ASEAN Engineering Journal

Full Paper

SUPPLEMENTARY TOOLS IN BASELINE INFORMATION BUILDING FOR WATER RESOURCES PROJECTS UNDER THE NEW NORMAL

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Article history
Received
11 March 2021
Received in revised form
25 August 2021
Accepted
25 August 2021
Published online
28 February 2022

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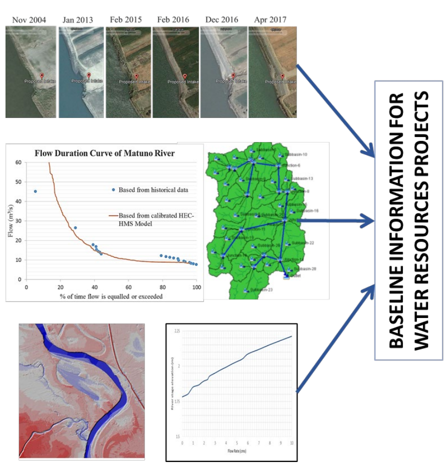
Graphical abstract



Abstract

Research and industry-related engineering projects are affected in many ways by the COVID-19 pandemic. For example, data gathering becomes more challenging in recent times. The main objective of this paper is to demonstrate alternative ways to gather baseline data related to water resources projects. There are supplemental open-source tools available for baseline information building that are used in the past years that are expected to play more significant roles now. The data gathering phase of some projects were used as examples. Firstly, the importance and basic know-hows of Google Earth Pro ™ in the context of rapid reconnaissance and appraisal (RRA) are portrayed. Google Earth Pro's Street View and available historical satellite images enable spatially and temporally varied virtual tour of study areas, which can help in site characterization and identification of important study and design parameters. Secondly, the use of hydrologic modeling to obtain estimates of flow data is illustrated. Hydrologic Engineering Center – Hydrologic Modeling System (HEC-HMS) is shown to be capable of generating approximate flood hydrographs for ungaged rivers and flow duration curves for water supply studies. Lastly, the capability of hydraulic models to estimate water levels is presented. Instead of getting anecdotal water levels in the field, hydraulic modeling packages such as Hydrologic Engineering Center – River Analysis System (HEC-RAS) and SOBEK-River are technically feasible to get water levels for water resources projects. Although the results are subjected to some limitations, as in the case of uncalibrated models, these provide opportunities to obtain valuable information amidst the pandemic.

Keywords: Water resources projects, new normal, hydrologic modeling, hydraulic modeling

1.0 INTRODUCTION

The impacts of COVID-19 pandemic made everyone change lifestyle and live under a new normal. Research and industry-related engineering projects are also affected in many ways. For example, for preliminary stages of a project, data gathering becomes more challenging because of limited movements. Field reconnaissance cannot be done as easily as before because of possible lockdowns in some places, additional logistical requirements for the conduct of site visits, and willingness of some engineers to be exposed to health risks. However, research and engineering industry-related projects must still push through, and professionals must still move forward and face the challenges of this new normal.

For any engineering projects or studies, it is important to gather baseline information about the project site. Each project is said to be unique even though the same proposed development shall be made, mainly because of varying local conditions. Therefore, it is very important to have a comprehensive understanding of the project site prior to any designs or assessments. For water-related projects, baseline information includes, among others the following: meteorologic conditions like rainfall, temperature and humidity; physical attributes like topography, land use and soil type; and hydrologic and hydraulic characteristics such as streamflow values, surface roughness, and type and location of control sections.

The main objective of this paper is to demonstrate supplemental and alternative ways to gather baseline information related to water-resources projects. With the advancements of computing technology and availability of several open-source tools, researchers and professionals are presented the opportunity to become productive while working remotely from the project site. It must be noted that the ideas presented in this paper are not new, they are being used in the past few years, but are now expected to play more significant and expanded roles. This paper aims to initiate the discourse about these tools and hopes that professionals in water resources projects will likewise share their experiences on how to cope with the new normal.

The discussions below contain case studies on past and present projects that illustrate the usage of some open-source tools in gathering baseline information.

2.0 DISCUSSION OF SUPPLEMENTARY TOOLS

2.1 Alternative or Supplementary Methods of Performing RRA

Rapid Reconnaissance and Appraisal (RRA) is usually done before or right after the start of any project. This is done in order to have a feel and appreciation of the site. Key baseline information is also obtained during this process. RRA involves one or multiple short visits in the field to do survey, key informant interviews and participant observation [1]. In water resources projects, RRA plays a crucial role in project scoping and formulating future data gathering activities. Because of the new normal, it is more difficult to mobilize a field team to do RRA especially for remote areas or for long-duration field works.

Google Earth Pro ™ is a three-dimensional software model of the earth. One can view satellite images of places across the globe at different resolutions. When the software became free in 2015, it had been used extensively for technical studies and various professional applications. Recent examples of its application in the field of water engineering includes sanitation planning [2], near-shore coastal processes [3] and disaster risk management [4]. With the addition of Google Street View, a feature in Google Earth Pro ™ that provides interactive images of places captured along streets, this software offers a robust information system.

The mentioned satellite and street-level images can play a pivotal role in the conduct of RRA. As a support tool for example, one can first access the site through Street View in order to plan ahead of time the specific places to visit. In some cases, when the needed information is already reflected in the images, Street View can be an alternative to actual site visits. The satellite images on the other hand can help validate the land use of an area and discover important land features which might be missed during actual site visit. In some places, multiple satellite images taken at different times are available, which can help in the determination of historical events in a project site. Below are two (2) situations that shows how Google Earth Pro ™ can be used in baseline data gathering.

Case Study No. 1 – Environmental Impact Study in Leyte, Philippines

One of the usual requirements in applying for Environmental Compliance Certificate (ECC) for any developments is the conduct of Environmental Impact Study (EIS). Major part of an EIS is baseline information gathering and impact assessment of the water environment within the direct impact area of a proposed development. For a proposed industrial park development in Leyte, the EIS was scheduled March-April 2020, when local travel is nearly impossible. For this case, Google Earth Pro ™ served as an important tool in doing virtual RRA. The virtual tour was able to extract key EIS requirements such as local drainage characterization and locating surface waters within the project site. Partial results are summarized in Figures 1 and 2 to showcase the usefulness of information extracted via Google Earth Pro.

On drainage characterization: *"The project site is rural, predominantly agricultural in nature, with residential areas located along the national road. Consistent with the described land use, local drainage system is undeveloped, largely relying on surface runoff to be drained in undeveloped areas. As can be seen in Figure 1, there are no open channels nor subsurface drainages found inside the study area."*

Figure 1 Roads around the project site showing the general characteristics of local drainage system. *Extracted from Google Earth Street View, 2016. Copyright 2020.*

Figure 2 contains images of waterways in the project site, which are required to be shown to the Technical Review Committee of Department of Environment and Natural Resources (DENR) as part of the EIS.

Figure 2 Photographs of surface water bodies inside the project site, with Quiot River (bottom) as the primary river in the area. *Extracted from Google Earth Street View, 2016. Copyright 2020.*

Case Study No. 2 – Design of River Water Intake in Pangasinan, Philippines

In the engineering design of river water intakes, baseline information is much needed to establish loading conditions and determine the suitable design considerations. This example demonstrates how historical satellite imagery can provide inputs to the design process.

A water supply system is to be developed in a certain locality in Pangasinan, with Agno River as the main source. Satellite images of the proposed location of river water intake were taken and shown in Figure 3. With reference to the figure, there are obvious changes to the riverbank through the years. There are some images that show natural scouring (between 2004-2013 and between February 2016 – December 2016). There are also indications that man-made modifications were done (February 2016 and April 2017). It can be deduced that the riverbanks are prone to erosion. This information made the design engineers carefully analyze the potential scour depths to ensure structural stability of the intake. Also, the type of intake and ancillary structures are influenced by this finding.

Figure 3 Historical satellite images of the proposed location of intake, suggesting scouring (natural) and realignments (man-made) of banks happened in the area.

2.2 Role of Hydrologic Modeling in Flow Estimation

One of the most important baseline data in water resources projects is the quantity of water, normally in terms of volumetric flow or discharge. For flood or drainage projects, the peak discharge or direct runoff hydrograph for extreme conditions are needed. For water supply projects, reliable flow and flow duration curves must be estimated.

The Rational Method is the most used formula to estimate peak flow. However, its usage is limited to drainage areas less than 81 hectares [5] and can only be used for design purposes. It cannot be used for flood studies or assessments because of inherent conservativeness of results. In cases when Rational Method is not valid, flood frequency analysis is used. It requires several years of streamflow record and if possible, site validation during a flood event. An alternative procedure is by means of hydrologic modeling. Several international [6,7] and local [8] applications of hydrologic modeling for excess water management are published in various journals.

Water supply projects require flow reliability analysis to determine the amount of surface water available from a source. The traditional method of performing reliability studies is to establish a gaging station and do medium-term to long-term flow measurements. In this way, flow duration curves can be derived. An alternative method is to establish a hydrologic model and develop a synthetic flow duration curve. Detailed methodology can be found in the work of Cisneros (2017). Two (2) examples of hydrologic modeling applications are presented below.

Case No. 3 – Flood Study of San Juan River in Quezon City, Philippines

Flood studies especially for urban setting oftentimes rely on extensive interviews to establish baseline conditions. With the aid of a hydrologic model, the amount of field work can be reduced by identifying beforehand the critical areas, where foot survey is essential. It means more efficient execution of field work while minimizing the involvement of public.

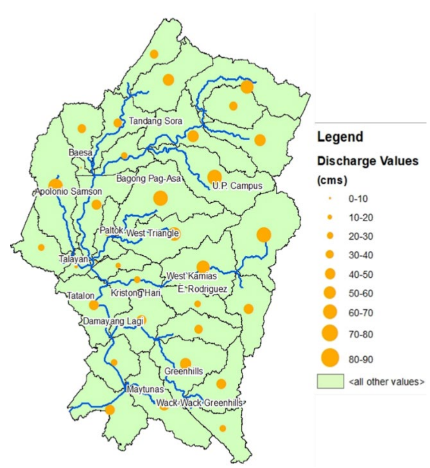


Figure 4 Simulated discharges for different sub-basins of San Juan River Watershed during Habagat 2012.

In the case of San Juan River Flood Study, a hydrologic model using Soil and Water Assessment Tool (SWAT) by FAO-United Nations was set up. One of the key results is shown in Figure 4. Different locations produce varying amounts of runoff. For field works that focus on understanding the source of flood, areas that produce little runoff need not be visited.

Case Study No. 4 – Feasibility Study and Preliminary Engineering Design of Run-of-River Hydropower in Nueva Vizcaya, Philippines

Preliminary engineering design of run-of-river hydropower plants requires flow reliability analysis to know how much flow at any given time can be used. The flow duration curve usually becomes a key data in determining the rated capacity of hydropower and projected annual power generation. For the proposed hydropower development in Nueva Vizcaya, synthetic flow duration curve was derived using Hydrologic Engineering Center- Hydrologic Modeling Software (HEC-HMS). The modeling platform is shown in Figure 5. Basically, long-term rainfall data is entered along with physical characteristics of the watershed to perform rainfall-runoff transformation.

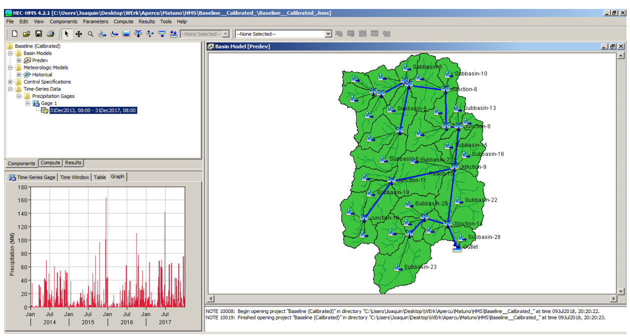


Figure 5 Screenshot of HEC-HMS platform showing the rainfall hyetograph (lower left) and subbasins (right) of the Matuno catchment area

Figure 6 shows the resulting synthetic flow duration curve based on the modeling activity and how it compares with the historical data. There are slight differences, but the modeled response is in the conservative side which can be considered reliable for engineering purposes. This case study proves that for a similar project in the future, if the pandemic can cause some concerns regarding prolonged site visits, the same methodology can be applied.

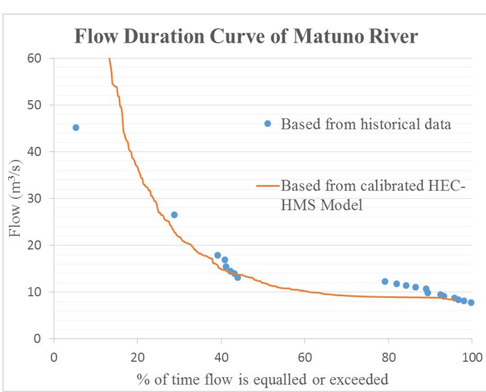


Figure 6 Historical and synthetic flow duration curve of the project site

2.3 Hydraulic Modeling Instead of Gathering Anecdotal Water Levels

Part of Technical Due Diligence (TDD) of any development project is the determination of flood levels in a project site. Similarly, water supply projects require information about water levels in the river to come up with optimized engineering design. The most common way to determine water levels is to interview locals, and make some inferences based on these anecdotes. For more critical applications, monitoring stations are established, requiring extensive field works. Hydraulic modeling can largely reduce the number of fieldworks required for a project. Under the new normal, to minimize interaction with the locals, indicative water levels from hydraulic models can substitute the anecdotal accounts. The hydraulic modeling algorithm has been stable in the last ten (10) years and therefore considered as a standard tool in river engineering projects [10,11]. Under the current situation, its usage can be further expanded to TDDs and small projects.

Application of Hydraulic Modeling in Case Study No. 2

For the design of raw water intake, flood levels of Agno River must be estimated for proper site grading, and to ensure that critical facilities like electromechanical equipment will not be flooded. The exact location is not frequented by people. Water levels are estimated using SOBEK-River, a 2-dimensional hydraulic modelling software. As one of the major rivers in the Philippines, there are sufficient upstream and downstream data that served as boundary conditions. The results are described in Figure 7.

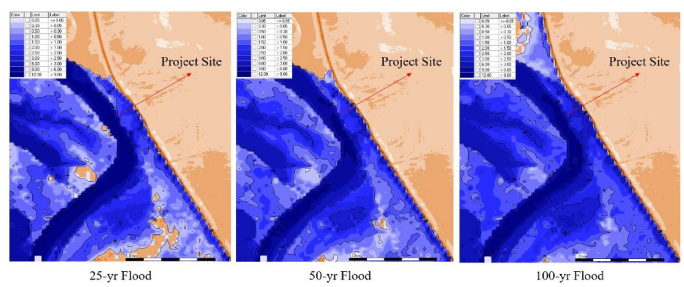


Figure 7 Flood map showing depth of inundation (in m) for different return periods

Case Study No. 5: Design of Riverbed Infiltration Gallery in Batangas

An infiltration gallery is a horizontal well or group of horizontal wells that transmit water to or from underground sources. An infiltration gallery was proposed to be installed at a river bed in Batangas to serve as a raw water intake. The available heads for different flow regimes are needed in the hydraulic design of infiltration galleries, and therefore, a 1-d quasi-unsteady hydraulic model of the river was constructed using Hydrologic Engineering Center – River Analysis System (HEC-RAS). The model was subjected to different flow values, ultimately deriving the stage rating curve in Figure 8. Under traditional methods, it would take several months of stream flow measurements to approximate this rating curve, but using HEC-

RAS, the task became relatively easier. It must be noted that streamflow measurements should still be done to obtain data points for calibration and validation of the model. However, field activity will not be as extensive if supplemented by this type of modeling technology. As a side note, for this project, the predevelopment river stages are not sufficient to obtain the desired yield of the gallery, hence, in-line ancillary structures such as weir and stilling basin were incorporated in the design.

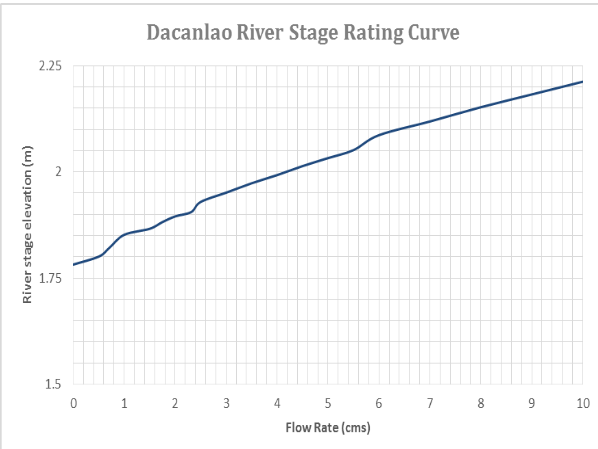


Figure 8 Stage rating curve of the river where an infiltration gallery is proposed to be installed, as estimated using HEC-RAS

3.0 CONCLUSIONS

This paper shows through examples some useful tools that could be used to supplement or to substitute the traditional approaches in baseline information building related to water resources projects. With the challenges to project executions brought about by the pandemic, it is timely to explore alternatives in doing data gathering. Plenty of these tools are open-source, like Google Earth Pro, SWAT, HEC-HMS and HEC-RAS. Other software like SOBEK-River are commercial, but offer ease of use and technical support from developers.

Satellite imagery and online street photographs can be used to remotely perform RRA. Hydrologic and hydraulic modeling packages can make field visits more efficient, can reduce the frequency of field works, and can minimize interaction with locals during the conduct of site visits. These potential changes are all beneficial to working under the new normal.

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