Water balance analysis and hydraulic structure design to prevent peatland fires

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Abstract. Land fires have become a new phenomenon in Indonesia that has occurred continuously every year and on a large scale since 2010. Land fires mostly occur on peatlands during the dry season and the focus of this research is to find the solution for fire problem in peatlands. In this case, a hydrological approach is carried out to explain the causes of the fires that occur, and a solution is also made using this scientific approach. Many peatland fires occurred when the groundwater level on the peat reaches 0.4 m below the surface of the land. Then a water balance analysis was carried out to calculate the potential for water in peatlands and also the water needed for evapotranspiration and other needs. After obtaining the amount of water demand, a long storage design with a volume of 1,097,344 m³ was planned which was divided into six reservoirs. Long storage was designed with a transverse length of 35 m in the canals and with runners that have a height of 4 m from the riverbed. With storage in long storage, it was hoped that the existing water can be used in an effort to rewet peatlands and prevent potential fires.

1. Introduction
Peat is an organic material that occurs naturally from waste decomposed plants are imperfect and accumulate in swamps [2]. Peat ecosystem is an arrangement of Peat elements is a whole that affects each other in form balance, stability, and productivity. Based on the influence of its flow, peat is divided into two, namely topogen and ombrogen peat. Topogeneous peat is peat with soil influenced by tidal flow from the sea, whereas peat is ombrogen is peat that is not affected by tidal flows. Peat ombrogens are usually located upstream or higher than topogen.

When a fire occurs, three main factors are causing it: materials fuel, oxygen, and sources of ignition. This concept of three factors causing fire is called also the Fire Triangle.

These three factors are related to one another when a fire occurs. Oxygen is an element that is burned together with the fuel material (fuel). In this peat fire, what becomes fuel is the trees and branches plants, and the peat itself. While heat (heat) is generated by source of fire at the location of the fire. There are two types of fire sources, namely: natural and human. Natural factors can be like lightning and volcanic lava while factors humans, namely from burning done intentionally or not deliberate.

Peatland fires in Central Kalimantan have occurred very frequently. These fires do not occur at just one point, but there are thousands of hotspots which burns land in Central Kalimantan, especially peatlands.
Based on the previous research, it is concluded that the fires occurred in Central Kalimantan on concession and settlement land 88% does not spread to other areas [1]. In Pulang Pisau district itself has had peatland fires in all sub-PHU. In 2015 alone, there were around 14,000 hotspots in Central Kalimantan with 9 thousand hotspots occurred on peatlands.

The following shows the distribution of hotspots in the peatlands of sub-Peat Hydrological Unit 4 districts Pulang Pisau based on PRIMS data (Information Agency for Ecosystem Restoration Peat):

Water is one of the factors that influence how easy or not land is peat burns. This is evidenced by some research that has been done shows that there is a relationship between the number of hotspots and the ground water level at peatlands, namely the lower ground water level (GWL) indicates that the increasing number of hotspots/fires that occurred [10].

The groundwater level in peatlands is influenced by the rainfall that occurs in that area. Research shows that when the rainy season occurs then The GWL will increase while in the dry season the GWL will slowly decrease. And on when August the rainfall returned to the big, but the GWL only increased in 11 months October. This shows the time lag that occurs in the increase in GWL in the land peat [11].

Peatland island with very easy soil conditions escape the water contained in it. While the composition of the soil peat itself is 95% water (in the case of peat in its state good). When canals are made on peatland, this results in more easily the water escapes to the channel. Thus, causing groundwater that is in peat decreases and on a large scale the water table decreases. This causes peat soil to become dry and
flammable. The restoration process on peatlands must be planned with a system integrated starting from the peatland itself, its hydrological system, ecology, and the economic impact on the communities living on these peatlands [12].

2. Research methods
This research began with data collection; rain data, climatological data, and data on peatland characteristics in the protected zone of Sub-KHG 4 District Pulang Pisau, Central Kalimantan. The first step was collecting rain data and climatological data so that the output was obtained in the form of reliable rain and its evapotranspiration value. Design rainfall and evapotranspiration were processed for a month. From the second total output was calculated its water balance by reducing the mainstay rain evapotranspiration. There are many methods for calculating value evapotranspiration, one of which is the Penman-Monteith method [16]. The minus value obtained from the water balance becomes the basis in determining water requirements. In this study, to meet the needs of water, a long storage pool was built.

The water control model with a new paradigm was a controlled drainage system. This model tries to keep the water depth in the channel at a certain height [4]. For peatlands, at least the water depth was at the channel should be maintained at a height of 40 cm. Long storage was planned based on previously obtained water needs and consider the topography of the area. Design Rainfall calculated based on the distribution or distribution of maximum daily rainfall during (minimum) 10 consecutive years [7]. This storage was designed as a canal blocking as a structure that holds the flow of water for long-purposed plan. The canal can accommodate water as needed.

3. Results and discussion
Water balance was obtained from reliable rain data that enters the ground later minus the amount of evaporation of inspiration. The water balance calculated here was potential water storage in peatlands. The assumption used here was rainwater, not all can be stored in peatlands so that some of it becomes a runoff. Water can be considered as storage was water that enters the peatland through infiltration. Besides, it was also influenced by the value of evapotranspiration that occurs at the surface.

From Figure 4, the water balance value had a value lowest in the period September. This shows that at that time the evapotranspiration that occurred did not come from rain which previously decreased, but from water in the peatland content. This was one of the causes of the oxidation of existing C emissions inside the peatland. And in the end, it will make things easier the occurrence of fires on peatlands.

Figure 5 is a picture of the inflow and outflow (outflow) on the planned long storage. Reservoir routing was carried out for analyzing flood flow in long storage for 10 hours. Inflow data retrieved of the flood values that had been calculated using the Nakayasu method in the sub-chapter previous. Then these values were used in the calculation to that generate an outflow value. From the picture above, the storage function of long storage which reduced the outflow to the channel.
Figure 4. Evaporation, rainfall, and water balance in Sub-PHU 4 Pulang Pisau, Central Kalimantan.

Figure 5. Inflow and outflow in canal blocking spillway.

In general, two lines described flow in a channel, namely flow in and outflow. These two schools had different forms because influenced by the function of the existing reservoir in the channel. The inflow started from the value 0 and then hits the peak at the 6th hour. After that, the value slowly descended until it was almost near zero. Likewise, with the outflow or an outflow whose value entered a peak at the 7.5th hour and then reduced slowly until it approaches zero. The inflow rate started from 0 m$^3$ sec$^{-1}$ in the first hour to the 3rd hour. Then the incoming water discharged at the 4th hour was 6,840 m$^3$ sec$^{-1}$. And the peak of the flow admission amounted to 95.5389 m$^3$ sec$^{-1}$, namely at the 6th hour. And then the value declined to near zero. When compared to the outflow graph (outflow) it can be said that
the trendline was slightly different, namely in the first hour up to the 4th outflow value 0 m$^3$ sec$^{-1}$. Then at the 5th hour had a value amounting to 5,709 m$^3$ sec$^{-1}$. The discharge continued to increase until the peak of the outflow was equal to 70,652 m$^3$ sec$^{-1}$. The peak discharge flow occurred at the 7.5th hour indicated the influence of the reservoir to slow down the course of the flow.

So that a spillway width of 15 m will create peak flow at this flood probe was 1.8 m high from the lighthouse spillway. Namely by seeing elevation at the peak of the outflow at the 6th hour with a height of 5.8 m.

Figure 6. Canal blocking plotting in Sub-PHU 4 Pulang Pisau.

With consideration in the form of the slope of the channel, the total long storage was planned 15 km long which was divided into six reservoirs. Every shelter had a volume of 182,890 m$^3$. To hold water in the reservoir, a screen was stretched on the channel. The type of canal blocking was one with overflow. To determine spillway dimension, flood discharge tracking or routing was used. Thus, the total volume of six reservoir was 1,097,344 m$^3$.

Based on the Regulation of the Director-General of Pollution and Environmental Damage Control Number: P.9/PPKL/PKG/PKL.0/7/2018, for canals that have a width of more than 20 m, a permanent type canal block made of concrete was used [8]. Therefore, the KSE-PB-P-1 type canal blocking was chosen, which was a large permanent canal block with a spillway.

Thus, the canal blocking design was made in the Sub-KHG 4 canals by changing some parts of the initial design in the Regulation of the Director-General of Pollution and Environmental Damage Control Number: P.9/PPKL/PKG/PKL.0/7/2018 [8]. The design change was due to adjusting the existing conditions in the Sub-KHG 4 channels.

After the construction of the canal blocking, it was necessary to carry out the operation and maintenance of the long storage construction to ensure that all components were running and functioning as planned. Long storage can function optimally after the water reservoir in the container was filled. Then the water can be used to re-wet the peatlands. In general, there were no special operations to perform the functions of this structure, but some maintenance was needed. Maintenance activities can be carried out by the group constructing the canal blocking or by residents who were close to the long storage construction.

Operational activities that can be carried out to prevent fires on peatlands were monitoring regularly (daily/weekly) the water level in wells around the land and recording them. The results of monitoring were then evaluated to measure the level of risk of forest fires in the dry season based on the decrease in groundwater levels that occur. If the groundwater level showed a high risk of disaster, a warning will
be issued to residents and fire mitigation efforts will be made, such as watering/wetting the land with artificial rain or by spraying well water or using water in long storage. Inspection and building inventory were also carried out periodically/annually to then evaluate the condition of the building.

**Figure 7.** Canal blocking design (top view)

Maintenance activities that have been constructed needed to be carried out regularly and periodically so that the canal blocking continues to function optimally and early action against damage to the insulation can be minimized. Changes in weather and the increasing age of construction caused damage to the canal blocking. Routine canal blocking maintenance was to remove plants whose position can disturb the canal blocking structure, clean moss on the structure, and clean up trash in the canals and around the canal blocking. Evaluation of the state of canal blocking construction resulted from periodic inspection activities. Repair of concrete canal blockings can be done by replacing or repairing the concrete partition. Rehabilitation activities needed to be carried out if the construction performance was below 50% and special maintenance activities if it was between 50-70%. The maintenance planning process, group formation, and reporting and complaint mechanisms can be facilitated in a joint evaluation forum. This forum can consist of village government, canal blocking development groups, and related parties.

The use of water in long storage reservoirs can be used when wetting peatlands were needed by direct watering. As has been done by the BRG team and the community in West Kalimantan who collaborated to water the land.

Watering peatlands is carried out when:
1. There was no rain for seven consecutive days.
2. There is an indication of fire from the observer.
3. The groundwater level in peatlands drops to more than 40 cm.

4. Conclusions
After all analyses, it was concluded that a long storage was needed to accommodate the water needs with a volume of 1,097,344 m$^3$. And by considering the canal channel as a storage for long storage, then six long storage was needed, each with a volume of 182,890.6 m$^3$. The canal divider was 35 m long and 5 m wide on its body. The runoff in this canal block had a height of 4 m from the bottom of the channel.

5. References
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