# The Destruction of the Nova Kachovka Dam

## The flooding of the surrounding area's close to the river Dnjepr

CT3533: Earth Observation

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## The flooding of the surrounding area's close to the river Dnjepr

by

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| Cover: | Nova Kachovka dam after its destruction on the 6 of June |
| Style: | TU Delft Report Style, with modifications by Daan Zwaneveld |

# Contents

# 1 Introduction

On June 6 2023, the Nova Kachovka dam located in the river the Djnepr, was destroyed. The Nova Kachovka dam is a large dam that is located close the town Nova Kachovka in the south of Ukraine and is one of the six dams that are present in the river the Dnjepr. The dam is used for the production of electricity and as a water regulator to allow irrigation of nearby agriculture land aswell as irrigation of areas elsewhere in the country. It was also built to allow better transportation on and across the river. The lake behind the dam has a surface area of 2155 $km^2$ and a water volume of 18.2 $km^3$. Due to the large amount of water present it was use full as cooling water for the nuclear power plant in Zaporija. On June 6 the dam was damaged by a large explosion resulting in a lot of water moving downstream and into neighbouring areas. Not only areas close to the dam were affected also areas on split-off's of the river were affected further downstream. The destruction resulted in the evacuation of around ten thousand people and led to dangerous water levels for irrigation and transportation of water as well as cooling water for the nuclear power plant.
There are few to no studies done on the flooding of areas that occured due to the destruction of the dam. This report aims to map the flooding and analyse the extent of this disaster by use of public available earth observation data. The dedicated areas of interest are areas that are close to the river, the area around the dam itself, as well as areas downstream the river and areas close to split-offs of the river. Data is used in a timeframe around the 6th of june 2023, to determine the size of water areas before and after the disaster. A research question is stated to aid in the objective of the study. The research question stated is 'How did the destruction of the Nova Kachovka dam changed the landscape of area's depended on the dam?' by focusing on the onset of water in certain areas.
First a preliminary analysis is done on the signals of interests as well the parameters and characteristics of those signals. Chapter 3 will present a short literature study that is done to obtain knowledge about possible use full methods, techniques and operational platforms that could be use full for this study. It also explains the chosen methodology for this study as well as the used workflow. In chapter 4 the method and workflow is applied and results will be presented. Lastly a discussion and conclusion of this report will be given.

# 2

# Preliminary Analysis

**The signal's of interest**
With the destruction of Nova Kachovka the dam a huge amount of water was released in to the surrounding areas. Not only area's downstream were impacted but also area's more upstream of the dam. In order to determine what the impact of the destruction is, it is important to look at signals that can tell something about the change in water levels and the presence of water bodies in neighbouring area's. For that reason this research focuses on the impact due to the water that was released and therefore data on water levels and the presence of water. The signal that needs to be looked out for is flooding of area's and specifically a signal that distincts water from surrounding areas.

**Parameters and characteristics**
In order to define the water level in more detail and to better characterize it, is important to approach it from a top-down level. Starting with the user requirements. Some examples of user requirements as stated in [2] and [6] are: continuity of data, the availability of the data, the land that is covered, the time of the observation and the timeliness of observation. Furthermore one level down, the user-requirements lead to mission requirements. These mission requirements are important to define in order to determine with what data we are dealing and how to interpret the data. Then those mission requirements translate into technical requirements needed to realise a mission. But for this research only the parameters and characteristics that can be obtained from the user and mission requirements are needed.

As mentioned its important to define the parameters and requirements that stem from the user and mission requirements. Therefore we can define the following parameters and characteristics while keeping in mind the user and mission requirements: it is important that the data is readily available and accessible to the public to be able to carry out this research. Secondly the primary area that should be covered is the area around and neighbouring the dam itself, furthermore areas around the river Dnjepr must also be covered to be able to determine the impact on areas further up or down the river. Those areas constitute mostly of villages, agriculture land, bridges and roads. Thirdly the time span in which observations must be done are in the time span of day's/week's/months, therefore on a relative small time scale as the most impact on the areas occurs mostly when the water arrives in these areas. But one must not forget that when the water is settled damage admits the chaos will become more apparent. Therefore also the time scale over some weeks or months is of importance as to compare areas before and after the destruction. Fourthly the revisit time should be small and the continuity of data should be high in order to obtain information on events that lead to rapid change in water level.

From these characteristics we can narrow down to some parameters such as the spatial resolution which should be down to several kilometers and meters in order to obtain high quality data, as well as a good temporal resolution in the order of days, to monitor rapid changing events such as flooding off certain areas. Further more its important to have data that can show the distinction between water and land as well as changes in infrastructure, therefore a good spectral resolution is needed. The water level can possibly be determined in terms of height in meters or its reflective properties distinctively from land. Concluding the preliminary analysis a sum up of the parameters and characteristics of interest for this research are given below:

Characteristics

- Readily available data
- Primary areas are areas around the dam and close to the river Dnjepr
- High temporal resolution
- High spatial resolution
- fast revisit time

Parameters

- areas of interests are villages, agriculture land, and infrastructures such as roads, bridges and housing
- the spatial resolution should be in the order of meters to kilometers
- the temporal resolution should be in the order of primarily days and weeks
- the timeliness of the data should also be in the order of days and weeks

These are the most important characteristics to take into account in acquiring data for this research. It is important that data is presented on areas, before and after destruction of the dam to really compare and distinguish change due to the floodings that occurred.

# 3

# Short Literature study and methods

## 3.1. literature study

To determine the relevance of this study it is important to orient this research with respect to already existing studies about the research topic. The impact of the natural/human initiated disasters due to the Ukraine-Russian war conflict. The destruction of important infrastructure in Ukraine has a big impact on liveability, habitability, traffic infrastructure and agricultural land on areas close to important infrastructure. Since the annexing of Crimea in 2014, some studies have been done analysing the impact of the conflict on specific topics such as war related building damage [7], environmental consequences due to the conflict [5], analysis of damaged agriculture fields in Ukraine [1] and the analysis of floods using neural networks [4]. Because the destruction of the Nova Kachovka dam is rather recent, studies have yet to be done to analyse its impact on areas close by. But other studies exist that analyse the impact on the environment due to the Ukraine-Russian conflict. Note must be taken that the destruction of the dam is assumed by most to be Russia's doing but there is no certainty on that. The floodings that occurred after the destruction of the dam falls in the category of the topics of the aforementioned studies and therefore those studies can be used as a basis for the method and techniques used in this research. Some examples of done studies and their techniques are given hereafter:

| | **Article Title** | **Topic** |
|---|---|---|
| 1 | Grid system for flood extent extraction from satellite images | Neural networks for flood monitoring in Ukraine and China |
| 2 | The use of remote sensing data that is studying the environmental consequences of the Russian invasion of Ukraine | Studying environmental consequences due to the Russian invasion of Ukraine |
| 3 | War Related Building Damage Assessment in Kyiv, Ukraine, Using Sentinel-1 Radar and Sentinel-2 Optical Images | War related building damage in Kyiv |
| 4 | Spatiotemporal Analysis and War Impact Assessment of Agricultural Land in Ukraine Using RS and GIS Technology | War impact on agricultural land in Ukraine |
| 5 | War Damage Detection Based on Satellite Data | Damage on agricultural land in Ukraine |

| | **Indexes/techniques** | **Extra data** | **Chosen Satellites** |
|---|---|---|---|
| 1 | SAR | - | ERS-2, ENVISAT, RADAR-SAT-1 |
| 2 | Spectral and Thermal Imaging | FIRS<br>(Fire Information for Resource Management) | NOAA-2, SUOMI NPP, AQUA, TERRA<br>SENTINEL-1/2 |
| 3 | SAR, Spectral Imaging | OSM (OpenStreetMap), UNOSAT,<br>WSF (WorldSettlementFootprint) | SENTINEL-1, SENTINEL-2 |
| 4 | NDVI, GF-SG, SR | - | LANDSAT-8 |
| 5 | NDVI, Spectral Imaging | ACLED | SENTINEL-2 |

## 3.2. Methods and techniques used

Observing the studies and relating the used techniques to the satellites used, it can be seen that for flooding SAR is mostly used. SAR together with spectral imaging are good techniques for determining environmental consequences due to a disaster. As can be seen in study 1, SAR is mostly used for determining where floods happened. Study 3 mostly uses SAR and Spectral Imaging for assessing building damage. As seen in studies 2 and 5 Spectral Imaging is mainly used for studying environmental consequences due to the ongoing conflict in Ukraine. Looking at those studies SAR and Spectral Imaging are reasonable techniques to be used for studying the impact of the floods occurred due to the destruction of the dam as floods can influence the environment on a big scale. Satellites that provide high resolution data on the SAR and Spectral techniques are Sentinel 1 and 2. Therefore the type of techniques that would be most suited for this study by looking at the studies found in the short literature study, are SAR (synthetic aperture rader) and spectral imaging to determine floodings in areas such as for agriculture, housing or industry. The two observables most suited are radiation in the visible/optical wave lengths and RF/microwave. This in order to detect through the atmosphere as RF/microwave pierce through the atmosphere and interference due to the atmosphere is very low. Also to detect the differences between land and water as certain optical bands are very suited for this distinction. The satellites Sentinel 1 and 2 provide high resolution data on these techniques and therefore the data from those satellites is chosen to be used.

### 3.2.1. Methodology for data processing

The data from both Sentinel 1 and 2 will be analysed with the following method: first data from the areas of interest before the destruction of the dam is analysed. This is to get an overview of the area before the disaster happened. After having established an overview, data from after the destruction of the dam is analysed and compared to the data from before the destruction. The data will be then be compared to try and correlate changes in environment to the flooding and on set of water. Data from both the spectral imaging and SAR in the same area and time can be used to try and cross correlate certain characteristics of the environment as they can be used complementary. This method needs data in a time span of some days or weeks to be able to analyse rapid changes to the environment. Data from both satellites can be used to enhance temporal resolution due to extra satellite coverage.

## 3.3. Workflow

To determine and distinguish differences in the data that are due to real-time changes or disturbances that are due to atmospheric reflection, geometric properties, radiometric properties or the amount and direction of back scatter for example, it is of importance to setup a workflow to correctly analyse and interpret the raw data that is obtained from the platforms of interest. The workflow starts with the raw data that is obtained from the different platforms. Those data can be obtained from different kinds of open data hubs such as 'Sentinel Hub', 'Copernicus Scihub', 'Google earth engine' or NASA's 'EOSDIS Worldview'. As mentioned is 4.1 the platforms of interest are Sentinel 1 and 2 and therefore 'Copernicus Scihub' can be used to obtain raw data on the areas of interest. An overview of the raw data that is used in this research can be found in section 4.1. Based on the technique used to measure the data, such as spectral imaging, thermal imaging or Radar, different pre-processing methods can be used to correct for unwanted disturbances as mentioned before. The raw data that is obtained is processed using a software platform called 'SNAP'.

*Sentinel 1 workflow:*

- Subset: ensuring the correct area
- multi-looking: to reduce excess noise and spekles
- Calibration: to correct for bias in the back scatter
- Terrain correction: This is to correct for disturbed terrain
- Stacking: the two different dates are stacked to allow comparison of the two scenes
- RGB: the stack is transformed into an RGB image to visualize changes

*Sentinel 2 workflow:*

- Subset: ensuring the correct area
- Extraction: Preferred bands are extracted
- Resample: to resample every band to the same resolution to allow Indexing
- SWM index: band math is used to obtain the SWM index
- Stacking: the two different dates are stacked

to allow comparison of the two scenes

- RGB: the stack is transformed into an RGB image to visualize changes

The workflows for both the raw data from sentinel 1 and sentinel 2 (3.1, 3.2) are shown below in two workflow diagrams.

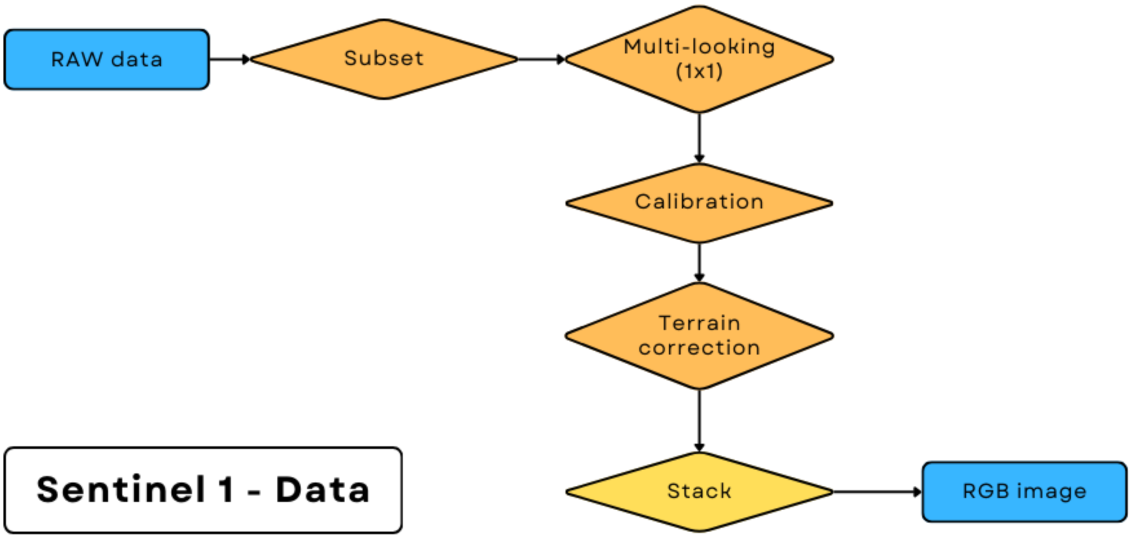



**Figure 3.1:** Sentinel 1 data workflow

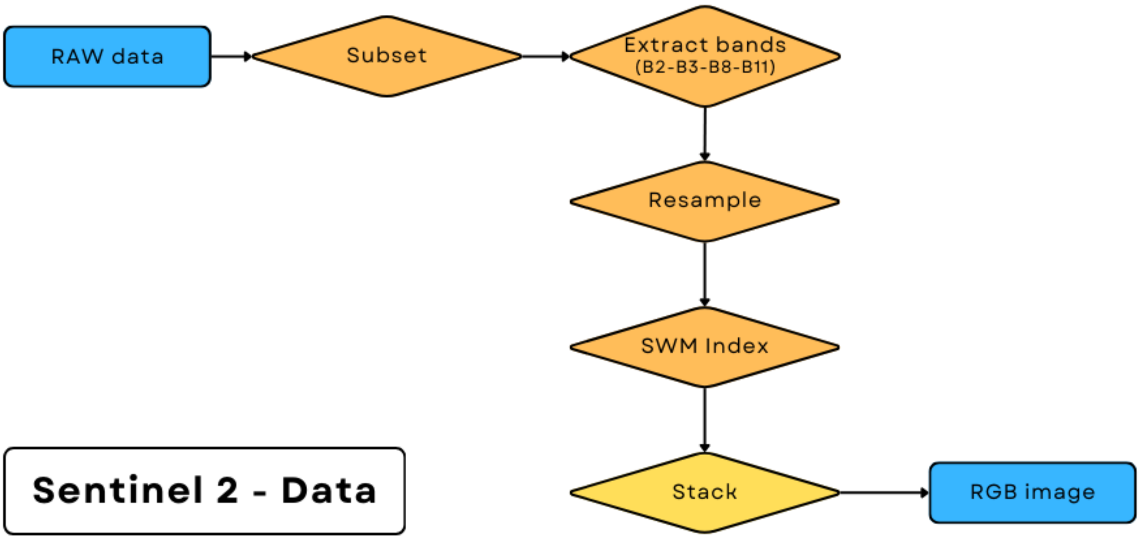



**Figure 3.2:** Sentinel 2 data workflow

# 4

# Applying the method and its results

The workflows as mentioned above are applied on the following areas of interest. The Nova Kachovka dam, the general river area down stream, Hola Prystan and Afanassivika located within a split-off of the river Dnjepr. For interpretation of the images with regards to the geographic areas some images are flipped to allow easier interpretation. In the processing tool SNAP all the images were processed using their reference GEO-location so therefore the final images can appear to be skewed or in a different orientation as they are projected on their reference locations. First the raw data will be presented. Then two areas will be showed in more detail with regards to the two workflows and finally the final data of all areas will be presented and compared. Some optical images appear to dark for good usage but the bands that were present in the data could be used in such a way that the data was still use full. Note that all images given below are already subsets to the desired area of interest.

## 4.1. Overview of Raw data

The first area of interest is the Nova Kachovka dam and neighbouring infrastructure both shown in the optical and radar wavelengths, figures 4.1a,4.1b,4.2a and4.2b. The dates of the optical images are 5 and 18 June 2023 and the dates of the radar images are 1 and 13 June 2023.

**(a)** Nova Kachovka Dam on 06-05, optical wavelengths

**(b)** Nova Kachovka Dam on 06-18, optical wavelengths

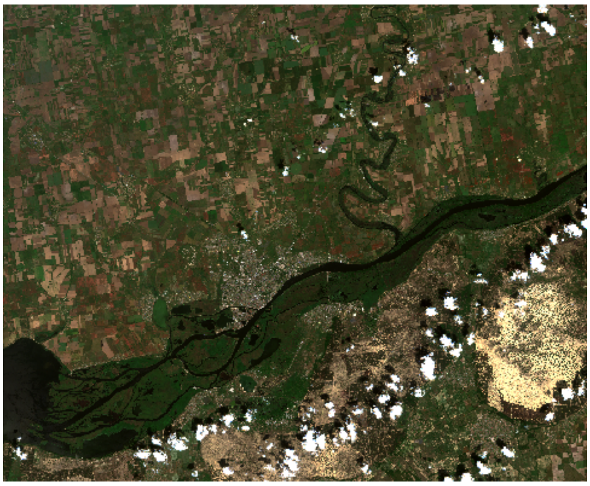
**Figure 4.1:** Nova Kachovka dam

**(a)** Nova Kachovka Dam on 06-01, radar wavelengths

**(b)** Nova Kachovka Dam on 06-13, radar wavelengths

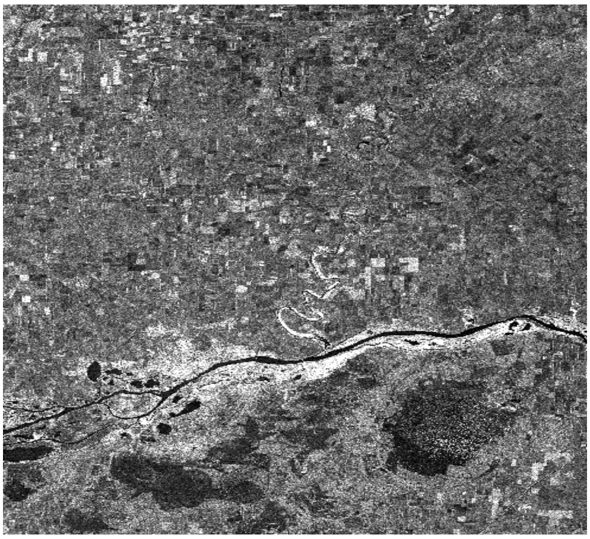
**Figure 4.2:** Nova Kachovka dam

The second area is the general river area down stream of the dam. The dates of the optical images are 3 and 18 June 2023 and the dates of the radar images are 2 and 14 June 2023.



**(a)** General river area down stream on 06-03, optical wavelengths

**(b)** General river area down stream on 06-18, optical wavelengths



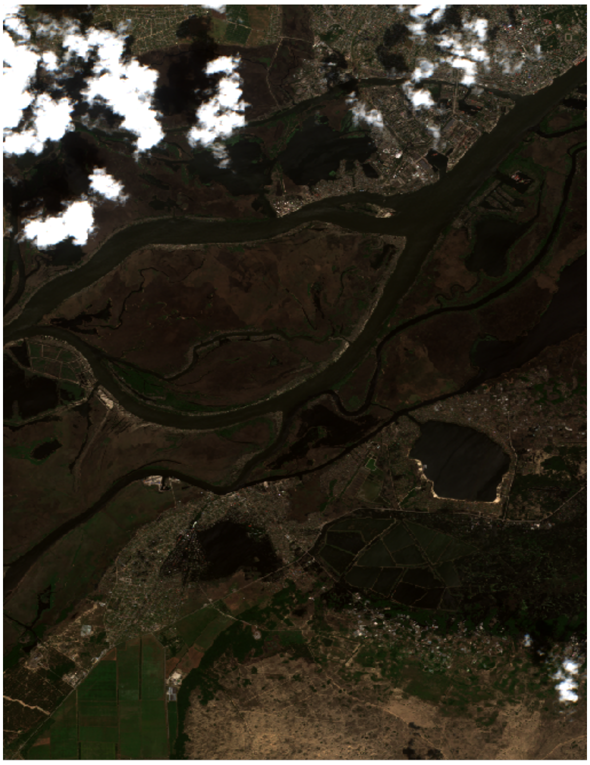
**(c)** General river area down stream on 06-02, radar wavelengths

**(d)** General river area down stream on 06-14, radar wavelengths

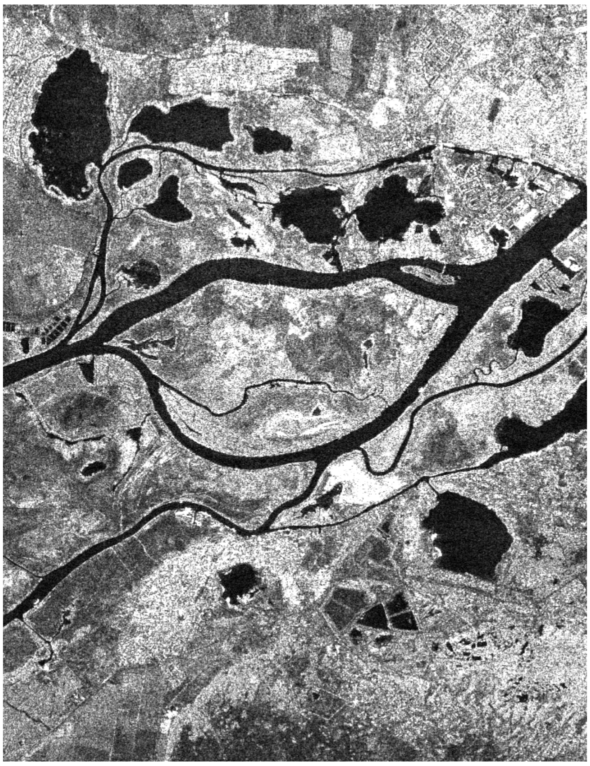
**Figure 4.3:** General river area down stream

The third area is area close to Hola Prystan. Hola Prystan is the town in the lower left corner of the images. The dates of the optical images are 3 and 18 June 2023 and the dates of the radar images are 2 and 14 June 2023.

**(a)** Hola Prystan on 06-03, optical wavelengths



**(b)** Hola Prystan on 06-18, optical wavelengths

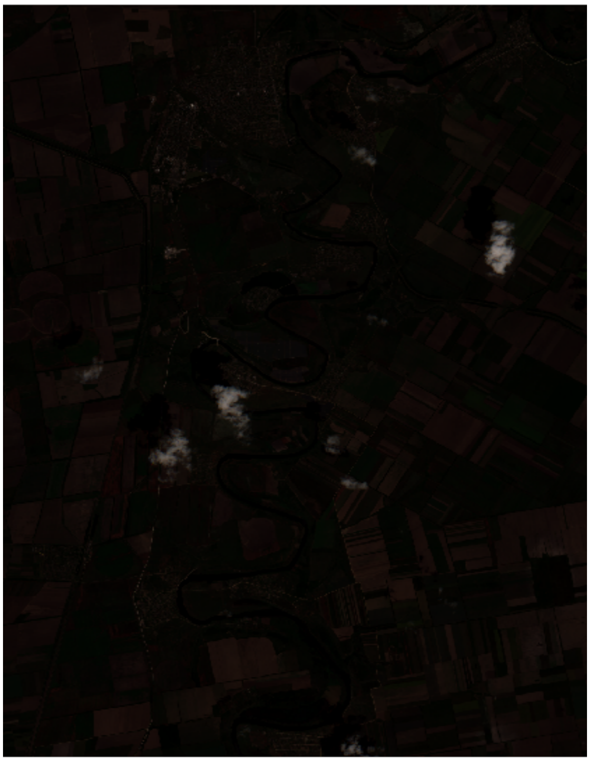


**(c)** Hola Prystan on 06-02, radar wavelengths

**(d)** Hola Prystan on 06-14, radar wavelengths

**Figure 4.4:** Hola Prystan

The fourth area is Afassanivika which is a village that lies in a split off of the river Dnjper. The dates of the optical images are 3 and 18 June 2023 and the dates of the radar images are 2 and 14 June 2023.



**(a)** Afassanivika on 06-03, optical wavelengths

**(b)** Afassanivika on 06-18, optical wavelengths

**(c)** Afassanivika on 06-02, radar wavelengths

**(d)** Afassanivika on 06-14, radar wavelengths

**Figure 4.5:** Afassanivika

## 4.2. Explanation and application of the workflow

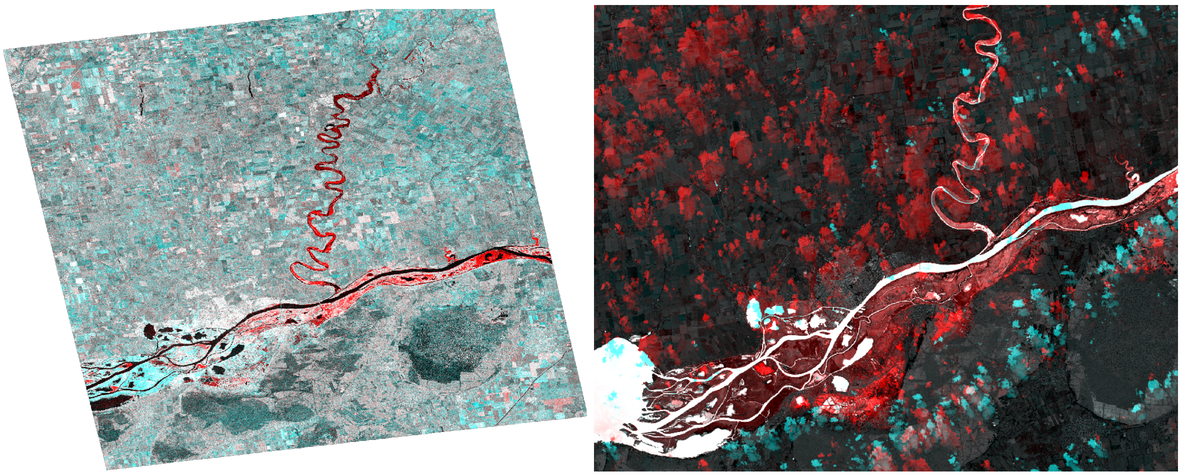
To obtain the end results that all represent a flood map of the area of interest in RGB it will be shown in this section how this is done according to the aforementioned workflow.

*The workflow of Sentinel 1 in the processing program 'SNAP' is done as follows:* taking the general down river area as an example, first from the original obtained data set the area of interest is chosen and a subset is made to zoom in on the required area of interest, see figures 4.3a, 4.3b, 4.3c and 4.3d. The subset is applied to multi-looking this is to reduce the speckle artefacts created in the image due to constructive and destructive interference of the reflected light. After the multi-looking calibration is done in order to directly relate output values to the received back scatter of the scene. The band that is used for the pre-processing of radar images is the VV band as this band provided the best distinction between land and water. Then the image is terrain corrected and this is done in order to correct for distortion due to the angle of the imager w.r.t the scene. The workflow is done in parallel with data from the two different dates. After the terrain correction both images are stacked on top on each other. This allows 'SNAP' to create a data-set in which the desired bands of interest from the different scenes can be used in the same data set and to compare the back scatter on both images. At last an RGB image can be created using the VV bands from both the different images at different dates which then leads to a flood map as seen in figure 4.8b.

*The workflow of Sentinel 2 in the processing program 'SNAP' is done as follows:* again lets take the general down river area as an example. First a subset of the raw data is chosen to zoom in on the area of interest. After the subset, four different bands are extracted from the data. Those are the B2, B3, B9 and B11 bands. After the extraction of the bands the bands must be re-sampled in order to apply the index. The resampling ensures that each band has the same spatial resolution in the scene. To obtain a good distinction between water bodies and land the SWM index is used. 'According to the Crisis information centre at ESA a good index that allows for the classification of water is the Sentinel Water Mask inddex. This index can be used to obtain an scene of an image in which water and land have distinct intensities which allows for easier classification of water bodies. The index is comprised out of the aforementioned B2, B3, B8 and B11 bands. The index is applied according to the following band math equation 4.1, [3].

$$SWM = \frac{B2 + B3}{B8 + B11} \tag{4.1}$$

After establishing the index the images from both days can be stacked on top of each other and with the SWM index one can establish a relative RGB Image as can be seen in figure 4.6b.



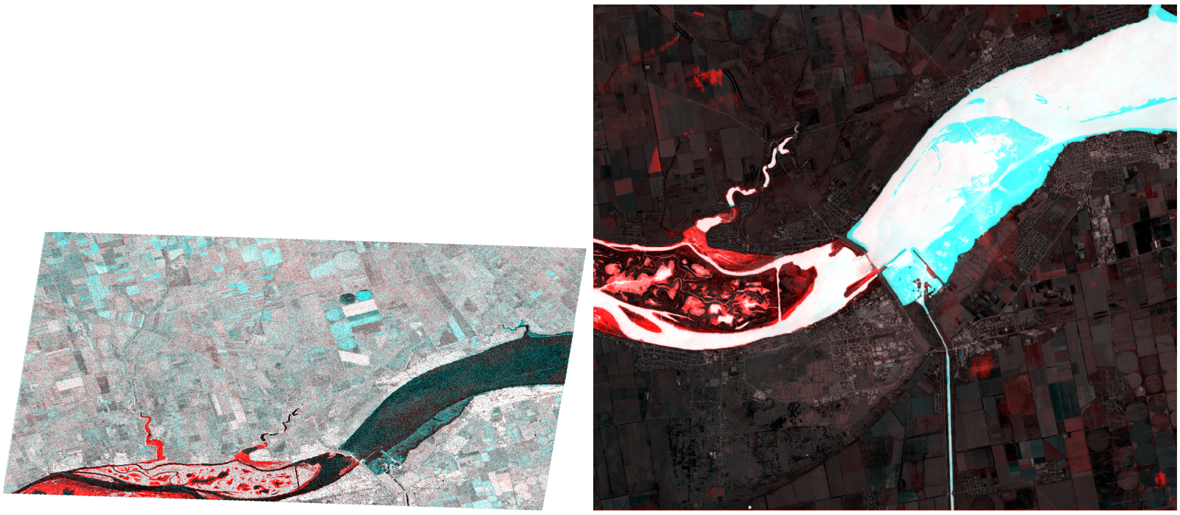
**(a)** General river area flood map

**(b)** General river area flood map

**Figure 4.6:** Floodmap examples

## 4.3. Final results

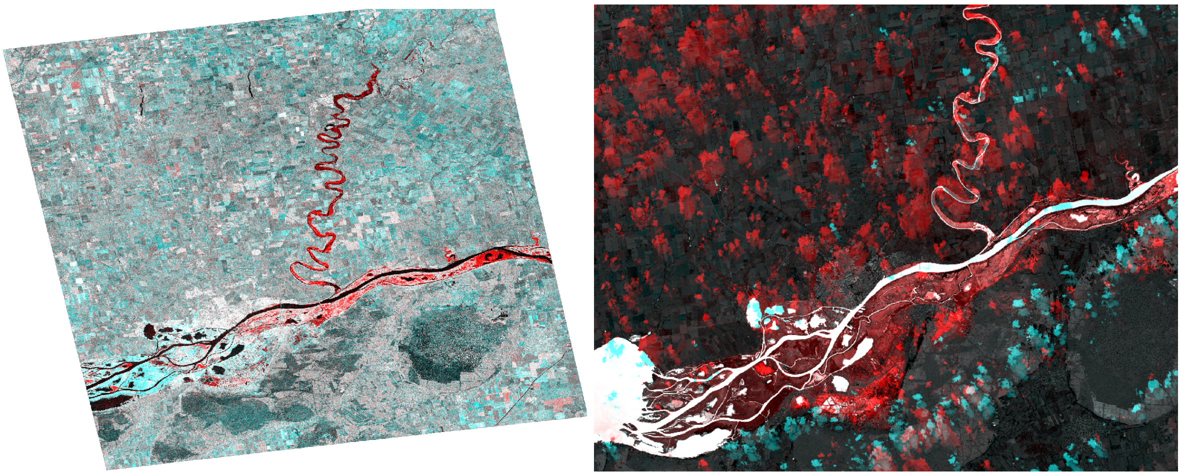
Below one can see the final results of processing the data for each area. **Flood map Nova Kachovka dam (Radar - Optical):**



**(a)** Nova Kachovka dam - Radar - (1 and 13 June 2023) **(b)** Nova Kachovka dam - Optical - (5 and 18 June 2023)

**Figure 4.7:** Floodmaps of the Nova Kachovka dam

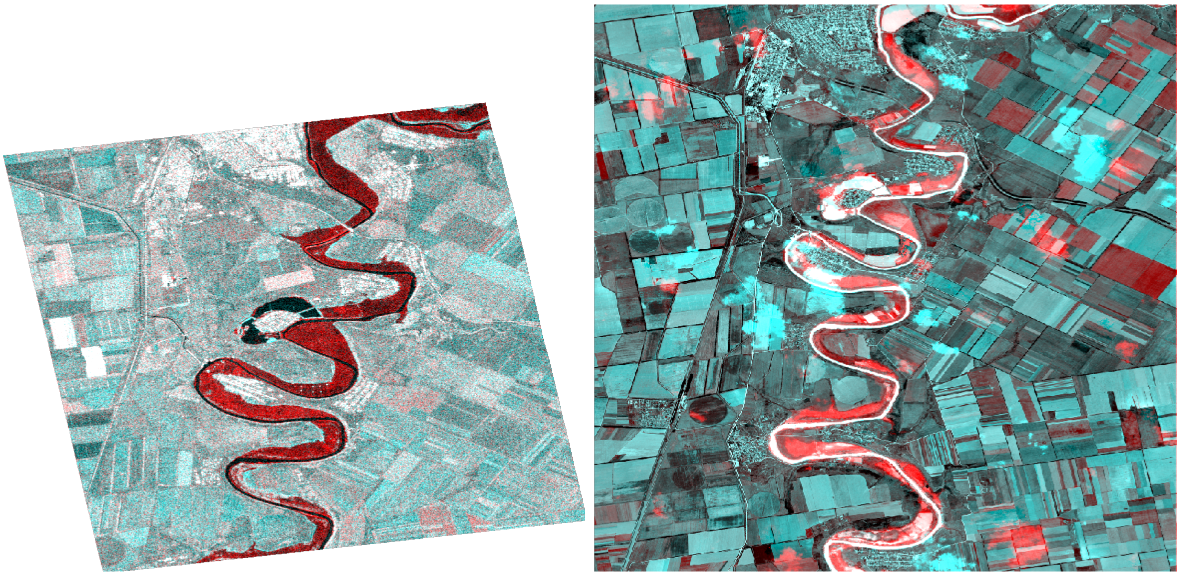
**Flood map general river area (Radar - Optical):**



**(a)** General river area - Radar - (2 and 14 June) **(b)** General river area - Optical - (3 and 18 June)

**Figure 4.8:** Floodmaps of the general river area

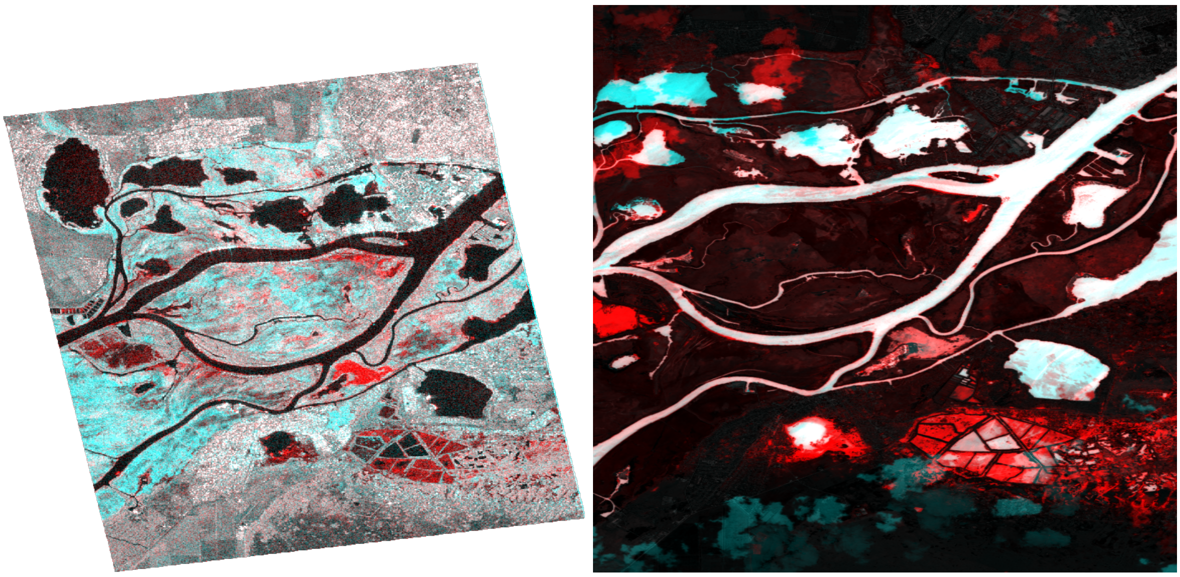
**Flood map Aafassanivka (Radar - Optical):**



**(a)** Afanassivika - Radar - (2 and 14 June) **(b)** Afanassivika - Optical - (3 and 18 June)

**Figure 4.9:** Floodmaps of Afanassivika

**Flood map Hola PRystan (Radar - Optical):**



**(a)** Hola Prystan - Radar - (2 and 14 June) **(b)** Hola Prystan - Optical - (3 and 18 June)

**Figure 4.10:** Floodmaps of Hola Prystan

To understand the images the following must be noted. In the radar images where the water bodies remains the same shape and flooding does not occur, the area appears black while in the optical images those appear white. Furthermore the red colour indicates an increase in water content while the blue colour indicates a decrease in water content. Infrastructure shows to have a rather constant colour of grey/blueish.

# 5
# Discussion and conclusion

Looking at the results it can be seen that radar imaging is preferred for the determination of areas where floods happened as the changes are more obvious and do not suffer from artefacts of the atmosphere. The flooded areas appear dark in a dark red colour indicating a large change in area properties. However care must be taken in the fact that also farm land that is irrigated can appear coloured as well. The optical images are less use full for detection of flooded areas as the atmosphere interfere with the perceived data, as clouds are made of water. Clouds can appear as either red coloured blue coloured based on their presence on different dates. An example of this can be seen in figure 4.8b. By comparing figure 4.3a and 4.3b with their respective processed RGB counterparts in figure 4.8b and figure 4.8a, one can clearly observe the position of the clouds and determine the influence of clouds in the processed images. The optical processed images are therefore hard to interpret. However the optical images can still be use full as we can use them to cross-correlate with the radar images and verify which areas flooded. It is preferred that some sort of atmospheric correction or mask is done to eliminate the influence of clouds. Finally, the radar images should be used for determination while optical images should be used for validation, not vice-versa as the optical images are to unreliable for this.

To conclude Sentinel 1 and 2 provide high resolution data both in terms of spatial resolution and temporal resolution that is use full for analysing the extent of floods after a disaster happened. From this research it can be concluded that radar imaging already provides a very good distinction between land and water and is therefore use full in the generation of flood maps for certain areas. The spectral data can be very use full as a cross-correlation tool but it must be noted that it is very vulnerable for atmospheric interference and must not be used as a determination tool. This research has compared two different dates, one before and one after the destruction of the dam. For further research it would be valuable to compare multiple dates from before and after to obtain a timeline indication of the floods that happened in certain areas. It is also needed that the workflow is extend on certain corrections to allow for more reliable data especially the masking or correction of the atmosphere in the optical data.

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# A
# Extra figures

Some extra images and figures especially on the SWM index.

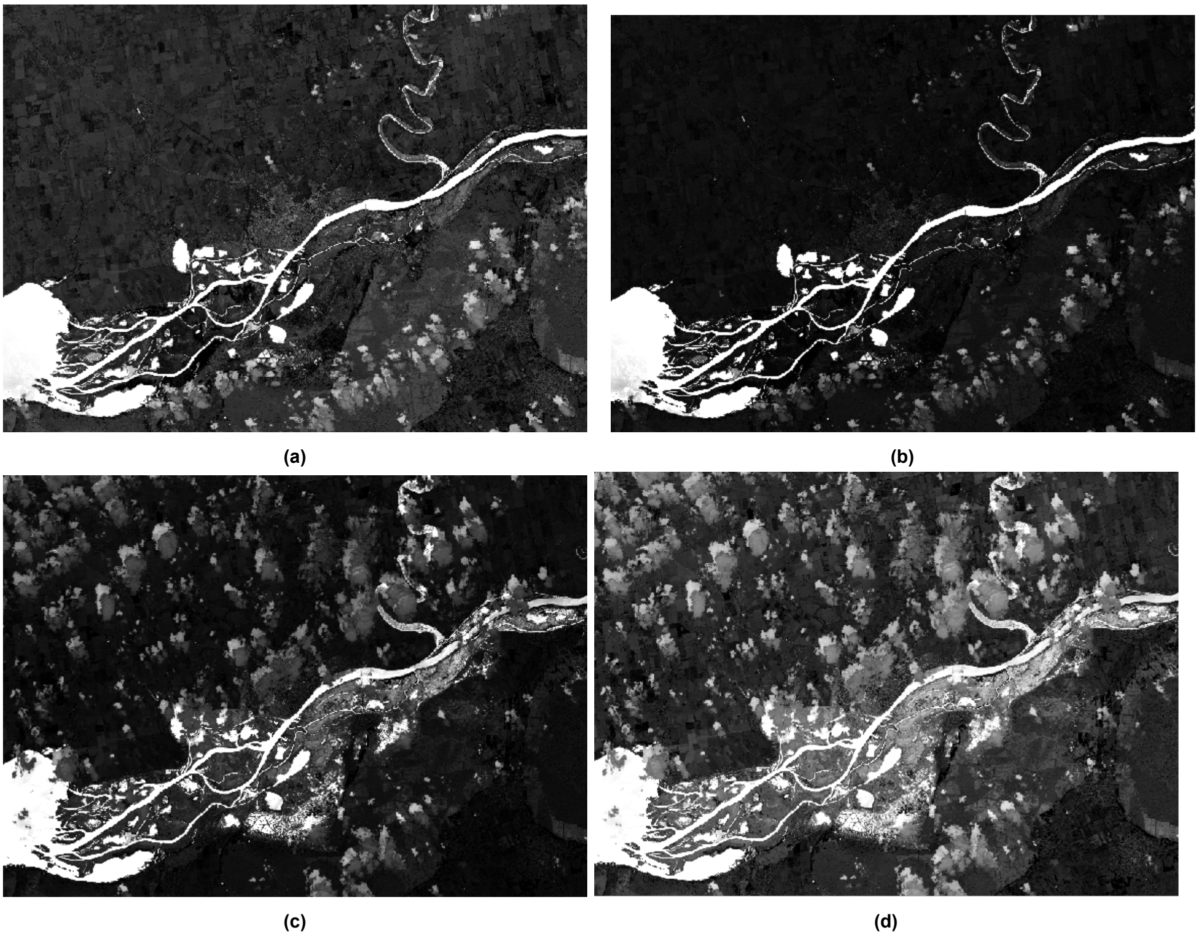

**Figure A.1:** SWM-index images containing the B2-B3-B8-B11 bands - general down river area

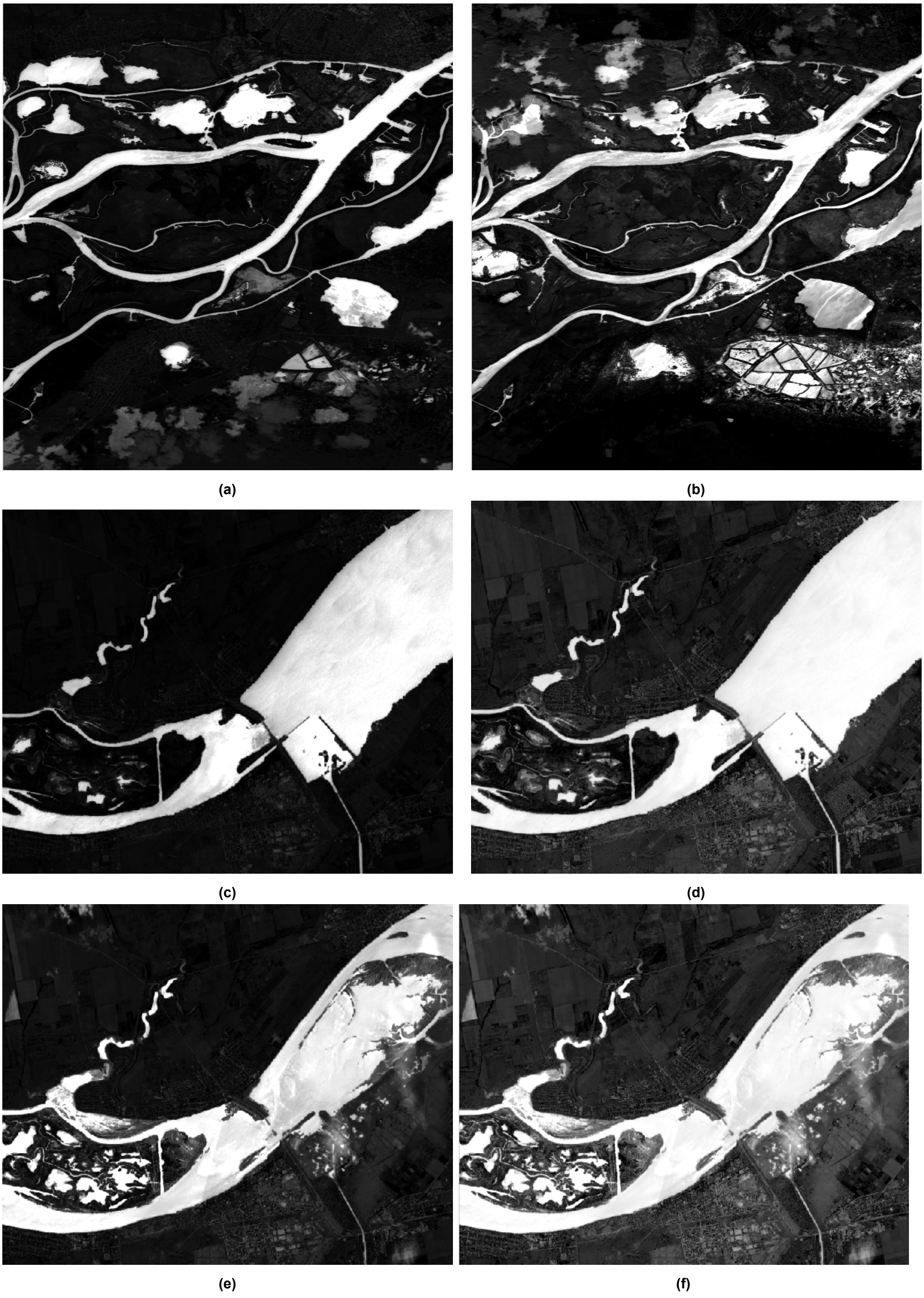

Figure A.2: SWM-index images containing the B2-B3-B8-B11 bands - Holy Prystan and Nova Kachovka dam