CONCLUSION AND RECOMMENDATIONS

1. Conclusion

This study on the impacts of land use evolution on water and sediment yield of Pasak Basin was conducted using land use types interpreted from satellite imagery with GIS, the Royal Irrigation Department's streamflow, sediment and rainfall records during 1980 – 2004. Markov chain model was employed to simulate the land use evolution between this period in terms of forest, agricultural, water, urban and miscellaneous areas. Stepwise multiple regression analysis was used to detect their impact and to obtain representative prediction models for this watershed. Flow timing pattern was also investigated in terms of flow interval parameter including quarter flow, half flow, 5% and 1% flow interval and flow date parameter including quartile flow, half flow and 3rd quartile flow date using time series analysis based on daily discharge data obtained from three stations of Royal Irrigation Department for the best available period. The results as discussed before could be concluded as follows:

1.1 Land use evolution

Forest area was found to be decreased from 30.89% of basin area in 1980 to 23.27 % in 2004 for the whole Pasak and 45% to 35% for the upper part of Pasak basin. A major amount (38%) of forest area was found converted to agriculture from 1980 to 2000 and 14% from 2000 to 2004. About 59 % of forest area was found to remain unchanged during the period 1980 – 2000 and 84% remain unchanged during 2000-2004.

During the period 1980 – 2000 about 3% of urban area and 2% of agricultural area were found converted to water bodies. It was due to construction of Pasak Jolasid Dam for which agricultural area were converted and lowland villages were moved. Overall the trend was found decreasing for forest area and increasing for agricultural area.

1.2 Streamflow characteristics in concurrence of land use changes

For lower Pasak, the basin average annual rainfall during the studied period was 1222.51 mm of which about 239 mm or 9% was found transformed into runoff on annual average. About 90% of annual flow was occurred during wet period while only 10% flowed in dry season. Before dam construction, the highest streamflow was found to be occurred in the month of October that was about 810.38 MCM or 56.92 mm in height while after dam construction peak was found occurred in September that was regulated. Overall the trend for runoff during wet period was found increasing while during dry season it was found decreasing though the difference was smaller indicating the effect of deforestation.

For upper Pasak, the mean annual rainfall was found 1052.78 mm of which about 186.28 mm or 17.62% was found transformed into runoff each year. About 88.52% of annual flow was occurred during wet period while 11.48% flowed in dry season. The highest streamflow was found to be occurred in the month of September that was about 205.02 MCM or 58.91 mm in height. The trend for runoff during wet period was found increasing while during dry season it was found decreasing but at the more distinct rate than lower part of Pasak Basin indicating the effect of deforestation and topography also.

For middle part of Pasak, annual rainfall and runoff showed high variation that might be due to rainfall stations encountered in calculating sub-basin average rainfall were not representative to the basin. The mean annual water yield was found about 82.98 MCM or about 234.63 mm in height of which 87.77% flowed in wet season and 12.24% flowed in dry season. The trend of runoff during wet season was found decreasing and during dry season increasing unlikely than other two parts. The reason might be due to the extreme use of water for other purposes, small size of the watershed and rainfall amount in dry and wet season.

1.3 Flow timing

The flow timing were investigated for three parts of Pasak watershed – Upper for the period 1969 - 2001, middle for the period 1979 - 2002 and lower for the period 1974 - 2002. The parameters that were analyzed under this investigation are flow interval in terms of quarter flow, half flow, 5% flow and 1% flow; and flow date in terms of 1st quartile, half flow and 3rd quartile flow.

The mean annual quarter flow intervals were found 28, 17 and 17 days and half flow intervals were found 72, 54 and 47 days for upper part (S4B), middle part (S13) and lower part (S9) respectively. On average, quarter flow intervals were found 11 days longer in case of upper part than middle and lower part and half flow intervals were found 18 days longer than middle and 25 days longer than lower part of Pasak Basin.

The mean annual 5% flow intervals were found 95, 108 and 127 days; and 1% flow intervals were found 53, 55 and 54 days for upper, middle and lower part pf Pasak respectively. On average 5% flow intervals were 13 days shorter than middle and 32 days shorter than lower Pasak whereas 1% flow intervals were 2 days and 1 days less longer than middle and lower Pasak. Thus the upper part of Pasak has the shortest flow variability than other two parts indicating somewhat better condition of forest resources in this part.

The trend of flow timing as analyzed for upper Pasak over the period of 1969 – 2001 indicated that shortest high flow interval i.e. quarter flow and half flow interval showed decreasing tendency in the past and would become more shorter in the near future i.e. large quantity of runoff will be increasingly occurred in a shorter period of time. On the other hand longest low flow interval i.e. 5% and 1% flow interval showed increasing tendency indicating that longest flow interval will become more longer in the near future i. e. small quantity of runoff will be increasingly occurred in a longer period of time.

On the other hand, for middle part of Pasak analyzed over the period of 1976 – 2002 and for lower Pasak over the period of 1974 – 1998 (before dam construction) shortest flow interval showed increasing trend and the longest flow interval showed decreasing trend.

Flow timing pattern in terms of flow date indicated that in case of upper Pasak 1^{st} quartile flow date was increasingly moving backward of the water year and half flow date and 3^{rd} quartile flow date were moving forward of the water year implying that 25% flow occurred in a longer time due to more evaporation and less antecedent moisture in the soil requiring longer period to saturate soil, whereas 50% and 75% flow occurring in a shorter time indicating more runoff in a short time resulting from less forest cover in the upstream area. While in case of middle and lower Pasak flow dates were moving forward of the water year implying more runoff occurred in a shorter period.

1.4 Relationship between land use change, discharge and Sedimentation

In case of upper part of Pasak watershed, stepwise regression analysis indicated that runoff discharge during wet period have high correlation to annual rainfall (with r value 0.82). High positive correlation (r= 0.84) was found between forest and flow during dry period. Accordingly, forest showed high negative correlation and agriculture showed positive correlation with suspended sediment though it was based on three years data only. In case of middle part of Pasak, land use change have very low correlation with runoff discharge and suspended sediment. But wetflow have good correlation (r= 0.89) with sedimentation**.** In case of lower part of Pasak as considered only before the construction of Pasak Cholasid Dam in 1998 runoff discharge during wet period have high correlation with rainfall during wet period (R^2 = 0.84). Land use changes have shown very low correlation with discharge and sedimentation but total runoff have correlation with sedimentation (r= 0.64).

The analysis on the relation of runoff and sedimentation to rainfall and area of each land use types in the Pasak Basin in both linear and non-linear model of the stepwise regression produced best fitted equations for estimating total runoff, wetflow , dryflow and sediments as presented in Table 38. For upper Pasak no equation was suggested for predicting sedimentation due to three years sediment records. For middle part streamflow have insignificant relationship with land use factors and also with rainfall due to high variation of basin and individual average rainfall. For lower part, Qtotal was not selected in best fitted equations due to lower value of R2 and F ratio than Qwet.

Table 38 Suggested models for predicting streamflow and sedimentations in Pasak Basin

Upper Pasak	$Qtotal = -0.9625*Rannual^{1.46352} *For^{1.3688}$
	$Qwet = -66.6419 + 0.219323*Rannual$
	$Qdry = -86.831 + 0.001*For$
Middle part of Pasak	$SS = -17247.4 + 240.985*Qwet$
Lower part of Pasak	$Qwet = 5.79\text{-}009*Rwet^{3.517}$
	$SS = 369.97*Qtotal$

2. Recommendations

The study provided the useful recommendations for both improving the Pasak watershed management planning and for further studies as follows:

2.1 Resource management

1) The model derived from the relations of runoff and sedimentation to rainfall and area of land use types in Pasak Basin suggests that streamflow, specifically the dryflow, could be increased by increasing forest area in the upper part of Pasak Basin.

2) Streamflow timing investigation indicated that there would be a more water shortage in the upper part of Pasak Basin in the near future during dry season and excess water in the wet season. So there is an urgent need to undertake reforestation program and adequate soil conservation measures in order to hold more water in the soil. .

4) As it was observed that forest area changed to other land uses particularly agriculture required more water supplies for the paddy fields resulting to less water yield at the outlet especially during the dry period. So, in order to reduce excessive water withdrawal for agricultural purposes in the upstream areas during dry period, less water consumptive crops instead of crops that require more should be encouraged by the respective department. Moreover, modern technology regarding increasing agricultural productivity should also be extended in order to prevent forest conversion for agricultural purposes.

2.2 Technical problem and further study

1) This case study has been based on land use data obtained from various sources with different scale and in the different year of taking. Some of them have not been rectified which give incorrect information on land use. So to obtain correct output on land use change, appropriate land use change analysis with circumspection of digitization is needed.

2) Rainfall station should be installed in the middle part of Pasak basin to represent the flow and rainfall representative to this part in order to obtain better relationship between rainfall and streamflow

3) Historical data for streamflow and suspended sediment employed in this study especially for the upper Pasak were not continuous that affect the analysis of land use change impact upon them. So long term continuous historical hydrological records should be taken into consideration for making better prediction of them.

4) Water shortage problem in the upper part of Pasak basin during dry season and flood problem in the wet season could be tackled if forests conversion to other land uses would be stopped and thereby allowing more water to be absorbed by the soil.