SOME REMARKS ON THE WATER BALANCE ASPECTS OF NORTH WEST SURINAME

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North west Suriname being the foremost agricultural area in rice production has stringent demands for water both in quantity and quality. In the dry season suitable irrigation water becomes scarce and suitable management is required to maximize the use of this scarce resource especially since rice acreage is continually expanding whilst water resources remain fixed. For proper management, it is essential to know the amount and quality of water available, the capability of the current distribution and drainage systems, and irrigation water needs at the various sites. None of the previous studies in this area have adequately dealt with these subjects and there is a pressing need for continuing field monitoring and measurements that will improve the current almost non-existing water management in NW Suriname.

Noord west Suriname is verreweg het belangrijkste landbouwgebied voor rijst productie die strenge eisen stelt aan de kwaliteit en kwantiteit van het water. In de droge tijd wordt het geschikte irrigatie water schaars en vereist een passend beheer om het gebruik van deze schaarse natuurlijke hulpbron te maximaliseren, in het bijzonder daar het rijst areaal continue wordt uitgebreid terwijl de water bronnen constant blijven. Voor een goed beheer is belangrijk de kwantiteit en de kwaliteit van het beschikbare water, het vermogen van de huidige distributie en drainage systemen, en irrigatie water behoefte van andere plaatsen te weten. Geen van de eerder gedane studies in dit gebied heeft uitvoerig over deze onderwerpen gehandeld. Er bestaat daarom een dringende noodzaak voor continuering van veld monitoring en metingen, die het bijna niet bestaande waterbeheer in NW Suriname zal moeten verbeteren.

INTRODUCTION

Rice cultivation in Suriname has a relatively long history, however, large-scale rice production started only in the 1930s. The production of rice was then based on small areas within a polder irrigated either by the abundant rainfall or from the closely lying swamps. Irrigation water was therefore sufficient for only one rice crop a year. The first waterboards were established in this period and had as main function to take care of the management and maintenance of the water ways, dams, sluices and other structures within that area (Suwrutton, 1984).

However, due to great fluctuations in rainfall and gradual expansion of rice fields, these water sources soon became insufficient. In this respect some precautions were taken in the past to ensure these areas of sufficient fresh water.

First, the Nanni Creek was dammed in the early 1940s in order to raise the water level in the swamp (Campfens, 1982). Rice cultivation became more reliable. Later, in order to protect the rice fields from flooding by raised level of swamp water, dams were built - first in the west direction – "westelijke lekbeteugeling" and thereafter in the east direction – "oostelijke lekbeteugelingsdam." Second, the developments of rice areas along the Nickerie River and the establishment of the Wageningen rice polder led to closing the Arawarra Creek by constructing a sluice in 1964 (W.L.A., 1980a). This creek joins the Wayambo River to connect the Nickerie River basin with that of the Coppename River.

Meanwhile, the need of irrigation water has been increasing basically because of expansion of the existing rice areas and through the development of new rice varieties. The latter made it possible to harvest paddy twice a year. Through these developments, water shortage became more acute which is a combination of the following factors:

- unplanned and uncontrolled development of rice fields,
- unplanned and uncontrolled use of the available irrigation water,
- low and negligible maintenance of the irrigation and drainage canals;
- uncontrolled pumping of water out of the irrigation canals by individuals for agricultural purposes,

- dependability of one water source – the Nanni Swamp, and
- insufficient legislation.

These factors resulted in water shortage in the east and the west polders of the Nickerie district, especially during the second crop. The rice fields situated along the lower Nickerie River suffer also from these factors. The salt wedge, which is an important indicator for fresh water subtraction, reaches on many occasions up to Wageningen and forms a direct threat for the entire area. For this water shortage problem, which is one of the bottle necks in the development of north west Suriname, two solutions were proposed:

- *the Multipurpose Corantijnkanaal Project (M.C.P.)(B.L.O., 1976).* This project includes the establishment of the Corantijn Canal, a 66 km long channel through the Nanni Swamp, starting from Wakay, 140 km upstream the mouth of the Corantijn River and ending at the Nanni inlet and the creation of 12.500 ha new rice areas. This channel should also provide irrigation water to the east and the west polders.
- *the Stondansie project (B.L.O., 1964).* This project includes construction of a dam in the Nickerie River, about 240 km upstream at Stondansie. The main goal is to maintain the salt limit in the Nickerie River at a location, whereby pumping from the river would bring no harm to the rice cultivation at Wageningen and at the lower Nickerie River, especially in the dry period of the year.

Of these two proposals only the first one has partly been realized, partly, because the main objective has still not been achieved. Water shortage is still critical.

RECENT STUDIES IN THE AREA

The Nanni Swamp is one of the main water resources of the north west region of the country. The first measurements concerning the water regime were published in 1948. A detailed study done by Sevenhuysen, was published in 1977. Main goal of this study was to set up a water balance of this swamp.

With the construction of the Corantijn Canal which started in 1976 and was finished in 1986 (Binda, 1995), in fact the largest freshwater source was established. This source is the third in this region. The other two are the Nanni Swamp and the Nickerie River. However, by establishing the Corantijn Canal not all problems are solved as has been stated in several documents (B.L.O., 1976, W.L.A., 1978, W.L.A., 1982). Many polders and farmers still struggle with insufficient irrigation water, including Wageningen and rice areas along the lower Nickerie River.

In this regard the Hydraulic Research Division of the Ministry of Public Works, initiated a study in 1978. The study, part of the Urgentie Project 24, was named "the combined use of the Corantijn Canal, the Nanni Swamp and the Nickerie River." Its main objective was to create a water model on the basis of hydrological and hydraulic studies, which would simulate the available water of these main sources in order to get the maximum benefit for the rice areas. The model, therefore, consists of various hydrological elements of different water sources. This study was unfortunately never completed.

In 1988, another project, related with the irrigation problems of the region known as "the feasibility study of the rehabilitation of the van Wouw Canal" was initiated (O.A.S., 1990). The main objective of this study was to determine the technical, financial, socio-economic and institutional feasibility of rehabilitating the canal network that could regulate the irrigation of the major rice-producing area of the country.

In November 1989, hydrological, water quality and environmental studies has been initiated by the MCP-Authority and Haskoning (Haskoning, 1993). In November 1993, a final draft was presented with the following results:

- completion of an environmental programme, apart from the pesticides programme;

- implementation of the water quality monitoring programme;
- a water management model and data base;
- partial collection of hydrological data.

MAIN WATER RESOURCES OF NORTH-WEST SURINAME

Corantijn Canal

The Corantijn Canal is located at 140 km upstream the mouth of Corantijn River because of the salt intrusion. By measurements it is determined that the salt limit of 300 mg per liter will be registered once in 5 year period at this location. The runoff characteristics of this location are determined by measuring the discharges at Mataway, 194 km upstream from Wakay. The maximum registered discharge of the Corantijn River at this station is 6000 m^3/s, lowest 30 m^3/s, and mean of the entire period is 1600 m^3/s. The pumping capacity at Wakay is 30 m^3/s and can be increased up to 50 m^3/s.

According to these data water may be extracted throughout the whole year from the river with exception of extreme dry years. These dry years could be eliminated, if the Kabalebo project would be realized. The Kabalebo project would then regulate the whole Corantijn River water downstream the Kabalebo River, which means that water levels and discharges would be artificially regulated.

The canal along its whole length of 66 km is enclosed on both sides by dams consisting mainly of clay material from the canal itself. The right bank of the canal is open at four locations and is thus connected with the Nanni Swamp. At some locations the dams are very low and water may easily spill out. Under these conditions, the water balance will be as follows:

$$Q_{in} + P - \Delta Q_{stor} - Q_{out} - Q_{spil} \pm Q_{can} - E - Q_{dir} = 0,$$

where,

Q_{in} = incoming discharge at the pumping station at Wakay. According to the design the incoming discharge is defined as 30 m^3/s;

P = precipitation. The mean annual precipitation of 10 consecutive years is equal to 1890 mm/year;

ΔQ_{stor} = storage in the canal. According to Heesbeen & Schaap (1990), the water level in the swamp can range between +2.50 m and +4.00 N.S.P.;

Q_{out} = discharge which reaches the Nanni inlet;

Q_{can} = discharge from or into the swamp through the canal inlets. In the dry season when the swamp water level is low, Q_{can} will become negative when it is being pumped at Wakay. During and at the end of the rainy seasons Q_{can} is likely to be positive. The water level would then be higher in the swamp in relation to that of the canal. It should be noted that the balance of inflow and outflow of these creeks will be negative, which means that higher losses will occur, especially in the dry season, when the evaporation in the swamp is at its highest.

Q_{spil} = Discharge which is spilled at high water levels. The condition of the dams is such that at high water levels the dam on the left side overflows due to the subsidence, which took place during the time, since the dam was built. According to Heesbeen and Schaap (1990) this value has been estimated to be 35 mm on a yearly basis. The percolation value into the deep layers can be neglected.

Q_{dir} = Discharge to new rice areas, which has been developed along the Corantijn Canal and extracting irrigation water directly from the canal. This parameter Q_{dir} is entirely new in the water balance equation of the Corantijn Canal and expresses the direct connection of rice fields on the main irrigation channel.

E = Evaporation which is composed of the open water evaporation (E_0) and evaporation through transpiration of plants (E_t).

$E_t = f * E_0$.

where,

E_t = is transpiration and f is factor depending on the vegetation. According to Sevenhuysen (1977) this factor is equal to 0.9 for grass swamp.

The irrigation capacity of the Corantijn Canal, given by Heesbeen and Schaap (1990), is mostly based on design values. Values as 30 m^3/s and 50 m^3/s for the Corantijn Canal at present are not achievable. Moreover, the expansion of new rice areas besides the 12500 ha projected MCP area, the nearly overgrown Corantijn Canal, spills and inlets from and / or to the swamp, are factors, which also need to be considered.

The requirement of water especially during the dry season is high and, therefore, the canal should be in best condition. In the rainy season when the water level in the Nanni Swamp is high, the pumping station at Wakay is closed. After this period, when the water level in the swamp lowers, the station resumes pumping in order to compensate for the water shortage. At the beginning of the pumping period, the vegetation covers are pushed away by the sudden, strong current and gather at certain locations, causing a bottle-neck in the canal. This problem can last for weeks. Water supply is then disrupted and the whole scheme is adversely affected. In these situations farmers take their own actions to ensure irrigation water for their crop. The cost of this disruption is rather high and this has still not been adequately studied. To prevent this from happening, it will be advisable to pump water through the canal from time to time during the wet season. This will keep the canal relatively clean and operational.

The area, which is now under irrigation by the Corantijn Canal, is not known, as is the amount of water derived from the different resources. In this respect, two simultaneous measurements should be taken in the Corantijn Canal – the first one 100 m down stream the pumping station, and the second 100 m before the end of the canal at the Nanni inlet. This approach is necessary in order to determine what percentage of the pumped water reaches the Nanni inlet.

Nanni Swamp

By measuring simultaneous discharges before and after the Nanni inlet, the contribution of the Nanni Swamp can be determined. The general formula is expressed as follows:

$$Q_{nan} = Q_{inl} - Q_{wak} \pm \Delta Q ,$$

where,

Q_{nan} = Discharge from the Nanni Swamp,

Q_{wak} = Discharge at Wakay, which is equal to the pumping capacity

ΔQ = The difference between discharge at Wakay and discharge reaches the Nanni inlet.

Q_{inl} = Discharge at the Nanni inlet. This is the amount of water, which passes through the sluice into the van Wouw Canal. In the van Wouw Canal various discharge measurements have been taken before the establishment of the Corantijn Canal. However, an obvious relationship between the discharge parameters was not found (Kselik, 1983).

Other locations of water subtractions from the Nanni Swamp are the intake points "HA" and "IKUGH", which supply irrigation water for the eastern polders. Discharge measurements have only been done at intake HA, in order to find a relationship between the discharge and the water level, as was done at the Nanni inlet.

Taking the above mentioned into consideration, the water balance of the swamp can be written as follows:

$$P + Q_{uper} - Q_{inl} - Q_{ha} - Q_{ikugh} - Q_{per} - Q_{lek} - E = 0,$$

where,

P = Precipitation,

Q_{uper}= Discharge from the upper stream of the Nanni Swamp,

Q_{inl} = Discharge at the Nanni inlet,

Q_{ha} = Discharge at the sluice HA,

Q_{ikugh} = Discharge at sluice IKUGH,

Q_{per} = Losses through deep percolation,
Q_{lek} = Losses through seepage, and
E = Evaporation.

Sevenhuysen (1977) studied the various elements of this equation. However, some elements of this balance require further study. These are:

- Q_{lek} - Losses of water during the wet seasons, especially in the south west and south east direction of the swamp. In the southwest direction water could flow through the Kapuori creek into the Corantijn River, in the south east through the Maratakka Canal and from the Maratakka Swamp into the Maratakka River.
- E - Evaporation from the swamp. The swamp evaporation is determined by formulae using meteorological data. This gives an indication of the evaporation in that area. For a more precise determination of the evapotranspiration (empirical) field studies should be undertaken.
- Q_{inl} - Discharge at the Nanni inlet. The contribution of the Nanni Swamp to the total available irrigation water is still unknown.
- Q_{ikugh} - Discharge at the sluice of IKUGH. Up to now there are no indications of the rate of the discharges at this location. No measurement has been done, while this sluice irrigates about 6000 ha.
- Q_{ha} - Discharge at intake HA. This sluice irrigates about 1800 ha. At this location only some measurements have been executed, which are not enough for reliable conclusions.
- Q_{uper} - Discharge from the upper stream of the Nanni Swamp which can only be estimated.
- Q_{per} - Losses through deep percolation which can be neglected.
- P- Precipitation. A network of meteorological and hydrological stations should again be placed in the swamp area. These stations should be revived in order to obtain the necessary data.

Above description clearly indicates that for the water balance of the Nanni Swamp there is no sufficient data. Indeed, in order to get the maximum benefit from the swamp, c.q. a higher irrigation capacity, a detailed study has to be done.

Nickerie River

The importance of a water balance for the Nickerie River, especially for the catchment area above Wageningen polder, lies in determining the amount of water, which can be extracted from the river for irrigation purposes. The irrigation station is Wageningen itself, located about 40 km up stream. At this point a power full pump has been installed which extracts water from the river and this has a negative impact on the river water regime, especially in the dry periods. The saltwater wedge then may be found up to the station and pumping of water must then be stopped which results in a water shortage at Wageningen. To obtain better understanding of the salt-water intrusion and derive more benefit from the river regime, some studies have been initiated (B.L.O., 1964, W.L.A., 1978, W.L.A., 1980a).

The data collected at station Stondansie, 240 km upstream the Nickerie River, were hydrological (mainly water level, discharge measurement) and meteorological (mainly rainfall). The discharge characteristics of this station can be found in several W.L.A. publications.

Other data, concerning discharge measurements, are tidal measurements taken at:

- Nickerie River mouth in 1962 (Surinam Transportation Study, 18-09-62);
- Koffimakkakreek in 1964 (W.L.A., 1965, – Stondansie Project nota nr. 2 deel 1 en deel 4.);
- Post Utrecht and in the Maratakka River in 1978 (W.L.A., 1978). These measurements had two goals:
  a) to get a better view of the salt intrusion process, and
  b) to elaborate the calculation method for

determining the available irrigation water.

- Upstream of the intake of the Wageningen pumping station and in the Maratakka River in 1980 (Kselik & Waterberg, 1984). These measurements are a continuation of those taken in 1978.
- Measurements in 1981 and 1982. These measurements were taken in connection with the "Urgentie Project 24". The first phase of the project included measurements of hydrological and meteorological factors in the catchment areas of Maratakka and Nickerie rivers, such as:
  a) observation of water levels in the mentioned river basins,
  b) measurements of river stream velocities,
  c) water sampling for determination of chlorinate and the salt wedge,
  d) measurements of cross and longitudinal profiles, and
  e) observation and registration of rainfall.

  The second phase dealt with the Nanni Swamp study (water levels, water samples, and discharge coefficient of the swamp, pegasus study, etc.) :
  a) water use in the rice areas of Nickerie polders (water inlet and outlet, calibration of sluices, compilation of the RICIR computer program).
  b) continuation of the above mentioned observations, measurements and calibration of the model after the completion of the Corantijn Canal.
  c) observation and registration of rainfall in the basin of the polders and the swamp.
- Daily water sampling at Wageningen has been going on since 1965.
- Soundings of the Nickerie River and the Maratakka River.

These measurements were taken in connection with the salt intrusion and computation of the irrigation capacity of the Nickerie River. A computer model for the computation of tides and salinity in estuaries was used to predict the unsteady salinity intrusion. It appeared that the discharges from the several drainage sluices along the lower Nickerie River and discharges from the swamp and from the Maratakka River determine the hydrological regime of the Nickerie River during the dry seasons, rather than the discharges at Stondansie. In the light of these, the water balance of the Nickerie River can be described as:

$$P - E - Q \pm S = 0,$$

where,

P - Precipitation, E - Evapotranspiration, Q - Discharge to the sea, S - Storage in the river.
If the element S, storage, is taken 0, the formula will compose of three elements: P, E and Q. The elements P and Q are determined through measurements and observations. $E = P - Q$.

The Discharge Q is determined as follows:

$$Q = Q_{wag} + Q_{mar} + Q_{sluice}.$$

where,

Q_{wag} = Discharge at Wageningen - post Utrecht,
Q_{mar} = Discharge from the Maratakka River,
Q_{sluice} = Discharge from sluices to the Nickerie River.

$$Q_{wag} = Q_{ston} + Q_{kof} \pm Q_{swamp} - Q_{arawara}$$

where,

Q_{ston} = Discharge at Stondansie,
Q_{kof} = Discharge at Koffimakka Creek,
$\pm Q_{swamp}$ = Discharge from or to the swamp,
$Q_{arawarra}$ = Loss (discharge) at Arawarra Sluice

The discharge measurements made in the past are not sufficient enough to establish a relationship between the hydrological, meteorological and/or other parameters. However, from the measurements made in the second half of 1964, the following relationship can be derived:

$Q_{wag} = Q_{ston} + 7$, when $Q_{ston} < 14$ m^3/s,
$Q_{wag} = 1.5Q_{ston}$, when $Q_{ston} > 14$ m^3/s.

These relationships are valid for decade discharges as mentioned in W.L.A. (1980a). However, these relationships were not emphasized by the measurements of 1980. Rather, these measurements showed that the swamp lying between the Stondansie and Wageningen, through which the Nickerie River flows, had a negative discharge at the end of the dry season. This illustrates the complexity of establishing a relationship between the different factors in order to derive water from the Nickerie River at Wageningen easily, without measuring the discharge in this tidal area, a time consuming and laborious job. To do this, more measurements have to be made. A Q-H (discharge to water level) relation at Wageningen seems to be impossible to establish. It is affected by various factors such as rainfall, tidal regime, swamp effects, human interference, etc. As a result a simple relation with the discharge is difficult to find. Even a Q to Q (discharge to discharge) relation of different sites seems to be difficult, due to the above mentioned factors.

A third solution for getting the discharge at Wageningen is to establish a rainfall-runoff relationship for the area between Stondansie and Wageningen, added to the discharge values of Stondansie catchment. This study has not been done.

Discharge measurements taken at some of the outlet sluices indicate that the total discharges during the dry period in the Nickerie River is greater than that of Nickerie River at post Utrecht and Marakka mouth together. This value is obtained in the period when the Corantijn Canal was not in operation. Moreover, not all sluices and culverts were measured.

The water drained into the Nickerie River has its effects on the movement of the salt wedge, especially in the dry periods of the year, when the upstream discharges are quite small. In these periods water-use is highest and extraction of water is necessary. It might be concluded that a natural recycling of drained water is taking place without the required inundation of the large areas (artificial reservoirs or as locally called – Wadoeks). This phenomenon has not been studied in depth. The salt intrusion in the Nickerie River is not only influenced by the tidal movement, the variation of the amplitude of the tide, the fresh water income from the upper streams, but depends also largely on the drained water from the agricultural area. The possibility of extracting water from the Nickerie River without any fear of silting the fertile agricultural lands is poorly studied. The recycling possibility in combination with the salt wedge movement might form a fourth water resource for the Nickerie area.

It is suggested that a detailed study in the areas of the lower Nickerie River should be done, which should include the following subjects:

- Continuation of monitoring of salt-water movement. This information can be directly provided to the users when to extract water from the river.
- Continuation of the discharge measurement at the various outlets. Expansion of rice fields and exploitation of Corantijn Canal characterize the present situation, whereby extra amount of fresh water is being drained in the Nickerie River which has a certain positive effect on the salt wedge movement. The question is "to what extent does this amount push back the salt wedge?"
- New methods and rice varieties are being used at the present time. These and other human activities in agriculture warrant detailed studies.
- Water management of this area should be clearly established. That means – where, when and how much water is to be extracted from the river.

CONCLUSIONS

The establishment of the Corantijn Canal in 1986 has not solved the problems in this region of Suriname adequately. This Multi-purpose Corantijn Canal Project (MCP) had three important goals, two of which are: creation of new rice fields (± 12500 ha), the so-called MCP-polders, and to provide irrigation water, especially in the dry season to guarantee a second crop.

For realization of these goals, accurate knowledge of the water resources is needed. For this purpose, the Urgentie Project No. 24 was initiated in 1980 (W.L.A., 1980a). This study with various sub-studies was finalized in 1985, without any remarkable results. A continuation of this study was the Hydrological, Water Quality and Environmental Studies, initiated in 1989. On the basis of the already gathered data and some new observations, the executors of the study presented some preliminary results in the form of models and programs in 1993. However, these models and programs have yet to be evaluated and this means that various data are still needed. Moreover, the results of the evaluation might require adjustment to the programs and models. The latter is more practical keeping in mind the on going development in north west Suriname.

Impact of the Corantijn water on the other two water resources – the Nanni Swamp and the Nickerie River – has not yet been studied. Through the completion of the Corantijn Canal the Nanni Swamp became a reservoir (the northern part). The irrigation capacity of the Nanni reservoir is under these circumstances also unknown. How to enlarge the reservoir capacity and/or to gain the maximum benefit from the swamp ought to be studied. The salt-water intrusion in the Nickerie River will get a new dimension through the drainage of the Corantijn water into the Nickerie River. This very important indicator of the water extraction from the Nickerie River is also not sufficiently studied.

In any case, in order to get an idea about the three water resources and the ability to manage them for optimal use, the above mentioned studies must be finalized. A water management and distribution scheme is highly necessary for this rice district. In case this is not possible, monitoring of the water areas and the water quality, especially that of the Nickerie River is proposed. The monitoring can be done by measuring hydrological factors – discharges, water-levels, water-streams, etc., and meteorological factor rainfall, evaporation, etc. These data which may give useful indications in taking measures and precautions should be directly available through organizations and institutions to the users.

ACKNOWLEDGEMENT

The author thanks Mr. R.P.T. Ting-A-Kee for his helpful suggestions and assistance in preparing an earlier draft of this paper. He also thanks the personnel of the Hydrological Section of the Hydraulic Research Division.

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