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Modeling of Dissolved oxygen and Temperature of Periyar river, South India using QUAL2K

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ABSTRACT:

Numerous studies has been done on the water quality of river Periyar, South India. Most of the studies are done when a pollution event occurs. Such random analysis does not suffice the need for a management plan. Inorder to prepare a management plan, understanding past and present trend of the river is very much important. Moreover, prediction of future will give a clear pathway in preparing the framework for conservation of river. Here, in this article, variation of water temperature and dissolved oxygen through 28 year time period is evaluated using trend analysis. Then, surface water temperature and dissolved oxygen are modeled using QUAL 2K with 2007-2008 monthly data. WEAP water quality model was used for forecasting of QUAL 2k model. From the analysis, we could find that there is an annual increase in surface water temperature and decrease in dissolved oxygen per year. QUAL 2K model shows that the trend of surface water temperature and dissolved oxygen in the river is in agreement with the calibrated 2008 and 2013 data. From the WEAP analysis, we could observe that by 2030 surface water temperature of the river would be 29^{o}C and dissolved oxygen would be 3.7mg/l. Such studies will help in evaluating new management plans for the future health of the river.

Keywords: *Dissolved oxygen, Forecast, QUAL2K, Surface water temperature, Trend analysis, WEAP, Water quality modeling.*

I. INTRODUCTION

Research on regional and global climate changes and variabilities and their impacts on water resources have received considerable attention in recent years. Potential impacts of climate change and its effects have been much in discussion but relatively fewer studies are being done on changes in water quality. From a global perspective, climate change is usually perceived as an increase in average air temperature. So with increase in air temperature, surface water temperature increases (Hassan et al 1998; and Hammond & Pryce 2001). This affects the water quality of river. Most of the bacteriological activities and chemical activities of the river increase with increase in water temperature, which reduces the dissolved oxygen in the river.

The 2007 conference of the parties to the United Nations Framework Convention on Climate Change in Bali and the latest Intergovernmental Panel on Climate Change (IPCC) report (2007) confirmed the consensus among scientists and policy makers that human induced global climate change is now occurring. However, there is uncertainty in the magnitude of future temperature changes both at global and regional scale. So here, an attempt is made to model the dissolved oxygen and water temperature of river Periyar. Assessing the trend and modeling of dissolved oxygen and water temperature is essential to understand the water quality of Periyar river with increasing water temperature. Kerala is the land of rivers and backwaters that criss-cross the state physique like blood veins. They fertilize the land and turn the waste into the wealth of rich, black alluvial soil. The lowlands or coastal area, made up of river deltas, back waters and the Arabian coast, is eventually a land of coconuts and rice. Aggressive human intervention, especially indiscriminate sand mining in almost all of Kerala's major rivers including Periyar , Pampa, Manimala, Achankovil etc has driven almost all the tributaries, which once used to facilitate agriculture activities and water transport in the region, to the verge of death.Periyar river, the largest river in Kerala, originates in the Sivagiri hills along the border of Kerala-Tamil Nadu. It eventually, flows into the Vembanadu Lake and to the Arabian Sea. The famous Thattekadu wildlife and bird sanctuary is situated on the bank of Periyar river at the side of Mullaperiyar river dam. Unlike other rivers, Periyar flows through ecologically sensitive areas as well as through Kerala's highest industrial belt.

The stretch between Angamaly and Kochi is highly critical as it is an industrialized zone along the river basin. Eloor, an island of 11.21 sq km within this riverine system at this region itself accommodates more than 247 industries of which 106 produce chemicals , including Hindustan Insecticide Limited (HIL), Fertilizers and Chemicals Travancore Ltd (FACT), Indian Rare Earths Ltd, Travancore Cochin Chemicals, Cochin Minerals and Rutile Ltd (CMRL) etc. Hence the Eloor - Edayar region along the periyar river about 20 km from the point where the Periyar River meets the Lakshadweep Sea, presents a typical example of industrial pollution. According to the report of Green peace 2003 year, the industries take considerable amount of fresh water from Periyar River and discharge treated or partially treated effluents that amount to more than 170 million litres per day. Analysis of the past trend and present status of the river is imperative for establishing strategies for future health and management of the rivers.

Mathematical modeling is a useful tool to validate the estimations of pollutant loads into an aquatic environment, to establish cause–effect relations between pollution sources and water quality and also to assess the response of the aquatic environment to different scenarios. The simulations results are a useful management tool that can assist policy makers in determining realistic strategies that take into account the basin specific conditions and also in predicting the effect of accidental discharges or additional pollutant loads.
QUAL2K is a one dimensional, steady-state model of water quality and in-stream flow. It is neither stochastic nor dynamic simulation model. The QUAL2K model can simulate up to 16 water quality determinants along a river and its tributaries (Brown and Barnwell 1987). The river reach is divided into a number of subreaches of equal length. The model uses the following assumptions: (a) the advective transport is based on the mean flow, (b) the water quality indicators completely are completely mixed over the cross-section and (c) the dispersive transport is correlated with the concentration gradient. The model allows the user to simulate any combination of the following determinants: (a) Dissolved Oxygen, (b) Temperature, (c) Phosphorous, (d) Nitrate, Nitrite,Ammonium and Organic Nitrogen, (e) Chlorophyll-a, (f) up to three conservative solutes, (g) one non-conservative constituent solute, and (h) coliform bacteria.

II. METHODOLOGY

Secondary data of variables from the Periyar River during 1980-2008 was obtained from the Kerala State Pollution Control Board, Indian Meteorological Department, Neeleswaram station of Central Water Commission, Kochi for surface water temperature & dissolved oxygen, air temperature respectively. In order to understand the relation between dissolved oxygen and hydro climatic variables in the river especially surface water temperature, primarily a trend analysis was performed for all the variables. Thirty years annual average data of surface water temperature, air temperature and dissolved oxygen are used for analyzing the trend. 30years is taken as the time period and average annual data as the time unit. Difference of data between the first year and second year are recorded. Continuing in this manner, the recording for the difference in data between each time unit is carried out until the 30 year time period is over. Add all the data to get total for all the time units. Divide the sum total by the number of time units over the time period. This data is then subjected to correlation and simple linear regression statistical analysis using SPSS 6.1 software. The equations obtained from the linear regression analysis are used to predict values of surface water temperature and dissolved oxygen of the river from the air temperature

QUAL2Kw is one-dimensional, steady state stream water quality model and is implemented in the Microsoft Windows environment. It is well documented and is freely available (http://www.epa.gov/). The model can simulate a number of constituents including temperature, pH, carbonaceous biochemical demand, sediment oxygen demand, dissolved oxygen, organic nitrogen, ammonia nitrogen, nitrite and nitrate nitrogen, organic phosphorus, inorganic phosphorus, total nitrogen, total phosphorus, phytoplankton and bottom algae.
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QUAL2K is a river and stream water quality model (Brown and Barnwell 1987) and is similar to the older version in the following respects:

- One dimensional. The channel is well-mixed vertically and laterally.
- Branching. The system can consist of a main stem river with branched tributaries.
- Steady state hydraulics. Non-uniform, steady flow is simulated.
- Diel heat budget. The heat budget and temperature are simulated as a function of meteorology on a diel time scale.
- Diel water-quality kinetics. All water quality variables are simulated on a diel time scale.
- Heat and mass inputs. Point and non-point loads and withdrawals are simulated.

For QUAL2K modeling, the river is divided into 7 reaches. Reach of the river is decided based on the effluent discharge point to the river. First reach of the river is the upstream of the river with no industries along the river. Second reach starts with the beginning of industries along the river to the Pathalam earthen bund. The third reach begins from the Pathalam bund to the discharge point of Sudchem. The Fourth reach starts from the discharge point of sudchem to Travancore Cochin Chemicals. The Fifth reach is from the Travancore Cochin Chemicals to the Pallikadavu discharge point, which is devoid of any industry. The sixth reach starts from Pallikadavu to Eloor ferry. The seventh reach of the river is from the discharge point of the Kuzhikandam canal to Eloor Ferry. Temperature and Dissolved Oxygen was modeled using QUAL 2K. Data collected from the sampling site and secondary data from the literature were used for modeling.

Figure 1: Showing of sample site.

Here, initial parameter set is selected from the analysis result of the sample collected, followed by revisions to improve agreement between model results and measured data. Final parameters are then chosen to optimize the agreement between the modeled results and the measured data. Ideally, the range of feasible values is determined by measured data. For some parameters, however no observations are available. Then, the feasible range is determined by parameter values employed in similar models or by the judgment of the modeler (Ceres and Cole, 1994).

Prediction of these parameters to the periyar river is done using WEAP water quality model. WEAP is a microcomputer tool for integrated water resources planning. Developed by the Stockholm Environmental Institute (SEI), the WEAP model provides a tightly integrated planning and water resources simulation environment that draws upon expertise in policy and decision making, water resources, and financial analysis (Sieber et al., 2005).

Here using WEAP, the water temperature and dissolved oxygen are predicted. Two steps are involved in the process. Current accounts year is chosen to serve as the base year of the model. Then, a reference scenario is established from the current accounts to simulate likely evolution of the system. The predicted data range from 2009-2030.

III. RESULT

River has its own behavioral trend across time. Analysing the trend helps in understanding the river. In order to plan the future course of action we need to analyze the past. Here, we have collected secondary data of surface water temperature, air temperature and dissolved oxygen of Periyar river and it is given in the table below.

Table1: showing 28 year data for Air temperature, Water temperature and Dissolved Oxygen

Year	Air Temperature	Water Temperature	Dissolved Oxygen
1980	**28.02**	**29.3**	**3.58**
1981	**27.81**	**31.1**	**7.05**
1982	**27.9**	**30.4**	**5.1**
1983	**27.91**	**29.6**	**6.67**
1984	**27.48**	**28.5**	**7.04**
1985	**27.67**	**30.3**	**6.63**

1986	**26.46**	**31.4**	**7.0**
1987	**28.41**	**28.8**	**6.66**
1988	**27.97**	**29.0**	**6.65**
1989	**27.54**	**28.3**	**6.5**
1990	**27.66**	**28.8**	**7.11**
1991	**27.86**	**28.6**	**6.55**
1992	**27.43**	**27.4**	**6.59**
1993	**27.53**	**27.4**	**6.84**
1994	**27.54**	**27.4**	**7.0**
1995	**27.61**	**26.5**	**7.17**
1996	**27.72**	**28.2**	**7.26**
1997	**28.02**	**28.7**	**6.8**
1998	**28.13**	**28.8**	**6.7**
1999	**27.42**	**24.9**	**6.84**
2000	**27.44**	**26.1**	**6.84**
2001	**27.49**	**26.5**	**6.62**
2002	**27.73**	**27.8**	**5.08**
2003	**27.91**	**28.3**	**5.41**
2004	**27.604**	**28.08**	**5.98**
2005	**28.69**	**27.9**	**5.7**
2006	**27.65**	**28.0**	**6.19**
2007	**27.7**	**27.75**	**5.54**
2008	**27.68**	**28.83**	**5.14**

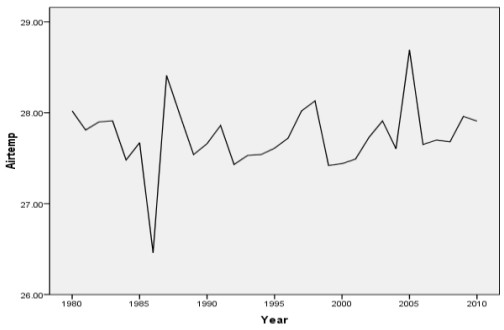

Figure 2: Variation of Air Temperature 2008

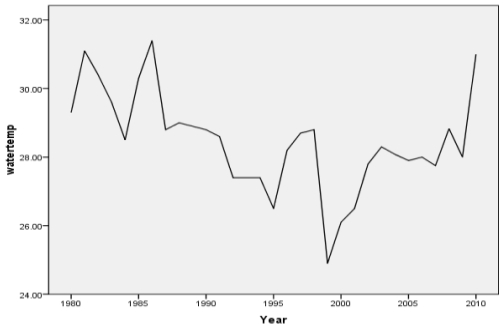

Figure 3: Variation of Water Temperature from 1980-1980-2008

From the graph, we could observe that air temperature displayed values within 27 ^{o}C and 29 ^{o}C with one exception during 1986, where the temperature went below 27 ^{o}C. The historical data analysis shows that air temperature and water temperature increases through the years till 1999 after which temperature dips down and then increases after 2000. Dissolved oxygen graph indicates a zig- zag variation but the overall trend of dissolved oxygen in the river is decreasing.

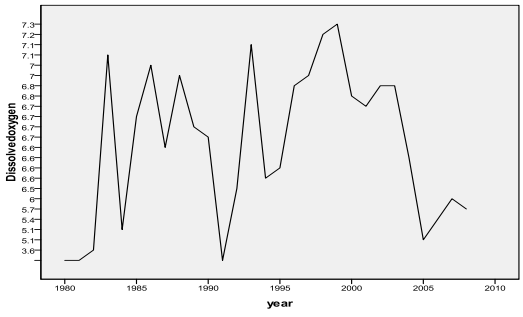

Figure 4: variation of dissolved oxygen from 1980-2008

Table 2: Result of Trend analysis variable

S.No	Variable	Trend
1	Water temperature	+0.012°C/yr
2	Air temperature	+0.018°C/yr
3	Dissolved Oxygen	-0.065mgO2/l/yr

Relationship between hydro climatic variables air temperature, water temperature and dissolved oxygen are studied using correlation coefficient (SPSS 16.1). Correlation analysis of air temperature and water temperature shows positive correlation that is increase in one variable invariably, increases the other variable. Whereas correlation analysis between dissolved oxygen and water temperature shows negative correlation that is, increase in water temperature decreases dissolved oxygen in the river. Furthermore, to establish the relation between variables, simple linear regression analysis was performed between air temperature and water temperature, dissolved oxygen and water temperature and equations are derived. The regression equations are as follows;

Water Temperature = 22.858 + 0.202 x Air temperature ----I

Dissolved oxygen= 9.197 – 0.103 x Water temperature-------II

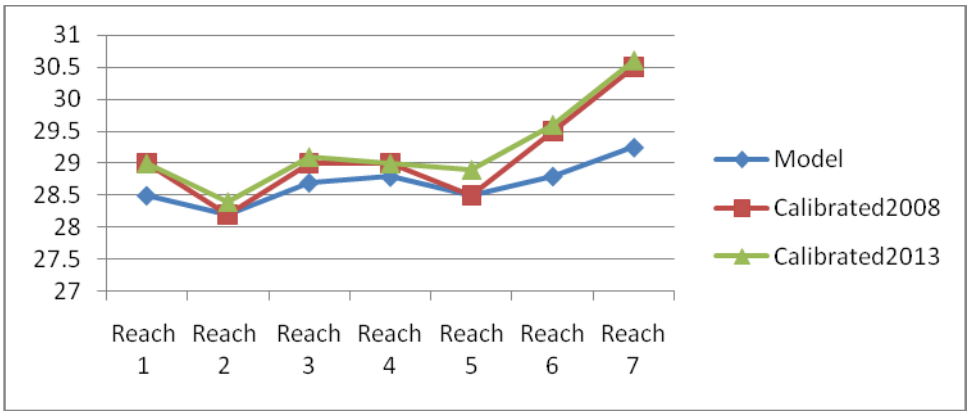

Fig 5: Graph of Temperature Modeling

Table 3: Temperature Model Data

	Model	Calibrated2008	Calibrated2013
Reach 1	28.5	29	29
Reach 2	28.2	28.2	28.4
Reach 3	28.7	29	29.1
Reach 4	28.79	29	29
Reach 5	28.5	28.5	28.9
Reach 6	28.8	29.5	29.6
Reach 7	29.25	30.5	30.6

From the graph we could observe that the calibration using the April – may 2008 (average) data is in sync with the model data except for the last two reaches of the river. Using Qual 2k we could develop a good temperature model. Graph of temperature model with April 2007 – March 2008 as model data and April – May 2008 & 2013 average as calibrated (observed) data. In this temperature model also we could find that the observed temperatures of the last two reaches are not in corroboration with the model. Observed temperature values of the last two reaches are slightly above the model in which temperature of the last reach is above the maximum temperature data. Graph controlling the model, calibration data of 2008 and 2013 shows that calibrated data of all reaches are in agreement with the model data. Temperature model is found to slightly decrease towards the lower reaches 5, 6 & 7. Temperature is found to decrease slightly towards the reach 5 and then increase towards reach 6 and 7.Calibration model and the calibration values are very low in the reach 1 and are found to increase for reach 2 and 3. Model is found to be steady towards reaches 3 and 4, then the graph lowers slightly towards reach 5 and then the graph increases steadily. Calibration data of 2008 and 2013 shows similar trend with the model.

3.1 Dissolved Oxygen Model of the River Periyar

Model was prepared with monthly dissolved oxygen data of river Periyar from April 2007 – May 2008 the data was calibrated with dissolved oxygen April – May 2008 & 2013.

Table 4: showing Dissolved oxygen model data

Model data	Calibration data 2008	Calibration data 2013
6.9	6.08	5.9
6.5	5.3	5.5
6.62	6.68	5.6
6.4	5.67	5.1
6.7	6.4	6.0
3.78	5.47	4.0
3.27	2.33	2.0

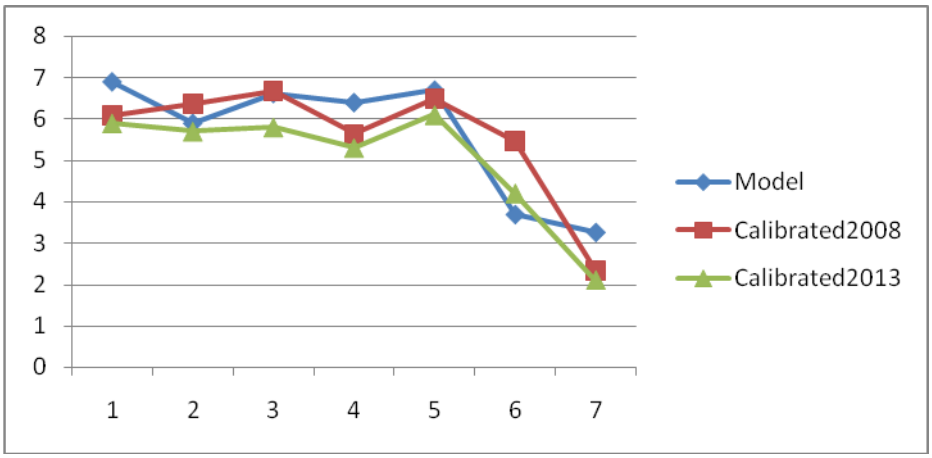

Fig 6: Graph of Dissolved Oxygen modeling

From the graph it is clear that the model developed shows that it is very much in agreement with the calibrated DO value of 2008 and 2013 (April – May average) values vary from the calibrated /observed values of the model for the model reaches 1, 6,& 7. Forecasting of temperature data is done using WEAP (Water Evaluation and assessment program).

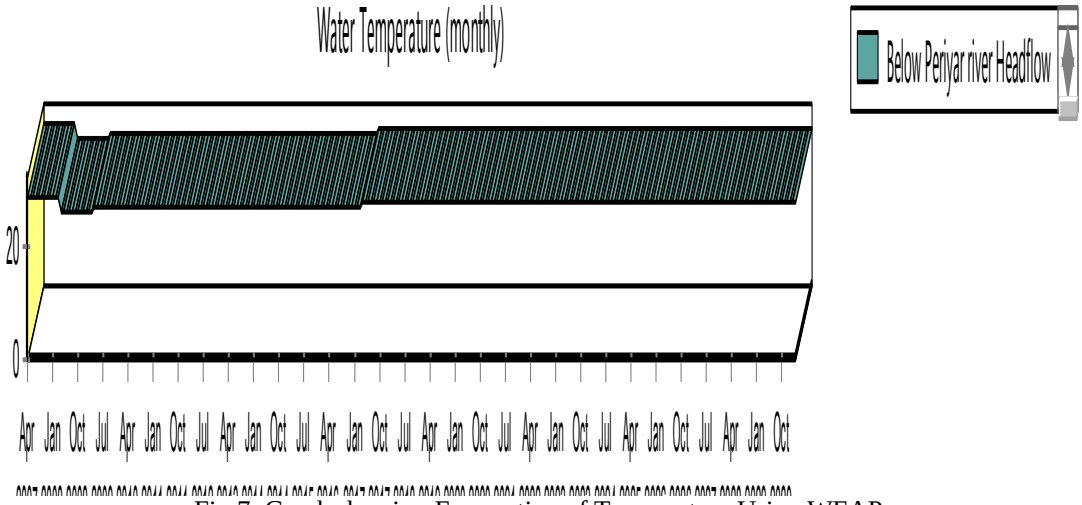

Fig 7: Graph showing Forecasting of Temperature Using WEAP.

From the graph we could observe that the surface water temperature will be 29^{o}C by 2030. Forecasting of dissolved oxygen is done to the 1980-2007 data through time series forecasting of water quality model, water Evaluation and Assessment Program (WEAP)

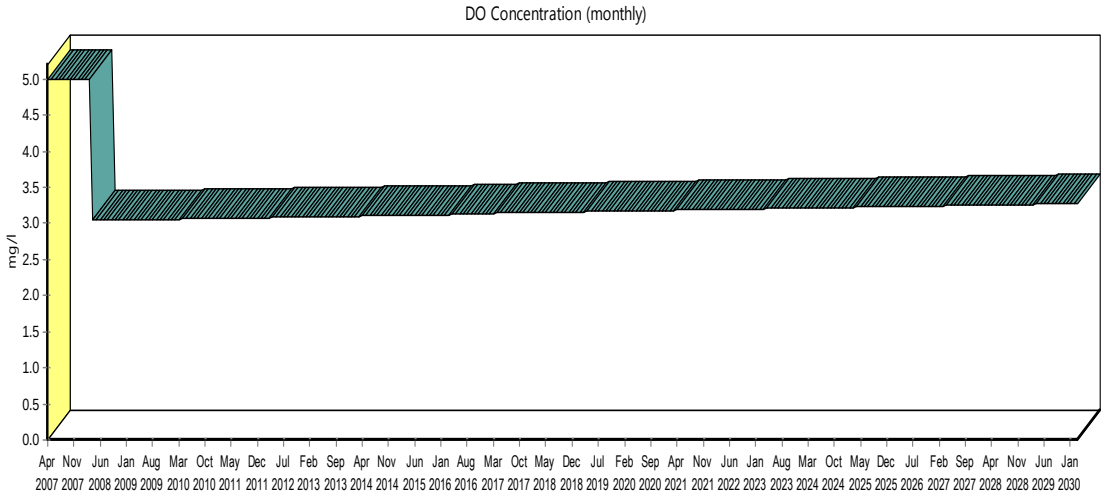

Fig 8: Graph Showing Forecasting of Dissolved Oxygen using WEAP

From the graph we could observe that by 2030 dissolved oxygen of the river would be 3.7 mg oxygen /l.

IV. DISCUSSION

Trend analysis of 30 year surface water temperature shows an increase of +0.012^{o}C /yr and dissolved oxygen of -0.065mg oxygen/yr. So, with increase in surface water temperature, the dissolved oxygen in the river is decreasing. Temperature model of the river with qual2k indicates that the calibrated values (2008 and 2013) are slightly higher from the model data, but the trend along each reach is similar for both model and calibrated data. For dissolved oxygen model, the calibrated values (2008 and 2013) are slightly lower than the model data, but the trend is similar to the model along each reach throughout the river. Forecasting using WEAP water quality model clearly indicates that the average surface water temperature will be 29^{o}C whereas dissolved oxygen will be 3.7mg oxygen /l by 2030.

Currently the river receives 25314m^{3}/day of effluent discharge. As water temperature increases, the rate of chemicals discharged to the river increase its reactions, which in turn affects the biological activity, further lowering the dissolved oxygen in the river. Inter governmental Panel on Climate Change projects that an increase in average temperature of several degrees as a result of climate change will lead to an increase in average global precipitation over the course of the 21st century. With increase in runoff and precipitation water will carry higher levels of nutrients, pollutants and pathogens, which will reduce the water quality. Moreover, increase in water temperature can lead to a bloom in microbial populations which affects the health of the river.

With increase in water temperature, self –purifying capacity of the river decreases further reducing the dissolved oxygen. With surface water temperature at 29^{o}C , dissolved oxygen at 3.7mg/l and with effluent discharge to the river continuing at the present scenario, by 2030 the Periyar river will be in grave condition. Immediate plans and management action needs to be done in regeneration and sustenance of dissolved oxygen in Periyar river.

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