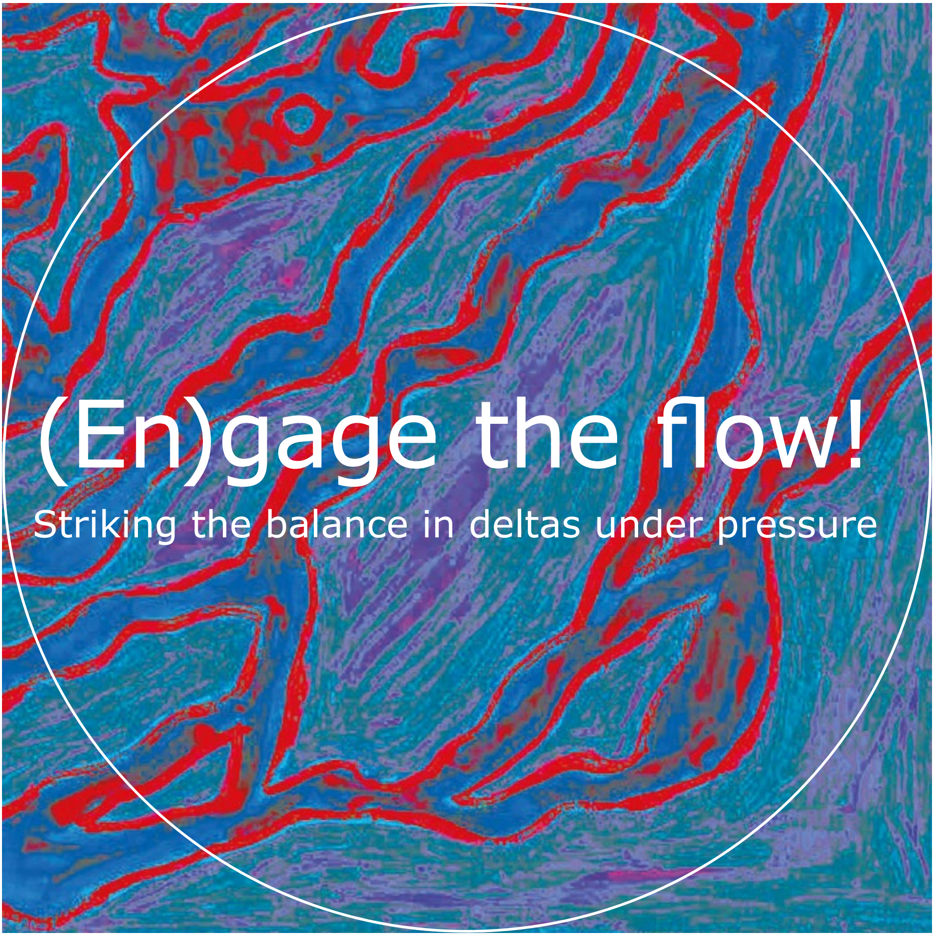

(En)gage the flow!

Striking the balance in deltas under pressure

Prof.dr A.J.F. (Ton) Hoitink

Inaugural lecture upon taking up the position of Personal Professor in the Hydrology and Quantitative Water Management Group at Wageningen University & Research on 25 January 2018

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(En)gage the flow!

Striking the balance in deltas under pressure

Esteemed Rector Magnificus, Dear Colleagues, students, family and friends,

Introduction

"If anyone be too lazy to keep his dam in proper condition, and does not so keep it; if then the dam break and all the fields be flooded, then shall he in whose dam the break occurred be sold for money, and the money shall replace the corn which he has caused to be ruined"[1]. This may have been the very first written record demonstrating human's involvement with flowing water, which goes back to Ancient Mesopotamia. Protecting human settlements from floods has remained a serious challenge ever since that era. In river deltas, coping with floods is particularly challenging, because ocean influences such as tides and storm surges have an influence on the river flow. Perhaps I am biased, but I think deltas are the most prominent landforms one can identify when taking a virtual flight in Google Earth (Figure 1). They are hotspots for economic development, where harbours are located, industry is concentrated, and fertile grounds cause that farmers do not easily give up their land. While flood prevention remains a major threat for living in deltas today, modern times introduce additional challenges. First of all, there is a growing awareness that bringing back biodiversity is an urgent need – it assures a wide variety of

Figure 1 – Three-dimensional view on the Ganges-Brahmaputra-Meghna Delta, obtained from Google Earth.

indispensable services to humans, where the ecologist here in Wageningen know much more about than I do. In deltas, biodiversity is especially threatened by the large-scale loss of salt marshes, which are among the most important ecosystems on earth.

The same urgency applies to the effects of climate change, causing not only increased peak discharges in the river, but also problems during low river discharge. Dry periods with low flow in the river cause hindrance for ship traffic, with direct economic consequences. It also leads to intrusion of saltwater into the delta, which jeopardizes freshwater availability for drinking water, industry and agriculture. In addition, land use changes occur at a scale that rigorously alters the flow and sediment dynamics in rivers and deltas. The sediment input to the rivers has diminished by the building of dams and reservoirs, causing river incision. Considering the changes in the climate and the large-scale land use conversions and engineering works, historical records tell us less and less about the future of river flows in deltas. In this public lecture, I will try to convince that in such an era of change, intensive monitoring and the thorough understanding of processes controlling the physical processes of water, sediment and salt are essential. Prior to continuing with this, I will explain several things about my background.

Personal history

Towards the end of high school I wanted to become an architect. My students will confirm this would not have been a good idea: my 3D sketches on the blackboard are definitely not the strongest part of my lectures. As an alternative, I chose a new study programme at the University of Twente entitled Civil Engineering and Management. The start of that study programme corresponded more or less with the closure of an office of Delft Hydraulics in Emmeloord, and quite a few former Delft Hydraulics employees moved to Twente to start a career in academia. Their stories about research related to the Delta Works intrigued me and made me decide to take the path that I took, on a quest to discover the physics behind rivers and deltas (Figure 2). Like many students here in Wageningen, I also had an urge to travel, which led to an internship that was part of an irrigation project in Argentina. On the foot of the Andes, I came into contact with scientists studying mega floods that occur when ice dams break higher up in the Andes, which is when a lake full of water creates a canyon in the mountains. Fascinating phenomena like that help to motivate, I learned by experience, and are thus very useful in lectures. After an MSc thesis project at Delft Hydraulics, in Delft, I moved to Utrecht University for a PhD study at the Physical Geography Department. I very much enjoyed doing fieldwork as part of a multidisciplinary team, which is perhaps the most intense form of cooperation in science. Taking a first glimpse at a dataset pretty much feels like opening a

Figure 2 – Former outdoor facility of Delft Hydraulics in De Voorst, where the navigability of rivers was tested using a physical scale model. Image courtesy: https://beeldbank.rws.nl, Rijkswaterstaat / WL de Voorst.

present: it is nice if your expectations come true, but it is even more fun if the data present something totally unexpected.

At the time I applied for a position as a lecturer in Wageningen, I knew little about the history of hydraulics in Wageningen, other than that the university was famous for its irrigation projects. I found out about a laboratory in operation where a wide variety of the discharge measurement structures had been investigated in the past. The laboratory at De Nieuwlanden had close ties with Delft Hydraulics, who had actually two employees seconded at Wageningen University to carry out hydraulic research related to discharge measurement and fishways. The key assignment I had, directly after I started in Wageningen, was to prepare for moving of the lab to De Born, where it is now. Outside The Netherlands, I visited laboratories in Braunschweig and Karlsruhe in Germany, and I pictured a new lab where I would expand the range of facilities to recirculate sediment in current flumes. Laboratory experiments are expensive and time-consuming, but are indispensable when studying turbulent flow. Processes of sediment transport are particularly reliant on experiments, if only because sand particles are not perfect spheres. An anecdote illustrating this is about Hans Einstein, who told his farther Albert about his plans to study sediment transport. Einstein Senior responded that he had thought about the subject, but he considered the physics far too difficult. For students, the laboratory is a venue to gain hands-on experience with fluid mechanics, which is considered a highly conceptual and difficult course needed to understand the flow of water. Part of the theory can be explained very well in a lecture room, but counterintuitive phenomena, such as the pressure drop where velocity is highest in a Venturi meter, cannot do without a demonstration in an experimental setting.

Research focussed on flow, sediment transport and delta morphology at Wageningen University is carried out in three chair groups. I am part of the Hydrology and Quantitative Water Management Group, which assures close connection to hydrological forecasting and water balance studies. The Land Degradation and

Development Group offers expertise about sediment supply to the river, by studying soil erosion. The Soil Geography and Landscape Group accommodates researchers with whom I developed new course Hydrology and Geology of Deltas. Other chair groups closely connected to my field of research include the Meteorology and Air Quality Group, who share my fascination for turbulence, the Water Systems and Global Change Group, which has a focus on the impact of climate change on deltas, and the Water Resources Management Group. Together with Wageningen Environmental Research we are part of the Delta Alliance, which is not an airline, but an international network organisation with the mission of improving the resilience of the world's deltas.

Understanding branching channel networks

A conceptual view on deltas I have obtained from field investigations over the years is given in this figure (Figure 3)[2]. I have been particularly interested in cases with tides, which are important in most of the larger deltas on earth. The top panel shows a plan view, featuring a meandering river that becomes less sinuous when approaching the delta. The bed slope becomes gentler towards the coast, merging with a virtually flat lowland plain where the river branches out in several channels. The river forms a delta where the discharge interacts with the tidal motion. During low flows, as shown in the central panel, the mean water level roughly corresponds to the sealevel up until the foot of the slope. Under such circumstances, the flood tide brings in more sediment than what the ebb flow transports back to the sea, and thus, there is accumulation of sediment. During high flows, much of the accumulated sediment is flushed out of the

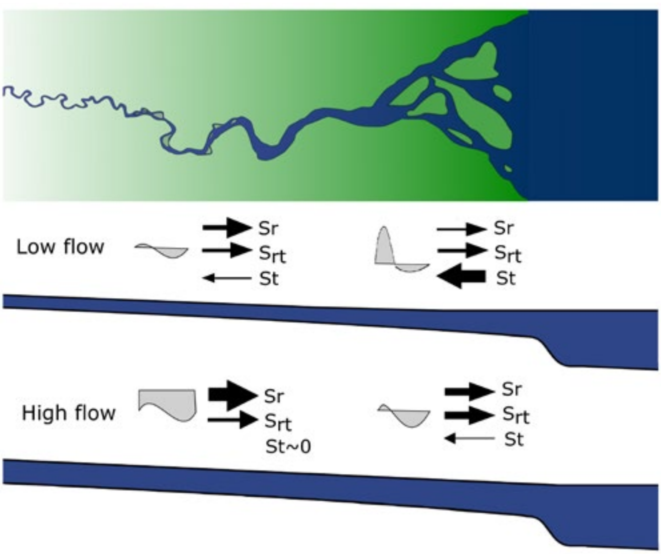

Figure 3 – In tidal rivers, sediment transport by the river (Sr), by tides (St) and by the interaction between river discharge and tides (Srt) are balanced differently throughout the season[2].

system. It is sometimes assumed that in nearly pristine rivers there is a balance between input and output to sea. The sediment fluxes averaged over several years are then the same in any cross section of the river. Such an equilibrium is a very attractive assumption, but there is no field evidence that such equilibrium exists at the scale of the land-sea interface as depicted here. There is no such thing as a delta in a morphological equilibrium. If the influx of sediment equals the outflux, the delta will grow along its boundary, and the boundary conditions will change.

I can illustrate this with a more detailed example based on the Kapuas lowland plain in Indonesia (Figure 4)[3], which still receives significant amounts of sediment input, as opposed to rivers that are sediment starved due to construction of weirs and reservoirs. The city of Sanggau, located about 300 km inland, corresponds to the most upstream point where the concept of equilibrium may apply. Here, water level variation is unambiguously related to the river discharge, resulting in a textbook example of a rating curve. The coarsest material produced in the heart of Borneo, the gravel, does not make it beyond this city, and never reaches the ocean. The coastal plain located downstream challenges my imagination. The river becomes deeper and deeper, up to the coastal region where the delta emerges as a plug of sediment, and the river trifurcates in shallow delta channels. Albeit not monotonously, the grain size reduces towards the coast by a factor four. Inland from the delta, three side channels branch off from the river. The junction connecting these channels to the main river are very much like an Escher picture: the topology does not reveal the flow direction. The composition of bed sediment is different in these side channels, showing a coarsening trend towards to the coast.

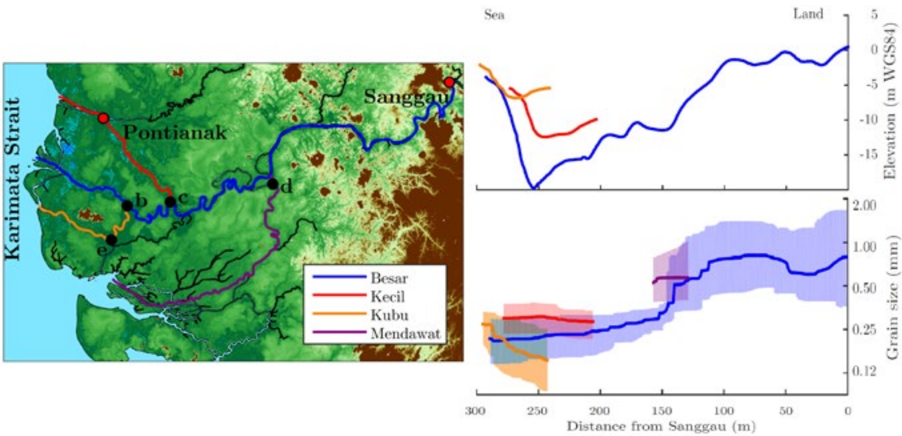

Figure 4 – In the nearly pristine Kapuas River on Borneo, Indonesia, each branch has its own character. The harbor of Pontianak is cleverly located along the Kapuas Kecil branch, where fine sediment tends not to settle.

Part of the audience might be questioning why I am telling you all this, and if there is any relevance that would justify spending Dutch tax payers' money on this exploration of Borneo. Off course, I could respond that nobody asked Darwin that question, who referred to the heart of Borneo as 'one great luxuriant hothouse made by nature for herself'[4], but luckily there is a direct societal link. The largest city in this region is Pontianak, which hosts a harbour where goods are exchanged between the Province of West Kalimantan and the rest of the world. The interesting fact is that this city is not located along the main river, but along the side channel where the bed sediment is relatively coarse. Although we did not get hold of dredging information, my estimation is that the amount of dredging needed to maintain this coarse-bedded channel to the harbour of Pontianak is relatively small. The majority of the river input of sediment accumulates in the delta, whereas the tides keep the side channels open for ships, and prevent siltation. Considering the problems of siltation and high turbidity in many harbour areas, this might be a lead to the holy grail of delta engineering: the design of a channel network where silt accumulates in a natural environment, while the harbour and economic activity are located some place else, while still being connected to the main river and the hinterland. Understanding the land-ocean interface such as exemplified by the Kapuas requires linking four disciplines: hydrology, physical oceanography, geology, and ecology. To speak with my favourite therapist, Doctor Katz, these four disciplines are all touching the same pink elephant.

Research areas

My approach towards the analysis of deltas is primarily the one of an observationalist. I identify the following themes I would like to continue working on in the near future.

Feedbacks between bedforms, sediment transport and discharge waves

In the Netherlands, the bed morphology is being monitored with high resolution from multibeam measurements once every two weeks for a large part of the river system and the delta. This contains a wealth of data that can be coupled to information of water levels, the slope of the water surface, and discharge. Bedforms are often considered as two-dimensional features, distributed uniformly in the river. The increased accuracy and comprehensiveness of the water level and geometry data that is being collected continuously nowadays allows to infer hydraulic roughness directly from the flow and geometry data. New metrics that translate bed scans to hydraulic roughness can be developed and tested. This may be used to improve the roughness predictors, and to better be able to close the water balance. The bed dynamics like you can see in the movie implicitly hides detailed information about

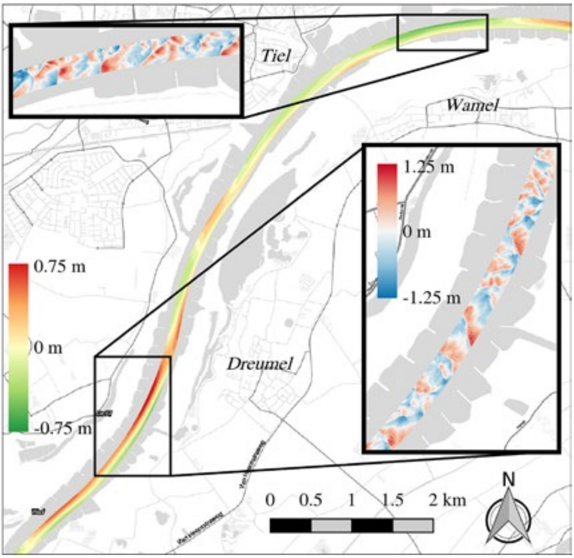

Figure 5 – Maintenance scans of the bottom topography of the River Waal reveal how sand dunes migrate over the underlying sand bars[5].

sediment transport (Figure 5)[5]. With a river section where the bed sediment is reasonably uniform, it should be possible to verify how well existing sediment transport formula perform at the scale of an entire river section.

In comprehensive hydrodynamic models that capture a river branching out in several channels in a coastal lowland plain, the bed roughness is typically considered to be a tuning parameter. In a flow model of the Mahakam land-sea continuum, for example, we assumed there is a roughness value in the river domain, one in the coastal part of the modelling domain, and across the delta, the roughness values were linearly interpolated[6]. When the exercise of inferring hydraulic roughness directly from data that I have in mind is carried out for consecutive river sections along the river, all the way to the coast, it may become possible to get a better view on the gradual roughness transition in the fluvial to tidal transition zone. Such a general view is missing. There are clues that silt and clay, which become more abundant towards the coast, counteract the formation of dunes[7]. When getting so close to the coast that the tide reverses the flow, the bed roughness during flood will be very much different from that during the ebb, which is reinforced by the outgoing discharge. The difference in roughness length between ebb and flood can differ by a decade, which adds to the list of possible causes of tidal asymmetry, calling for further exploration. I intend to use high accuracy monitoring methods to unravel the feedbacks between bedforms, sediment transport rates and discharge waves along the fluvial to tidal transition zone.

Fine sediment household in deltas

Deltas are filters of sand, silt and clay. For sands, a source to sink approach can often be adopted. In other words, it is a matter of finding out where sand issued to the river settles. The origin of silt and clay is sometimes mysterious. For long, river and delta morphologists have considered silt and clay irrelevant for morphology, considering it wash load. Cohesive sediment is now increasingly becoming recognized as a important property influencing delta morphological behaviour[8], which justifies the study of fine sediment not only from a dredging perspective. There are many theories about the formation of estuarine turbidity maxima, but prediction of the occurrence of extremely high concentrations leading to the loss of biodiversity is a contemporary challenge[9]. The Ems Estuary is being referred to as an extreme example of a problem case in this context. Under high concentrations of silt, turbulence is being damped and the physical processes become intrinsically different[10]. Fluid mud may be created, leading to hyper turbidity when the peak flow velocities are large enough to entrain the mud into the water column. One can question whether or not there is a gradual transition towards such conditions, or an abrupt shift of regime. I expect the transition is gradual, which is bad news for the potential of a Nature paper. Even in the Mahakam River, where concentrations are not that extraordinary high, silt grains cannot be considered a passive tracer. Measurements with acoustic Doppler current profilers showed the turbulent Prandtl-Schmidt number is often significantly different from unity[11], which invalidates a common assumption in suspended sediment models. It is not always possible to translate acoustic backscatter to suspended sediment concentration, but in cases where this is feasible, the measurement of flow and suspended sediment are exactly co-located.

Another factor complicating silt dynamics relates to the complex interplay between river flow and tides in delta channel networks. Tides do not only cause oscillation of the water surface, but also a steady setup that alters the division of river discharge over distributary channels that would occur in absence of the tide[12]. This steady contribution is sometimes overlooked. In the Yangtze Delta, the tide-averaged discharge in the North Branch can even reverse sign, such that a river outlet becomes actually an inlet[13]. This North Branch is gradually silting up, which is attributed to land reclamation. I expect that age and residence time theory can be employed to improve understanding of accretion rates in deltas, and, more generally, to understand the prevalence of silt. Tidal flats collect sediment because of the long residence time of water above the flats. I propose to establish the degree in which depositions rates can simply be explained from age and residence time, which may be possible for various size fractions in parallel.

Extreme events

As a third avenue for my research in the coming years, I would like to focus on flow and exchange processes during extremes. In The Netherlands and in many other urbanized deltas, salt intrusion as a result of low flows during summer is high on the agenda. It poses a global threat to the availability of freshwater in deltas, as a consequence of climate change and channel deepening. The problem requires a joint effort because of the multiscale nature of the problem. I intend to contribute to the development of simple models that predict the salt intrusion length in branching channel network, which simulate salt concentration as a lagged response to variation in river discharge, tidal phase and and storm surge setup. Recent techniques that were developed to predict nonlinear river tides[14] can be extended to allow the prediction of salt concentration at crucial stations in the delta. To better understand the physical processes governing salt intrusion, I plan to further analyse the exchange processes at channel junctions. Field research in the Berau Delta showed that the three-dimensional flow processes may cause the occurrence of isolated patches of salt water, resulting in reversed salinity gradients[15]. Such phenomena justify a dense measurement network. I would like to advocate the idea of collecting more data sets such as acquired on the ferry from Den Helder to Texel. For example, a wealth of data could be obtained by deploying an acoustic velocity profiler and salinity sensors on the ferry that continuously crosses the New Waterway towards the harbour of Rotterdam (Figure 6).

Figure 6 – Ferries crossing rivers, such as in between Rozenburg and Maassluis, have the potential to play an important role in real-time monitoring of rivers in an era of climate change.
Image courtesy: Rick van der Sterren

The opposite extreme, the high flows such as we experienced in the beginning of this month, are also affected by climate change. The bed evolution during the passage of a peak discharge event I find particularly interesting. The floodplains are then inundated, which is when the discharge is known with less accuracy. Discharge measurements taken during conditions when the floodplains are inundated are too few, while the river may carry the highest sediment load under these circumstances. Dedicated field campaigns are needed to quantify the discharge under such circumstances. There exist promising new methods for ground-based measurements of surface velocities, including large-scale particle image velocimetry (PIV) and ultrahigh frequency radar (UHF radar). These methods have the potential to monitor the flow continuously[16], as long as some roughness at the water surface is present, and the relation between surface flow and depth-mean flow is not spoiled by the wind. Another interesting approach to gauge shallow flow in floodplains is acoustic travel time tomography. The word tomography refers to section by section imaging of a volume. It relates the changes of scattered sound waves emitted at one place and received at another to flow velocity. The "images" are created by sound waves travelling back and forth through the shallow flow between a pair of acoustic sensors. Considering the different pros and cons of alternative monitoring techniques, the challenge is to develop a multi-instrument approach that creates synergy.

Complex flows interacting with the landscape

A final theme of research concerns the interaction between complex flows and the landscape. In sharp bends of the Mahakam River the flow plunges into deep scour holes in the river bed[17]. In these meanders, erosion occurs at the inner bend and deposition in the outer bend, exactly opposite to what is customary in lowland rivers. As a consequence, the planform development of rivers with sharp bends is different, which applies not only in the tropics but also in smaller rivers such as De Dommel here in The Netherlands (Figure 7)[18]. Sophisticated models are needed to simulate the flow in the scours, because it is non-hydrostatic and the standard Reynolds averaged Navier-Stokes models are incapable of reproducing such flows. It is important to be able to understand how and where these scour holes develop, because the steep bed slopes may jeopardize bridge pillars and the down flow may be dangerous for swimmers. Clearly, analysis of the fluid mechanics of sharp bend is not enough to achieve this. The presence of peat, clay and other erosion resistant material seem to be soil geographical ingredients that play a role, and soil physical processes such as seepage need to be drawn into the analysis. In the case of the Mahakam, the banks sometimes seem rock solid, suggesting processes of cementation.

At the scale of the river landscape, I would like to better understand where dike

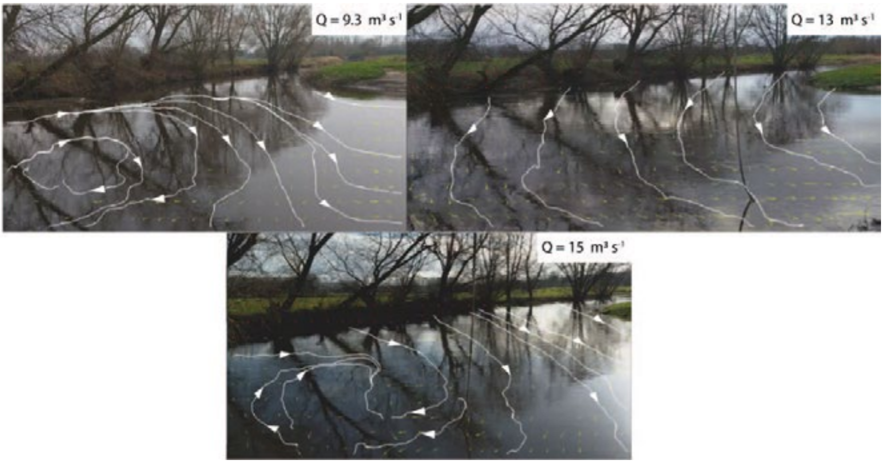

Figure 7 – Complex flow in a sharp bend of the River Dommel is dependent on the river discharge (Q)[18].

breaches and avulsion occur, which determines where a river changes its course. Recent theory focussed on the Mississippi Delta suggests that the location of avulsions often corresponds to the location up to where backwater reaches[19]. The reduction of flow velocity causes deposition of sediment, causing the flow to run into the banks. Close by, such process has been observed in the Lunterse Beek, where a chute cutoff resulted from a plug of sediment that formed because of backwater. In lowland streams, the causes of backwater are many[20]. The downstream boundary is often a river, and therefore, the river level governs the backwater length. Further towards the coast, tides have a profound influence on backwater profiles, which has remained relatively unexplored. Off course, there are other relevant causes of dike breaching. During a catastrophic flood during cyclone Aila in the Ganges-Brahmaputra Delta in 2009, inundation of a polder inside the delta did not occur during the highest water levels[21]. The dike breaches were likely caused by flow impinging on the slope of the dike, at locations where tidal channels were located prior to embankment. Whereas in the Netherland we accept immense maintenance costs of high quality dikes, the people in Bangladesh try to find clever, low-cost solutions. The current practise of gradual raise of land level by periodic depoldering in Bangladesh, referred to as tidal river management[22], is a promising concept of sediment management.

Clever solutions are needed to further transform the embanked delta landscape in The Netherlands to a system that better guarantees safety, assures navigability of the fairways, guarantees the availability of freshwater, promotes biodiversity and minimizes maintenance costs. Longitudinal training dams hold promise to be such a clever solution, which may replace the traditional groynes and alter the Dutch river landscape. A pilot study over a length of 10 kilometers is currently being carried out in the River Waal. Indeed, the longitudinal dams may raise water levels during low flow, reduce water levels during high flow and create a natural environment in the side channel between the longitudinal dam and the river bank (Figure 8). The flow processes governing the exchange of water and sediment between the main channel and the side channel are key to understanding the morphodynamic developments, which are difficult to predict. In one of the gaps between the dams in the Waal, two horizontal acoustic Doppler current profilers have been installed to monitor flow and suspended sediment continuously. Time will tell if indeed the measure will also help to counter channel incision, by reducing the peak flow velocities.

Cooperation

Having explained my focus areas for the years to come, it must be clear that I will not be able to realize these ambitions by myself. I am very much pleased with the research infrastructure we have in my field of research, both inside and outside The Netherlands. At the start of my career I was an active member of the Netherlands Center of Coastal Studies (NCK) and here in Wageningen I have broadened my scope to The Netherlands Center of River Studies (NCR). Deltas define the overlap between NCR and NCK, so my activity continues in both platforms. Rijkswaterstaat, Deltares and the Foundation of Applied Water Research, or STOWA, are the key governmental agencies in this context.

Figure 8 – In the River Waal near the city of Ophemerd, traditional river groynes (right in the image) have been replaced by a longitudinal dam (left in the image). Longitudinal dams increase water levels during low discharge, and reduce water levels during high discharge. Image courtesy: https://beeldbank.rws.nl, Rijkswaterstaat, Ruimte voor de Rivier / Jasja Vliegt.

After a period in which the resources for research and knowledge development within Rijkwaterstaat had declined, the tide has turned and the number of employees at Rijkwaterstaat with a research background is increasing again. That is good news. Concrete ways of cooperation such as 'Waal Samen', in which we as researchers are actively involved in decisions about our river system, work very well. Looking at Rijkswaterstaat from a distance, please allow me to make two critical remarks. The expertise regarding monitoring of rivers, streams and estuaries is split over divisions including WVL, abbreviating Water, Traffic and the Living Environment, and CIV, the Central Information Service. I expect the monitoring programme of the Dutch river system may can optimized when CIV and WVL would operate less independently, which would require an investment to involve CIV employees in research. Secondly, I was astonished to see how much sand the contractor that has created the longitudinal training dams in the Waal had illegally extracted from the river during construction. A deep sand pit was created. I would not be surprised if the same contractor is hired for sediment suppletion of the Waal in the near future, which would be ironic. Illegal sand mining should not be tolerated, as much as that large companies such as Shell shouldn't have an influence on government decisions about corporate taxes. I haven't seen Prime Minister Mark Rutte in the audience, but perhaps he is listening via WUR TV.

Regarding Deltares, I am very much in favour of a closer cooperation with Wageningen Environmental Research, formerly Alterra. I am convinced this is to the benefit of both institutes. Of course, it is up to the directors to decide how much closer this cooperation should be, but the hint I would like to give is that a delta looks much like a triangle. To further optimize the return on investments in our laboratory, I stimulate the exchange of knowledge, instruments and facilities. In our university, the supporting staff has shrunk over the past decades, driven by a permanent search for improved efficiency. When a supporting staff member retires, the chair group has to decide if the position is being filled by a new supporting staff member, or scientific staff. It is often too tempting to choose for the latter, and this is a threat. We might end up doing only what is possible with existing data from the internet, while the source of new data from the field and the laboratory is drying up. A critical mass of supporting staff is indispensable to be able to setup field and lab experiments with the next generation instrumentation. It takes a long time before innovations that require infrastructure and technical support pay off in terms of scientific harvest. Vice versa, it takes a long time before a drop in field and laboratory investments becomes manifest in a deterioration of publication statistics.

STOWA depends on the consent of water boards to invest in research. The ongoing merger of water boards creates larger organizations that hopefully have more means to contribute to research, and to setup projects at larger scale. I have been actively involved in stream restoration projects in which often a very pragmatic approach is adopted. The streams are being restored in places where farmers and other land owners are willing to sell their land for a reasonable price, which sometimes results in a patchy landscape. I am not an ecologist, but I expect that the ecological benefits are a nonlinear function of the square meters available. For example if the land available for stream restoration doubles, then perhaps the ecological benefits multiply by a factor four. The integral restoration of a single stream from source to outlet, such that the discharge dynamics and sediment transport become uninterrupted by weirs, may yield more ecological values than a multitude of local projects in various sub-catchments.

Education

I am lecturing fluid mechanics as part of the Bachelor programme Soil, Water and Atmosphere in the third year. In six weeks' time, the students are supposed to grasp the basics of flow processes in geophysics, which still remains a challenge. Within the Environmental Sciences Group I am part of the group of lecturers that has difficulty with the limited mathematical knowledge of part of the student population. I am coping with this by providing multi-level study material, exercises and exam questions. This means that students with only a limited background in mathematics gain a basic understanding in geophysical fluid mechanics and can pass the exam, while students with a more profound background remain challenged to attain a higher level. After many improvements over the past six years, this approach has become successful. I expect it would be better if students would have more time in between lectures, to create the space to better digest the concepts. Currently, an additional course on environmental hydraulics is being evaluated, which would resolve the problem of too many new concepts in a short period of time.

Over the past months, two students have visited me who decided to take a one-year break in between their Bachelor and Master programmes. They decided to take the time to make a conscious decision about the Master they would choose. I have helped one of them finding an internship, which I hope will be inspiring. The fact that quite a few students need a year off after their Bachelor may indicate that the study programme has become so dense, and the courses so intensive, that the space for self-development has become too limited. It is wise to take the time to make a careful decision about the study direction, because financially it is nearly impossible enrol in a new MSc programme after graduation. On the other, an entire extra year in between the Master and Bachelor should not become a default option. I am in favour of investigating the option to create the flexibility in the start date of the MSc programme, which is now fixed at the first of September.

Regarding MSc courses, there is a tendency to attract students from various backgrounds, basically to maximize subscriptions. This results in a heterogeneous population of students, which is not to the benefit of the level achieved in a course. Specialized courses that build on detailed knowledge from the Bachelor courses have become scarce. I cherish the possibility to design Capita Selecta, which I offer to students only in combination with a Master thesis project, because we are not being paid for it. With such a Capita Selecta, the student can specialize in a subject through self-study and weekly meetings, prior to starting with the thesis. This procedure has proven to be beneficial for students who have the ambition to dig deeper in a research topic, and it yields better thesis reports. I hope lecturers will maintain their autonomy in this.

As for the quality of education, my impression is that the existing indicators do not all stimulate to improve quality. The official, anonymous student evaluations are being taken very seriously, which is good, but they lack a correction for the bias towards the opinion of students who did not have the appropriate prerequisite knowledge. The student association Pyrus carries out evaluations in parallel. My personal appreciation for these unofficial evaluations is actually higher than for the official ones, because the opinion about the course is being formulated based on consensus in a group of students. The group discussions that form the basis for the Pyrus evaluations result in a much more balanced judgement than the Twitter-like comments in the anonymous reviews.

PhD research

The PhD researchers whom I supervise often collect their data with their bare hands. By now you know how much I value field and experimental data, and setting up an experiment requires a distinct type of competence. Collecting data by yourself, instead of using existing data, is not the fastest route to an extensive publication record. I think there is a need to address the fact that it has become more difficult to carry out experimental research. There is an unwritten rule that a successful PhD thesis contains four chapters that can be published. In a way, MSc thesis research is therefore more relaxed: there is no immediate problem if an MSc thesis does not result in a peer reviewed paper. Especially when a PhD researcher collects an extensive new dataset, a thesis with sufficient content for three peer reviewed papers can be worth a doctorate degree, in my view. At the same time, you don't have to worry I would not support the publication of a fourth, fifth or sixth paper. After all, I am a product of my generation. Embedding MSc thesis work in PhD projects can be fruitful way of optimizing research results, while maintaining a relaxed atmosphere to explore new grounds.

Acknowledgements

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When students ask a question where I do not have an answer to, I always send them to Drs Paul Torfs, who has been extremely helpful. There is a vacancy for that role, now that he has retired. Ing Wubbo Boiten, Ing Anton Dommerholt and Ir Jan Verhagen represented hydraulics when I arrived in Wageningen, in a way I preserve their heritage. Drs Matthijs Boersema has played an important role during the initial years of the laboratory. With Dr Bart Vermeulen I have been working together uninterruptedly from the moment I met him as a Bachelor student. His computer code is magic. I am very happy you have obtained a permanent position, Bart, and I am glad we can continue working together. I am grateful to all other PhD and Postdoc researchers with whom I have worked over the years – it has been a great pleasure.

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Esteemed Rector Magnificus,
Ik heb gezegd.

References

[1] Dellapenna, J. W., & Gupta, J. (2009). The evolution of the law and politics of water (p. 10). Dordrecht: Springer.

[2] Hoitink, A.J.F., Wang, Z.B., Vermeulen, B., Huismans, Y., & Kästner, K. (2017). Tidal controls on river delta morphology. *Nature Geoscience*, 10, 637.

[3] Kästner, K., Hoitink, A.J.F., Vermeulen, B., Geertsema, T. J., & Ningsih, N. S. (2017). Distributary channels in the fluvial to tidal transition zone. *Journal of Geophysical Research: Earth Surface*, 122(3), 696-710.

[4] Wilson, E.O. (2006). From so simple a beginning: The four great books of Charles Darwin. WW Norton & Co.

[5] De Ruijsscher, T.V., Naqshband, S., & Hoitink, A.J.F. (2020). Effect of non-migrating bars on dune dynamics in a lowland river. *Earth Surface Processes and Landforms*, 45(6), 1361-1375.

[6] De Brye, B., Schellen, S., Sassi, M.G., Vermeulen, B., Kärnä, T., Deleersnijder, E., & Hoitink, A.J.F. (2011). Preliminary results of a finite-element, multi-scale model of the Mahakam Delta (Indonesia). *Ocean Dynamics*, 61(8), 1107-1120.

[7] Schindler, R.J., Parsons, D.R., Ye, L., Hope, J.A., Baas, J.H., Peakall, J., Manning, A.J., Aspden, R.J., Malarkey, J., Simmons, S., Paterson, D.M., Lichtman, I.D., Davies, A.G., Thorne, P.D.,& Bass, S.J. (2015), Sticky stuff: Redefining bedform prediction in modern and ancient environments, *Geology*, vol. 43, pp. 399-402

[8] Edmonds, D. A., & Slingerland, R. L. (2010). Significant effect of sediment cohesion on delta morphology. *Nature Geoscience*, 3(2), 105-109.

[9] Hoitink, A.J.F., Nittrouer, J.A., Passalacqua, P., Shaw, J.B., Langendoen, E.J., Huismans, Y., & van Maren, D.S. (2020). Resilience of river deltas in the Anthropocene. *Journal of Geophysical Research: Earth Surface*, 125(3)

[10] Winterwerp, J.C., and Wang, Z.B. (2013). Man-induced regime shifts in small estuaries - I: Theory. *Ocean Dynamics*, 63(11-12), 1279–1292.

[11] Sassi, M.G., F. Hoitink, A.J.F, & Vermeulen, B. (2013). Quantified turbulent diffusion of suspended sediment using acoustic Doppler current profilers. *Geophysical Research Letters*, 40(21), 5692-5697.

[12] Hoitink, A.J.F., & Jay, D.A. (2016). Tidal river dynamics: Implications for deltas. *Reviews of Geophysics*, 54(1), 240-272.

[13] Zhang, W., Feng, H., Zhu, Y., Zheng, J., & Hoitink, A.J.F. (2019). Subtidal flow reversal associated with sediment accretion in a delta channel. *Water Resources Research*, 55(12), 10781-10795.

[14] Matte, P., Jay, D. A., & Zaron, E. D. (2013). Adaptation of classical tidal harmonic analysis to nonstationary tides, with application to river tides. *Journal of Atmospheric and Oceanic Technology*, 30(3), 569-589.

[15] Buschman, F. A., Van Der Vegt, M., Hoitink, A. J. F., & Hoekstra, P. (2013).

Water and suspended sediment division at a stratified tidal junction. *Journal of Geophysical Research: Oceans*, 118(3), 1459-1472.

[16] Muste, M., & Hoitink, A.J.F. (2017). Measuring flood discharge. In *Oxford Research Encyclopedia of Natural Hazard Science*. doi: 10.1093/acrefore/9780199389407.013.121

[17] Vermeulen, B., Hoitink, A.J.F., & Labeur, R.J. (2015). Flow structure caused by a local cross-sectional area increase and curvature in a sharp river bend. *Journal of Geophysical Research: Earth Surface*, 120(9), 1771-1783.

[18] Geertsema, T. J. (2019). Water level and discharge dynamics in human-affected lowland rivers. PhD Thesis. Hydrology and Quantitative Water Management Group, Wageningen University & Research

[19] Chatanantavet, P., Lamb, M. P., & Nittrouer, J. A. (2012). Backwater controls of avulsion location on deltas. *Geophysical Research Letters*, 39, L01402.

[20] Eekhout, J. P. C., & Hoitink, A. J. F. (2015). Chute cutoff as a morphological response to stream reconstruction: The possible role of backwater. *Water Resources Research*, 51(5), 3339-3352.

[21] Auerbach, L.W., Goodbred, S.L., Jr., Mondal, D.R., Wilson, C.A., Ahmed, K.R., Roy, K., Steckler, M.S., Small, C., Gilligan, J.M.,& Ackerly, B.A. (2015) Flood risk of natural and embanked landscapes on the Ganges-Brahmaputra tidal delta plain, *Nature Climate Change*, 5 (2), pp. 153-157.

[22] Van Staveren, M.F., J.F. Warner and M.S.A. Khan (2017), Bringing in the tides. from closing down to opening up delta polders via Tidal River Management in the southwest delta of Bangladesh, *Water Policy*, vol. 19, pp. 147-164.

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'Climate change and the direct impacts of humans on rivers are reasons why historical records tell us less and less about the future. A profound understanding of contemporary flow processes and intensive monitoring are needed to prepare for the consequences of prospective river discharge extremes in deltas.'

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