allowable storage loss before implementation of sluicing	100
3.3.2.8	$T_{SL\ max}$	[months]	Maximum allowable duration of sluicing	6.0

المنارة للاستشارات
www.manaraa.com

Table A-43: Sediment Management – Density Current Venting

ID	Parameter	Units	Description	Value
3.3.3.1				
3.3.3.2	T_{DCV}	[months]	Duration of density current venting	1.00
3.3.3.3	YearDCVstart	[years]	Implementation year of denstiy current venting	2
3.3.3.4	CL_{DCV}	[%]	Maximum allowable storage loss before implementation of density current venting	100
3.3.3.5	s_{DCV}	[%]	Fraction of reservoir benefits the year density current venting occurs	60
3.3.3.6	DCVI	[US$]	Cost of capital investment	0

Table A-44: Sediment Management – Multiple Management

ID	ID	Sediment Management Technique	Start [Year]	End [Year]
3.4.1				
3.4.2				
3.4.3	1	Catchment Management	1	4
3.4.4	2	Dredging	5	60
3.4.5	3	Flushing	61	80
3.4.6	4	Trucking	81	120
3.4.7	5	Sluicing	121	300

المنارة للاستشارات

www.manaraa.com

Table A-45: Economic Parameters

ID	Parameter	Units	Description	Value
4.1				
4.2	c	[$/m3]	Unit cost of construction per m3 of reservoir capacity	4.10
4.3	C2	[$]	Total cost of reservoir impoundment	31,591,504
4.4	r	[%]	Discount rate	5.0
4.5	Mr	[%]	Market interest rate of annual retirement fund	6.0
4.6	P1	[$/m3]	Unit benefit of reservoir yield	0.1
4.7	V	[$]	Decommissioning cost	0
4.8	CL_NS	[%]	Capacity loss for characterization of a reservoir as non sustainable	95
4.9	C1	[$/a]	Total annual operation and maintenance costs	300,000
4.10				
4.11				
4.12				
4.13			Application of declining discount rate?	No
4.14	Ymax	[years]	Maximum duration of financial analysis	300

المنارة للاستشارات

www.manaraa.com

Millsite Reservoir

Table A-46: Reservoir Geometry

ID	Parameter	Units	Description	Value
1.1.1	So_gr	[m^3]	Original gross storage capacity of the reservoir	22,202,640
1.1.2	So_a	[m^3]	Original active storage capacity of the reservoir	15,048,456
1.1.3	So_d	[m^3]	Original inactive storage capacity of the reservoir	7,154,184
1.1.4	Se_gr	[m^3]	Existing gross storage capacity of the reservoir	19,005,460
1.1.5	Se_a	[m^3]	Existing active storage of the reservoir	12,881,478
1.1.6	Se_d	[m^3]	Existing inactive storage of the reservoir	6,123,982
1.1.7	Wbot	[m]	Representative reservoir bottom width at the dam location	8
1.1.8	--	--	--	--
1.1.9	ELOWL	[masl]	Maximum pool elevation of reservoir	1,897.9
1.1.10	ELMWL	[masl]	Minimum operation water level	1,877.6
1.1.11	Elbmin	[masl]	Minimum reservoir bed elevation at dam site	1,861.7
1.1.12	Lres	[m]	Reservoir length	2,293
1.1.13	ncomp	[-]	Number of reservoir compartments	4

المنارة للاستشارات
www.manaraa.com

Table A-47: Hydrology and Sediment

ID	Parameter	Units	Description	Value
2.1.1.1	MAR	[million m^3/a]	Mean annual reservoir water inflow	58.9
2.1.1.2	Cv	[-]	Coefficient of variation of annual run-off volume	0.20
2.1.1.3	Twater	[°C]	Representative water temperature in the reservoir	10.5
2.1.2.1	r_d	[tonnes/m^3]	Specific weight of in-situ reservoir sediment (bulk density)	1.33
2.1.2.2	MAS	[million tonnes/a]	Mean annual total (suspended and bedload) sediment inflow mass	0.121
2.1.2.3		[g/l]	Average annual concentration of suspended load	1.847
2.1.2.3	ExceedT	[%]	Percentage of time exceeded	30, 60, 90
	ExceedMAR	[%]	Percentage of mean annual water inflow	40, 20, 3
	ExceedMAS	[%]	Percentage of mean annual sediment inflow	25, 5, 3
2.1.2.4	pcl	[%]	% clay of suspended sediment inflow	--
2.1.2.5	psi	[%]	% silt of suspended sediment inflow	--
2.1.2.6	psa	[%]	% sand of suspended sediment inflow	--
2.1.2.7	ws_cl	[m/s]	Settling velocity of clay particles	--
2.1.2.8	ws_si	[m/s]	Settling velocity of silt particles	--
2.1.2.9	ws_sa	[m/s]	Settling velocity of sand particles	--
2.1.2.10	TE_Method		Trap efficiency method	Brune
2.1.2.11	Brune Curve No	[-]		3
2.1.2.12	p_b	[%]	% bedload of total sediment inflow	10.00
2.1.2.13	T_b	[%]	Duration of bedload transport	15
2.1.3.1	Zpr		Standardized normal nariate at pr*100%	2.33
2.1.3.2	Gd		Gould's correction factor	1.50
2.1.3.3	Sd		Standard deviation of annual run-off	11,787,582
2.1.3.4	Distribution		Distribution of annual inflows	Lognormal

www.manaraa.com

Table A-48: Sediment Management – Dredging

ID	Parameter	Units	Description	Value
3.2.2.1	Cw	[%]	Concentration by weight of sediment removed to water removed by traditional dredging	70
3.2.2.2	CLD	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for dredging	50
3.2.2.3	ASD	[%]	Maximum percent of reservoir storage that can be restored during each dredging event	44
3.2.2.4	MD	[m3]	Amount of sediment removed per dredging event	6,621,321
3.2.2.5	PD	[$/m3]	Unit value of water used in dredging operations	0.01
3.2.2.6	CD	[$/m3]	Unit cost of dredging	18.66
3.2.2.7	Shall the unit cost of dredging be determined automatically?			No
3.2.2.8	Shall the implementation strategy of dredging be determined through economic optimization?			No
3.2.2.9	Cycle1DR	[years]	Duration of phase 1 (No dredging)	15
3.2.2.10	Cycle2DR	[years]	Cycle length in phase 2 (Dredging operation)	15
3.2.2.11	Shall a sustainable solution be determined automatically?			No
3.2.2.12	Where do you want to perform dredging?			Active Storage

Table A-49: Sediment Management – HSRS

ID	Parameter	Units	Description	Value
3.2.3.1	Type	1 or 2	Sediment type category to be removed by Hydrosuction Sediment Removal System (HSRS)	1
3.2.3.2	D	[m]	Assume a trial pipe diameter for HSRS	0.62
3.2.3.3	NP	1, 2, or 3	Number of pipes for HSRS	3
3.2.3.4	YA	[%]	Maximum fraction of total yield that is allowed to be used in HSRS operations	10
3.2.3.5	CLH	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for HSRS	50
3.2.3.6	PH	[$/m3]	Unit value of water released downstream of dam in river by HSRS operations	0.01
3.2.3.7	HI	[US$]	Cost of capital investment to install HSRS	302,000
3.2.3.8	DU	[Years]	The expected life of HSRS	60
3.2.3.9	Shall the implementation strategy of HSRS be determined through economic optimization?			No
3.2.3.10	Year HSRSstart	[Years]	Timing of HSRS installation	15
3.2.3.11	HSRSlimit	[m]	Length limit for implementation of HSRS	2,293

www.manaraa.com

Table A-50: Sediment Management – Sediment By-pass

ID	Parameter	Units	Description	Value
3.3.1.1	C_{B-P}	[US$]	Cost for implementation of by-pass structure	805,540
3.3.1.2	OMC_{B-P}	[US$/a]	Annual operation and maintenance Costs of by-pass structures	650,950
3.3.1.3	Shall the duration and implementation year be defined through economic optimization?			No
3.3.1.4	$Year_{BP\ Start}$	[years]	Implementation year of by-pass	15
3.3.1.5	T_{BP}	[months]	Duration of sediment by-pass	1.5
3.3.1.6	CL_{B-P}	[%]	Maximum allowable storage loss before implementation of sediment by-pass	50
3.3.1.7	$T_{B-P\ max}$	[months]	Maximum allowable duration of by-pass operation	2
3.3.1.8	BP_Efficiency	[%]	Water by-pass efficiency	75
3.3.1.9	BPbedload_Efficiency	[%]	Bedload by-pass efficiency	10
3.3.1.10	BPsuspendedload_ Efficiency	[%]	Suspended load by-pass efficiency	90
3.3.1.11	BPlimit	[m]	Length limit for feasibility of by-pass structure	2,293

Table A-51: Economic Parameters

ID	Parameter	Units	Description	Value
4.1				
4.2	c	[$/m3]	Unit cost of construction per m3 of reservoir capacity	2.37
4.3	C2	[$]	Total cost of reservoir impoundment	0
4.4	r	[%]	Discount rate	5.00
4.5	Mr	[%]	Market interest rate of annual retirement fund	5.90
4.6	P1	[$/m3]	Unit benefit of reservoir yield	0.1
4.7	V	[$]	Decommissioning cost	0
4.8	CL_NS	[%]	Capacity loss for characterization of a reservoir as non sustainable	75
4.9	C1	[$/a]	Total annual operation and maintenance costs	500,000
4.10				
4.11				
4.12				
4.13			Application of declining discount rate?	No
4.14	Ymax	[years]	Maximum duration of financial analysis	300

المنارة للاستشارات
www.manaraa.com

Sanmenxia

Table A-52: Reservoir Geometry

ID	Parameter	Units	Description	Value
1.1.1	So_gr	[m³]	Original gross storage capacity of the reservoir	9,640,000,000
1.1.2	So_a	[m³]	Original active storage capacity of the reservoir	7,840,000,000
1.1.3	So_d	[m³]	Original inactive storage capacity of the reservoir	1,800,000,000
1.1.4	Se_gr	[m³]	Existing gross storage capacity of the reservoir	5,590,000,000
1.1.5	Se_a	[m³]	Existing active storage of the reservoir	5,300,000,000
1.1.6	Se_d	[m³]	Existing inactive storage of the reservoir	290,000,000
1.1.7	Wbot	[m]	Representative reservoir bottom width at the dam location	450
1.1.8	--	--	--	--
1.1.9	ELOWL	[masl]	Maximum pool elevation of reservoir	335
1.1.10	ELMWL	[masl]	Minimum operation water level	300
1.1.11	Elbmin	[masl]	Minimum reservoir bed elevation at dam site	280
1.1.12	Lres	[m]	Reservoir length	114,000
1.1.13	ncomp	[-]	Number of reservoir compartments	5

المنارة للاستشارات
www.manaraa.com

Table A-53: Hydrology and Sediment

ID	Parameter	Units	Description	Value
2.1.1.1	MAR	[million m^3/a]	Mean annual reservoir water inflow	43,036
2.1.1.2	Cv	[-]	Coefficient of variation of annual run-off volume	0.27
2.1.1.3	Twater	[°C]	Representative water temperature in the reservoir	14
2.1.2.1	r_d	[tonnes/m^3]	Specific weight of in-situ reservoir sediment (bulk density)	1.4
2.1.2.2	MAS	[million tonnes/a]	Mean annual total (suspended and bedload) sediment inflow mass	1,000
2.1.2.3		[g/l]	Average annual concentration of suspended load	20.913
2.1.2.3	ExceedT	[%]	Percentage of time exceeded	30, 60, 90
	ExceedMAR	[%]	Percentage of mean annual water inflow	40, 20, 3
	ExceedMAS	[%]	Percentage of mean annual sediment inflow	25, 5, 3
2.1.2.4	pcl	[%]	% clay of suspended sediment inflow	--
2.1.2.5	psi	[%]	% silt of suspended sediment inflow	--
2.1.2.6	psa	[%]	% sand of suspended sediment inflow	--
2.1.2.7	ws_cl	[m/s]	Settling velocity of clay particles	--
2.1.2.8	ws_si	[m/s]	Settling velocity of silt particles	--
2.1.2.9	ws_sa	[m/s]	Settling velocity of sand particles	--
2.1.2.10	TE_Method		Trap efficiency method	Brune
2.1.2.11	Brune Curve No	[-]		2
2.1.2.12	p_b	[%]	% bedload of total sediment inflow	10
2.1.2.13	T_b	[%]	Duration of bedload transport	5
2.1.3.1	Zpr		Standardized normal nariate at pr*100%	2.33
2.1.3.2	Gd		Gould's correction factor	1.50
2.1.3.3	Sd		Standard deviation of annual run-off	11,619,720,000
2.1.3.4	Distribution		Distribution of annual inflows	Lognormal

www.manaraa.com

Table A-54: Sediment Management – Flushing

ID	Parameter	Units	Description	Value
3.2.1.1	Y	[-]	Indicator of deposits type	1,600
3.2.1.2	Ans	3 or 1	Sediment removal difficulty	1
3.2.1.3	Qf	[m3/s]	Representative flushing discharge	2,000
3.2.1.4	Tf	[days]	Duration of flushing after complete drawdown	123
3.2.1.5	Cal_SSfl	[-]	Calibration parameter for Mignot equation	10
3.2.1.6	CLF	[%]	Maximum percent of capacity loss allowable	99
3.2.1.7	s1	[%]	Fraction of run-of-river benefits	90
3.2.1.8	s2	[%]	Fraction of storage benefits	90
3.2.1.9	FI	[US$]	Cost of capital investment	0
3.2.1.10	Elfl_dam	[masl]	Water elevation at dam during flushing	300
3.2.1.12	Shall the implementation strategy of flushing be determined through economic optimization?			No
3.2.1.13	CycleNS	[Years]	Time interval between flushing events during the 1st phase (Reservoir storage > sustainable long term reservoir capacity)	1
3.2.1.14	CycleS	[Years]	Time interval between flushing events during the 2nd phase (Reservoir storage < sustainable long term reservoir capacity)	1
3.2.1.15	OMC_FL	[US$/a]	Annual operation and maintenance costs of flushing	0

Table A-55: Sediment Management – Dredging

ID	Parameter	Units	Description	Value
3.2.2.1	Cw	[%]	Concentration by weight of sediment removed to water removed by traditional dredging	30
3.2.2.2	CLD	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for dredging	99
3.2.2.3	ASD	[%]	Maximum percent of reservoir storage that can be restored during each dredging event	100
3.2.2.4	MD	[m3]	Amount of sediment removed per dredging event	1,000,000
3.2.2.5	PD	[$/m3]	Unit value of water used in dredging operations	0.02
3.2.2.6	CD	[$/m3]	Unit cost of dredging	3
3.2.2.7	Shall the unit cost of dredging be determined automatically?			No
3.2.2.8	Shall the implementation strategy of dredging be determined through economic optimization?			No
3.2.2.9	Cycle1DR	[years]	Duration of phase 1 (No dredging)	1
3.2.2.10	Cycle2DR	[years]	Cycle length in phase 2 (Dredging operation)	1
3.2.2.11	Shall a sustainable solution be determined automatically?			No
3.2.2.12	Where do you want to perform dredging?			Both active and inactive storage

المنارة للاستشارات
www.manaraa.com

Table A-56: Sediment Management – HSRS

ID	Parameter	Units	Description	Value
3.2.3.1	Type	1 or 2	Sediment type category to be removed by Hydrosuction Sediment Removal System (HSRS)	1
3.2.3.2	D	[m]	Assume a trial pipe diameter for HSRS	0.4
3.2.3.3	NP	1, 2, or 3	Number of pipes for HSRS	1
3.2.3.4	YA	[%]	Maximum fraction of total yield that is allowed to be used in HSRS operations	30
3.2.3.5	CLH	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for HSRS	99
3.2.3.6	PH	[$/m3]	Unit value of water released downstream of dam in river by HSRS operations	0.02
3.2.3.7	HI	[US$]	Cost of capital investment to install HSRS	0
3.2.3.8	DU	[Years]	The expected life of HSRS	25
3.2.3.9	Shall the implementation strategy of HSRS be determined through economic optimization?			Yes
3.2.3.10	Year HSRSstart	[Years]	Timing of HSRS installation	1
3.2.3.11	HSRSlimit	[m]	Length limit for implementation of HSRS	114,000

Table A-57: Sediment Management – Trucking

ID	Parameter	Units	Description	Value
3.2.4.1	CLT	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for trucking	99
3.2.4.2	AST	[%]	Maximum percent of reservoir storage that can be restored during each trucking event	100
3.2.4.3	MT	[m3]	Amount of sediment removed per trucking event	500,000
3.2.4.4	CT	[US$/m3]	Unit Cost of trucking	13
3.2.4.5	Shall the implementation strategy of trucking be determined through economic optimization?			Yes
3.2.4.6	Cycle1TR	[years]	Implementation year	1
3.2.4.7	Cycle2TR	[years]	Frequency of trucking operation	1
3.2.4.8	Shall a sustainable solution be determined automatically?			Yes
3.2.4.9	Where do you want to perform trucking?			Active storage
3.2.4.10	sTR	[%]	Fraction of reservoir water yield the year trucking occurs	30

المنارة للاستشارات
www.manaraa.com

Table A-58: Economic Parameters

ID	Parameter	Units	Description	Value
4.1				
4.2	c	[$/m3]	Unit cost of construction per m3 of reservoir capacity	0.16
4.3	C2	[$]	Total cost of reservoir impoundment	0
4.4	r	[%]	Discount rate	5.0
4.5	Mr	[%]	Market interest rate of annual retirement fund	5.9
4.6	P1	[$/m3]	Unit benefit of reservoir yield	0.2
4.7	V	[$]	Decommissioning cost	0
4.8	CL_NS	[%]	Capacity loss for characterization of a reservoir as non sustainable	95
4.9	C1	[$/a]	Total annual operation and maintenance costs	15,424,000
4.10				
4.11				
4.12				
4.13			Application of declining discount rate?	No
4.14	Ymax	[years]	Maximum duration of financial analysis	300

المنارة للاستشارات
www.manaraa.com

Sefid-Rud

Table A-59: Reservoir Geometry

ID	Parameter	Units	Description	Value
1.1.1	So_gr	[m³]	Original gross storage capacity of the reservoir	1,760,000,000
1.1.2	So_a	[m³]	Original active storage capacity of the reservoir	1,600,000,000
1.1.3	So_d	[m³]	Original inactive storage capacity of the reservoir	160,000,000
1.1.4	Se_gr	[m³]	Existing gross storage capacity of the reservoir	1,320,000,000
1.1.5	Se_a	[m³]	Existing active storage of the reservoir	1,270,000,000
1.1.6	Se_d	[m³]	Existing inactive storage of the reservoir	50,000,000
1.1.7	Wbot	[m]	Representative reservoir bottom width at the dam location	500
1.1.8	--	--	--	--
1.1.9	ELOWL	[masl]	Maximum pool elevation of reservoir	82
1.1.10	ELMWL	[masl]	Minimum operation water level	30
1.1.11	Elbmin	[masl]	Minimum reservoir bed elevation at dam site	0
1.1.12	Lres	[m]	Reservoir length	25,000
1.1.13	ncomp	[-]	Number of reservoir compartments	5

المنارة للاستشارات

www.manaraa.com

Table A-60: Hydrology and Sediment

ID	**Parameter**	**Units**	**Description**	**Value**
2.1.1.1	MAR	[million m^3/a]	Mean annual reservoir water inflow	5,000
2.1.1.2	Cv	[-]	Coefficient of variation of annual run-off volume	0.50
2.1.1.3	Twater	[°C]	Representative water temperature in the reservoir	10
2.1.2.1	r_d	[tonnes/m^3]	Specific weight of in-situ reservoir sediment (bulk density)	1.25
2.1.2.2	MAS	[million tonnes/a]	Mean annual total (suspended and bedload) sediment inflow mass	50
2.1.2.3		[g/l]	Average annual concentration of suspended load	9.00
2.1.2.3	ExceedT	[%]	Percentage of time exceeded	30, 60, 90
	ExceedMAR	[%]	Percentage of mean annual water inflow	40, 20, 3
	ExceedMAS	[%]	Percentage of mean annual sediment inflow	25, 5, 3
2.1.2.4	pcl	[%]	% clay of suspended sediment inflow	--
2.1.2.5	psi	[%]	% silt of suspended sediment inflow	--
2.1.2.6	psa	[%]	% sand of suspended sediment inflow	--
2.1.2.7	ws_cl	[m/s]	Settling velocity of clay particles	--
2.1.2.8	ws_si	[m/s]	Settling velocity of silt particles	--
2.1.2.9	ws_sa	[m/s]	Settling velocity of sand particles	--
2.1.2.10	TE_Method		Trap efficiency method	Brune
2.1.2.11	Brune Curve No	[-]		2
2.1.2.12	p_b	[%]	% bedload of total sediment inflow	10
2.1.2.13	T_b	[%]	Duration of bedload transport	5
2.1.3.1	Zpr		Standardized normal nariate at pr*100%	2.33
2.1.3.2	Gd		Gould's correction factor	1.50
2.1.3.3	Sd		Standard deviation of annual run-off	2,500,000,000
2.1.3.4	Distribution		Distribution of annual inflows	Lognormal

المنارة للاستشارات
www.manaraa.com

Table A-61: Sediment Management – Flushing

ID	Parameter	Units	Description	Value
3.2.1.1	Y	[-]	Indicator of deposits type	650
3.2.1.2	Ans	3 or 1	Sediment removal difficulty	3
3.2.1.3	Qf	[m3/s]	Representative flushing discharge	100
3.2.1.4	Tf	[days]	Duration of flushing after complete drawdown	120
3.2.1.5	Cal_SSfl	[-]	Calibration parameter for Mignot equation	10
3.2.1.6	CLF	[%]	Maximum percent of capacity loss allowable	95
3.2.1.7	s1	[%]	Fraction of run-of-river benefits	90
3.2.1.8	s2	[%]	Fraction of storage benefits	90
3.2.1.9	FI	[US$]	Cost of capital investment	0
3.2.1.10	Elfl_dam	[masl]	Water elevation at dam during flushing	30
3.2.1.12	Shall the implementation strategy of flushing be determined through economic optimization?			No
3.2.1.13	CycleNS	[Years]	Time interval between flushing events during the 1st phase (Reservoir storage > sustainable long term reservoir capacity)	1
3.2.1.14	CycleS	[Years]	Time interval between flushing events during the 2nd phase (Reservoir storage < sustainable long term reservoir capacity)	1
3.2.1.15	OMC_FL	[US$/a]	Annual operation and maintenance costs of flushing	0

Table A-62: Sediment Management – Dredging

ID	Parameter	Units	Description	Value
3.2.2.1	Cw	[%]	Concentration by weight of sediment removed to water removed by traditional dredging	30
3.2.2.2	CLD	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for dredging	95
3.2.2.3	ASD	[%]	Maximum percent of reservoir storage that can be restored during each dredging event	80
3.2.2.4	MD	[m3]	Amount of sediment removed per dredging event	30,000,000
3.2.2.5	PD	[$/m3]	Unit value of water used in dredging operations	0.005
3.2.2.6	CD	[$/m3]	Unit cost of dredging	5
3.2.2.7	Shall the unit cost of dredging be determined automatically?			Yes
3.2.2.8	Shall the implementation strategy of dredging be determined through economic optimization?			No
3.2.2.9	Cycle1DR	[years]	Duration of phase 1 (No dredging)	1
3.2.2.10	Cycle2DR	[years]	Cycle length in phase 2 (Dredging operation)	1
3.2.2.11	Shall a sustainable solution be determined automatically?			Yes
3.2.2.12	Where do you want to perform dredging?			Active storage

المنارة للاستشارات
www.manaraa.com

Table A-63: Sediment Management – HSRS

ID	Parameter	Units	Description	Value
3.2.3.1	Type	1 or 2	Sediment type category to be removed by Hydrosuction Sediment Removal System (HSRS)	1
3.2.3.2	D	[m]	Assume a trial pipe diameter for HSRS	0.46
3.2.3.3	NP	1, 2, or 3	Number of pipes for HSRS	1
3.2.3.4	YA	[%]	Maximum fraction of total yield that is allowed to be used in HSRS operations	10
3.2.3.5	CLH	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for HSRS	95
3.2.3.6	PH	[\$/m3]	Unit value of water released downstream of dam in river by HSRS operations	0.005
3.2.3.7	HI	[US\$]	Cost of capital investment to install HSRS	250,000
3.2.3.8	DU	[Years]	The expected life of HSRS	25
3.2.3.9	Shall the implementation strategy of HSRS be determined through economic optimization?			No
3.2.3.10	Year HSRSstart	[Years]	Timing of HSRS installation	1
3.2.3.11	HSRSlimit	[m]	Length limit for implementation of HSRS	25,000

Table A-64: Sediment Management – Trucking

ID	Parameter	Units	Description	Value
3.2.4.1	CLT	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for trucking	95
3.2.4.2	AST	[%]	Maximum percent of reservoir storage that can be restored during each trucking event	80
3.2.4.3	MT	[m3]	Amount of sediment removed per trucking event	30,000,000
3.2.4.4	CT	[US\$/m3]	Unit Cost of trucking	13
3.2.4.5	Shall the implementation strategy of trucking be determined through economic optimization?			Yes
3.2.4.6	Cycle1TR	[years]	Implementation year	1
3.2.4.7	Cycle2TR	[years]	Frequency of trucking operation	1
3.2.4.8	Shall a sustainable solution be determined automatically?			No
3.2.4.9	Where do you want to perform trucking?			Active storage
3.2.4.10	sTR	[%]	Fraction of reservoir water yield the year trucking occurs	30

www.manaraa.com

Table A-65: Economic Parameters

ID	Parameter	Units	Description	Value
4.1				
4.2	c	[$/m3]	Unit cost of construction per m3 of reservoir capacity	0.16
4.3	C2	[$]	Total cost of reservoir impoundment	0
4.4	r	[%]	Discount rate	5.0
4.5	Mr	[%]	Market interest rate of annual retirement fund	5.9
4.6	P1	[$/m3]	Unit benefit of reservoir yield	0.1
4.7	V	[$]	Decommissioning cost	0
4.8	CL_NS	[%]	Capacity loss for characterization of a reservoir as non sustainable	75
4.9	C1	[$/a]	Total annual operation and maintenance costs	2,816,000
4.10				
4.11				
4.12				
4.13			Application of declining discount rate?	No
4.14	Ymax	[years]	Maximum duration of financial analysis	300

المنارة للاستشارات
www.manaraa.com

Three Gorges

Table A-66: Reservoir Geometry

ID	Parameter	Units	Description	Value
1.1.1	So_gr	[m³]	Original gross storage capacity of the reservoir	39,300,000,000
1.1.2	So_a	[m³]	Original active storage capacity of the reservoir	23,510,700,859
1.1.3	So_d	[m³]	Original inactive storage capacity of the reservoir	15,789,299,141
1.1.4	Se_gr	[m³]	Existing gross storage capacity of the reservoir	--
1.1.5	Se_a	[m³]	Existing active storage of the reservoir	--
1.1.6	Se_d	[m³]	Existing inactive storage of the reservoir	--
1.1.7	Wbot	[m]	Representative reservoir bottom width at the dam location	250
1.1.8	--	--	--	--
1.1.9	ELOWL	[masl]	Maximum pool elevation of reservoir	175
1.1.10	ELMWL	[masl]	Minimum operation water level	145
1.1.11	Elbmin	[masl]	Minimum reservoir bed elevation at dam site	4
1.1.12	Lres	[m]	Reservoir length	566,000
1.1.13	ncomp	[-]	Number of reservoir compartments	5

* Existing storages not displayed because Three Gorges was evaluated as a Greenfield Project

المنارة للاستشارات
www.manaraa.com

Table A-67: Hydrology and Sediment

ID	Parameter	Units	Description	Value
2.1.1.1	MAR	[million m^3/a]	Mean annual reservoir water inflow	437,940
2.1.1.2	Cv	[-]	Coefficient of variation of annual run-off volume	0.10
2.1.1.3	Twater	[°C]	Representative water temperature in the reservoir	18
2.1.2.1	r_d	[tonnes/m^3]	Specific weight of in-situ reservoir sediment (bulk density)	1.26
2.1.2.2	MAS	[million tonnes/a]	Mean annual total (suspended and bedload) sediment inflow mass	530
2.1.2.3		[g/l]	Average annual concentration of suspended load	1.089
2.1.2.3	ExceedT	[%]	Percentage of time exceeded	30, 60, 90
	ExceedMAR	[%]	Percentage of mean annual water inflow	40, 20, 3
	ExceedMAS	[%]	Percentage of mean annual sediment inflow	25, 5, 3
2.1.2.4	pcl	[%]	% clay of suspended sediment inflow	--
2.1.2.5	psi	[%]	% silt of suspended sediment inflow	--
2.1.2.6	psa	[%]	% sand of suspended sediment inflow	--
2.1.2.7	ws_cl	[m/s]	Settling velocity of clay particles	--
2.1.2.8	ws_si	[m/s]	Settling velocity of silt particles	--
2.1.2.9	ws_sa	[m/s]	Settling velocity of sand particles	--
2.1.2.10	TE_Method		Trap efficiency method	Brune
2.1.2.11	Brune Curve No	[-]		2
2.1.2.12	p_b	[%]	% bedload of total sediment inflow	10
2.1.2.13	T_b	[%]	Duration of bedload transport	5
2.1.3.1	Zpr		Standardized normal nariate at pr*100%	2.33
2.1.3.2	Gd		Gould's correction factor	1.50
2.1.3.3	Sd		Standard deviation of annual run-off	43,794,043,200
2.1.3.4	Distribution		Distribution of annual inflows	Lognormal

www.manaraa.com

Table A-68: Sediment Management – Flushing

ID	Parameter	Units	Description	Value
3.2.1.1	Y	[-]	Indicator of deposits type	650
3.2.1.2	Ans	3 or 1	Sediment removal difficulty	3
3.2.1.3	Qf	[m3/s]	Representative flushing discharge	26,000
3.2.1.4	Tf	[days]	Duration of flushing after complete drawdown	122
3.2.1.5	Cal_SSfl	[-]	Calibration parameter for Mignot equation	10
3.2.1.6	CLF	[%]	Maximum percent of capacity loss allowable	95
3.2.1.7	s1	[%]	Fraction of run-of-river benefits	90
3.2.1.8	s2	[%]	Fraction of storage benefits	90
3.2.1.9	FI	[US$]	Cost of capital investment	0
3.2.1.10	Elfl_dam	[masl]	Water elevation at dam during flushing	145
3.2.1.12	Shall the implementation strategy of flushing be determined through economic optimization?			No
3.2.1.13	CycleNS	[Years]	Time interval between flushing events during the 1st phase (Reservoir storage > sustainable long term reservoir capacity)	1
3.2.1.14	CycleS	[Years]	Time interval between flushing events during the 2nd phase (Reservoir storage < sustainable long term reservoir capacity)	1
3.2.1.15	OMC_FL	[US$/a]	Annual operation and maintenance costs of flushing	0

Table A-69: Sediment Management – Dredging

ID	Parameter	Units	Description	Value
3.2.2.1	Cw	[%]	Concentration by weight of sediment removed to water removed by traditional dredging	30
3.2.2.2	CLD	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for dredging	95
3.2.2.3	ASD	[%]	Maximum percent of reservoir storage that can be restored during each dredging event	100
3.2.2.4	MD	[m3]	Amount of sediment removed per dredging event	1,000,000
3.2.2.5	PD	[$/m3]	Unit value of water used in dredging operations	0.02
3.2.2.6	CD	[$/m3]	Unit cost of dredging	3
3.2.2.7	Shall the unit cost of dredging be determined automatically?			No
3.2.2.8	Shall the implementation strategy of dredging be determined through economic optimization?			No
3.2.2.9	Cycle1DR	[years]	Duration of phase 1 (No dredging)	1
3.2.2.10	Cycle2DR	[years]	Cycle length in phase 2 (Dredging operation)	1
3.2.2.11	Shall a sustainable solution be determined automatically?			No
3.2.2.12	Where do you want to perform dredging?			Both active and inactive storage

www.manaraa.com

Table A-70: Sediment Management – HSRS

ID	Parameter	Units	Description	Value
3.2.3.1	Type	1 or 2	Sediment type category to be removed by Hydrosuction Sediment Removal System (HSRS)	1
3.2.3.2	D	[m]	Assume a trial pipe diameter for HSRS	0.4
3.2.3.3	NP	1, 2, or 3	Number of pipes for HSRS	1
3.2.3.4	YA	[%]	Maximum fraction of total yield that is allowed to be used in HSRS operations	30
3.2.3.5	CLH	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for HSRS	95
3.2.3.6	PH	[\$/m3]	Unit value of water released downstream of dam in river by HSRS operations	0.02
3.2.3.7	HI	[US\$]	Cost of capital investment to install HSRS	0
3.2.3.8	DU	[Years]	The expected life of HSRS	25
3.2.3.9	Shall the implementation strategy of HSRS be determined through economic optimization?			No
3.2.3.10	Year HSRSstart	[Years]	Timing of HSRS installation	1
3.2.3.11	HSRSlimit	[m]	Length limit for implementation of HSRS	566,000

Table A-71: Sediment Management – Trucking

ID	Parameter	Units	Description	Value
3.2.4.1	CLT	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for trucking	95
3.2.4.2	AST	[%]	Maximum percent of reservoir storage that can be restored during each trucking event	100
3.2.4.3	MT	[m3]	Amount of sediment removed per trucking event	500,000
3.2.4.4	CT	[US\$/m3]	Unit Cost of trucking	13
3.2.4.5	Shall the implementation strategy of trucking be determined through economic optimization?			No
3.2.4.6	Cycle1TR	[years]	Implementation year	1
3.2.4.7	Cycle2TR	[years]	Frequency of trucking operation	1
3.2.4.8	Shall a sustainable solution be determined automatically?			No
3.2.4.9	Where do you want to perform trucking?			Active storage
3.2.4.10	sTR	[%]	Fraction of reservoir water yield the year trucking occurs	30

المنارة للاستشارات
www.manaraa.com

Table A-72: Economic Parameters

ID	Parameter	Units	Description	Value
4.1				
4.2	c	[$/m3]	Unit cost of construction per m3 of reservoir capacity	0.16
4.3	C2	[$]	Total cost of reservoir impoundment	25,000,000,000
4.4	r	[%]	Discount rate	5.0
4.5	Mr	[%]	Market interest rate of annual retirement fund	5.9
4.6	P1	[$/m3]	Unit benefit of reservoir yield	0.2
4.7	V	[$]	Decommissioning cost	0
4.8	CL_NS	[%]	Capacity loss for characterization of a reservoir as non sustainable	75
4.9	C1	[$/a]	Total annual operation and maintenance costs	62,880,000
4.10				
4.11				
4.12				
4.13			Application of declining discount rate?	No
4.14	Ymax	[years]	Maximum duration of financial analysis	300

المنارة للاستشارات
www.manaraa.com

APPENDIX B. RESCON 2 MODELS: NO SEDIMENT MANAGEMENT

Abdel Karim

Table B-1: Reservoir Geometry

ID	Parameter	Units	Description	Value
1.1.1	So_gr	[m^3]	Original gross storage capacity of the reservoir	11,333,333
1.1.2	So_a	[m^3]	Original active storage capacity of the reservoir	11,333,333
1.1.3	So_d	[m^3]	Original inactive storage capacity of the reservoir	0
1.1.4	Se_gr	[m^3]	Existing gross storage capacity of the reservoir	8,866,666
1.1.5	Se_a	[m^3]	Existing active storage of the reservoir	8,866,666
1.1.6	Se_d	[m^3]	Existing inactive storage of the reservoir	0
1.1.7	Wbot	[m]	Representative reservoir bottom width at the dam location	600
1.1.8	--	--	--	--
1.1.9	ELOWL	[masl]	Maximum pool elevation of reservoir	140
1.1.10	ELMWL	[masl]	Minimum operation water level	130
1.1.11	Elbmin	[masl]	Minimum reservoir bed elevation at dam site	130
1.1.12	Lres	[m]	Reservoir length	1,600
1.1.13	ncomp	[-]	Number of reservoir compartments	5

المنارة للاستشارات
www.manaraa.com

Table B-2: Hydrology and Sediment

ID	Parameter	Units	Description	Value
2.1.1.1	MAR	[million m^3/a]	Mean annual reservoir water inflow	48
2.1.1.2	Cv	[-]	Coefficient of variation of annual run-off volume	0.80
2.1.1.3	Twater	[°C]	Representative water temperature in the reservoir	18
2.1.2.1	r_d	[tonnes/m^3]	Specific weight of in-situ reservoir sediment (bulk density)	1.2
2.1.2.2	MAS	[million tonnes/a]	Mean annual total (suspended and bedload) sediment inflow mass	0.22
2.1.2.3		[g/l]	Average annual concentration of suspended load	4.069
2.1.2.3	ExceedT	[%]	Percentage of time exceeded	25, 50, 75
	ExceedMAR	[%]	Percentage of mean annual water inflow	35, 18, 10
	ExceedMAS	[%]	Percentage of mean annual sediment inflow	35, 18, 10
2.1.2.4	pcl	[%]	% clay of suspended sediment inflow	--
2.1.2.5	psi	[%]	% silt of suspended sediment inflow	--
2.1.2.6	psa	[%]	% sand of suspended sediment inflow	--
2.1.2.7	ws_cl	[m/s]	Settling velocity of clay particles	--
2.1.2.8	ws_si	[m/s]	Settling velocity of silt particles	--
2.1.2.9	ws_sa	[m/s]	Settling velocity of sand particles	--
2.1.2.10	TE_Method		Trap efficiency method	Brune
2.1.2.11	Brune Curve No	[-]		2
2.1.2.12	p_b	[%]	% bedload of total sediment inflow	10.00
2.1.2.13	T_b	[%]	Duration of bedload transport	5
2.1.3.1	Zpr		Standardized normal nariate at pr*100%	2.33
2.1.3.2	Gd		Gould's correction factor	1.50
2.1.3.3	Sd		Standard deviation of annual run-off	38,400,00
2.1.3.4	Distribution		Distribution of annual inflows	Lognormal

www.manaraa.com

Table B-3: Sediment Management – Catchment Management

ID	Parameter	Units	Description	Value
3.1.1	CM_Method	[-]	Catchment management method	De-intensification of land use practices
3.1.2	MASb reduction	[%]	Expected reduction of bedload inflow in reservoir due to catchment management	0
3.1.3	MASs reduction	[%]	Expected reduction of suspended load inflow in reservoir due to catchment management	0
3.1.4	YearMAS reduction Start	[Years]	How many years after its implementation will catchment management affect sediment inflow in reservoir?	1
3.1.5				
3.1.6	C_CM	[US$]	Costs for implementation of catchment management measures	0
3.1.7	OMC_CM	[US$/a]	Annual operation and maintenance costs of catchment management	0
3.1.8	Shall the implementation year of catchment management be determined through economic optimization?			No
3.1.9	Year CMstart	[years]	Implementation year of catchment management	1
3.1.10	CL_CM	[%]	Maximum allowable storage loss before implementation of catchment management	100

المنارة للاستشارات
www.manaraa.com

Table B-4: Sediment Management – Flushing

ID	Parameter	Units	Description	Value
3.2.1.1	Y	[-]	Indicator of deposits type	650
3.2.1.2	Ans	3 or 1	Sediment removal difficulty	3
3.2.1.3	Qf	[m3/s]	Representative flushing discharge	100
3.2.1.4	Tf	[days]	Duration of flushing after complete drawdown	30
3.2.1.5	Cal_SSfl	[-]	Calibration parameter for Mignot equation	10
3.2.1.6	CLF	[%]	Maximum percent of capacity loss allowable	80
3.2.1.7	s1	[%]	Fraction of run-of-river benefits	50
3.2.1.8	s2	[%]	Fraction of storage benefits	50
3.2.1.9	FI	[US$]	Cost of capital investment	0
3.2.1.10	Elfl_dam	[masl]	Water elevation at dam during flushing	120
3.2.1.12	Shall the implementation strategy of flushing be determined through economic optimization?			Yes
3.2.1.13	CycleNS	[Years]	Time interval between flushing events during the 1st phase (Reservoir storage > sustainable long term reservoir capacity)	42
3.2.1.14	CycleS	[Years]	Time interval between flushing events during the 2nd phase (Reservoir storage < sustainable long term reservoir capacity)	14
3.2.1.15	OMC_FL	[US$/a]	Annual operation and maintenance costs of flushing	0

Table B-5: Sediment Management – Dredging

ID	Parameter	Units	Description	Value
3.2.2.1	Cw	[%]	Concentration by weight of sediment removed to water removed by traditional dredging	25
3.2.2.2	CLD	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for dredging	5
3.2.2.3	ASD	[%]	Maximum percent of reservoir storage that can be restored during each dredging event	60
3.2.2.4	MD	[m3]	Amount of sediment removed per dredging event	50,000
3.2.2.5	PD	[$/m3]	Unit value of water used in dredging operations	0.00
3.2.2.6	CD	[$/m3]	Unit cost of dredging	2.5
3.2.2.7	Shall the unit cost of dredging be determined automatically?			No
3.2.2.8	Shall the implementation strategy of dredging be determined through economic optimization?			No
3.2.2.9	Cycle1DR	[years]	Duration of phase 1 (No dredging)	1
3.2.2.10	Cycle2DR	[years]	Cycle length in phase 2 (Dredging operation)	1
3.2.2.11	Shall a sustainable solution be determined automatically?			Yes
3.2.2.12	Where do you want to perform dredging?			Both active and inactive storage

www.manaraa.com

Table B-6: Sediment Management – HSRS

ID	Parameter	Units	Description	Value
3.2.3.1	Type	1 or 2	Sediment type category to be removed by Hydrosuction Sediment Removal System (HSRS)	2
3.2.3.2	D	[m]	Assume a trial pipe diameter for HSRS	3
3.2.3.3	NP	1, 2, or 3	Number of pipes for HSRS	3
3.2.3.4	YA	[%]	Maximum fraction of total yield that is allowed to be used in HSRS operations	100
3.2.3.5	CLH	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for HSRS	22
3.2.3.6	PH	[$/m3]	Unit value of water released downstream of dam in river by HSRS operations	0.00
3.2.3.7	HI	[US$]	Cost of capital investment to install HSRS	2,000,000
3.2.3.8	DU	[Years]	The expected life of HSRS	20
3.2.3.9	Shall the implementation strategy of HSRS be determined through economic optimization?			No
3.2.3.10	Year HSRSstart	[Years]	Timing of HSRS installation	10
3.2.3.11	HSRSlimit	[m]	Length limit for implementation of HSRS	5,000

Table B-7: Sediment Management – Trucking

ID	Parameter	Units	Description	Value
3.2.4.1	CLT	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for trucking	22
3.2.4.2	AST	[%]	Maximum percent of reservoir storage that can be restored during each trucking event	100
3.2.4.3	MT	[m3]	Amount of sediment removed per trucking event	50,000
3.2.4.4	CT	[US$/m3]	Unit Cost of trucking	10
3.2.4.5	Shall the implementation strategy of trucking be determined through economic optimization?			No
3.2.4.6	Cycle1TR	[years]	Implementation year	1
3.2.4.7	Cycle2TR	[years]	Frequency of trucking operation	1
3.2.4.8	Shall a sustainable solution be determined automatically?			Yes
3.2.4.9	Where do you want to perform trucking?			Both active and inactive storage
3.2.4.10	sTR	[%]	Fraction of reservoir water yield the year trucking occurs	50

المنارة للاستشارات
www.manaraa.com

Table B-8: Sediment Management – Sediment By-pass

ID	Parameter	Units	Description	Value
3.3.1.1	$C_{B\text{-}P}$	[US$]	Cost for implementation of by-pass structure	150,000,000
3.3.1.2	$OMC_{B\text{-}P}$	[US$/a]	Annual operation and maintenance Costs of by-pass structures	5,000,000
3.3.1.3	Shall the duration and implementation year be defined through economic optimization?			Yes
3.3.1.4	$Year_{BP\ Start}$	[years]	Implementation year of by-pass	12
3.3.1.5	T_{BP}	[months]	Duration of sediment by-pass	0.5
3.3.1.6	$CL_{B\text{-}P}$	[%]	Maximum allowable storage loss before implementation of sediment by-pass	22
3.3.1.7	$T_{B\text{-}P\ max}$	[months]	Maximum allowable duration of by-pass operation	3
3.3.1.8	BP_Efficiency	[%]	Water by-pass efficiency	50
3.3.1.9	BPbedload_Efficiency	[%]	Bedload by-pass efficiency	100
3.3.1.10	BPsuspendedload_ Efficiency	[%]	Suspended load by-pass efficiency	60
3.3.1.11	BPlimit	[m]	Length limit for feasibility of by-pass structure	5,000

Table B-9: Sediment Management – Sluicing

ID	Parameter	Units	Description	Value
3.3.2.1	EL_{SL}	[masl]	Reservoir pool elevation during sluicing	135
3.3.2.2	C_{SL}	[US$]	Cost for implementation of sluicing structure	0
3.3.2.3	OMC_{SL}	[US$/a]	Annual operation and maintenance costs of sluicing structures	100,000
3.3.2.4	Shall the duration and implementation year be defined through economic optimization?			No
3.3.2.5	$Year_{SL\ Start}$	[years]	Implementation year of sluicing	10
3.3.2.6	T_{SL}	[months]	Duration of sluicing operation	0.50
3.3.2.7	CL_{SL}	[%]	Maximum allowable storage loss before implementation of sluicing	22
3.3.2.8	$T_{SL\ max}$	[months]	Maximum allowable duration of sluicing	1.0

المنارة للاستشارات

www.manaraa.com

Table B-10: Sediment Management – Density Current Venting

ID	Parameter	Units	Description	Value
3.3.3.1				
3.3.3.2	T_{DCV}	[months]	Duration of density current venting	0.50
3.3.3.3	YearDCVstart	[years]	Implementation year of denstiy current venting	10
3.3.3.4	CL_{DCV}	[%]	Maximum allowable storage loss before implementation of density current venting	22
3.3.3.5	s_{DCV}	[%]	Fraction of reservoir benefits the year density current venting occurs	20
3.3.3.6	DCVI	[US$]	Cost of capital investment	0

Table B-11: Sediment Management – Multiple Management

ID	ID	Sediment Management Technique	Start [Year]	End [Year]
3.4.1				
3.4.2				
3.4.3	1	Catchment Management	1	22
3.4.4	2	Dredging	23	60
3.4.5	3	Flushing	61	80
3.4.6	4	Trucking	81	120
3.4.7	5	Sluicing	121	300

المنارة للاستشارات

www.manaraa.com

Table B-12: Economic Parameters

ID	Parameter	Units	Description	Value
4.1				
4.2	c	[$/m3]	Unit cost of construction per m3 of reservoir capacity	2.21
4.3	C2	[$]	Total cost of reservoir impoundment	25,046,666
4.4	r	[%]	Discount rate	10.0
4.5	Mr	[%]	Market interest rate of annual retirement fund	12.0
4.6	P1	[$/m3]	Unit benefit of reservoir yield	0.4
4.7	V	[$]	Decommissioning cost	37,000,000
4.8	CL_NS	[%]	Capacity loss for characterization of a reservoir as non sustainable	95
4.9	C1	[$/a]	Total annual operation and maintenance costs	40,075
4.10				
4.11				
4.12				
4.13			Application of declining discount rate?	No
4.14	Ymax	[years]	Maximum duration of financial analysis	300

المنارة للاستشارات
www.manaraa.com

Banja

Table B-13: Reservoir Geometry

ID	Parameter	Units	Description	Value
1.1.1	So_gr	[m³]	Original gross storage capacity of the reservoir	403,000,000
1.1.2	So_a	[m³]	Original active storage capacity of the reservoir	178,000,000
1.1.3	So_d	[m³]	Original inactive storage capacity of the reservoir	225,000,000
1.1.4	Se_gr	[m³]	Existing gross storage capacity of the reservoir	403,000,000
1.1.5	Se_a	[m³]	Existing active storage of the reservoir	178,000,000
1.1.6	Se_d	[m³]	Existing inactive storage of the reservoir	225,000,000
1.1.7	Wbot	[m]	Representative reservoir bottom width at the dam location	270
1.1.8	--	--	--	
1.1.9	ELOWL	[masl]	Maximum pool elevation of reservoir	175.0
1.1.10	ELMWL	[masl]	Minimum operation water level	160.0
1.1.11	Elbmin	[masl]	Minimum reservoir bed elevation at dam site	95.0
1.1.12	Lres	[m]	Reservoir length	16,000
1.1.13	ncomp	[-]	Number of reservoir compartments	5

المنارة للاستشارات
www.manaraa.com

Table B-14: Hydrology and Sediment

ID	Parameter	Units	Description	Value
2.1.1.1	MAR	[million m^3/a]	Mean annual reservoir water inflow	1,484
2.1.1.2	Cv	[-]	Coefficient of variation of annual run-off volume	0.28
2.1.1.3	Twater	[°C]	Representative water temperature in the reservoir	14.7
2.1.2.1	r_d	[tonnes/m^3]	Specific weight of in-situ reservoir sediment (bulk density)	1.4
2.1.2.2	MAS	[million tonnes/a]	Mean annual total (suspended and bedload) sediment inflow mass	2.42
2.1.2.3		[g/l]	Average annual concentration of suspended load	36.000
2.1.2.3	ExceedT	[%]	Percentage of time exceeded	30, 60, 90
	ExceedMAR	[%]	Percentage of mean annual water inflow	40, 20, 3
	ExceedMAS	[%]	Percentage of mean annual sediment inflow	25, 5, 3
2.1.2.4	pcl	[%]	% clay of suspended sediment inflow	--
2.1.2.5	psi	[%]	% silt of suspended sediment inflow	--
2.1.2.6	psa	[%]	% sand of suspended sediment inflow	--
2.1.2.7	ws_cl	[m/s]	Settling velocity of clay particles	--
2.1.2.8	ws_si	[m/s]	Settling velocity of silt particles	--
2.1.2.9	ws_sa	[m/s]	Settling velocity of sand particles	--
2.1.2.10	TE_Method		Trap efficiency method	Churchill
2.1.2.11	Brune Curve No	[-]		--
2.1.2.12	p_b	[%]	% bedload of total sediment inflow	10
2.1.2.13	T_b	[%]	Duration of bedload transport	5
2.1.3.1	Zpr		Standardized normal nariate at pr*100%	2.33
2.1.3.2	Gd		Gould's correction factor	1.50
2.1.3.3	Sd		Standard deviation of annual run-off	415,520,000
2.1.3.4	Distribution		Distribution of annual inflows	Lognormal

للاستشارات المنارة
www.manaraa.com

Table B-15: Sediment Management – Catchment Management

ID	**Parameter**	**Units**	**Description**	**Value**
3.1.1	CM_Method	[-]	Catchment management method	Construction of Check Dams
3.1.2	MASb reduction	[%]	Expected reduction of bedload inflow in reservoir due to catchment management	100
3.1.3	MASs reduction	[%]	Expected reduction of suspended load inflow in reservoir due to catchment management	0
3.1.4	YearMAS reduction Start	[Years]	How many years after its implementation will catchment management affect sediment inflow in reservoir?	1
3.1.5				
3.1.6	C_CM	[US$]	Costs for implementation of catchment management measures	20,000,000
3.1.7	OMC_CM	[US$/a]	Annual operation and maintenance costs of catchment management	200,000
3.1.8	Shall the implementation year of catchment management be determined through economic optimization?			No
3.1.9	Year CMstart	[years]	Implementation year of catchment management	5
3.1.10	CL_CM	[%]	Maximum allowable storage loss before implementation of catchment management	1

www.manaraa.com

Table B-16: Sediment Management – Flushing

ID	Parameter	Units	Description	Value
3.2.1.1	Y	[-]	Indicator of deposits type	650
3.2.1.2	Ans	3 or 1	Sediment removal difficulty	3
3.2.1.3	Qf	[m3/s]	Representative flushing discharge	300
3.2.1.4	Tf	[days]	Duration of flushing after complete drawdown	5
3.2.1.5	Cal_SSfl	[-]	Calibration parameter for Mignot equation	10
3.2.1.6	CLF	[%]	Maximum percent of capacity loss allowable	80
3.2.1.7	s1	[%]	Fraction of run-of-river benefits	50
3.2.1.8	s2	[%]	Fraction of storage benefits	50
3.2.1.9	FI	[US$]	Cost of capital investment	130
3.2.1.10	Elfl_dam	[masl]	Water elevation at dam during flushing	110
3.2.1.12	Shall the implementation strategy of flushing be determined through economic optimization?			No
3.2.1.13	CycleNS	[Years]	Time interval between flushing events during the 1st phase (Reservoir storage > sustainable long term reservoir capacity)	10
3.2.1.14	CycleS	[Years]	Time interval between flushing events during the 2nd phase (Reservoir storage < sustainable long term reservoir capacity)	1
3.2.1.15	OMC_FL	[US$/a]	Annual operation and maintenance costs of flushing	0

Table B-17: Sediment Management – Dredging

ID	Parameter	Units	Description	Value
3.2.2.1	Cw	[%]	Concentration by weight of sediment removed to water removed by traditional dredging	30
3.2.2.2	CLD	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for dredging	50
3.2.2.3	ASD	[%]	Maximum percent of reservoir storage that can be restored during each dredging event	20
3.2.2.4	MD	[m3]	Amount of sediment removed per dredging event	1,000,000
3.2.2.5	PD	[$/m3]	Unit value of water used in dredging operations	0.00
3.2.2.6	CD	[$/m3]	Unit cost of dredging	
3.2.2.7	Shall the unit cost of dredging be determined automatically?			Yes
3.2.2.8	Shall the implementation strategy of dredging be determined through economic optimization?			No
3.2.2.9	Cycle1DR	[years]	Duration of phase 1 (No dredging)	10
3.2.2.10	Cycle2DR	[years]	Cycle length in phase 2 (Dredging operation)	1
3.2.2.11	Shall a sustainable solution be determined automatically?			No
3.2.2.12	Where do you want to perform dredging?			Both active and inactive storage

المنارة للاستشارات
www.manaraa.com

Table B-18: Sediment Management – HSRS

ID	Parameter	Units	Description	Value
3.2.3.1	Type	1 or 2	Sediment type category to be removed by Hydrosuction Sediment Removal System (HSRS)	1
3.2.3.2	D	[m]	Assume a trial pipe diameter for HSRS	1
3.2.3.3	NP	1, 2, or 3	Number of pipes for HSRS	1
3.2.3.4	YA	[%]	Maximum fraction of total yield that is allowed to be used in HSRS operations	10
3.2.3.5	CLH	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for HSRS	100
3.2.3.6	PH	[$/m3]	Unit value of water released downstream of dam in river by HSRS operations	0.00
3.2.3.7	HI	[US$]	Cost of capital investment to install HSRS	20,000,000
3.2.3.8	DU	[Years]	The expected life of HSRS	20
3.2.3.9	Shall the implementation strategy of HSRS be determined through economic optimization?			No
3.2.3.10	Year HSRSstart	[Years]	Timing of HSRS installation	10
3.2.3.11	HSRSlimit	[m]	Length limit for implementation of HSRS	17,000

Table B-19: Sediment Management – Trucking

ID	Parameter	Units	Description	Value
3.2.4.1	CLT	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for trucking	80
3.2.4.2	AST	[%]	Maximum percent of reservoir storage that can be restored during each trucking event	30
3.2.4.3	MT	[m3]	Amount of sediment removed per trucking event	10,000,000
3.2.4.4	CT	[US$/m3]	Unit Cost of trucking	13
3.2.4.5	Shall the implementation strategy of trucking be determined through economic optimization?			No
3.2.4.6	Cycle1TR	[years]	Implementation year	10
3.2.4.7	Cycle2TR	[years]	Frequency of trucking operation	5
3.2.4.8	Shall a sustainable solution be determined automatically?			Yes
3.2.4.9	Where do you want to perform trucking?			Both active and inactive storage
3.2.4.10	sTR	[%]	Fraction of reservoir water yield the year trucking occurs	0

المنارة للاستشارات
www.manaraa.com

Table B-20: Sediment Management – Sediment By-pass

ID	Parameter	Units	Description	Value
3.3.1.1	C_{B-P}	[US$]	Cost for implementation of by-pass structure	30,000,000
3.3.1.2	OMC_{B-P}	[US$/a]	Annual operation and maintenance Costs of by-pass structures	300,000
3.3.1.3	Shall the duration and implementation year be defined through economic optimization?			No
3.3.1.4	$Year_{BP\ Start}$	[years]	Implementation year of by-pass	5
3.3.1.5	T_{BP}	[months]	Duration of sediment by-pass	4.0
3.3.1.6	CL_{B-P}	[%]	Maximum allowable storage loss before implementation of sediment by-pass	100
3.3.1.7	$T_{B-P\ max}$	[months]	Maximum allowable duration of by-pass operation	6
3.3.1.8	BP_Efficiency	[%]	Water by-pass efficiency	80
3.3.1.9	BPbedload_Efficiency	[%]	Bedload by-pass efficiency	100
3.3.1.10	BPsuspendedload_ Efficiency	[%]	Suspended load by-pass efficiency	60
3.3.1.11	BPlimit	[m]	Length limit for feasibility of by-pass structure	17,000

Table B-21: Sediment Management – Sluicing

ID	Parameter	Units	Description	Value
3.3.2.1	EL_{SL}	[masl]	Reservoir pool elevation during sluicing	168
3.3.2.2	C_{SL}	[US$]	Cost for implementation of sluicing structure	0
3.3.2.3	OMC_{SL}	[US$/a]	Annual operation and maintenance costs of sluicing structures	200,000
3.3.2.4	Shall the duration and implementation year be defined through economic optimization?			No
3.3.2.5	$Year_{SL\ Start}$	[years]	Implementation year of sluicing	1
3.3.2.6	T_{SL}	[months]	Duration of sluicing operation	4.00
3.3.2.7	CL_{SL}	[%]	Maximum allowable storage loss before implementation of sluicing	100
3.3.2.8	$T_{SL\ max}$	[months]	Maximum allowable duration of sluicing	6.0

المنارة للاستشارات

www.manaraa.com

Table B-22: Sediment Management – Density Current Venting

ID	Parameter	Units	Description	Value
3.3.3.1				
3.3.3.2	T_{DCV}	[months]	Duration of density current venting	1.00
3.3.3.3	YearDCVstart	[years]	Implementation year of denstiy current venting	50
3.3.3.4	CL_{DCV}	[%]	Maximum allowable storage loss before implementation of density current venting	100
3.3.3.5	s_{DCV}	[%]	Fraction of reservoir benefits the year density current venting occurs	50
3.3.3.6	DCVI	[US$]	Cost of capital investment	0

Table B-23: Sediment Management – Multiple Management

ID	ID	Sediment Management Technique	Start [Year]	End [Year]
3.4.1				
3.4.2				
3.4.3	1	Catchment Management	1	15
3.4.4	2	Dredging	16	120
3.4.5	3	Flushing	121	180
3.4.6	4	Trucking	181	250
3.4.7	5	Sluicing	251	300

المنارة للاستشارات

www.manaraa.com

Table B-24: Economic Parameters

ID	Parameter	Units	Description	Value	
4.1					
4.2	c	[$/m3]	Unit cost of construction per m3 of reservoir capacity	0.36	
4.3	C2	[$]	Total cost of reservoir impoundment	143,871,000	
4.4	r	[%]	Discount rate	6	
4.5	Mr	[%]	Market interest rate of annual retirement fund	8	
4.6	P1	[$/m3]	Unit benefit of reservoir yield	0.4	
4.7	V	[$]	Decommissioning cost	50,000,000	
4.8	CL_NS	[%]	Capacity loss for characterization of a reservoir as non sustainable	95	
4.9	C1	[$/a]	Total annual operation and maintenance costs	1,440,000	
4.10					
4.11					
4.12					
4.13			Application of declining discount rate?	Yes	
4.13a	DDR1	[%]		0 – 30	6.00%
4.13b	DDR2	[%]		31 – 75	5.14%
4.13c	DDR3	[%]	Definition of Declining Discount Rate	76 – 125	4.28%
4.13d	DDR4	[%]		126 – 200	3.42%
4.13e	DDR5	[%]		201 – 300	2.58%
4.13f	DDR6	[%]		301 – …	1.72%
4.14	Ymax	[years]	Maximum duration of financial analysis	300	

المنارة للاستشارات
www.manaraa.com

Bin El Ouidane

Table B-25: Reservoir Geometry

ID	Parameter	Units	Description	Value
1.1.1	So_gr	[m^3]	Original gross storage capacity of the reservoir	1,507,500,000
1.1.2	So_a	[m^3]	Original active storage capacity of the reservoir	1,507,500,000
1.1.3	So_d	[m^3]	Original inactive storage capacity of the reservoir	500,000
1.1.4	Se_gr	[m^3]	Existing gross storage capacity of the reservoir	1,253,400,000
1.1.5	Se_a	[m^3]	Existing active storage of the reservoir	1,253,300,000
1.1.6	Se_d	[m^3]	Existing inactive storage of the reservoir	100,000
1.1.7	Wbot	[m]	Representative reservoir bottom width at the dam location	1,000
1.1.8	--	--	--	--
1.1.9	ELOWL	[masl]	Maximum pool elevation of reservoir	810
1.1.10	ELMWL	[masl]	Minimum operation water level	740
1.1.11	Elbmin	[masl]	Minimum reservoir bed elevation at dam site	710
1.1.12	Lres	[m]	Reservoir length	20,000
1.1.13	ncomp	[-]	Number of reservoir compartments	5

المنارة للاستشارات

www.manaraa.com

Table B-26: Hydrology and Sediment

ID	Parameter	Units	Description	Value
2.1.1.1	MAR	[million m^3/a]	Mean annual reservoir water inflow	1,050
2.1.1.2	Cv	[-]	Coefficient of variation of annual run-off volume	0.58
2.1.1.3	Twater	[°C]	Representative water temperature in the reservoir	12
2.1.2.1	r_d	[tonnes/m^3]	Specific weight of in-situ reservoir sediment (bulk density)	1.2
2.1.2.2	MAS	[million tonnes/a]	Mean annual total (suspended and bedload) sediment inflow mass	7.00
2.1.2.3		[g/l]	Average annual concentration of suspended load	6.00
2.1.2.3	ExceedT	[%]	Percentage of time exceeded	25, 50, 75
	ExceedMAR	[%]	Percentage of mean annual water inflow	75, 50, 25
	ExceedMAS	[%]	Percentage of mean annual sediment inflow	60, 30, 25
2.1.2.4	pcl	[%]	% clay of suspended sediment inflow	--
2.1.2.5	psi	[%]	% silt of suspended sediment inflow	--
2.1.2.6	psa	[%]	% sand of suspended sediment inflow	--
2.1.2.7	ws_cl	[m/s]	Settling velocity of clay particles	--
2.1.2.8	ws_si	[m/s]	Settling velocity of silt particles	--
2.1.2.9	ws_sa	[m/s]	Settling velocity of sand particles	--
2.1.2.10	TE_Method		Trap efficiency method	Brune
2.1.2.11	Brune Curve No	[-]		2
2.1.2.12	p_b	[%]	% bedload of total sediment inflow	10.0
2.1.2.13	T_b	[%]	Duration of bedload transport	10
2.1.3.1	Zpr		Standardized normal nariate at pr*100%	2.33
2.1.3.2	Gd		Gould's correction factor	1.50
2.1.3.3	Sd		Standard deviation of annual run-off	609,000,000
2.1.3.4	Distribution		Distribution of annual inflows	Lognormal

www.manaraa.com

Table B-27: Sediment Management – Catchment Management

ID	Parameter	Units	Description	Value
3.1.1	CM_Method	[-]	Catchment management method	De-intensification of land use practices
3.1.2	MASb reduction	[%]	Expected reduction of bedload inflow in reservoir due to catchment management	5
3.1.3	MASs reduction	[%]	Expected reduction of suspended load inflow in reservoir due to catchment management	5
3.1.4	YearMAS reduction Start	[Years]	How many years after its implementation will catchment management affect sediment inflow in reservoir?	1
3.1.5				0
3.1.6	C_CM	[US$]	Costs for implementation of catchment management measures	0
3.1.7	OMC_CM	[US$/a]	Annual operation and maintenance costs of catchment management	0
3.1.8	Shall the implementation year of catchment management be determined through economic optimization?			No
3.1.9	Year CMstart	[years]	Implementation year of catchment management	1
3.1.10	CL_CM	[%]	Maximum allowable storage loss before implementation of catchment management	100

www.manaraa.com

Table B-28: Sediment Management – Flushing

ID	Parameter	Units	Description	Value
3.2.1.1	Y	[-]	Indicator of deposits type	650
3.2.1.2	Ans	3 or 1	Sediment removal difficulty	3
3.2.1.3	Qf	[m3/s]	Representative flushing discharge	50
3.2.1.4	Tf	[days]	Duration of flushing after complete drawdown	2
3.2.1.5	Cal_SSfl	[-]	Calibration parameter for Mignot equation	10
3.2.1.6	CLF	[%]	Maximum percent of capacity loss allowable	25
3.2.1.7	s1	[%]	Fraction of run-of-river benefits	50
3.2.1.8	s2	[%]	Fraction of storage benefits	50
3.2.1.9	FI	[US$]	Cost of capital investment	0
3.2.1.10	Elfl_dam	[masl]	Water elevation at dam during flushing	740
3.2.1.12	Shall the implementation strategy of flushing be determined through economic optimization?			No
3.2.1.13	CycleNS	[Years]	Time interval between flushing events during the 1st phase (Reservoir storage > sustainable long term reservoir capacity)	5
3.2.1.14	CycleS	[Years]	Time interval between flushing events during the 2nd phase (Reservoir storage < sustainable long term reservoir capacity)	14
3.2.1.15	OMC_FL	[US$/a]	Annual operation and maintenance costs of flushing	0

Table B-29: Sediment Management – Dredging

ID	Parameter	Units	Description	Value
3.2.2.1	Cw	[%]	Concentration by weight of sediment removed to water removed by traditional dredging	30
3.2.2.2	CLD	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for dredging	25
3.2.2.3	ASD	[%]	Maximum percent of reservoir storage that can be restored during each dredging event	1
3.2.2.4	MD	[m3]	Amount of sediment removed per dredging event	10,000,000
3.2.2.5	PD	[$/m3]	Unit value of water used in dredging operations	3.00
3.2.2.6	CD	[$/m3]	Unit cost of dredging	7
3.2.2.7	Shall the unit cost of dredging be determined automatically?			No
3.2.2.8	Shall the implementation strategy of dredging be determined through economic optimization?			No
3.2.2.9	Cycle1DR	[years]	Duration of phase 1 (No dredging)	1
3.2.2.10	Cycle2DR	[years]	Cycle length in phase 2 (Dredging operation)	1
3.2.2.11	Shall a sustainable solution be determined automatically?			Yes
3.2.2.12	Where do you want to perform dredging?			Both active and inactive storage

المنارة للاستشارات

www.manaraa.com

Table B-30: Sediment Management – HSRS

ID	Parameter	Units	Description	Value
3.2.3.1	Type	1 or 2	Sediment type category to be removed by Hydrosuction Sediment Removal System (HSRS)	2
3.2.3.2	D	[m]	Assume a trial pipe diameter for HSRS	1
3.2.3.3	NP	1, 2, or 3	Number of pipes for HSRS	3
3.2.3.4	YA	[%]	Maximum fraction of total yield that is allowed to be used in HSRS operations	100
3.2.3.5	CLH	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for HSRS	100
3.2.3.6	PH	[$/m3]	Unit value of water released downstream of dam in river by HSRS operations	0.00
3.2.3.7	HI	[US$]	Cost of capital investment to install HSRS	2,000,000
3.2.3.8	DU	[Years]	The expected life of HSRS	25
3.2.3.9	Shall the implementation strategy of HSRS be determined through economic optimization?			No
3.2.3.10	Year HSRSstart	[Years]	Timing of HSRS installation	1
3.2.3.11	HSRSlimit	[m]	Length limit for implementation of HSRS	5,000

Table B-31: Sediment Management – Trucking

ID	Parameter	Units	Description	Value
3.2.4.1	CLT	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for trucking	25
3.2.4.2	AST	[%]	Maximum percent of reservoir storage that can be restored during each trucking event	1
3.2.4.3	MT	[m3]	Amount of sediment removed per trucking event	10,000,000
3.2.4.4	CT	[US$/m3]	Unit Cost of trucking	13
3.2.4.5	Shall the implementation strategy of trucking be determined through economic optimization?			No
3.2.4.6	Cycle1TR	[years]	Implementation year	1
3.2.4.7	Cycle2TR	[years]	Frequency of trucking operation	10
3.2.4.8	Shall a sustainable solution be determined automatically?			Yes
3.2.4.9	Where do you want to perform trucking?			Both active and inactive storage
3.2.4.10	sTR	[%]	Fraction of reservoir water yield the year trucking occurs	50

www.manaraa.com

Table B-32: Sediment Management – Sediment By-pass

ID	Parameter	Units	Description	Value
3.3.1.1	C_{B-P}	[US$]	Cost for implementation of by-pass structure	0
3.3.1.2	OMC_{B-P}	[US$/a]	Annual operation and maintenance Costs of by-pass structures	0
3.3.1.3	Shall the duration and implementation year be defined through economic optimization?			No
3.3.1.4	$Year_{BP\ Start}$	[years]	Implementation year of by-pass	1
3.3.1.5	T_{BP}	[months]	Duration of sediment by-pass	1.0
3.3.1.6	CL_{B-P}	[%]	Maximum allowable storage loss before implementation of sediment by-pass	100
3.3.1.7	$T_{B-P\ max}$	[months]	Maximum allowable duration of by-pass operation	1
3.3.1.8	BP_Efficiency	[%]	Water by-pass efficiency	80
3.3.1.9	BPbedload_Efficiency	[%]	Bedload by-pass efficiency	100
3.3.1.10	BPsuspendedload_ Efficiency	[%]	Suspended load by-pass efficiency	60
3.3.1.11	BPlimit	[m]	Length limit for feasibility of by-pass structure	5,000

Table B-33: Sediment Management – Sluicing

ID	Parameter	Units	Description	Value
3.3.2.1	EL_{SL}	[masl]	Reservoir pool elevation during sluicing	790
3.3.2.2	C_{SL}	[US$]	Cost for implementation of sluicing structure	0
3.3.2.3	OMC_{SL}	[US$/a]	Annual operation and maintenance costs of sluicing structures	100,000
3.3.2.4	Shall the duration and implementation year be defined through economic optimization?			No
3.3.2.5	$Year_{SL\ Start}$	[years]	Implementation year of sluicing	1
3.3.2.6	T_{SL}	[months]	Duration of sluicing operation	1.00
3.3.2.7	CL_{SL}	[%]	Maximum allowable storage loss before implementation of sluicing	25
3.3.2.8	$T_{SL\ max}$	[months]	Maximum allowable duration of sluicing	2.0

المنارة للاستشارات
www.manaraa.com

Table B-34: Sediment Management – Density Current Venting

ID	Parameter	Units	Description	Value
3.3.3.1				
3.3.3.2	T_{DCV}	[months]	Duration of density current venting	0.50
3.3.3.3	YearDCVstart	[years]	Implementation year of denstiy current venting	1
3.3.3.4	CL_{DCV}	[%]	Maximum allowable storage loss before implementation of density current venting	25
3.3.3.5	s_{DCV}	[%]	Fraction of reservoir benefits the year density current venting occurs	80
3.3.3.6	DCVI	[US$]	Cost of capital investment	0

Table B-35: Sediment Management – Multiple Management

ID	ID	Sediment Management Technique	Start [Year]	End [Year]
3.4.1				
3.4.2				
3.4.3	1	Catchment Management	1	25
3.4.4	2	Dredging	26	60
3.4.5	3	Flushing	61	80
3.4.6	4	Trucking	81	120
3.4.7	5	Sluicing	121	300

المنارة للاستشارات
www.manaraa.com

Table B-36: Economic Parameters

ID	Parameter	Units	Description	Value
4.1				
4.2	c	[$/m3]	Unit cost of construction per m3 of reservoir capacity	0.27
4.3	C2	[$]	Total cost of reservoir impoundment	399,861,908
4.4	r	[%]	Discount rate	5.0
4.5	Mr	[%]	Market interest rate of annual retirement fund	6.0
4.6	P1	[$/m3]	Unit benefit of reservoir yield	3
4.7	V	[$]	Decommissioning cost	400,000,000
4.8	CL_NS	[%]	Capacity loss for characterization of a reservoir as non sustainable	95
4.9	C1	[$/a]	Total annual operation and maintenance costs	3,998,619
4.10				
4.11				
4.12				
4.13			Application of declining discount rate?	No
4.14	Ymax	[years]	Maximum duration of financial analysis	300

المنارة للاستشارات
www.manaraa.com

Gavins Point Dam

Table B-37: Reservoir Geometry

ID	Parameter	Units	Description	Value
1.1.1	So_gr	[m³]	Original gross storage capacity of the reservoir	709,621,270
1.1.2	So_a	[m³]	Original active storage capacity of the reservoir	250,291,544
1.1.3	So_d	[m³]	Original inactive storage capacity of the reservoir	459,329,726
1.1.4	Se_gr	[m³]	Existing gross storage capacity of the reservoir	525,736,802
1.1.5	Se_a	[m³]	Existing active storage of the reservoir	188,996,721
1.1.6	Se_d	[m³]	Existing inactive storage of the reservoir	336,740,081
1.1.7	Wbot	[m]	Representative reservoir bottom width at the dam location	2500
1.1.8	--	--	--	--
1.1.9	ELOWL	[masl]	Maximum pool elevation of reservoir	368.9
1.1.10	ELMWL	[masl]	Minimum operation water level	363.0
1.1.11	Elbmin	[masl]	Minimum reservoir bed elevation at dam site	352.1
1.1.12	Lres	[m]	Reservoir length	25,000
1.1.13	ncomp	[-]	Number of reservoir compartments	5

المنارة للاستشارات
www.manaraa.com

Table B-38: Hydrology and Sediment

ID	Parameter	Units	Description	Value
2.1.1.1	MAR	[million m^3/a]	Mean annual reservoir water inflow	28,385
2.1.1.2	Cv	[-]	Coefficient of variation of annual run-off volume	1.00
2.1.1.3	Twater	[°C]	Representative water temperature in the reservoir	30
2.1.2.1	r_d	[tonnes/m^3]	Specific weight of in-situ reservoir sediment (bulk density)	1.2
2.1.2.2	MAS	[million tonnes/a]	Mean annual total (suspended and bedload) sediment inflow mass	4.89
2.1.2.3		[g/l]	Average annual concentration of suspended load	0.155
2.1.2.3	ExceedT	[%]	Percentage of time exceeded	30, 60, 90
	ExceedMAR	[%]	Percentage of mean annual water inflow	40, 20, 3
	ExceedMAS	[%]	Percentage of mean annual sediment inflow	25, 5, 3
2.1.2.4	pcl	[%]	% clay of suspended sediment inflow	--
2.1.2.5	psi	[%]	% silt of suspended sediment inflow	--
2.1.2.6	psa	[%]	% sand of suspended sediment inflow	--
2.1.2.7	ws_cl	[m/s]	Settling velocity of clay particles	--
2.1.2.8	ws_si	[m/s]	Settling velocity of silt particles	--
2.1.2.9	ws_sa	[m/s]	Settling velocity of sand particles	--
2.1.2.10	TE_Method		Trap efficiency method	Brune
2.1.2.11	Brune Curve No	[-]		2
2.1.2.12	p_b	[%]	% bedload of total sediment inflow	10
2.1.2.13	T_b	[%]	Duration of bedload transport	5
2.1.3.1	Zpr		Standardized normal nariate at pr*100%	2.33
2.1.3.2	Gd		Gould's correction factor	1.50
2.1.3.3	Sd		Standard deviation of annual run-off	28,384,760,000
2.1.3.4	Distribution		Distribution of annual inflows	Lognormal

المنارة للاستشارات
www.manaraa.com

Table B-39: Sediment Management – Flushing

ID	Parameter	Units	Description	Value
3.2.1.1	Y	[-]	Indicator of deposits type	300
3.2.1.2	Ans	3 or 1	Sediment removal difficulty	3
3.2.1.3	Qf	[m3/s]	Representative flushing discharge	1,700
3.2.1.4	Tf	[days]	Duration of flushing after complete drawdown	14
3.2.1.5	Cal_SSfl	[-]	Calibration parameter for Mignot equation	10
3.2.1.6	CLF	[%]	Maximum percent of capacity loss allowable	100
3.2.1.7	s1	[%]	Fraction of run-of-river benefits	90
3.2.1.8	s2	[%]	Fraction of storage benefits	90
3.2.1.9	FI	[US$]	Cost of capital investment	0
3.2.1.10	Elfl_dam	[masl]	Water elevation at dam during flushing	363
3.2.1.12	Shall the implementation strategy of flushing be determined through economic optimization?			Yes
3.2.1.13	CycleNS	[Years]	Time interval between flushing events during the 1st phase (Reservoir storage > sustainable long term reservoir capacity)	1
3.2.1.14	CycleS	[Years]	Time interval between flushing events during the 2nd phase (Reservoir storage < sustainable long term reservoir capacity)	1
3.2.1.15	OMC_FL	[US$/a]	Annual operation and maintenance costs of flushing	0

Table B-40: Sediment Management – Dredging

ID	Parameter	Units	Description	Value
3.2.2.1	Cw	[%]	Concentration by weight of sediment removed to water removed by traditional dredging	30
3.2.2.2	CLD	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for dredging	100
3.2.2.3	ASD	[%]	Maximum percent of reservoir storage that can be restored during each dredging event	100
3.2.2.4	MD	[m3]	Amount of sediment removed per dredging event	1,000,000
3.2.2.5	PD	[$/m3]	Unit value of water used in dredging operations	0.02
3.2.2.6	CD	[$/m3]	Unit cost of dredging	20
3.2.2.7	Shall the unit cost of dredging be determined automatically?			No
3.2.2.8	Shall the implementation strategy of dredging be determined through economic optimization?			Yes
3.2.2.9	Cycle1DR	[years]	Duration of phase 1 (No dredging)	1
3.2.2.10	Cycle2DR	[years]	Cycle length in phase 2 (Dredging operation)	1
3.2.2.11	Shall a sustainable solution be determined automatically?			No
3.2.2.12	Where do you want to perform dredging?			Active storage

المنارة للاستشارات
www.manaraa.com

Table B-41: Sediment Management – HSRS

ID	Parameter	Units	Description	Value
3.2.3.1	Type	1 or 2	Sediment type category to be removed by Hydrosuction Sediment Removal System (HSRS)	1
3.2.3.2	D	[m]	Assume a trial pipe diameter for HSRS	0.61
3.2.3.3	NP	1, 2, or 3	Number of pipes for HSRS	3
3.2.3.4	YA	[%]	Maximum fraction of total yield that is allowed to be used in HSRS operations	30
3.2.3.5	CLH	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for HSRS	100
3.2.3.6	PH	[$/m3]	Unit value of water released downstream of dam in river by HSRS operations	0.02
3.2.3.7	HI	[US$]	Cost of capital investment to install HSRS	1,000,000
3.2.3.8	DU	[Years]	The expected life of HSRS	25
3.2.3.9	Shall the implementation strategy of HSRS be determined through economic optimization?			Yes
3.2.3.10	Year HSRSstart	[Years]	Timing of HSRS installation	1
3.2.3.11	HSRSlimit	[m]	Length limit for implementation of HSRS	25,000

Table B-42: Sediment Management – Trucking

ID	Parameter	Units	Description	Value
3.2.4.1	CLT	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for trucking	100
3.2.4.2	AST	[%]	Maximum percent of reservoir storage that can be restored during each trucking event	100
3.2.4.3	MT	[m3]	Amount of sediment removed per trucking event	500,000
3.2.4.4	CT	[US$/m3]	Unit Cost of trucking	13
3.2.4.5	Shall the implementation strategy of trucking be determined through economic optimization?			Yes
3.2.4.6	Cycle1TR	[years]	Implementation year	1
3.2.4.7	Cycle2TR	[years]	Frequency of trucking operation	1
3.2.4.8	Shall a sustainable solution be determined automatically?			No
3.2.4.9	Where do you want to perform trucking?			Active storage
3.2.4.10	sTR	[%]	Fraction of reservoir water yield the year trucking occurs	90

المنارة للاستشارات
www.manaraa.com

Table B-43: Economic Parameters

ID	Parameter	Units	Description	Value
4.1				
4.2	c	[$/m3]	Unit cost of construction per m3 of reservoir capacity	0.16
4.3	C2	[$]	Total cost of reservoir impoundment	0
4.4	r	[%]	Discount rate	6
4.5	Mr	[%]	Market interest rate of annual retirement fund	6
4.6	P1	[$/m3]	Unit benefit of reservoir yield	0.2
4.7	V	[$]	Decommissioning cost	0
4.8	CL_NS	[%]	Capacity loss for characterization of a reservoir as non sustainable	100
4.9	C1	[$/a]	Total annual operation and maintenance costs	1,000,000
4.10				
4.11				
4.12				
4.13			Application of declining discount rate?	No
4.14	Ymax	[years]	Maximum duration of financial analysis	300

المنارة للاستشارات
www.manaraa.com

Iron Gate

Table B-44: Reservoir Geometry

ID	Parameter	Units	Description	Value
1.1.1	So_gr	[m³]	Original gross storage capacity of the reservoir	100,000,000
1.1.2	So_a	[m³]	Original active storage capacity of the reservoir	70,000,000
1.1.3	So_d	[m³]	Original inactive storage capacity of the reservoir	30,000,000
1.1.4	Se_gr	[m³]	Existing gross storage capacity of the reservoir	1
1.1.5	Se_a	[m³]	Existing active storage of the reservoir	1
1.1.6	Se_d	[m³]	Existing inactive storage of the reservoir	0
1.1.7	Wbot	[m]	Representative reservoir bottom width at the dam location	50
1.1.8	--	--	--	
1.1.9	ELOWL	[masl]	Maximum pool elevation of reservoir	231
1.1.10	ELMWL	[masl]	Minimum operation water level	200
1.1.11	Elbmin	[masl]	Minimum reservoir bed elevation at dam site	130
1.1.12	Lres	[m]	Reservoir length	4,800
1.1.13	ncomp	[-]	Number of reservoir compartments	5

المنارة للاستشارات
www.manaraa.com

Table B-45: Hydrology and Sediment

ID	Parameter	Units	Description	Value
2.1.1.1	MAR	[million m^3/a]	Mean annual reservoir water inflow	1,500
2.1.1.2	Cv	[-]	Coefficient of variation of annual run-off volume	0.20
2.1.1.3	Twater	[°C]	Representative water temperature in the reservoir	20
2.1.2.1	r_d	[tonnes/m^3]	Specific weight of in-situ reservoir sediment (bulk density)	1.35
2.1.2.2	MAS	[million tonnes/a]	Mean annual total (suspended and bedload) sediment inflow mass	4.00
2.1.2.3		[g/l]	Average annual concentration of suspended load	2.44
2.1.2.3	ExceedT	[%]	Percentage of time exceeded	30, 60, 90
	ExceedMAR	[%]	Percentage of mean annual water inflow	40, 20, 3
	ExceedMAS	[%]	Percentage of mean annual sediment inflow	25, 5, 3
2.1.2.4	pcl	[%]	% clay of suspended sediment inflow	--
2.1.2.5	psi	[%]	% silt of suspended sediment inflow	--
2.1.2.6	psa	[%]	% sand of suspended sediment inflow	--
2.1.2.7	ws_cl	[m/s]	Settling velocity of clay particles	--
2.1.2.8	ws_si	[m/s]	Settling velocity of silt particles	--
2.1.2.9	ws_sa	[m/s]	Settling velocity of sand particles	--
2.1.2.10	TE_Method		Trap efficiency method	Churchill
2.1.2.11	Brune Curve No	[-]		2
2.1.2.12	p_b	[%]	% bedload of total sediment inflow	10.00
2.1.2.13	T_b	[%]	Duration of bedload transport	5
2.1.3.1	Zpr		Standardized normal nariate at pr*100%	2.33
2.1.3.2	Gd		Gould's correction factor	1.50
2.1.3.3	Sd		Standard deviation of annual run-off	300,000,000
2.1.3.4	Distribution		Distribution of annual inflows	Lognormal

www.manaraa.com

Table B-46: Sediment Management – Catchment Management

ID	Parameter	Units	Description	Value
3.1.1	CM_Method	[-]	Catchment management method	Construction of Check Dams
3.1.2	MASb reduction	[%]	Expected reduction of bedload inflow in reservoir due to catchment management	40
3.1.3	MASs reduction	[%]	Expected reduction of suspended load inflow in reservoir due to catchment management	20
3.1.4	YearMAS reduction Start	[Years]	How many years after its implementation will catchment management affect sediment inflow in reservoir?	1
3.1.5				
3.1.6	C_CM	[US$]	Costs for implementation of catchment management measures	20,000,000
3.1.7	OMC_CM	[US$/a]	Annual operation and maintenance costs of catchment management	200,000
3.1.8	Shall the implementation year of catchment management be determined through economic optimization?			Yes
3.1.9	Year CMstart	[years]	Implementation year of catchment management	5
3.1.10	CL_CM	[%]	Maximum allowable storage loss before implementation of catchment management	100

www.manaraa.com

Table B-47: Sediment Management – Flushing

ID	Parameter	Units	Description	Value
3.2.1.1	Y	[-]	Indicator of deposits type	300
3.2.1.2	Ans	3 or 1	Sediment removal difficulty	3
3.2.1.3	Qf	[m3/s]	Representative flushing discharge	180
3.2.1.4	Tf	[days]	Duration of flushing after complete drawdown	1
3.2.1.5	Cal_SSfl	[-]	Calibration parameter for Mignot equation	10
3.2.1.6	CLF	[%]	Maximum percent of capacity loss allowable	95
3.2.1.7	s1	[%]	Fraction of run-of-river benefits	50
3.2.1.8	s2	[%]	Fraction of storage benefits	50
3.2.1.9	FI	[US$]	Cost of capital investment	0
3.2.1.10	Elfl_dam	[masl]	Water elevation at dam during flushing	180
3.2.1.12	Shall the implementation strategy of flushing be determined through economic optimization?			Yes
3.2.1.13	CycleNS	[Years]	Time interval between flushing events during the 1st phase (Reservoir storage > sustainable long term reservoir capacity)	3
3.2.1.14	CycleS	[Years]	Time interval between flushing events during the 2nd phase (Reservoir storage < sustainable long term reservoir capacity)	14
3.2.1.15	OMC_FL	[US$/a]	Annual operation and maintenance costs of flushing	0

Table B-48: Sediment Management – Dredging

ID	Parameter	Units	Description	Value
3.2.2.1	Cw	[%]	Concentration by weight of sediment removed to water removed by traditional dredging	30
3.2.2.2	CLD	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for dredging	80
3.2.2.3	ASD	[%]	Maximum percent of reservoir storage that can be restored during each dredging event	30
3.2.2.4	MD	[m3]	Amount of sediment removed per dredging event	3,000,000
3.2.2.5	PD	[$/m3]	Unit value of water used in dredging operations	0.00
3.2.2.6	CD	[$/m3]	Unit cost of dredging	3
3.2.2.7	Shall the unit cost of dredging be determined automatically?			No
3.2.2.8	Shall the implementation strategy of dredging be determined through economic optimization?			No
3.2.2.9	Cycle1DR	[years]	Duration of phase 1 (No dredging)	18
3.2.2.10	Cycle2DR	[years]	Cycle length in phase 2 (Dredging operation)	01
3.2.2.11	Shall a sustainable solution be determined automatically?			Yes
3.2.2.12	Where do you want to perform dredging?			Both active and inactive storage

المنارة للاستشارات

www.manaraa.com

Table B-49: Sediment Management – HSRS

ID	Parameter	Units	Description	Value
3.2.3.1	Type	1 or 2	Sediment type category to be removed by Hydrosuction Sediment Removal System (HSRS)	2
3.2.3.2	D	[m]	Assume a trial pipe diameter for HSRS	1
3.2.3.3	NP	1, 2, or 3	Number of pipes for HSRS	2
3.2.3.4	YA	[%]	Maximum fraction of total yield that is allowed to be used in HSRS operations	100
3.2.3.5	CLH	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for HSRS	30
3.2.3.6	PH	[$/m3]	Unit value of water released downstream of dam in river by HSRS operations	0.00
3.2.3.7	HI	[US$]	Cost of capital investment to install HSRS	20,000,000
3.2.3.8	DU	[Years]	The expected life of HSRS	20
3.2.3.9	Shall the implementation strategy of HSRS be determined through economic optimization?			Yes
3.2.3.10	Year HSRSstart	[Years]	Timing of HSRS installation	2
3.2.3.11	HSRSlimit	[m]	Length limit for implementation of HSRS	5,000

Table B-50: Sediment Management – Trucking

ID	Parameter	Units	Description	Value
3.2.4.1	CLT	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for trucking	30
3.2.4.2	AST	[%]	Maximum percent of reservoir storage that can be restored during each trucking event	100
3.2.4.3	MT	[m3]	Amount of sediment removed per trucking event	2,200,000
3.2.4.4	CT	[US$/m3]	Unit Cost of trucking	12
3.2.4.5	Shall the implementation strategy of trucking be determined through economic optimization?			Yes
3.2.4.6	Cycle1TR	[years]	Implementation year	1
3.2.4.7	Cycle2TR	[years]	Frequency of trucking operation	1
3.2.4.8	Shall a sustainable solution be determined automatically?			Yes
3.2.4.9	Where do you want to perform trucking?			Both active and inactive storage
3.2.4.10	sTR	[%]	Fraction of reservoir water yield the year trucking occurs	50

www.manaraa.com

Table B-51: Sediment Management – Sediment By-pass

ID	Parameter	Units	Description	Value
3.3.1.1	$C_{B\text{-}P}$	[US$]	Cost for implementation of by-pass structure	30,000,000
3.3.1.2	$OMC_{B\text{-}P}$	[US$/a]	Annual operation and maintenance Costs of by-pass structures	100,000
3.3.1.3	Shall the duration and implementation year be defined through economic optimization?			No
3.3.1.4	$Year_{BP\ Start}$	[years]	Implementation year of by-pass	4
3.3.1.5	T_{BP}	[months]	Duration of sediment by-pass	6.0
3.3.1.6	$CL_{B\text{-}P}$	[%]	Maximum allowable storage loss before implementation of sediment by-pass	100
3.3.1.7	$T_{B\text{-}P\ max}$	[months]	Maximum allowable duration of by-pass operation	6
3.3.1.8	BP_Efficiency	[%]	Water by-pass efficiency	80
3.3.1.9	BPbedload_Efficiency	[%]	Bedload by-pass efficiency	100
3.3.1.10	BPsuspendedload_ Efficiency	[%]	Suspended load by-pass efficiency	60
3.3.1.11	BPlimit	[m]	Length limit for feasibility of by-pass structure	5,000

Table B-52: Sediment Management – Sluicing

ID	Parameter	Units	Description	Value
3.3.2.1	EL_{SL}	[masl]	Reservoir pool elevation during sluicing	200
3.3.2.2	C_{SL}	[US$]	Cost for implementation of sluicing structure	15,000,000
3.3.2.3	OMC_{SL}	[US$/a]	Annual operation and maintenance costs of sluicing structures	0
3.3.2.4	Shall the duration and implementation year be defined through economic optimization?			No
3.3.2.5	$Year_{SL\ Start}$	[years]	Implementation year of sluicing	10
3.3.2.6	T_{SL}	[months]	Duration of sluicing operation	4.00
3.3.2.7	CL_{SL}	[%]	Maximum allowable storage loss before implementation of sluicing	100
3.3.2.8	$T_{SL\ max}$	[months]	Maximum allowable duration of sluicing	12.0

المنارة للاستشارات

www.manaraa.com

Table B-53: Sediment Management – Density Current Venting

ID	Parameter	Units	Description	Value
3.3.3.1				
3.3.3.2	T_{DCV}	[months]	Duration of density current venting	6.00
3.3.3.3	YearDCVstart	[years]	Implementation year of denstiy current venting	1
3.3.3.4	CL_{DCV}	[%]	Maximum allowable storage loss before implementation of density current venting	100
3.3.3.5	s_{DCV}	[%]	Fraction of reservoir benefits the year density current venting occurs	70
3.3.3.6	DCVI	[US$]	Cost of capital investment	0

Table B-54: Sediment Management – Multiple Management

ID	ID	Sediment Management Technique	Start [Year]	End [Year]
3.4.1				
3.4.2				
3.4.3	1	Catchment Management	1	15
3.4.4	2	Dredging	16	120
3.4.5	3	Flushing	121	180
3.4.6	4	Trucking	181	250
3.4.7	5	Sluicing	251	300

المنارة للاستشارات

www.manaraa.com

Table B-55: Economic Parameters

ID	Parameter	Units	Description	Value
4.1				
4.2	c	[$/m3]	Unit cost of construction per m3 of reservoir capacity	0.88
4.3	C2	[$]	Total cost of reservoir impoundment	130,937,531
4.4	r	[%]	Discount rate	5.0
4.5	Mr	[%]	Market interest rate of annual retirement fund	6.0
4.6	P1	[$/m3]	Unit benefit of reservoir yield	0.1
4.7	V	[$]	Decommissioning cost	50,000,000
4.8	CL_NS	[%]	Capacity loss for characterization of a reservoir as non sustainable	95
4.9	C1	[$/a]	Total annual operation and maintenance costs	1,309,375
4.10				
4.11				
4.12				
4.13			Application of declining discount rate?	No
4.14	Ymax	[years]	Maximum duration of financial analysis	300

www.manaraa.com

Mohammed V

Table B-56: Reservoir Geometry

ID	Parameter	Units	Description	Value
1.1.1	So_gr	[m³]	Original gross storage capacity of the reservoir	725,750,000
1.1.2	So_a	[m³]	Original active storage capacity of the reservoir	400,000,000
1.1.3	So_d	[m³]	Original inactive storage capacity of the reservoir	325,750,000
1.1.4	Se_gr	[m³]	Existing gross storage capacity of the reservoir	370,000,000
1.1.5	Se_a	[m³]	Existing active storage of the reservoir	240,000,000
1.1.6	Se_d	[m³]	Existing inactive storage of the reservoir	130,000,000
1.1.7	Wbot	[m]	Representative reservoir bottom width at the dam location	2,300
1.1.8	--	--	--	--
1.1.9	ELOWL	[masl]	Maximum pool elevation of reservoir	218
1.1.10	ELMWL	[masl]	Minimum operation water level	179
1.1.11	Elbmin	[masl]	Minimum reservoir bed elevation at dam site	170
1.1.12	Lres	[m]	Reservoir length	10,500
1.1.13	ncomp	[-]	Number of reservoir compartments	5

المنارة للاستشارات
www.manaraa.com

Table B-57: Hydrology and Sediment

ID	Parameter	Units	Description	Value
2.1.1.1	MAR	[million m^3/a]	Mean annual reservoir water inflow	750
2.1.1.2	Cv	[-]	Coefficient of variation of annual run-off volume	0.51
2.1.1.3	Twater	[°C]	Representative water temperature in the reservoir	20
2.1.2.1	r_d	[tonnes/m^3]	Specific weight of in-situ reservoir sediment (bulk density)	1.2
2.1.2.2	MAS	[million tonnes/a]	Mean annual total (suspended and bedload) sediment inflow mass	12.8
2.1.2.3		[g/l]	Average annual concentration of suspended load	15.36
2.1.2.3	ExceedT	[%]	Percentage of time exceeded	25, 50, 75
	ExceedMAR	[%]	Percentage of mean annual water inflow	40, 20, 10
	ExceedMAS	[%]	Percentage of mean annual sediment inflow	40, 20, 10
2.1.2.4	pcl	[%]	% clay of suspended sediment inflow	--
2.1.2.5	psi	[%]	% silt of suspended sediment inflow	--
2.1.2.6	psa	[%]	% sand of suspended sediment inflow	--
2.1.2.7	ws_cl	[m/s]	Settling velocity of clay particles	--
2.1.2.8	ws_si	[m/s]	Settling velocity of silt particles	--
2.1.2.9	ws_sa	[m/s]	Settling velocity of sand particles	--
2.1.2.10	TE_Method		Trap efficiency method	Brune
2.1.2.11	Brune Curve No	[-]		2
2.1.2.12	p_b	[%]	% bedload of total sediment inflow	10
2.1.2.13	T_b	[%]	Duration of bedload transport	5
2.1.3.1	Zpr		Standardized normal nariate at pr*100%	2.33
2.1.3.2	Gd		Gould's correction factor	1.50
2.1.3.3	Sd		Standard deviation of annual run-off	382,500,000
2.1.3.4	Distribution		Distribution of annual inflows	Lognormal

للاستشارات المنارة
www.manaraa.com

Table B-58: Sediment Management – Catchment Management

ID	Parameter	Units	Description	Value
3.1.1	CM_Method	[-]	Catchment management method	De-intensification of land use practices
3.1.2	MASb reduction	[%]	Expected reduction of bedload inflow in reservoir due to catchment management	0
3.1.3	MASs reduction	[%]	Expected reduction of suspended load inflow in reservoir due to catchment management	0
3.1.4	YearMAS reduction Start	[Years]	How many years after its implementation will catchment management affect sediment inflow in reservoir?	1
3.1.5				0
3.1.6	C_CM	[US$]	Costs for implementation of catchment management measures	0
3.1.7	OMC_CM	[US$/a]	Annual operation and maintenance costs of catchment management	0
3.1.8	Shall the implementation year of catchment management be determined through economic optimization?			No
3.1.9	Year CMstart	[years]	Implementation year of catchment management	1
3.1.10	CL_CM	[%]	Maximum allowable storage loss before implementation of catchment management	100

المنارة للاستشارات
www.manaraa.com

Table B-59: Sediment Management – Flushing

ID	Parameter	Units	Description	Value
3.2.1.1	Y	[-]	Indicator of deposits type	650
3.2.1.2	Ans	3 or 1	Sediment removal difficulty	3
3.2.1.3	Qf	[m3/s]	Representative flushing discharge	300
3.2.1.4	Tf	[days]	Duration of flushing after complete drawdown	10
3.2.1.5	Cal_SSfl	[-]	Calibration parameter for Mignot equation	1
3.2.1.6	CLF	[%]	Maximum percent of capacity loss allowable	100
3.2.1.7	s1	[%]	Fraction of run-of-river benefits	50
3.2.1.8	s2	[%]	Fraction of storage benefits	50
3.2.1.9	FI	[US$]	Cost of capital investment	0
3.2.1.10	Elfl_dam	[masl]	Water elevation at dam during flushing	179
3.2.1.12	Shall the implementation strategy of flushing be determined through economic optimization?			No
3.2.1.13	CycleNS	[Years]	Time interval between flushing events during the 1st phase (Reservoir storage > sustainable long term reservoir capacity)	2
3.2.1.14	CycleS	[Years]	Time interval between flushing events during the 2nd phase (Reservoir storage < sustainable long term reservoir capacity)	14
3.2.1.15	OMC_FL	[US$/a]	Annual operation and maintenance costs of flushing	0

Table B-60: Sediment Management – Dredging

ID	Parameter	Units	Description	Value
3.2.2.1	Cw	[%]	Concentration by weight of sediment removed to water removed by traditional dredging	25
3.2.2.2	CLD	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for dredging	55
3.2.2.3	ASD	[%]	Maximum percent of reservoir storage that can be restored during each dredging event	20
3.2.2.4	MD	[m3]	Amount of sediment removed per dredging event	100,000
3.2.2.5	PD	[$/m3]	Unit value of water used in dredging operations	0.00
3.2.2.6	CD	[$/m3]	Unit cost of dredging	8.53
3.2.2.7	Shall the unit cost of dredging be determined automatically?			No
3.2.2.8	Shall the implementation strategy of dredging be determined through economic optimization?			No
3.2.2.9	Cycle1DR	[years]	Duration of phase 1 (No dredging)	1
3.2.2.10	Cycle2DR	[years]	Cycle length in phase 2 (Dredging operation)	3
3.2.2.11	Shall a sustainable solution be determined automatically?			Yes
3.2.2.12	Where do you want to perform dredging?			Both active and inactive storage

المنارة للاستشارات

www.manaraa.com

Table B-61: Sediment Management – HSRS

ID	Parameter	Units	Description	Value
3.2.3.1	Type	1 or 2	Sediment type category to be removed by Hydrosuction Sediment Removal System (HSRS)	1
3.2.3.2	D	[m]	Assume a trial pipe diameter for HSRS	1
3.2.3.3	NP	1, 2, or 3	Number of pipes for HSRS	3
3.2.3.4	YA	[%]	Maximum fraction of total yield that is allowed to be used in HSRS operations	75
3.2.3.5	CLH	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for HSRS	100
3.2.3.6	PH	[$/m3]	Unit value of water released downstream of dam in river by HSRS operations	0.00
3.2.3.7	HI	[US$]	Cost of capital investment to install HSRS	2,000,000
3.2.3.8	DU	[Years]	The expected life of HSRS	20
3.2.3.9	Shall the implementation strategy of HSRS be determined through economic optimization?			No
3.2.3.10	Year HSRSstart	[Years]	Timing of HSRS installation	5
3.2.3.11	HSRSlimit	[m]	Length limit for implementation of HSRS	5,000

Table B-62: Sediment Management – Trucking

ID	Parameter	Units	Description	Value
3.2.4.1	CLT	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for trucking	70
3.2.4.2	AST	[%]	Maximum percent of reservoir storage that can be restored during each trucking event	25
3.2.4.3	MT	[m3]	Amount of sediment removed per trucking event	10,000,000
3.2.4.4	CT	[US$/m3]	Unit Cost of trucking	13
3.2.4.5	Shall the implementation strategy of trucking be determined through economic optimization?			No
3.2.4.6	Cycle1TR	[years]	Implementation year	1
3.2.4.7	Cycle2TR	[years]	Frequency of trucking operation	1
3.2.4.8	Shall a sustainable solution be determined automatically?			Yes
3.2.4.9	Where do you want to perform trucking?			Both active and inactive storage
3.2.4.10	sTR	[%]	Fraction of reservoir water yield the year trucking occurs	50

المنارة للاستشارات
www.manaraa.com

Table B-63: Sediment Management – Sediment By-pass

ID	Parameter	Units	Description	Value
3.3.1.1	$C_{\text{B-P}}$	[US$]	Cost for implementation of by-pass structure	1,000,000,000
3.3.1.2	$\text{OMC}_{\text{B-P}}$	[US$/a]	Annual operation and maintenance Costs of by-pass structures	5,000,000
3.3.1.3	Shall the duration and implementation year be defined through economic optimization?			No
3.3.1.4	$\text{Year}_{\text{BP Start}}$	[years]	Implementation year of by-pass	5
3.3.1.5	T_{BP}	[months]	Duration of sediment by-pass	3.0
3.3.1.6	$\text{CL}_{\text{B-P}}$	[%]	Maximum allowable storage loss before implementation of sediment by-pass	55
3.3.1.7	$T_{\text{B-P max}}$	[months]	Maximum allowable duration of by-pass operation	3
3.3.1.8	BP_Efficiency	[%]	Water by-pass efficiency	50
3.3.1.9	BPbedload_Efficiency	[%]	Bedload by-pass efficiency	100
3.3.1.10	BPsuspendedload_ Efficiency	[%]	Suspended load by-pass efficiency	60
3.3.1.11	BPlimit	[m]	Length limit for feasibility of by-pass structure	5,000

Table B-64: Sediment Management – Sluicing

ID	Parameter	Units	Description	Value
3.3.2.1	EL_{SL}	[masl]	Reservoir pool elevation during sluicing	200
3.3.2.2	C_{SL}	[US$]	Cost for implementation of sluicing structure	0
3.3.2.3	OMC_{SL}	[US$/a]	Annual operation and maintenance costs of sluicing structures	100,000
3.3.2.4	Shall the duration and implementation year be defined through economic optimization?			Yes
3.3.2.5	$\text{Year}_{\text{SL Start}}$	[years]	Implementation year of sluicing	1
3.3.2.6	T_{SL}	[months]	Duration of sluicing operation	5.50
3.3.2.7	CL_{SL}	[%]	Maximum allowable storage loss before implementation of sluicing	55
3.3.2.8	$T_{\text{SL max}}$	[months]	Maximum allowable duration of sluicing	6.0

المنارة للاستشارات
www.manaraa.com

Table B-65: Sediment Management – Density Current Venting

ID	Parameter	Units	Description	Value
3.3.3.1				
3.3.3.2	T_{DCV}	[months]	Duration of density current venting	4.00
3.3.3.3	YearDCVstart	[years]	Implementation year of denstiy current venting	1
3.3.3.4	CL_{DCV}	[%]	Maximum allowable storage loss before implementation of density current venting	70
3.3.3.5	s_{DCV}	[%]	Fraction of reservoir benefits the year density current venting occurs	20
3.3.3.6	DCVI	[US$]	Cost of capital investment	0

Table B-66: Sediment Management – Multiple Management

ID	ID	Sediment Management Technique	Start [Year]	End [Year]
3.4.1				
3.4.2				
3.4.3	1	Catchment Management	1	22
3.4.4	2	Dredging	23	40
3.4.5	3	Flushing	41	80
3.4.6	4	Trucking	81	120
3.4.7	5	Sluicing	121	300

المنارة للاستشارات
www.manaraa.com

Table B-67: Economic Parameters

ID	Parameter	Units	Description	Value
4.1				
4.2	c	[$/m3]	Unit cost of construction per m3 of reservoir capacity	2.21
4.3	C2	[$]	Total cost of reservoir impoundment	0
4.4	r	[%]	Discount rate	6.0
4.5	Mr	[%]	Market interest rate of annual retirement fund	7.0
4.6	P1	[$/m3]	Unit benefit of reservoir yield	0.4
4.7	V	[$]	Decommissioning cost	37,000,000
4.8	CL_NS	[%]	Capacity loss for characterization of a reservoir as non sustainable	95
4.9	C1	[$/a]	Total annual operation and maintenance costs	379,926
4.10				
4.11				
4.12				
4.13			Application of declining discount rate?	No
4.14	Ymax	[years]	Maximum duration of financial analysis	300

المنارة للاستشارات
www.manaraa.com

Tarbela

Table B-68: Reservoir Geometry

ID	Parameter	Units	Description	Value
1.1.1	So_gr	[m³]	Original gross storage capacity of the reservoir	14,350,000,000
1.1.2	So_a	[m³]	Original active storage capacity of the reservoir	10,967,000,000
1.1.3	So_d	[m³]	Original inactive storage capacity of the reservoir	3,383,000,000
1.1.4	Se_gr	[m³]	Existing gross storage capacity of the reservoir	9,383,000,000
1.1.5	Se_a	[m³]	Existing active storage of the reservoir	6,000,000,000
1.1.6	Se_d	[m³]	Existing inactive storage of the reservoir	3,383,000,000
1.1.7	Wbot	[m]	Representative reservoir bottom width at the dam location	1,650
1.1.8	--	--	--	--
1.1.9	ELOWL	[masl]	Maximum pool elevation of reservoir	472.4
1.1.10	ELMWL	[masl]	Minimum operation water level	420.0
1.1.11	Elbmin	[masl]	Minimum reservoir bed elevation at dam site	380.0
1.1.12	Lres	[m]	Reservoir length	88,000
1.1.13	ncomp	[-]	Number of reservoir compartments	5

المنارة للاستشارات
www.manaraa.com

Table B-69: Hydrology and Sediment

ID	Parameter	Units	Description	Value
2.1.1.1	MAR	[million m^3/a]	Mean annual reservoir water inflow	73,800
2.1.1.2	Cv	[-]	Coefficient of variation of annual run-off volume	0.12
2.1.1.3	Twater	[°C]	Representative water temperature in the reservoir	15
2.1.2.1	r_d	[tonnes/m^3]	Specific weight of in-situ reservoir sediment (bulk density)	1.34
2.1.2.2	MAS	[million tonnes/a]	Mean annual total (suspended and bedload) sediment inflow mass	194.30
2.1.2.3		[g/l]	Average annual concentration of suspended load	2.606
2.1.2.3	ExceedT	[%]	Percentage of time exceeded	16, 32, 44
	ExceedMAR	[%]	Percentage of mean annual water inflow	58, 30, 8
	ExceedMAS	[%]	Percentage of mean annual sediment inflow	40, 10, 2
2.1.2.4	pcl	[%]	% clay of suspended sediment inflow	--
2.1.2.5	psi	[%]	% silt of suspended sediment inflow	--
2.1.2.6	psa	[%]	% sand of suspended sediment inflow	--
2.1.2.7	ws_cl	[m/s]	Settling velocity of clay particles	--
2.1.2.8	ws_si	[m/s]	Settling velocity of silt particles	--
2.1.2.9	ws_sa	[m/s]	Settling velocity of sand particles	--
2.1.2.10	TE_Method		Trap efficiency method	Churchill
2.1.2.11	Brune Curve No	[-]		2
2.1.2.12	p_b	[%]	% bedload of total sediment inflow	1.00
2.1.2.13	T_b	[%]	Duration of bedload transport	5
2.1.3.1	Zpr		Standardized normal nariate at pr*100%	1.64
2.1.3.2	Gd		Gould's correction factor	0.60
2.1.3.3	Sd		Standard deviation of annual run-off	8,856,000,000
2.1.3.4	Distribution		Distribution of annual inflows	Lognormal

المنارة للاستشارات
www.manaraa.com

Table B-70: Sediment Management – Catchment Management

ID	Parameter	Units	Description	Value
3.1.1	CM_Method	[-]	Catchment management method	De-intensification of land use practices
3.1.2	MASb reduction	[%]	Expected reduction of bedload inflow in reservoir due to catchment management	5
3.1.3	MASs reduction	[%]	Expected reduction of suspended load inflow in reservoir due to catchment management	5
3.1.4	YearMAS reduction Start	[Years]	How many years after its implementation will catchment management affect sediment inflow in reservoir?	1
3.1.5				
3.1.6	C_CM	[US$]	Costs for implementation of catchment management measures	20,000,000
3.1.7	OMC_CM	[US$/a]	Annual operation and maintenance costs of catchment management	200,000
3.1.8	Shall the implementation year of catchment management be determined through economic optimization?			No
3.1.9	Year CMstart	[years]	Implementation year of catchment management	5
3.1.10	CL_CM	[%]	Maximum allowable storage loss before implementation of catchment management	100

للاستشارات المنارة
www.manaraa.com

Table B-71: Sediment Management – Flushing

ID	Parameter	Units	Description	Value
3.2.1.1	Y	[-]	Indicator of deposits type	380
3.2.1.2	Ans	3 or 1	Sediment removal difficulty	1
3.2.1.3	Qf	[m3/s]	Representative flushing discharge	3,100
3.2.1.4	Tf	[days]	Duration of flushing after complete drawdown	30
3.2.1.5	Cal_SSfl	[-]	Calibration parameter for Mignot equation	10
3.2.1.6	CLF	[%]	Maximum percent of capacity loss allowable	100
3.2.1.7	s1	[%]	Fraction of run-of-river benefits	50
3.2.1.8	s2	[%]	Fraction of storage benefits	50
3.2.1.9	FI	[US$]	Cost of capital investment	0
3.2.1.10	Elfl_dam	[masl]	Water elevation at dam during flushing	390
3.2.1.12	Shall the implementation strategy of flushing be determined through economic optimization?			Yes
3.2.1.13	CycleNS	[Years]	Time interval between flushing events during the 1st phase (Reservoir storage > sustainable long term reservoir capacity)	35
3.2.1.14	CycleS	[Years]	Time interval between flushing events during the 2nd phase (Reservoir storage < sustainable long term reservoir capacity)	14
3.2.1.15	OMC_FL	[US$/a]	Annual operation and maintenance costs of flushing	0

Table B-72: Sediment Management – Dredging

ID	Parameter	Units	Description	Value
3.2.2.1	Cw	[%]	Concentration by weight of sediment removed to water removed by traditional dredging	30
3.2.2.2	CLD	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for dredging	50
3.2.2.3	ASD	[%]	Maximum percent of reservoir storage that can be restored during each dredging event	30
3.2.2.4	MD	[m3]	Amount of sediment removed per dredging event	100,000,000
3.2.2.5	PD	[$/m3]	Unit value of water used in dredging operations	0.00
3.2.2.6	CD	[$/m3]	Unit cost of dredging	5
3.2.2.7	Shall the unit cost of dredging be determined automatically?			Yes
3.2.2.8	Shall the implementation strategy of dredging be determined through economic optimization?			No
3.2.2.9	Cycle1DR	[years]	Duration of phase 1 (No dredging)	1
3.2.2.10	Cycle2DR	[years]	Cycle length in phase 2 (Dredging operation)	10
3.2.2.11	Shall a sustainable solution be determined automatically?			Yes
3.2.2.12	Where do you want to perform dredging?			Both active and inactive storage

المنارة للاستشارات
www.manaraa.com

Table B-73: Sediment Management – HSRS

ID	Parameter	Units	Description	Value
3.2.3.1	Type	1 or 2	Sediment type category to be removed by Hydrosuction Sediment Removal System (HSRS)	1
3.2.3.2	D	[m]	Assume a trial pipe diameter for HSRS	1
3.2.3.3	NP	1, 2, or 3	Number of pipes for HSRS	3
3.2.3.4	YA	[%]	Maximum fraction of total yield that is allowed to be used in HSRS operations	10
3.2.3.5	CLH	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for HSRS	100
3.2.3.6	PH	[$/m3]	Unit value of water released downstream of dam in river by HSRS operations	0.00
3.2.3.7	HI	[US$]	Cost of capital investment to install HSRS	20,000,000
3.2.3.8	DU	[Years]	The expected life of HSRS	20
3.2.3.9	Shall the implementation strategy of HSRS be determined through economic optimization?			No
3.2.3.10	Year HSRSstart	[Years]	Timing of HSRS installation	1
3.2.3.11	HSRSlimit	[m]	Length limit for implementation of HSRS	5,000

Table B-74: Sediment Management – Trucking

ID	Parameter	Units	Description	Value
3.2.4.1	CLT	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for trucking	60
3.2.4.2	AST	[%]	Maximum percent of reservoir storage that can be restored during each trucking event	30
3.2.4.3	MT	[m3]	Amount of sediment removed per trucking event	100,000,000
3.2.4.4	CT	[US$/m3]	Unit Cost of trucking	12
3.2.4.5	Shall the implementation strategy of trucking be determined through economic optimization?			No
3.2.4.6	Cycle1TR	[years]	Implementation year	20
3.2.4.7	Cycle2TR	[years]	Frequency of trucking operation	10
3.2.4.8	Shall a sustainable solution be determined automatically?			Yes
3.2.4.9	Where do you want to perform trucking?			Both active and inactive storage
3.2.4.10	sTR	[%]	Fraction of reservoir water yield the year trucking occurs	50

المنارة للاستشارات
www.manaraa.com

Table B-75: Sediment Management – Sediment By-pass

ID	Parameter	Units	Description	Value
3.3.1.1	$\text{C}_{\text{B-P}}$	[US$]	Cost for implementation of by-pass structure	0
3.3.1.2	$\text{OMC}_{\text{B-P}}$	[US$/a]	Annual operation and maintenance Costs of by-pass structures	0
3.3.1.3	Shall the duration and implementation year be defined through economic optimization?			No
3.3.1.4	$\text{Year}_{\text{BP Start}}$	[years]	Implementation year of by-pass	1
3.3.1.5	T_{BP}	[months]	Duration of sediment by-pass	1
3.3.1.6	$\text{CL}_{\text{B-P}}$	[%]	Maximum allowable storage loss before implementation of sediment by-pass	100
3.3.1.7	$\text{T}_{\text{B-P max}}$	[months]	Maximum allowable duration of by-pass operation	6
3.3.1.8	BP_Efficiency	[%]	Water by-pass efficiency	80
3.3.1.9	BPbedload_Efficiency	[%]	Bedload by-pass efficiency	100
3.3.1.10	BPsuspendedload_ Efficiency	[%]	Suspended load by-pass efficiency	60
3.3.1.11	BPlimit	[m]	Length limit for feasibility of by-pass structure	5,000

Table B-76: Sediment Management – Sluicing

ID	Parameter	Units	Description	Value
3.3.2.1	EL_{SL}	[masl]	Reservoir pool elevation during sluicing	436
3.3.2.2	C_{SL}	[US$]	Cost for implementation of sluicing structure	0
3.3.2.3	OMC_{SL}	[US$/a]	Annual operation and maintenance costs of sluicing structures	0
3.3.2.4	Shall the duration and implementation year be defined through economic optimization?			No
3.3.2.5	$\text{Year}_{\text{SL Start}}$	[years]	Implementation year of sluicing	1
3.3.2.6	T_{SL}	[months]	Duration of sluicing operation	3
3.3.2.7	CL_{SL}	[%]	Maximum allowable storage loss before implementation of sluicing	100
3.3.2.8	$\text{T}_{\text{SL max}}$	[months]	Maximum allowable duration of sluicing	6

www.manaraa.com

Table B-77: Sediment Management – Density Current Venting

ID	Parameter	Units	Description	Value
3.3.3.1				
3.3.3.2	T_{DCV}	[months]	Duration of density current venting	1
3.3.3.3	YearDCVstart	[years]	Implementation year of denstiy current venting	1
3.3.3.4	CL_{DCV}	[%]	Maximum allowable storage loss before implementation of density current venting	100
3.3.3.5	s_{DCV}	[%]	Fraction of reservoir benefits the year density current venting occurs	40
3.3.3.6	DCVI	[US$]	Cost of capital investment	0

Table B-78: Sediment Management – Multiple Management

ID	ID	Sediment Management Technique	Start [Year]	End [Year]
3.4.1				
3.4.2				
3.4.3	1	Catchment Management	1	50
3.4.4	2	Dredging	51	100
3.4.5	3	Flushing	101	150
3.4.6	4	Trucking	151	250
3.4.7	5	Sluicing	251	300

المنارة للاستشارات

www.manaraa.com

Table B-79: Economic Parameters

ID	Parameter	Units	Description	Value	
4.1					
4.2	c	[$/m3]	Unit cost of construction per m3 of reservoir capacity	0.15	
4.3	C2	[$]	Total cost of reservoir impoundment	2,152,500,000	
4.4	r	[%]	Discount rate	5.0	
4.5	Mr	[%]	Market interest rate of annual retirement fund	6.0	
4.6	P1	[$/m3]	Unit benefit of reservoir yield	0.1	
4.7	V	[$]	Decommissioning cost	0	
4.8	CL_NS	[%]	Capacity loss for characterization of a reservoir as non sustainable	95	
4.9	C1	[$/a]	Total annual operation and maintenance costs	20,000,000	
4.10					
4.11					
4.12					
4.13			Application of declining discount rate?	Yes	
4.13a	DDR1	[%]		0 – 30	3.00%
4.13b	DDR2	[%]		31 – 75	2.57%
4.13c	DDR3	[%]	Definition of Declining Discount Rate	76 – 125	2.14%
4.13d	DDR4	[%]		126 – 200	1.71%
4.13e	DDR5	[%]		201 – 300	1.29%
4.13f	DDR6	[%]		301 - …	0.86%
4.14	Ymax	[years]	Maximum duration of financial analysis	300	

www.manaraa.com

Upper Karnali

Table B-80: Reservoir Geometry

ID	Parameter	Units	Description	Value
1.1.1	So_gr	[m^3]	Original gross storage capacity of the reservoir	17,860,000
1.1.2	So_a	[m^3]	Original active storage capacity of the reservoir	16,860,000
1.1.3	So_d	[m^3]	Original inactive storage capacity of the reservoir	1,000,000
1.1.4	Se_gr	[m^3]	Existing gross storage capacity of the reservoir	0
1.1.5	Se_a	[m^3]	Existing active storage of the reservoir	0
1.1.6	Se_d	[m^3]	Existing inactive storage of the reservoir	0
1.1.7	Wbot	[m]	Representative reservoir bottom width at the dam location	100
1.1.8	--	--	--	--
1.1.9	ELOWL	[masl]	Maximum pool elevation of reservoir	637
1.1.10	ELMWL	[masl]	Minimum operation water level	633
1.1.11	Elbmin	[masl]	Minimum reservoir bed elevation at dam site	614
1.1.12	Lres	[m]	Reservoir length	9,100
1.1.13	ncomp	[-]	Number of reservoir compartments	5

المنارة للاستشارات
www.manaraa.com

Table B-81: Hydrology and Sediment

ID	Parameter	Units	Description	Value
2.1.1.1	MAR	[million m^3/a]	Mean annual reservoir water inflow	15,667
2.1.1.2	Cv	[-]	Coefficient of variation of annual run-off volume	0.17
2.1.1.3	Twater	[°C]	Representative water temperature in the reservoir	15
2.1.2.1	r_d	[tonnes/m^3]	Specific weight of in-situ reservoir sediment (bulk density)	1.5
2.1.2.2	MAS	[million tonnes/a]	Mean annual total (suspended and bedload) sediment inflow mass	31.50
2.1.2.3		[g/l]	Average annual concentration of suspended load	1.709
2.1.2.3	ExceedT	[%]	Percentage of time exceeded	3, 10, 30
	ExceedMAR	[%]	Percentage of mean annual water inflow	86, 64, 32
	ExceedMAS	[%]	Percentage of mean annual sediment inflow	40, 25, 14
2.1.2.4	pcl	[%]	% clay of suspended sediment inflow	--
2.1.2.5	psi	[%]	% silt of suspended sediment inflow	--
2.1.2.6	psa	[%]	% sand of suspended sediment inflow	--
2.1.2.7	ws_cl	[m/s]	Settling velocity of clay particles	--
2.1.2.8	ws_si	[m/s]	Settling velocity of silt particles	--
2.1.2.9	ws_sa	[m/s]	Settling velocity of sand particles	--
2.1.2.10	TE_Method		Trap efficiency method	Churchill
2.1.2.11	Brune Curve No	[-]		1
2.1.2.12	p_b	[%]	% bedload of total sediment inflow	15.00
2.1.2.13	T_b	[%]	Duration of bedload transport	30
2.1.3.1	Zpr		Standardized normal nariate at pr*100%	1.64
2.1.3.2	Gd		Gould's correction factor	0.60
2.1.3.3	Sd		Standard deviation of annual run-off	2,663,390,000
2.1.3.4	Distribution		Distribution of annual inflows	Lognormal

المنارة للاستشارات

www.manaraa.com

Table B-82: Sediment Management – Catchment Management

ID	Parameter	Units	Description	Value
3.1.1	CM_Method	[-]	Catchment management method	De-intensification of land use practices
3.1.2	MASb reduction	[%]	Expected reduction of bedload inflow in reservoir due to catchment management	5
3.1.3	MASs reduction	[%]	Expected reduction of suspended load inflow in reservoir due to catchment management	5
3.1.4	YearMAS reduction Start	[Years]	How many years after its implementation will catchment management affect sediment inflow in reservoir?	1
3.1.5				
3.1.6	C_CM	[US$]	Costs for implementation of catchment management measures	20,000,000
3.1.7	OMC_CM	[US$/a]	Annual operation and maintenance costs of catchment management	200,000
3.1.8	Shall the implementation year of catchment management be determined through economic optimization?			No
3.1.9	Year CMstart	[years]	Implementation year of catchment management	5
3.1.10	CL_CM	[%]	Maximum allowable storage loss before implementation of catchment management	100

www.manaraa.com

Table B-83: Sediment Management – Flushing

ID	Parameter	Units	Description	Value
3.2.1.1	Y	[-]	Indicator of deposits type	300
3.2.1.2	Ans	3 or 1	Sediment removal difficulty	1
3.2.1.3	Qf	[m3/s]	Representative flushing discharge	2,000
3.2.1.4	Tf	[days]	Duration of flushing after complete drawdown	10
3.2.1.5	Cal_SSfl	[-]	Calibration parameter for Mignot equation	1
3.2.1.6	CLF	[%]	Maximum percent of capacity loss allowable	50
3.2.1.7	s1	[%]	Fraction of run-of-river benefits	50
3.2.1.8	s2	[%]	Fraction of storage benefits	50
3.2.1.9	FI	[US$]	Cost of capital investment	0
3.2.1.10	Elfl_dam	[masl]	Water elevation at dam during flushing	614
3.2.1.12	Shall the implementation strategy of flushing be determined through economic optimization?			Yes
3.2.1.13	CycleNS	[Years]	Time interval between flushing events during the 1st phase (Reservoir storage > sustainable long term reservoir capacity)	1
3.2.1.14	CycleS	[Years]	Time interval between flushing events during the 2nd phase (Reservoir storage < sustainable long term reservoir capacity)	14
3.2.1.15	OMC_FL	[US$/a]	Annual operation and maintenance costs of flushing	0

Table B-84: Sediment Management – Dredging

ID	Parameter	Units	Description	Value
3.2.2.1	Cw	[%]	Concentration by weight of sediment removed to water removed by traditional dredging	30
3.2.2.2	CLD	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for dredging	100
3.2.2.3	ASD	[%]	Maximum percent of reservoir storage that can be restored during each dredging event	100
3.2.2.4	MD	[m3]	Amount of sediment removed per dredging event	6,500,000
3.2.2.5	PD	[$/m3]	Unit value of water used in dredging operations	0.00
3.2.2.6	CD	[$/m3]	Unit cost of dredging	10
3.2.2.7	Shall the unit cost of dredging be determined automatically?			No
3.2.2.8	Shall the implementation strategy of dredging be determined through economic optimization?			No
3.2.2.9	Cycle1DR	[years]	Duration of phase 1 (No dredging)	2
3.2.2.10	Cycle2DR	[years]	Cycle length in phase 2 (Dredging operation)	2
3.2.2.11	Shall a sustainable solution be determined automatically?			Yes
3.2.2.12	Where do you want to perform dredging?			Both active and inactive storage

المنارة للاستشارات
www.manaraa.com

Table B-85: Sediment Management – HSRS

ID	Parameter	Units	Description	Value
3.2.3.1	Type	1 or 2	Sediment type category to be removed by Hydrosuction Sediment Removal System (HSRS)	2
3.2.3.2	D	[m]	Assume a trial pipe diameter for HSRS	1
3.2.3.3	NP	1, 2, or 3	Number of pipes for HSRS	3
3.2.3.4	YA	[%]	Maximum fraction of total yield that is allowed to be used in HSRS operations	100
3.2.3.5	CLH	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for HSRS	100
3.2.3.6	PH	[$/m3]	Unit value of water released downstream of dam in river by HSRS operations	0.00
3.2.3.7	HI	[US$]	Cost of capital investment to install HSRS	20,000,000
3.2.3.8	DU	[Years]	The expected life of HSRS	20
3.2.3.9	Shall the implementation strategy of HSRS be determined through economic optimization?			No
3.2.3.10	Year HSRSstart	[Years]	Timing of HSRS installation	5
3.2.3.11	HSRSlimit	[m]	Length limit for implementation of HSRS	5,000

Table B-86: Sediment Management – Trucking

ID	Parameter	Units	Description	Value
3.2.4.1	CLT	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for trucking	100
3.2.4.2	AST	[%]	Maximum percent of reservoir storage that can be restored during each trucking event	100
3.2.4.3	MT	[m3]	Amount of sediment removed per trucking event	10,000,000
3.2.4.4	CT	[US$/m3]	Unit Cost of trucking	12
3.2.4.5	Shall the implementation strategy of trucking be determined through economic optimization?			Yes
3.2.4.6	Cycle1TR	[years]	Implementation year	4
3.2.4.7	Cycle2TR	[years]	Frequency of trucking operation	3
3.2.4.8	Shall a sustainable solution be determined automatically?			Yes
3.2.4.9	Where do you want to perform trucking?			Both active and inactive storage
3.2.4.10	sTR	[%]	Fraction of reservoir water yield the year trucking occurs	50

www.manaraa.com

Table B-87: Sediment Management – Sediment By-pass

ID	Parameter	Units	Description	Value
3.3.1.1	$C_{B\text{-}P}$	[US$]	Cost for implementation of by-pass structure	50,000,000
3.3.1.2	$OMC_{B\text{-}P}$	[US$/a]	Annual operation and maintenance Costs of by-pass structures	5,000,000
3.3.1.3	Shall the duration and implementation year be defined through economic optimization?			No
3.3.1.4	$\text{Year}_{\text{BP Start}}$	[years]	Implementation year of by-pass	1
3.3.1.5	T_{BP}	[months]	Duration of sediment by-pass	6.0
3.3.1.6	$CL_{B\text{-}P}$	[%]	Maximum allowable storage loss before implementation of sediment by-pass	20
3.3.1.7	$T_{B\text{-}P\ \max}$	[months]	Maximum allowable duration of by-pass operation	12
3.3.1.8	BP_Efficiency	[%]	Water by-pass efficiency	50
3.3.1.9	BPbedload_Efficiency	[%]	Bedload by-pass efficiency	100
3.3.1.10	BPsuspendedload_ Efficiency	[%]	Suspended load by-pass efficiency	60
3.3.1.11	BPlimit	[m]	Length limit for feasibility of by-pass structure	5,000

Table B-88: Sediment Management – Sluicing

ID	Parameter	Units	Description	Value
3.3.2.1	EL_{SL}	[masl]	Reservoir pool elevation during sluicing	633
3.3.2.2	C_{SL}	[US$]	Cost for implementation of sluicing structure	0
3.3.2.3	OMC_{SL}	[US$/a]	Annual operation and maintenance costs of sluicing structures	0
3.3.2.4	Shall the duration and implementation year be defined through economic optimization?			No
3.3.2.5	$\text{Year}_{\text{SL Start}}$	[years]	Implementation year of sluicing	1
3.3.2.6	T_{SL}	[months]	Duration of sluicing operation	3.00
3.3.2.7	CL_{SL}	[%]	Maximum allowable storage loss before implementation of sluicing	100
3.3.2.8	$T_{SL\ \max}$	[months]	Maximum allowable duration of sluicing	4.0

www.manaraa.com

Table B-89: Sediment Management – Density Current Venting

ID	Parameter	Units	Description	Value
3.3.3.1				
3.3.3.2	T_{DCV}	[months]	Duration of density current venting	1.00
3.3.3.3	YearDCVstart	[years]	Implementation year of denstiy current venting	1
3.3.3.4	CL_{DCV}	[%]	Maximum allowable storage loss before implementation of density current venting	100
3.3.3.5	s_{DCV}	[%]	Fraction of reservoir benefits the year density current venting occurs	50
3.3.3.6	DCVI	[US$]	Cost of capital investment	0

Table B-90: Sediment Management – Multiple Management

ID	ID	Sediment Management Technique	Start [Year]	End [Year]
3.4.1				
3.4.2				
3.4.3	1	Catchment Management	1	5
3.4.4	2	Dredging	6	60
3.4.5	3	Flushing	61	80
3.4.6	4	Trucking	81	120
3.4.7	5	Sluicing	121	300

المنارة للاستشارات

www.manaraa.com

Table B-91: Economic Parameters

ID	Parameter	Units	Description	Value	
4.1					
4.2	c	[$/m3]	Unit cost of construction per m3 of reservoir capacity	2.65	
4.3	C2	[$]	Total cost of reservoir impoundment	47,350,355	
4.4	r	[%]	Discount rate	5.0	
4.5	Mr	[%]	Market interest rate of annual retirement fund	6.0	
4.6	P1	[$/m3]	Unit benefit of reservoir yield	0.1	
4.7	V	[$]	Decommissioning cost	0	
4.8	CL_NS	[%]	Capacity loss for characterization of a reservoir as non sustainable	95	
4.9	C1	[$/a]	Total annual operation and maintenance costs	1,000,000	
4.10					
4.11					
4.12					
4.13			Application of declining discount rate?	Yes	
4.13a	DDR1	[%]		0 – 30	3.00%
4.13b	DDR2	[%]		31 – 75	2.57%
4.13c	DDR3	[%]	Definition of Declining Discount Rate	76 – 125	2.14%
4.13d	DDR4	[%]		126 – 200	1.71%
4.13e	DDR5	[%]		201 – 300	1.29%
4.13f	DDR6	[%]		301 - …	0.86%
4.14	Ymax	[years]	Maximum duration of financial analysis	300	

www.manaraa.com

APPENDIX C. RESCON 2 MODELS: INCOMPLETE

Saigou

Table C-1: Reservoir Geometry

ID	Parameter	Units	Description	Value
1.1.1	So_gr	[m³]	Original gross storage capacity of the reservoir	2,452,000
1.1.2	So_a	[m³]	Original active storage capacity of the reservoir	
1.1.3	So_d	[m³]	Original inactive storage capacity of the reservoir	
1.1.4	Se_gr	[m³]	Existing gross storage capacity of the reservoir	1,517,000
1.1.5	Se_a	[m³]	Existing active storage of the reservoir	
1.1.6	Se_d	[m³]	Existing inactive storage of the reservoir	
1.1.7	Wbot	[m]	Representative reservoir bottom width at the dam location	
1.1.8	--	--	--	--
1.1.9	ELOWL	[masl]	Maximum pool elevation of reservoir	80
1.1.10	ELMWL	[masl]	Minimum operation water level	77.43
1.1.11	Elbmin	[masl]	Minimum reservoir bed elevation at dam site	70.2
1.1.12	Lres	[m]	Reservoir length	5,000
1.1.13	ncomp	[-]	Number of reservoir compartments	5

www.manaraa.com

Table C-2: Hydrology and Sediment

ID	Parameter	Units	Description	Value
2.1.1.1	MAR	[million m^3/a]	Mean annual reservoir water inflow	
2.1.1.2	Cv	[-]	Coefficient of variation of annual run-off volume	
2.1.1.3	Twater	[°C]	Representative water temperature in the reservoir	
2.1.2.1	r_d	[tonnes/m^3]	Specific weight of in-situ reservoir sediment (bulk density)	1.20
2.1.2.2	MAS	[million tonnes/a]	Mean annual total (suspended and bedload) sediment inflow mass	0.006
2.1.2.3		[g/l]	Average annual concentration of suspended load	
2.1.2.3	ExceedT	[%]	Percentage of time exceeded	
	ExceedMAR	[%]	Percentage of mean annual water inflow	
	ExceedMAS	[%]	Percentage of mean annual sediment inflow	
2.1.2.4	pcl	[%]	% clay of suspended sediment inflow	
2.1.2.5	psi	[%]	% silt of suspended sediment inflow	
2.1.2.6	psa	[%]	% sand of suspended sediment inflow	
2.1.2.7	ws_cl	[m/s]	Settling velocity of clay particles	
2.1.2.8	ws_si	[m/s]	Settling velocity of silt particles	
2.1.2.9	ws_sa	[m/s]	Settling velocity of sand particles	
2.1.2.10	TE_Method		Trap efficiency method	Brune
2.1.2.11	Brune Curve No	[-]		2
2.1.2.12	p_b	[%]	% bedload of total sediment inflow	
2.1.2.13	T_b	[%]	Duration of bedload transport	
2.1.3.1	Zpr		Standardized normal nariate at pr*100%	
2.1.3.2	Gd		Gould's correction factor	
2.1.3.3	Sd		Standard deviation of annual run-off	
2.1.3.4	Distribution		Distribution of annual inflows	

المنارة للاستشارات
www.manaraa.com

Table C-3: Sediment Management – Flushing

ID	Parameter	Units	Description	Value
3.2.1.1	Y	[-]	Indicator of deposits type	650
3.2.1.2	Ans	3 or 1	Sediment removal difficulty	3
3.2.1.3	Qf	[m3/s]	Representative flushing discharge	
3.2.1.4	Tf	[days]	Duration of flushing after complete drawdown	
3.2.1.5	Cal_SSfl	[-]	Calibration parameter for Mignot equation	
3.2.1.6	CLF	[%]	Maximum percent of capacity loss allowable	100
3.2.1.7	s1	[%]	Fraction of run-of-river benefits	90
3.2.1.8	s2	[%]	Fraction of storage benefits	90
3.2.1.9	FI	[US$]	Cost of capital investment	
3.2.1.10	Elfl_dam	[masl]	Water elevation at dam during flushing	77.43
3.2.1.12	Shall the implementation strategy of flushing be determined through economic optimization?			
3.2.1.13	CycleNS	[Years]	Time interval between flushing events during the 1st phase (Reservoir storage > sustainable long term reservoir capacity)	1
3.2.1.14	CycleS	[Years]	Time interval between flushing events during the 2nd phase (Reservoir storage < sustainable long term reservoir capacity)	1
3.2.1.15	OMC_FL	[US$/a]	Annual operation and maintenance costs of flushing	

Table C-4: Sediment Management – Dredging

ID	Parameter	Units	Description	Value
3.2.2.1	Cw	[%]	Concentration by weight of sediment removed to water removed by traditional dredging	30
3.2.2.2	CLD	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for dredging	100
3.2.2.3	ASD	[%]	Maximum percent of reservoir storage that can be restored during each dredging event	100
3.2.2.4	MD	[m3]	Amount of sediment removed per dredging event	1,000,000
3.2.2.5	PD	[$/m3]	Unit value of water used in dredging operations	0.02
3.2.2.6	CD	[$/m3]	Unit cost of dredging	3.00
3.2.2.7	Shall the unit cost of dredging be determined automatically?			
3.2.2.8	Shall the implementation strategy of dredging be determined through economic optimization?			
3.2.2.9	Cycle1DR	[years]	Duration of phase 1 (No dredging)	
3.2.2.10	Cycle2DR	[years]	Cycle length in phase 2 (Dredging operation)	
3.2.2.11	Shall a sustainable solution be determined automatically?			
3.2.2.12	Where do you want to perform dredging?			

المنارة للاستشارات
www.manaraa.com

Table C-5: Sediment Management – HSRS

ID	Parameter	Units	Description	Value
3.2.3.1	Type	1 or 2	Sediment type category to be removed by Hydrosuction Sediment Removal System (HSRS)	1
3.2.3.2	D	[m]	Assume a trial pipe diameter for HSRS	
3.2.3.3	NP	1, 2, or 3	Number of pipes for HSRS	1
3.2.3.4	YA	[%]	Maximum fraction of total yield that is allowed to be used in HSRS operations	30
3.2.3.5	CLH	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for HSRS	100
3.2.3.6	PH	[$/m3]	Unit value of water released downstream of dam in river by HSRS operations	0.02
3.2.3.7	HI	[US$]	Cost of capital investment to install HSRS	
3.2.3.8	DU	[Years]	The expected life of HSRS	25
3.2.3.9	Shall the implementation strategy of HSRS be determined through economic optimization?			
3.2.3.10	Year HSRSstart	[Years]	Timing of HSRS installation	
3.2.3.11	HSRSlimit	[m]	Length limit for implementation of HSRS	5,000

Table C-6: Sediment Management – Trucking

ID	Parameter	Units	Description	Value
3.2.4.1	CLT	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for trucking	100
3.2.4.2	AST	[%]	Maximum percent of reservoir storage that can be restored during each trucking event	100
3.2.4.3	MT	[m3]	Amount of sediment removed per trucking event	500,000
3.2.4.4	CT	[US$/m3]	Unit Cost of trucking	13.00
3.2.4.5	Shall the implementation strategy of trucking be determined through economic optimization?			
3.2.4.6	Cycle1TR	[years]	Implementation year	
3.2.4.7	Cycle2TR	[years]	Frequency of trucking operation	
3.2.4.8	Shall a sustainable solution be determined automatically?			
3.2.4.9	Where do you want to perform trucking?			
3.2.4.10	sTR	[%]	Fraction of reservoir water yield the year trucking occurs	

المنارة للاستشارات
www.manaraa.com

Table C-7: Economic Parameters

ID	Parameter	Units	Description	Value	
4.1					
4.2	c	[$/m3]	Unit cost of construction per m3 of reservoir capacity	3.02	
4.3	C2	[$]	Total cost of reservoir impoundment		
4.4	r	[%]	Discount rate	6	
4.5	Mr	[%]	Market interest rate of annual retirement fund	6	
4.6	P1	[$/m3]	Unit benefit of reservoir yield	0.2	
4.7	V	[$]	Decommissioning cost	0	
4.8	CL_NS	[%]	Capacity loss for characterization of a reservoir as non sustainable		
4.9	C1	[$/a]	Total annual operation and maintenance costs		
4.10					
4.11					
4.12					
4.13			Application of declining discount rate?	No	
4.13a	DDR1	[%]		0 – 30	3.00%
4.13b	DDR2	[%]		31 – 75	2.57%
4.13c	DDR3	[%]	Definition of Declining Discount Rate	76 – 125	2.14%
4.13d	DDR4	[%]		126 – 200	1.71%
4.13e	DDR5	[%]		201 – 300	1.29%
4.13f	DDR6	[%]		301 - …	0.86%
4.14	Ymax	[years]	Maximum duration of financial analysis	300	

www.manaraa.com

Shihmen

Table C-8: Reservoir Geometry

ID	Parameter	Units	Description	Value
1.1.1	So_gr	[m^3]	Original gross storage capacity of the reservoir	252,000,000
1.1.2	So_a	[m^3]	Original active storage capacity of the reservoir	
1.1.3	So_d	[m^3]	Original inactive storage capacity of the reservoir	
1.1.4	Se_gr	[m^3]	Existing gross storage capacity of the reservoir	80,000,000
1.1.5	Se_a	[m^3]	Existing active storage of the reservoir	
1.1.6	Se_d	[m^3]	Existing inactive storage of the reservoir	
1.1.7	Wbot	[m]	Representative reservoir bottom width at the dam location	
1.1.8	--	--	--	
1.1.9	ELOWL	[masl]	Maximum pool elevation of reservoir	245
1.1.10	ELMWL	[masl]	Minimum operation water level	173
1.1.11	Elbmin	[masl]	Minimum reservoir bed elevation at dam site	102
1.1.12	Lres	[m]	Reservoir length	
1.1.13	ncomp	[-]	Number of reservoir compartments	5

www.manaraa.com

Table C-9: Hydrology and Sediment

ID	Parameter	Units	Description	Value
2.1.1.1	MAR	[million m^3/a]	Mean annual reservoir water inflow	
2.1.1.2	Cv	[-]	Coefficient of variation of annual run-off volume	
2.1.1.3	Twater	[°C]	Representative water temperature in the reservoir	
2.1.2.1	r_d	[tonnes/m^3]	Specific weight of in-situ reservoir sediment (bulk density)	1.12
2.1.2.2	MAS	[million tonnes/a]	Mean annual total (suspended and bedload) sediment inflow mass	
2.1.2.3		[g/l]	Average annual concentration of suspended load	
2.1.2.3	ExceedT	[%]	Percentage of time exceeded	
	ExceedMAR	[%]	Percentage of mean annual water inflow	
	ExceedMAS	[%]	Percentage of mean annual sediment inflow	
2.1.2.4	pcl	[%]	% clay of suspended sediment inflow	
2.1.2.5	psi	[%]	% silt of suspended sediment inflow	
2.1.2.6	psa	[%]	% sand of suspended sediment inflow	
2.1.2.7	ws_cl	[m/s]	Settling velocity of clay particles	
2.1.2.8	ws_si	[m/s]	Settling velocity of silt particles	
2.1.2.9	ws_sa	[m/s]	Settling velocity of sand particles	
2.1.2.10	TE_Method		Trap efficiency method	Brune
2.1.2.11	Brune Curve No	[-]		2
2.1.2.12	p_b	[%]	% bedload of total sediment inflow	
2.1.2.13	T_b	[%]	Duration of bedload transport	
2.1.3.1	Zpr		Standardized normal nariate at pr*100%	
2.1.3.2	Gd		Gould's correction factor	
2.1.3.3	Sd		Standard deviation of annual run-off	
2.1.3.4	Distribution		Distribution of annual inflows	

للاستشارات المنارة
www.manaraa.com

Table C-10: Sediment Management – Flushing

ID	Parameter	Units	Description	Value
3.2.1.1	Y	[-]	Indicator of deposits type	650
3.2.1.2	Ans	3 or 1	Sediment removal difficulty	3
3.2.1.3	Qf	[m3/s]	Representative flushing discharge	
3.2.1.4	Tf	[days]	Duration of flushing after complete drawdown	
3.2.1.5	Cal_SSfl	[-]	Calibration parameter for Mignot equation	
3.2.1.6	CLF	[%]	Maximum percent of capacity loss allowable	100
3.2.1.7	s1	[%]	Fraction of run-of-river benefits	90
3.2.1.8	s2	[%]	Fraction of storage benefits	90
3.2.1.9	FI	[US$]	Cost of capital investment	
3.2.1.10	Elfl_dam	[masl]	Water elevation at dam during flushing	
3.2.1.12	Shall the implementation strategy of flushing be determined through economic optimization?			
3.2.1.13	CycleNS	[Years]	Time interval between flushing events during the 1st phase (Reservoir storage > sustainable long term reservoir capacity)	1
3.2.1.14	CycleS	[Years]	Time interval between flushing events during the 2nd phase (Reservoir storage < sustainable long term reservoir capacity)	1
3.2.1.15	OMC_FL	[US$/a]	Annual operation and maintenance costs of flushing	

Table C-11: Sediment Management – Dredging

ID	Parameter	Units	Description	Value
3.2.2.1	Cw	[%]	Concentration by weight of sediment removed to water removed by traditional dredging	30
3.2.2.2	CLD	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for dredging	100
3.2.2.3	ASD	[%]	Maximum percent of reservoir storage that can be restored during each dredging event	1,000,000
3.2.2.4	MD	[m3]	Amount of sediment removed per dredging event	
3.2.2.5	PD	[$/m3]	Unit value of water used in dredging operations	0.02
3.2.2.6	CD	[$/m3]	Unit cost of dredging	3.00
3.2.2.7	Shall the unit cost of dredging be determined automatically?			
3.2.2.8	Shall the implementation strategy of dredging be determined through economic optimization?			
3.2.2.9	Cycle1DR	[years]	Duration of phase 1 (No dredging)	
3.2.2.10	Cycle2DR	[years]	Cycle length in phase 2 (Dredging operation)	
3.2.2.11	Shall a sustainable solution be determined automatically?			
3.2.2.12	Where do you want to perform dredging?			

المنارة للاستشارات
www.manaraa.com

Table C-12: Sediment Management – HSRS

ID	Parameter	Units	Description	Value
3.2.3.1	Type	1 or 2	Sediment type category to be removed by Hydrosuction Sediment Removal System (HSRS)	1
3.2.3.2	D	[m]	Assume a trial pipe diameter for HSRS	
3.2.3.3	NP	1, 2, or 3	Number of pipes for HSRS	
3.2.3.4	YA	[%]	Maximum fraction of total yield that is allowed to be used in HSRS operations	30
3.2.3.5	CLH	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for HSRS	100
3.2.3.6	PH	[$/m3]	Unit value of water released downstream of dam in river by HSRS operations	0.02
3.2.3.7	HI	[US$]	Cost of capital investment to install HSRS	
3.2.3.8	DU	[Years]	The expected life of HSRS	25
3.2.3.9	Shall the implementation strategy of HSRS be determined through economic optimization?			
3.2.3.10	Year HSRSstart	[Years]	Timing of HSRS installation	
3.2.3.11	HSRSlimit	[m]	Length limit for implementation of HSRS	

Table C-13: Sediment Management – Trucking

ID	Parameter	Units	Description	Value
3.2.4.1	CLT	[%]	Maximum percent of capacity loss that is allowable at any time in reservoir for trucking	100
3.2.4.2	AST	[%]	Maximum percent of reservoir storage that can be restored during each trucking event	100
3.2.4.3	MT	[m3]	Amount of sediment removed per trucking event	500,000
3.2.4.4	CT	[US$/m3]	Unit Cost of trucking	13.00
3.2.4.5	Shall the implementation strategy of trucking be determined through economic optimization?			
3.2.4.6	Cycle1TR	[years]	Implementation year	
3.2.4.7	Cycle2TR	[years]	Frequency of trucking operation	
3.2.4.8	Shall a sustainable solution be determined automatically?			
3.2.4.9	Where do you want to perform trucking?			
3.2.4.10	sTR	[%]	Fraction of reservoir water yield the year trucking occurs	

www.manaraa.com

Table C-14: Economic Parameters

ID	Parameter	Units	Description	Value	
4.1					
4.2	c	[$/m3]	Unit cost of construction per m3 of reservoir capacity	0.16	
4.3	C2	[$]	Total cost of reservoir impoundment		
4.4	r	[%]	Discount rate	6	
4.5	Mr	[%]	Market interest rate of annual retirement fund	6	
4.6	P1	[$/m3]	Unit benefit of reservoir yield	0.2	
4.7	V	[$]	Decommissioning cost	0	
4.8	CL_NS	[%]	Capacity loss for characterization of a reservoir as non sustainable		
4.9	C1	[$/a]	Total annual operation and maintenance costs		
4.10					
4.11					
4.12					
4.13			Application of declining discount rate?	No	
4.13a	DDR1	[%]		0 – 30	3.00%
4.13b	DDR2	[%]		31 – 75	2.57%
4.13c	DDR3	[%]	Definition of Declining Discount Rate	76 – 125	2.14%
4.13d	DDR4	[%]		126 – 200	1.71%
4.13e	DDR5	[%]		201 – 300	1.29%
4.13f	DDR6	[%]		301 - …	0.86%
4.14	Ymax	[years]	Maximum duration of financial analysis	300	

www.manaraa.com