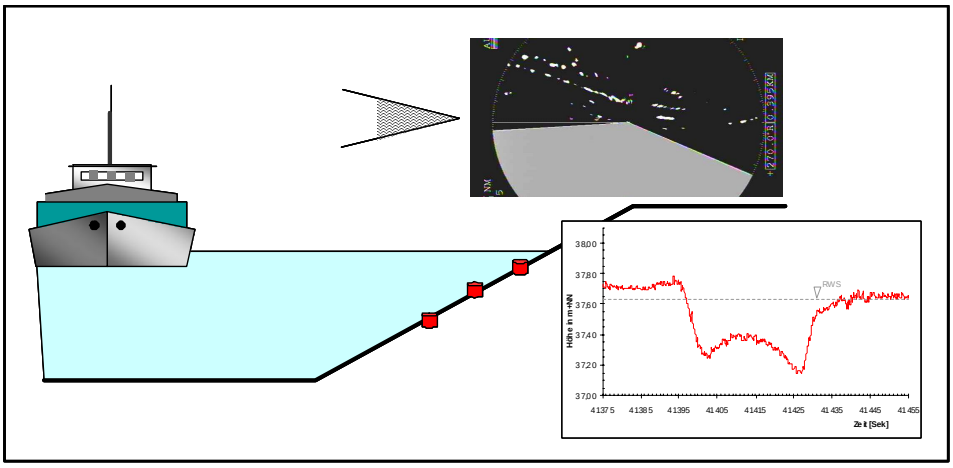
FEDERAL INSTITUE OF HYDROLOGY
Koblenz

FEDERAL WATERWAYS ENGINEERING AND RESEARCH INSTITUTE
Karlsruhe



Examinations of Technical-Biological Bank Protections on Inland Waterways

Information sheet:

Ship-Induced Waves and Flow around the Ship Hull – Measurement and Analysis

R & D – Project
(BAW – BfG)

Effective: ***November 2016***

Content

1. Measurement Task

Profound knowledge of ship-induced hydraulic charges on banks is necessary to choose appropriate alternative technical-biological bank protections. Ship-induced charges as a result of the interaction between ship and waterway cause water-level drawdown, waves and flows. These charges solely occur locally as well as temporarily and are primarily influenced by ship-size as well as ship-draught, ship-velocity and the distance between ship and bank.

The observation of the ship-traffic – also called *field campaign* – is suitable for the purpose of obtaining information about existing ship-fleets and the respective ship-induced hydraulic charges. During such a field campaign, all passing ships – cargo vessels, passenger ships, special vessels and pleasure crafts – are registered comprehensively according to technical data, localisation and velocity as well as hydraulic parameters in order to enable the finding of correlations between navigation-induced hydraulic charges on banks of the considered stretch, bank-stability as well as vegetation and fauna in the respective bank areas. The procedure during a field campaign and the realisation of analyses will be summarised and briefly explained in this paper.

2. Measurement Scope

The following parameters should be measured and registered during field campaigns:

- one-off cross-profiles in the gauging sections to obtain knowledge about the up-to-date condition of the water-body geometry and thus to enable subsequent calculations if necessary
- water-level deviations at the bank to determine the wave height
- vessel-localisation for the determination of bank-distances
- vessel-velocities, e. g. for the comparison between actual and admissible velocities
- vessel-sizes (according to assigned data) and vessel-draughts (according to calibration marks) to determine the cross-section ratio of water-body and vessel
- flow-velocities close to the bank to obtain the return current and wake velocities

A radar-set that is not visible for the steersmen and thus does not influence their way of operating the vessel enables the measurement of the localisations and velocities of the vessels. The vast majority of vessels can also be registered with the aid of cameras and video recorders. In order to establish a preferably large stock of technical data, from cargo vessels in particular, a registration survey comprising vessel-data can be performed at a nearby lock if possible. Figure 1 shows a possible version of a recording form.

ship-registration at the lock | ... name ... | ... river / canal | ... date | BUNDESANSTALT FÜR WASSERBAU Karlsruhe

date	time	direction		type					name	length	width	actual draught		shape of bow		total power		propeller			
		upstream	downstream	cargo vessel (single)	push-tow unit	passenger ship	recreational craft	other				at bow	at stern	pointed bow	blunt bow		acc. to unit	type: unducted	type: ducted	number	diameter
[-]	[-]	[-]	[-]	[-]	[-]	[-]		[-]	[-]	[m]	[m]	[m]	[m]	[-]	[-]	[PS]	[kW]	[-]	[-]	[-]	[m]

× please tick the appropriate box

only fill in if possible

Figure 1 Potential registration form

3. Representative Gauging Section

It is of prime importance to choose a suitable representative water-body cross section for the measuring process. The following aspects have to be considered when choosing the appropriate cross section:

- the cross section is located in a straight water-course where vessels pass with high speed
- the cross section profiles are at hand or can be sounded or surveyed
- it is possible to place all necessary gauges in the cross section
- the cross section is suitable for the measuring with the help of a radar-set

The following part contains the exemplary presentation of two measuring cross sections of the test stretches Stolzenau at the river Weser (built 1988/89) and Worms at the river Rhine (built 2011).

3.1 Gauging Sections of the Test Stretch near Stolzenau / Weser

Literature: (BAW, BfG, 2008)

The gauging sections Weser kilometre 242.040 and Weser kilometre 242.170 within the test stretch but downstream of the groynes were chosen as cross sections of reference and as the place for the positioning of the gauges. In this section, the water-course is nearly straight so that vessels can navigate at a higher speed (cf. figure 2), which leads to higher hydraulic charges on the banks. Vessels can also navigate closer to the river-bank resulting in higher charges as well. Misleading effects caused by the short stubby groynes on the right riverbank are not expected. For the interpretations of the correlation between ship-induced charges and bank stability as well as the settlement of flora and fauna along the banks, the results can also be applied to the test-stretch area with groynes, which constitutes a conservative approach.

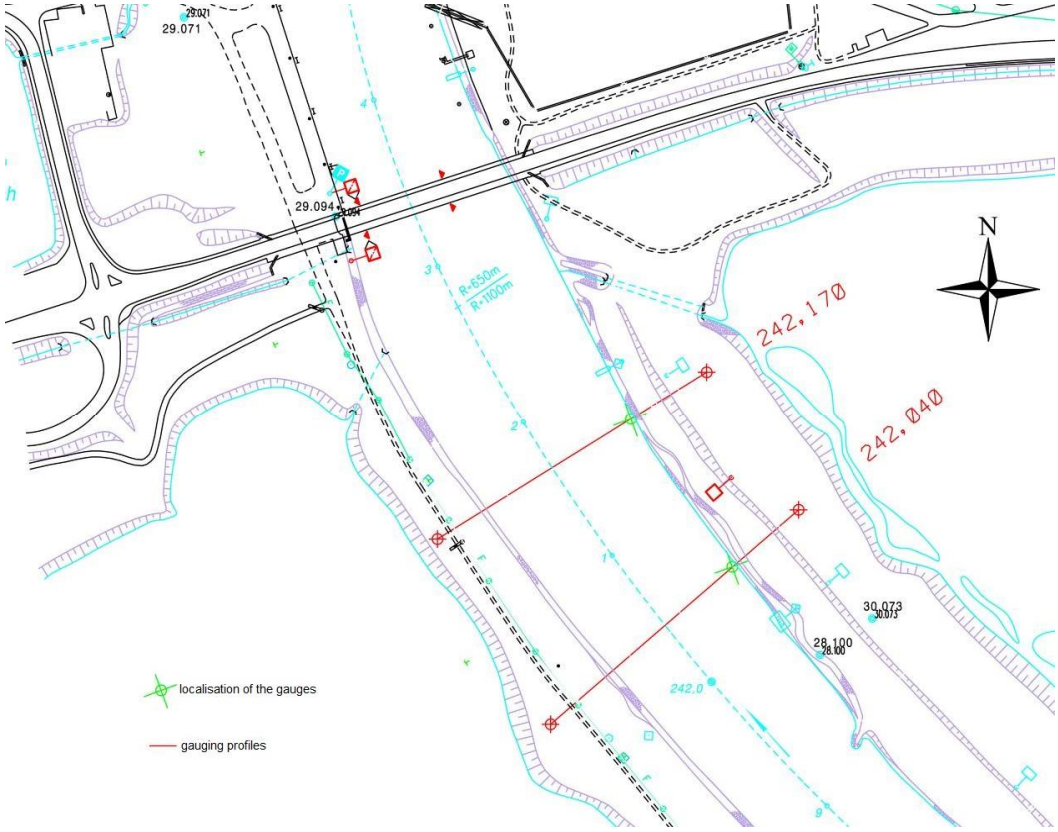


Figure 2 Localisation of the gauging profiles Weser kilometre 242.040 and Weser kilometre 242.170 used for the observation of ship-traffic downstream the test-stretch at the right -bank (BAW, BfG, 2008)

3.2 Gauging Sections of the Test Stretch near Worms / Rhine

Literature: (BAW; BfG, 2010)

The observation of ship-traffic at the river Rhine, near Worms, took place at three cross sections (cf. figure 3). Three equally spread cross sections were located as follows:

- Rhine kilometre 440.6 (gathering vessel-data, wave heights, flow velocities)
- Rhine kilometre 441.1 (gathering wave heights)
- Rhine kilometre 441.6 (gathering vessel-data, wave heights)

The installation of the gauges and the observation of the ship traffic were conducted at the right riverbank in all cross sections. The three cross sections are characterised by different geometrical conditions (undercut slope at kilometre 440.6 and slip-off slope at kilometre 441.6) as well as distinct fairway distances to the right bank (coloured blue in figure 3). This leads to various ship-induced charges on the banks across the test stretch, which can be assessed and taken into consideration on the basis of the observation of the ship traffic for the choice of appropriate alternative technical-biological bank protection measures.

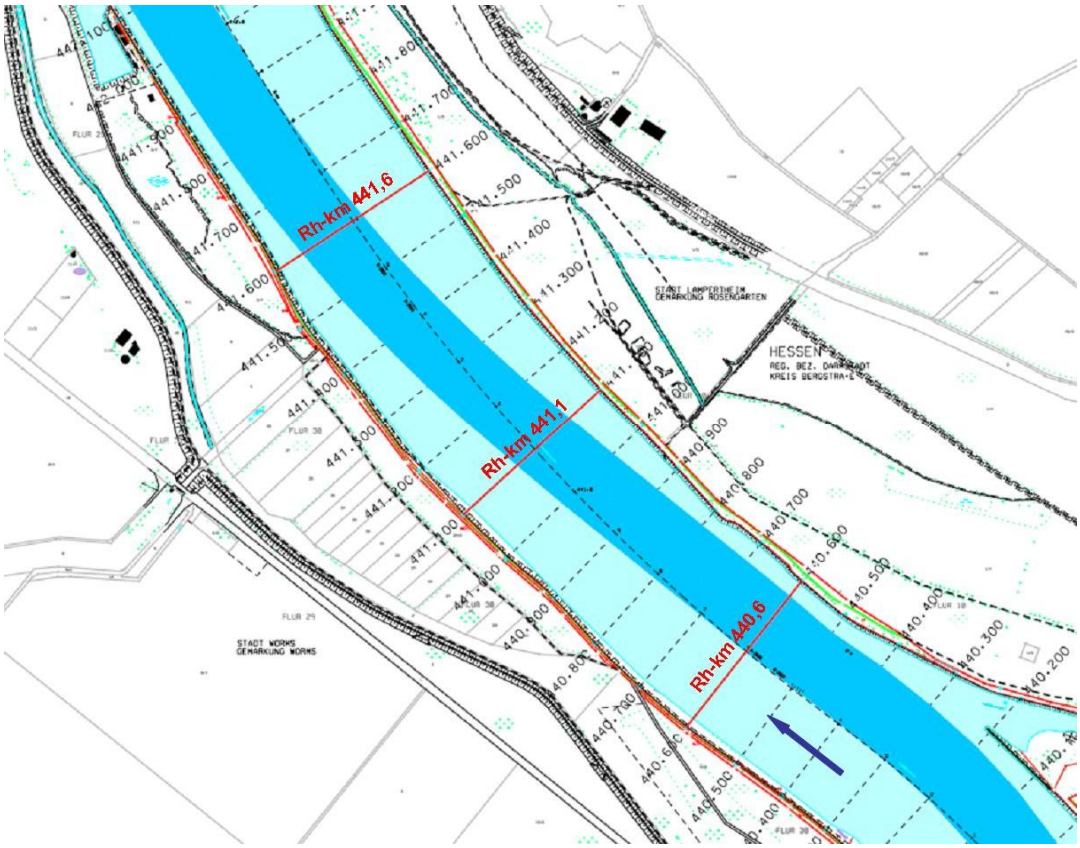


Figure 3 Localisation of the gauging profiles for the observation of ship traffic at the Rhine test stretch near Worms (BAW, BfG, 2010)

4. Gauges

The following chapter entails a short presentation of the gauges that were used.

- **digital radar coverage system**

A high resolution radar-system that is not visible for the ship traffic – placed in a tent or on a lorry (figure 4) – is used to gather ship-data such as vessel velocity and distance to the bank. The radar screen in figure 5 shows a passing cargo-vessel.

Figure 4 Radar-system in a tent (left picture, test-stretch Stolzenau/Weser) and on a lorry (right picture, test-stretch Worms/Rhine)

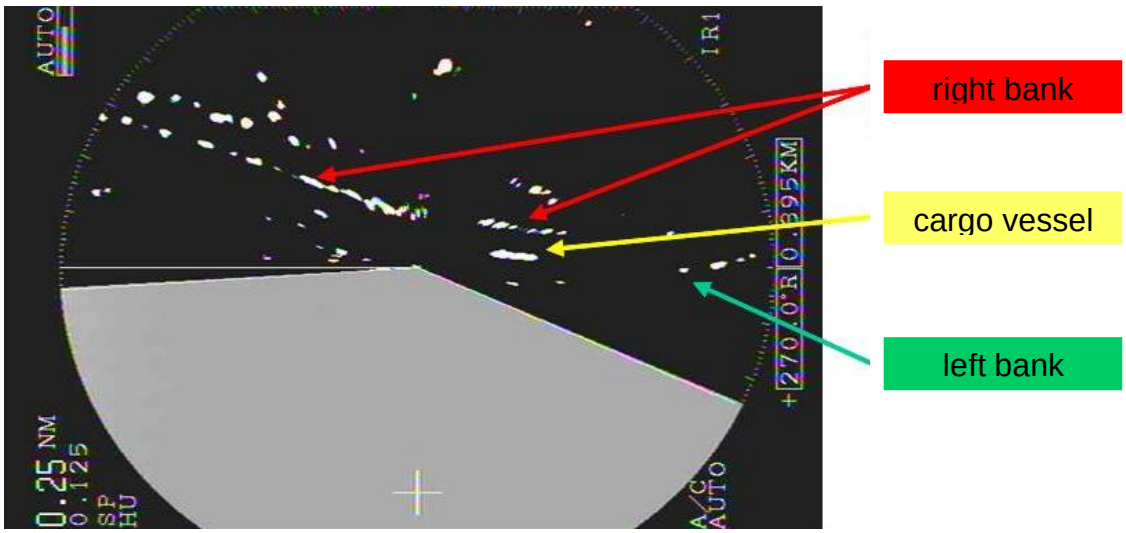


Figure 5 Radar-screen with passing cargo-vessel in downstream traffic (test-stretch Stolzenau/ Weser)

- **wave** gauges

At each cross-section, the ship-induced water level deviations are measured with two pressure measuring-probes (double measurement acquisition for the purpose of gathering data in case of electricity failure; internal power supply and data logger; measuring frequency 2, respectively 4 Hz). The measuring probes are placed 0.5 to 1 metre below water level (on the day of installation) in order to avoid a failure of data acquisition due to probe emergence. In case of the test stretch near Worms Rhine, three pairs of gauges were installed in different depths (approx. 0.5m, 1.0m and 1.5m below water surface). A barometrical pressure transducer was installed landwards to determine absolute pressure values. In order to maintain their position, the measuring gauges were attached to the bank with the aid of lead weights and chains.

A further wave measuring device is the AWAC ultra-sonic measuring probe (measuring frequency 4 Hz, power supply through externally attached battery). This probe captures the pressure using a piezo-electric pressure measuring probe, the orbital velocity by use of ultrasonic sensors and the water level surface through a so called Acoustic Surface Tracking (AST). The AWAC is placed vertically at the slope with the help of a concrete base.

- **velocity gauge**

A velocity probe, property of BAW, is used to provide data about the spatial flow velocity in areas close the bank (ADV probe, made by NORTEK, type VECTOR; acoustic Doppler procedure, measuring frequency 4 Hz). The mounting instructions of the wave probes apply for the installation depth of the flow probes as well.

- **ADCP gauge**

An Acoustic Doppler Current Profiler (ADCP) is used to determine the flow velocities. The ADCP is placed on a lowerable bracket that is attached to a survey boat and measures the perpendicular velocity profile in short intervals, the velocity of the boat above ground and the water depth.

For the purpose of discharge measurement, the gauging passages have to be conducted multiple times (i.e. four times, profile-passage at a slow velocity) in a single profile in order to guarantee reproducibility and thus precise data.

- **determination of position and height**

All determinations of position are provided by DGPS (measuring probes, survey boat).

- **survey boat**

The survey boat (length/width/depth: 5.1m/1.86m/24cm) is used for the sonar bearing. Additional passages conducted prior to the field campaign serve as a means of graphic rectification of the radar images.

5. Gauging procedure

For the purpose of observing a sufficient number of vessel-passages and establishing a substantial vessel-statistic, the observations of the ship traffic have usually been performed in a period of seven days. The choice of period for the measurements is mostly scheduled according to relevant water levels or according to busy times based on long-term ship-statistics. Depending on the lightning conditions, the daily observation period lasts generally from 6am until 8pm.

The installation and the removal of measuring gauges is usually conducted in co-operation with assigned engineering offices, BAW and the respective waterways and shipping office (German abbrev.: WSA) or a subordinated field office (German abbrev.: ABZ)

The position of the radar-system and of the hectometre-stones is measured via DGPS as a basis for the spatial rectification of the radar image. As a reference passage, the lane of the survey boat is recorded by means of both the DGPS and a radar image sequence.

For each passing ship, the following data set is gathered during the observation of ship-traffic,

> **date**, **time**, **name of the ship**, **direction**, **vessel-length**, **vessel-width**, **vessel-type**, **maximal tonnage** and, if visible, bow and stern **draught**.

Thanks to the personal of the local locks and district control units, it is mostly possible to gain further information on the vessels. These include:

> **date, time, name of the ship, direction, vessel-length, vessel-width, vessel-type, maximal tonnage, draught** according to calibration marks located at the bow and stern, **engine power, propeller number, power of the bow thruster, bow shape**

During the passage of pleasure crafts, it is often not possible to determine their length, width and draught: therefore, it is necessary to estimate these parameters. Photographic and video documentation of the passage of a pleasure craft proved to be very helpful at this point.

Discharge measuring, if conducted during the traffic observation, should be reiterated in regular intervals in order to include discharge changes occurring during the measuring period into the final analysis.

6. Analyses

The assigned engineering office compiles a final report on the observation of the traffic based on the available data. The report entails a description of the situation, the dimensioning technology used during the field campaign as well as the gauging procedure. The report also contains specific analyses and results.

After the processing of data, the next step includes the evaluation of radar images (vessel velocity and distance to the bank), wave height and flow velocities. Wave heights can be determined visually based on already processed data sets.

Figure 6 shows exemplary data and the respective analysis from the above mentioned traffic observation on the Rhine near the town of Worms.

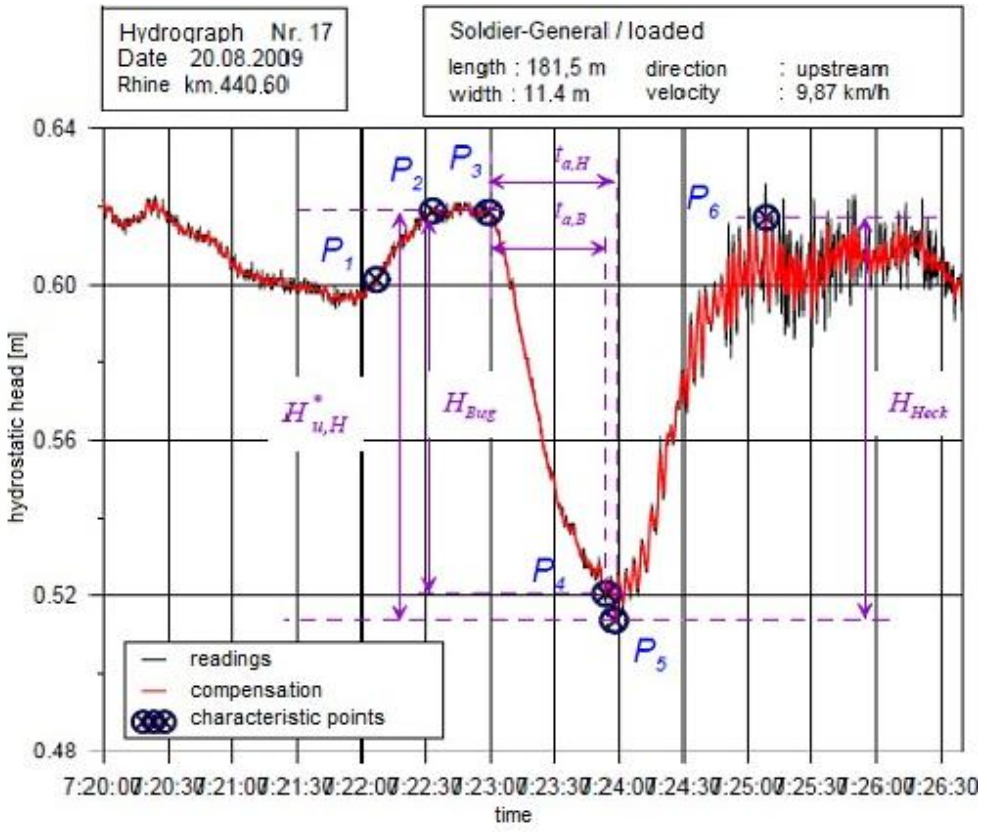


Figure 6 Hydrograph with waves during traffic observation on the Rhine near Worms with characteristic points for further analysis

The reading pairs have been picked up as follows:

- ***P₁*** corresponds with the water depth of the still water level prior to the wave event. This particular water level was determined visually and was usually picked 1 to 3 minutes prior to the ship passage.

- P_2 corresponds with the water depths of the maximal water level increase prior to the ship passage.
- P_3 corresponds with the water depth during the water level drawdown at the transition from a small gradient to a larger one
- P_4 corresponds with the water depth of the maximal water level drawdown at the bow section of the vessel.
- P_5 corresponds with the maximal water level drawdown at the stern section of the vessel. P_4 and P_5 have been picked as identical pairs of value in case of a single depression.
- P_6 corresponds with the water depth of the maximal water level increase after the ship passage.

For the final report, the obtained data should be further analysed statistically according to the following aspects:

- fleet structure
- vessel velocities
- distances to the bank
- wave heights
- flow velocities
- cross sections and longitudinal profiles

7. Literature

(BAW, BfG, 2010) Bundesanstalt für Wasserbau, Bundesanstalt für Gewässerkunde
Bericht Versuchsstrecke Text 31.03.2010
F & E – Projekt (BAW – BfG)
Eigenverlag, Karlsruhe 2010

(BAW, BfG, 2008) Bundesanstalt für Wasserbau, Bundesanstalt für Gewässerkunde
Untersuchungen zu alternativen technisch-biologischen Ufersicherungen an Binnenwasserstraßen
Teil 2: Versuchsstrecke Stolzenau / Weser km 241,550 – 242,300
F & E – Projekt (BAW – BfG)
Eigenverlag, Karlsruhe 2008