MS No.: hess-2017-88
MS Type: Research article
Special Issue: Coupled terrestrial-aquatic approaches to watershed-scale water resource sustainability
Title: Title: Assessment of Integrated Watershed Health based on Natural Environment, Hydrology, Water Quality, and Aquatic Ecology
Journal: Hydrology and Earth System Sciences

Anonymous Referee #1

COMMENTS: This study evaluated health condition of a watershed of the Han River basin (34,148 km2) in South Korea was performed using monitoring data and SWAT modeling results. Six essential indicators of healthy watersheds were used in the assessment: landscape condition, geomorphology, hydrology, water quality, habitat, and biological condition. The research findings from this study provided guidance for watershed management at the watershed scale based on specific management objectives and can combined with any of the other sub-indices in the Han River basin for use in determining priority conservation areas. This paper is well organized and well written generally. Detailed method description was incorporated. The scientific results and conclusions were presented in a clear, concise, and well-structured way. The number and quality of references is appropriate. But method and results should be reduced. The importance of six essential indicators of healthy watersheds was not well described. More in-depth discussion should be included to support the interpretations and conclusions. This manuscript can be reviewed after major revisions. What is the novel idea this manuscript provided to scientific knowledge? Please describe it and use your results and discussion to support it.

General

1. The last sentence of the abstract "The results suggest that approaches aimed at simultaneously improving the water quality, hydrology, and aquatic ecology conditions may be necessary to improve integrated watershed health." Is this the scientific questions being answered in this manuscript? Please provide specific discussion of results and summarize them in conclusion to support this point. Otherwise, I do not think this sentence should be here.

   ● Response:
   (Lines 25-27) We removed the last sentence of the abstract. And we revised this as follows: "As a result, during the most recent ten-year period of 2005–2014, the watershed health declined, as indicated by the worse results for the surface processes metric and soil water dynamics compared to the 1995–2004 period. The integrated watershed health tended to decrease farther downstream the watershed."

2. 2.4 Hydrology and water quality simulations using the SWAT model: the session is mainly focus on basic information about SWAT. If it is not specific for your project, it is better to put information in the Introduction rather than in Methods. And authors already described data collection related to SWAT model setup and SWAT outputs in 2.3, thus it is better to introduce SWAT model before discussing data related to it.

   ● Response:
   (Lines 148-157, and 193-200) 2.4 Hydrology and water quality simulations using the SWAT model: the session is mainly focus on not only basic information about SWAT but also model calibration and validation for hydrology and water quality simulation data. The information of this session are very important as methods for watershed health assessment. We added a new session 2.3 SWAT model description before 2.4 Data collection and removed basic information about SWAT in 2.5 Hydrology and water quality simulations using the SWAT model.

3. Is 90 m grid size DEM data sufficient to accurately simulate hydrology and water quality at such a large area? Is there any higher resolution elevation data can be used?

● Response:

(Lines 206-207) Our study area included parts of North Korea. We have 30 m DEM covered by South Korea, but we don’t have data in North Korea. Therefore, we used a world 90 m DEM from the Shuttle Radar Topography Mission (SRTM) of the International Centre for Tropical Agriculture (CIAT). As shown in the below figures 1, 2, 3, and 4, the results for hydrology and water quality were reasonable. I think that precipitation has an even greater impact on the hydrologic simulations than the DEM resolution does. In addition, the resolution of 90 m DEM deems appropriate for simulating the watershed hydrology for the 237 sub-watersheds (average area is 144 km^2) using the SWAT model.

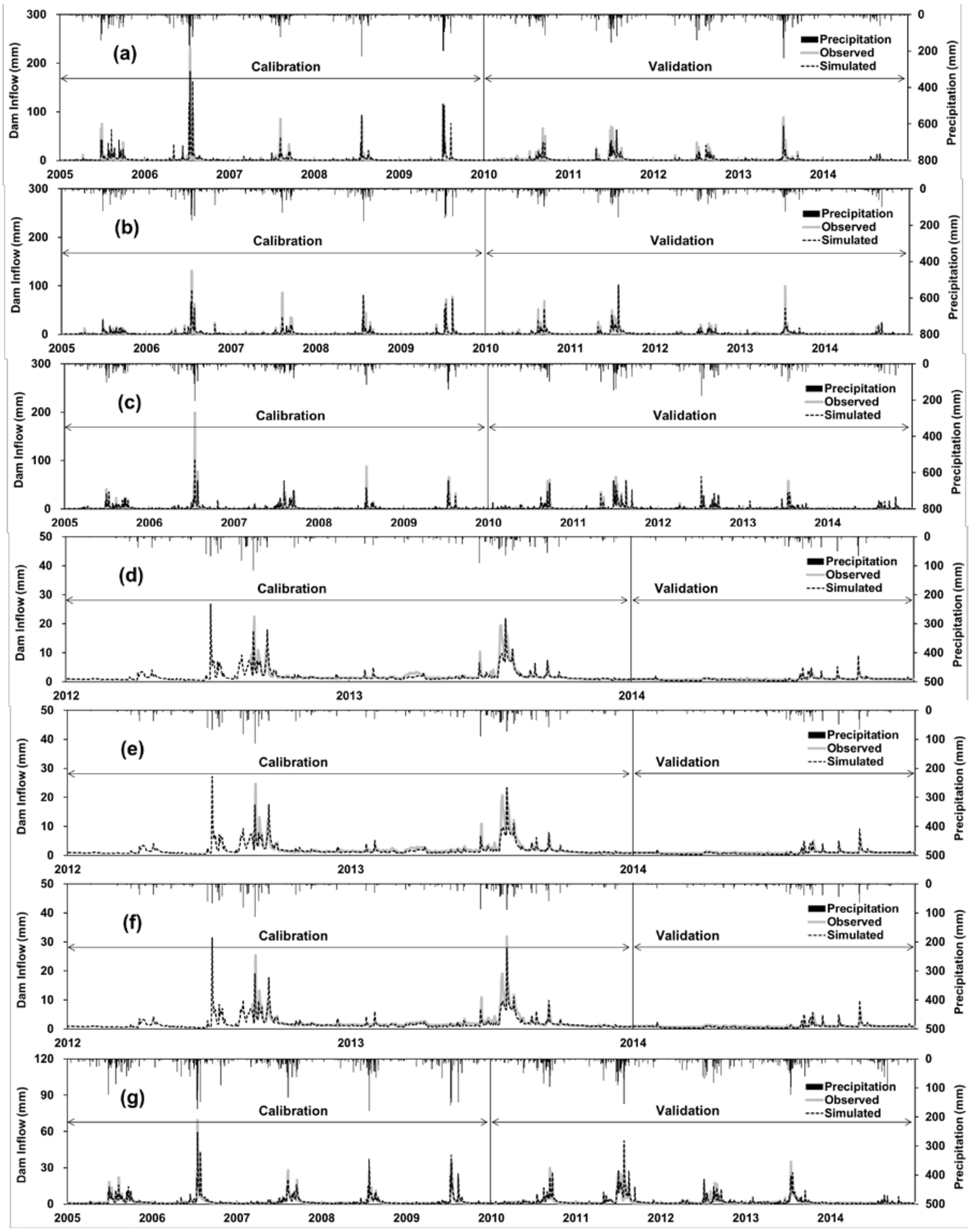

Figure 1 Comparison of the observed and SWAT-simulated daily dam inflow during the calibration (2005–2009) and validation (2010–2014) periods at (a) HSD, (b) SYD, (c) CJD, (d) KCW, (e) YJW, (f) IPW, and (c) PDD.

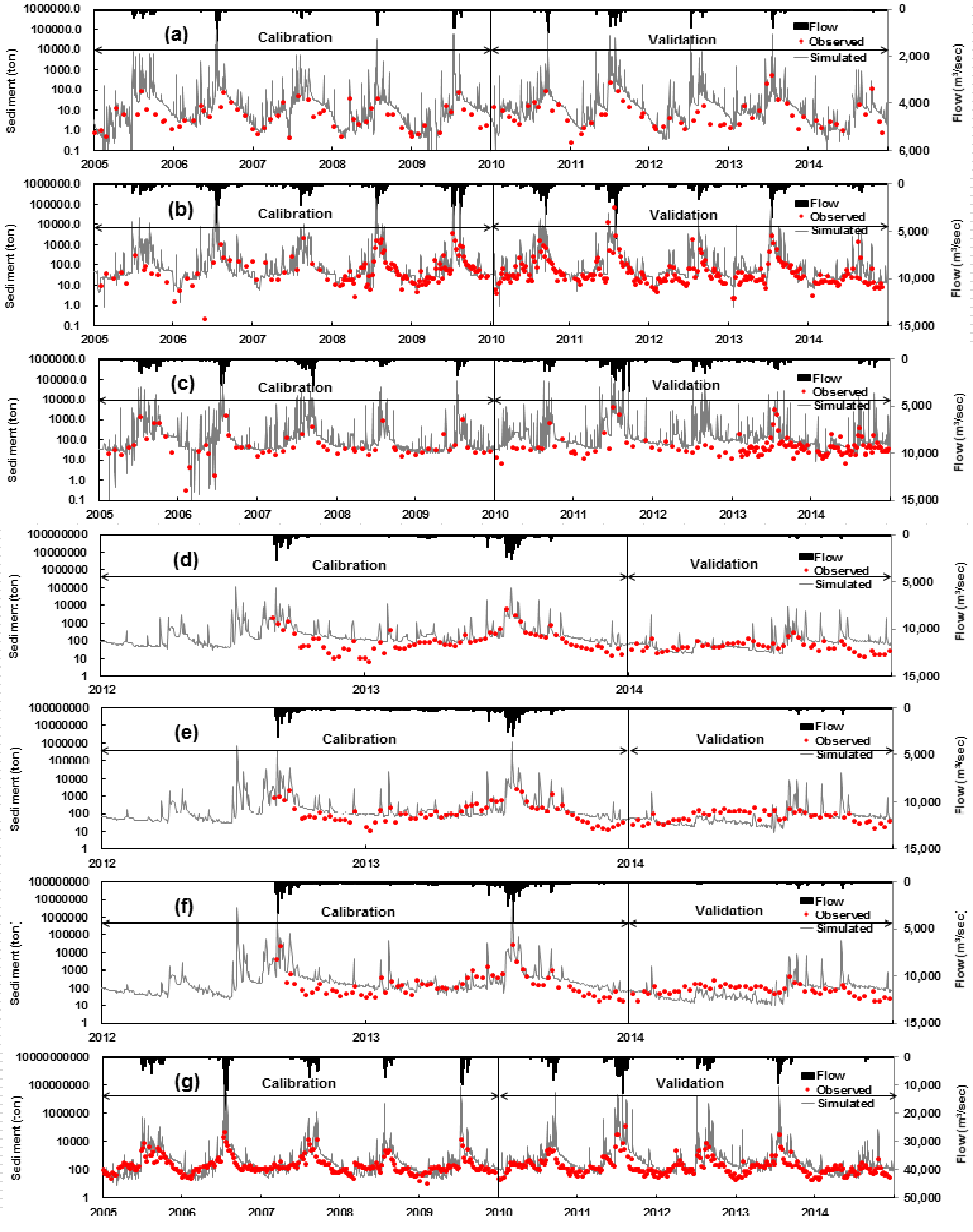

Figure 2 Comparison of the observed and SWAT-simulated daily sediment during the calibration (2005–2009) and validation (2010–2014) periods at (a) SG, (b) CSG, (c) JW, (d) KCW, (e) YJW, (f) IPW, and (c) PDD.

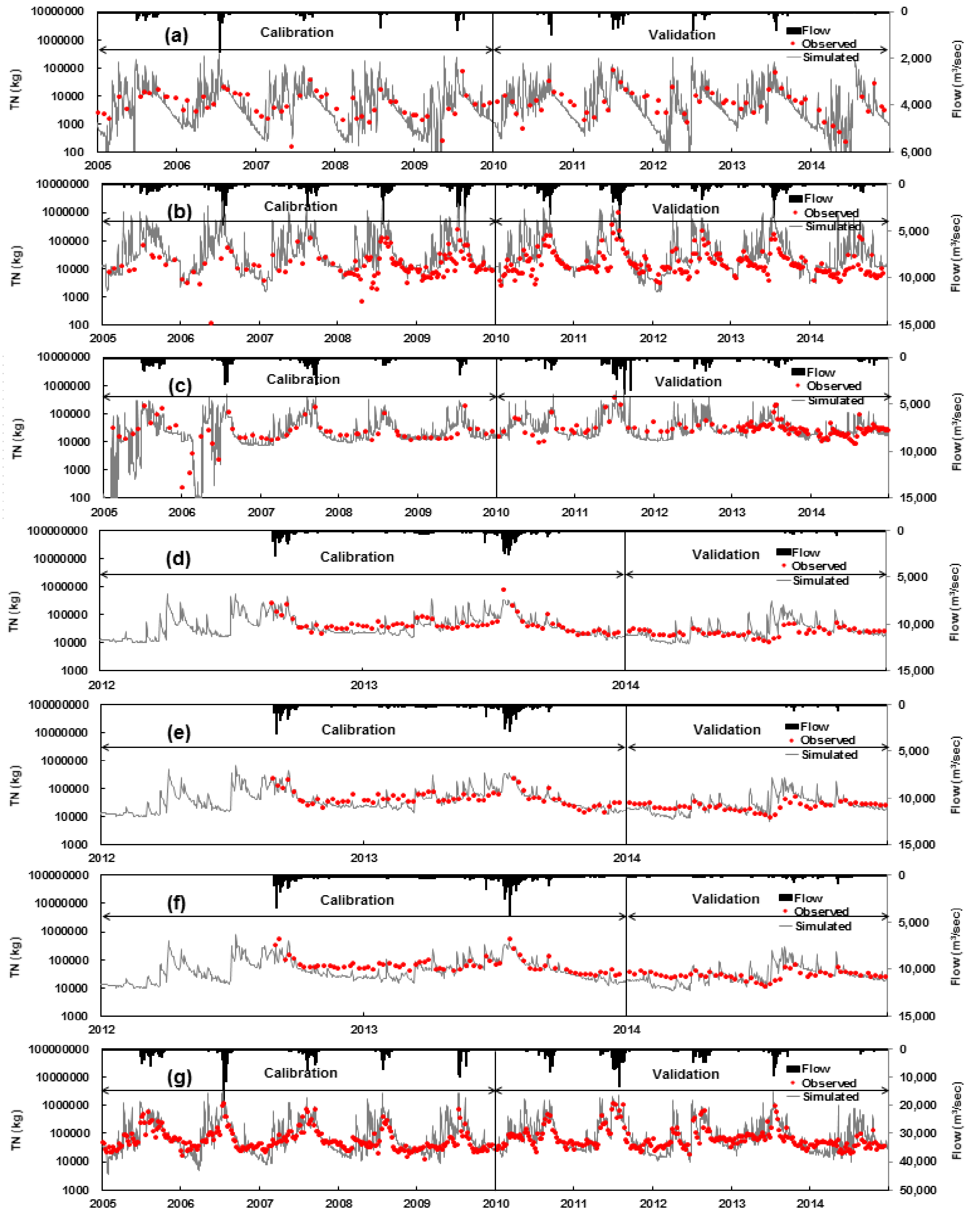

Figure 3 Comparison of the observed and SWAT-simulated daily T-N during the calibration (2005–2009) and validation (2010–2014) periods at (a) SG, (b) CSG, (c) JW, (d) KCW, (e) YJW, (f) IPW, and (c) PDD.

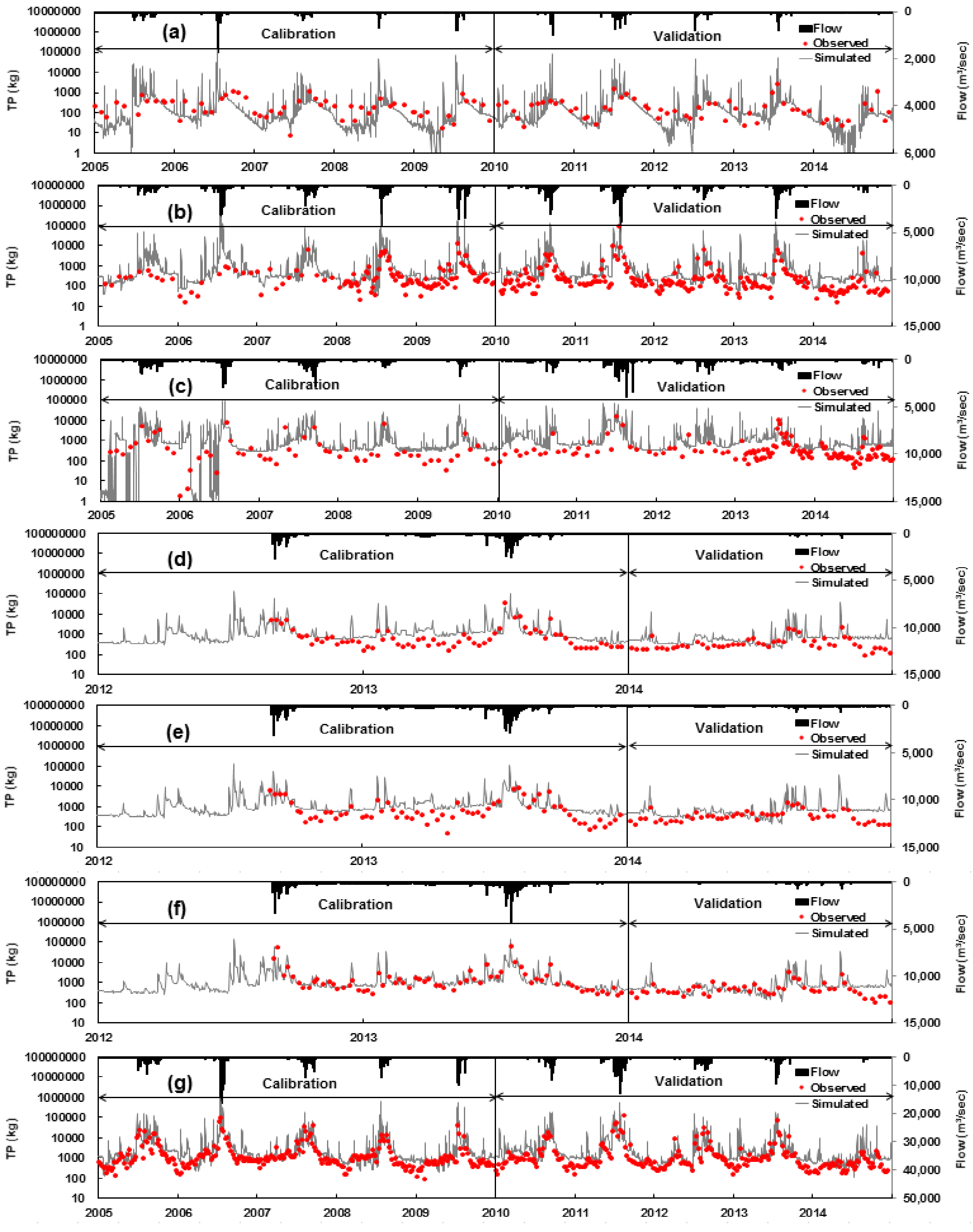

Figure 4 Comparison of the observed and SWAT-simulated daily T-P during the calibration (2005–2009) and validation (2010–2014) periods at (a) SG, (b) CSG, (c) JW, (d) KCW, (e) YJW, (f) IPW, and (c) PDD.

4. Is calibration period (2005–2009) and validation period (2010–2014) both incorporate wet and dry years?

   ● Response:
   (Lines 241-246) We incorporated both wet and dry years in calibration period (2005–2009) and validation period (2010–2014). The average annual precipitation of Han River basin is 1,300 mm. For the calibration period (2005–2009), wet and dry years are 2006 (1,625 mm) and 2008 (1,160 mm). For the validation period (2010–2014), wet and dry years are 2011 (1,640 mm) and 2014 (734 mm).

5. Statistical evaluation criteria R2, NSE and PBIAS are all sensitive to high values. Criteria less sensitive to high values, such as Modified NSE and KGE, may could be incorporated.

   ● Response:
   (Lines 281-284) We added NSE with inverse discharge (1/Q) in Table 2. We added new sentences: "Additionally, model calibration and validation included the NSE with inverse discharge (1/Q) for low flow. The average NSE with inverse discharge (1/Q) during the calibration (2005–2009) and validation (2010–2014) periods was 0.35 at HSD, 0.53 at SYD, 0.30 at CJD, 0.54 at KCW, 0.47 at YJW, 0.69 at IPW, and 0.58 at PDD."

6. Page 8 line 197: this paragraph described a lot of detailed information about dams. It is better to condense it and save more space for in-depth discussions. How was dam information being set in SWAT model?

   ● Response:
   (Lines 211-219 and 223-235) We removed paragraph that is about description of detailed dam informations. We addedd new sentences about dam information being set in SWAT model as follows: "The flow and water quality of the Han River are impacted by the discharge operations of these large dams and weirs; therefore, dam and weir operations must be incorporated into the modeling framework to enable successful modeling. In the SWAT model, dam operations are modeled based on measured daily discharges, measured monthly discharges, average annual discharges, or target storage volumes. In this study, the measured daily discharges from the four dams and three weirs were directly imported into the SWAT model."

7. Page 9 line 226: "The calibrated parameters and hydrograph of the calibration results in the Han River basin were described by 227 Chung et al (2017)." Parameter definition, physical meaning, range used for calibration and calibrated values are very important information. Please describe this information in supplementary materials to prove that your calibration and validation is reliable.

   ● Response:
   (Lines 260-268) We added new sentences about information for parameter definition and physical meaning as follows: "In this study, both calibration and validation were manually performed using a trial-and-error approach within recommended ranges to maximize the expert knowledge of watershed characteristics and modeling experience. The final values were selected based on a statistical evaluation of the performance measures. Twenty of the most influential parameters were selected for calibration. These parameters are related to surface runoff (CN2, CNCOEF, SURLAG, OV_N, and CH_N), evapotranspiration (ESCO), soil water (SOL_AWC and SOL_K), groundwater (GW_DELAY, GWQMN, ALPHA_BF, REVAPMN, and GW_REVAP), and reservoir operation (RES_ESA, RES_EVOL, RES_PSA, RES_PVOL, RES_VOL, RES_K, and EVRSV) processes."

   As shown below, adjusted parameter values and definitions were included in Table 1 of Chung et al (2017).

Table 1. Descriptions of calibrated parameters in Soil and Water Assessment Tool (SWAT) [32].

Parameter		Definition	Range	Adjusted Value (Average)	
				Dams	Weirs
Surface runoff	CN2	SCS curve number for moisture conditions	35–98	+12.5	+7
	CNCOEF	Plant ET curve number coefficient	0.5–2	2	2
	SURLAG	Surface runoff lag coefficient	1–24	4	4
	OV_N	Manning's "n" value for overland flow	0.01–30	0.14	0.14
	CH_N(1)	Manning's "n" value for tributary channels	0.01–30	0.014	0.014
Evapotranspiration	ESCO	Soil evaporation compensation coefficient	0–1	0.9125	0.95
Soil water	SOL_AWC	Available water capacity	0–1	0.135	0.14
	SOL_K	Saturated hydraulic conductivity (mm/hr)	0–2000	25.8	25.8
Ground water	GW_DELAY	Delay time for aquifer recharge (days)	0–500	29	31
	GWQMN	Threshold water level in a shallow aquifer for baseflow (mm)	0–5000	1375	1000
	ALPHA_BF	Baseflow recession constant	0–1	0.725	0.048
	REVAPMN	Threshold water level in a shallow aquifer for "revap" (mm)	0–1000	750	750
	GW_REVAP	Groundwater "revap" coefficient	0.02–0.2	0.02	0.02
Reservoir	RES_ESA	Reservoir surface area of the emergency spillway (km^2)	-	48.25	4
	RES_EVOL	Volume of water needed to fill the reservoir storage Volume of the emergency spillway (10^6 m^3)	-	1495.25	13.667
	RES_PSA	Reservoir surface area of the principal spillway (km^2)	-	43	3
	RES_PVOL	Reservoir storage volume of the principal spillway (10^6 m^3)	-	1257.25	11.33
	RES_VOL	Initial reservoir volume (10^6 m^3)	-	674.75	9
	RES_K	Hydraulic conductivity of the reservoir bottom (mm/hr)	0–1	0.2	0.3
	EVRSV	Lake evaporation coefficient	0–1	0.525	0.6

8. Results and discussion generally is redundant. This part need to be condensed. Some information can be incorporated in supplementary materials.

   ● Response:
   (Lines 460-563) Following the reviewer's suggestion, the manuscript has been revised overall and have we removed duplicate information as much as possible to condense 3. Results and discussion.

9. Page 10 line 237: "T-N was between 0.46 and" There should be a space between "0.46" and "and".

   ● Response:
   (Line 278) We added a space between "0.46" and "and".

10. Page 10 line 239: should there have a space before and after => ?

   ● Response:
   (Line 280) We added a space between before and after ≥.

11. Page 19 line 478: Please improve wording of the first sentence.

   ● Response:
   (Lines 523-525) We revised this as follows: "Figure 11 shows the poor watershed health of hydrology (Figure 11a), water quality (Figure 11b), and overlay results (Figure 11c) of a combination of both."

12. Conclusion did not interpolate researching findings well. The results showed the watershed health

declined and targeted the vulnerable areas, but what is boarder impacts of these results? How will it be beneficial for watershed management? It would be more meaningful if authors can incorporate this information.

● Response:

(Lines 601-606) We added new sentences about impacts of study results and beneficial effects for watershed management in Conclusion section as follows: “By listing all the information of the watershed health assessment, we can find vulnerable parts or healthy parts in the desired area and can provide basic data for action. The effectiveness of the watershed health that were evaluated in this study would be of reliable information because this approach entirely physically based. This approach can be utilized in a number of standard watersheds, local communities, and regions throughout the Han River basin and could be practically implemented in the watershed as a comprehensive watershed management plan by the government authorities or representative stakeholder.”

13. What is limitation of this study, such as water quantity, quality data, or model input limitations? How to improve it in the further study? What kind of take-home messages you would like to delivery to readers?

● Response:

(Lines 607-612) We added new sentences about limitation of water quantity, quality data, and model input in Conclusion section as follows: “Finally, the limitations of this study include the simulation of the water quantity and quality data for a possible long term changes in the watershed model. Although the prediction of long-term water quantity and quality data using the modeling is essential to assess water resource systems, the hydrologic and water quality conditions cannot be projected perfectly due to uncertainties in the models, climate data and other inputs required for the simulations. However, the results of this study are useful in terms of identifying potential watershed health issues regarding ongoing watershed change.”