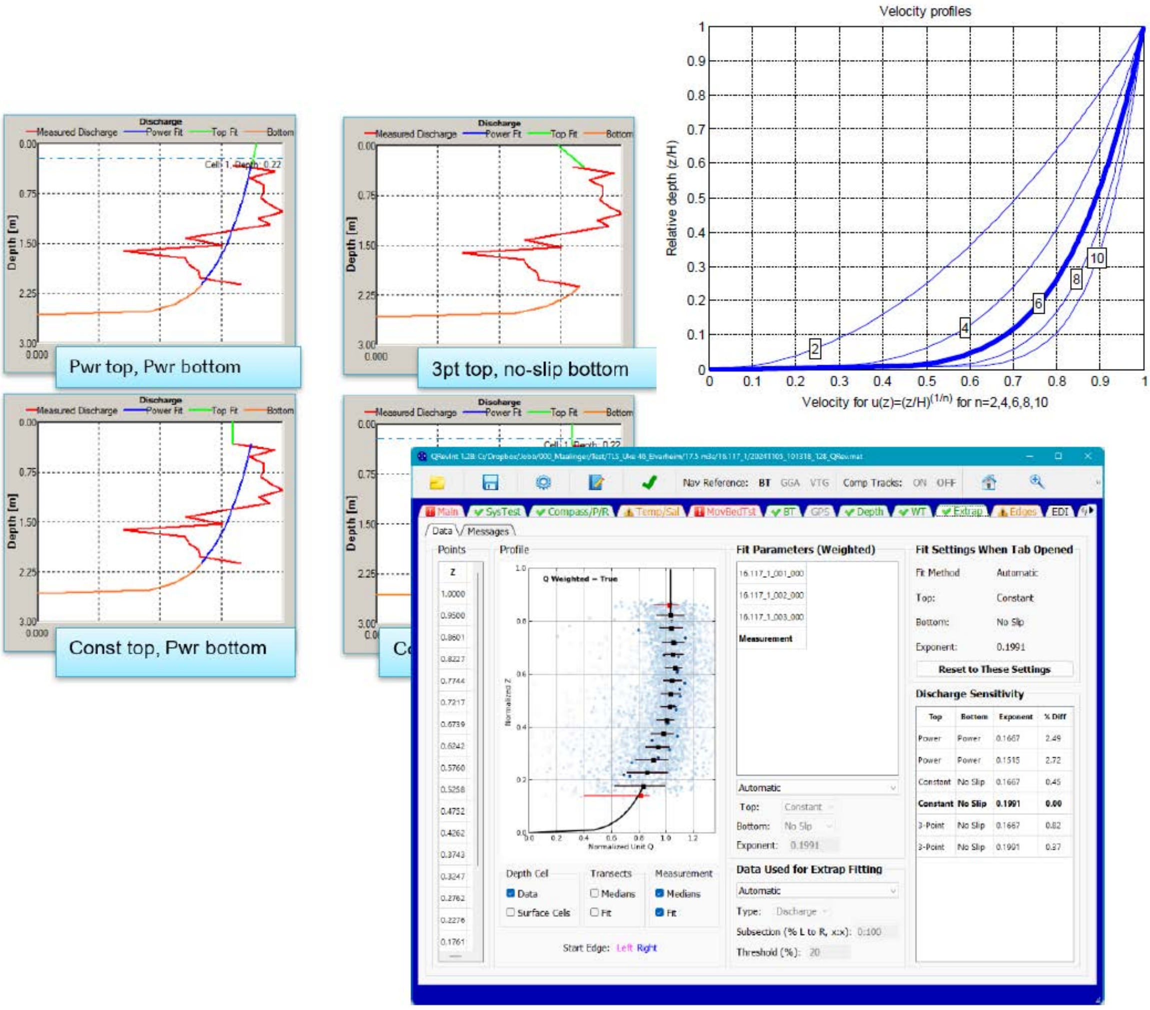


# The impact of using Extrap and Qrev software on ADCP measurements in Norway

RAPPORT NR 22 / 2026

SKREVET AV Kristoffer Florvaag-Dybvik

# THE IMPACT OF USING EXTRAP AND QREV SOFTWARE ON ADCP MEASUREMENTS IN NORWAY

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Sammendrag:

Rapporten viser hvordan innføringen av Extrap/Qrev har endret prosessering av ADCP-målinger i Norge og påvirket beregnede vannføringsverdier. Overgangen fra standard én-sjettedels ekstrapolering til metoder basert på observerte hastighetsprofiler har gitt mer fysisk realistiske estimater. Analysen viser en systematisk, men moderat reduksjon i beregnet vannføring, typisk 1–2 % samlet og 3–6 % i små, grunne elver.

Endringen bør dokumenteres og tas hensyn til ved revisjon av vannføringskurver, trendanalyser og sammenligning av historiske og moderne dataserier.

Emneord: ADCP, Constant/No-slip, Cross section, Discharge, Extrapolation, QrevInt, Power law, River Surveyor Live, WinRiver, WinRiver II, Velocity distribution, Vertical velocity profile

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*I NVE bruker vi kunstig intelligens til bearbeiding av tekst og analyse av data. Innholdet er kvalitetssikret av forfatteren og NVE står ansvarlig.*

Juni, 2026

# Short summary

This report evaluates how the introduction and increasing use of Extrap/Qrev software has changed the extrapolation of ADCP-based discharge measurements in Norway, and how this affects calculated discharge values used by NVE (The Norwegian Water Resources and Energy Directorate) for rating curves, statistics, and hydrological analyses. The study compares historical ADCP processing practices with current methods and quantifies the resulting differences in reported discharge.

An ADCP (Acoustic Doppler Current Profiler) cannot measure all the way to the surface and to the riverbed, so during the processing data must be extrapolated. Historically, most ADCP measurements were processed using the default one-sixth power-law extrapolation, regardless of river conditions. Since the introduction of Extrap (from 2013-2015) and its mandatory use through Qrev (from 2018) or QrevInt, it has become easier to choose extrapolation methods based on observed velocity profiles. This has led to a major shift in practice: Default extrapolation has largely been replaced by constant/no-slip or power-law methods with fitted exponents, with strong variation between ADCP instrument types and cross-section characteristics.

Analysis of several thousand measurements shows that this methodological change has introduced a systematic but moderate reduction in calculated discharge. Across all instruments and rivers, the median discharge decreases by approximately 1–2% compared with historical default processing. The largest reductions (typically 3–6%) occur in small, shallow rivers, particularly when constant/no-slip extrapolation is applied. Larger and deeper rivers show smaller effects.

The change does not reflect a loss of data quality; rather, it represents a move toward more physically realistic and defensible discharge estimates. However, the shift potentially creates a structural break between historical and modern data series. The report concludes that Extrap/Qrev improves methodological accuracy but introduces a systematic change. This impact must be clearly documented and considered when revising rating curves, analysing long-term runoff trends, or comparing discharge data across time.

(*This summary is written by Copilot but controlled and edited by the author*)

# Short summary (in Norwegian)

**Kort sammendrag**

Denne rapporten viser hvordan innføringen og den økende bruken av programvaren Extrap/Qrev har endret ekstrapolering av ADCP-målinger i Norge, og hvordan dette påvirker beregnede vannføringsverdier som brukes av NVE i vannføringskurver, statistikk og hydrologiske analyser. Studien sammenligner historisk praksis for ADCP-prosessering med dagens metoder og kvantifiserer de resulterende forskjellene i rapportert vannføring.

En ADCP kan ikke måle hele veien til overflaten eller bunnen, så i prosesseringen av ADCP-målinger blir data ekstrapolert. Historisk sett ble de fleste ADCP-målinger prosessert ved bruk av programmet WinRiver sin standard «én-sjettedels potensfunksjon-ekstrapolering», uavhengig av forholdene i elva. Siden innføringen av Extrap (fra 2013–2015) og obligatorisk bruk av Qrev (fra 2018) eller QrevInt, har det blitt enklere å velge ekstrapoleringsmetoder basert på observerte hastighetsprofiler. Dette har ført til et skifte i praksis: Standard ekstrapolering er i stor grad erstattet av constant/no-slip-ekstrapolering eller potenslov-metoder med tilpassede eksponenter, med betydelig variasjon mellom ulike ADCP-typer og egenskaper ved tverrprofilene.

Analyse av flere tusen målinger viser at denne metodiske endringen har introdusert en systematisk, men moderat reduksjon i beregnet vannføring. På tvers av alle instrumenter og elver reduseres median vannføring med om lag 1–2 % sammenlignet med historisk standardprosessering. De største reduksjonene (typisk 3–6 %) forekommer i små, grunne elver, særlig når constant/no-slip-ekstrapolering benyttes. Større og dypere elver viser mindre effekter.

Endringen reflekterer ikke redusert datakvalitet. Snarere representerer den en overgang til mer fysisk realistisk og faglig bedre funderte vannføringsestimater. Likevel kan skiftet innebære et brudd mellom historiske og moderne dataserier. Rapporten konkluderer med at Extrap/Qrev gir bedre metodisk nøyaktighet, men at det introduserer en systematisk endring. Effekten må dokumenteres tydelig og tas hensyn til ved revisjon av vannføringskurver, analyser av langsiktige avrenningstrender og sammenligning av vannføringsdata over tid.

(*Dette sammendraget er skrevet av Copilot, men kontrollert og redigert av forfatteren*.)

# Contents

# 1 Introduction

For decades, NVE's hydrometrists used mechanical current meters or the salt dilution method to measure discharge. From 1995 and onwards, various ADCPs (Acoustic Doppler Current Profilers) have taken over for the current meter on most gauging stations where the current meter had been used historically. From 2010 and onwards a new tool (USGS' Extrap software) became available to assist in post processing ADCP measurements in a more correct way. This led to a shift in how we processed data, and in the discharge values we store from the ADCP measurements.

We use values for measured discharge and corresponding stage (water level) to build a rating curve for each station. The rating curve is a mathematical relationship between stage and discharge.

NVE collect and store stage from our gauging stations, not discharge. Data users often need discharge time series, and our systems combine the rating curve and the stage time series to calculate and report discharge time series on the fly.

The rating curve is revised on an irregular basis, depending on observations. If we revise a rating curve using biased(*) discharge measurements, we risk introducing a shift in the time series for discharge.

*(*) The word <u>biased</u> in this respect means data from ADCP measurements that are processed so that the results are systematically different than they were previously*

## 1.1 A very brief history of changes

There have been several changes in the methods NVE have used to measure discharge. If we only include velocity/area methods:

- Current meter (Mechanical)
    - Manual method, typically five points per vertical to describe velocity profile as well as possible, calculations using millimetre scale paper.
    - "Flygel.exe". Old software, in use until 2004. This was a Norwegian version of a Swedish software. Five points per vertical. Software mimics the hand drawing method. It was probably in use from the late 1980s.
    - "Vinge", a more recent software, written in Denmark. This software uses the mid-section method and the reduced points method in ISO 748. Vinge was in use from 2006 and onwards, and it is still to a limited degree.
- Sontek Flowtracker uses the same calculation method as Vinge, and it has been in use to a limited extent from around 2005.
- Various ADCPs
    - Mainly using default vertical extrapolation, 1995-2010
    - Mainly *<u>not</u>* using default vertical extrapolation after 2010

Current meters, ADCPs and Extrap/Qrev software

When we started using ADCPs, and for many years, the ADCP was thought to perform better than the current meter, since it measures more of the cross-section. But the current meter methods are very robust when it comes to estimating the vertical mean velocity, at least as long as they are "nice theoretical" velocity profiles. Se the figure below. It shows the ratio of the true mean velocity to the calculated mean velocity for a vertical or section as it would be when using a point velocity meter and calculating the mean velocity using the reduced points methods in ISO 748. The figure only shows the ratios for “perfect” power law velocity profiles (Eq. 1 below), and for these, unless they are too close to a straight line (n close to 1) the calculated mean velocities are very close to the true mean velocities. The 0.5*(0.2/0.8) mean velocity is always closer than 1% from the true mean. The one-point method need n>3 to measure less than 2% from the true mean. NVE only use the one-point method if depth is less than 30 cm.

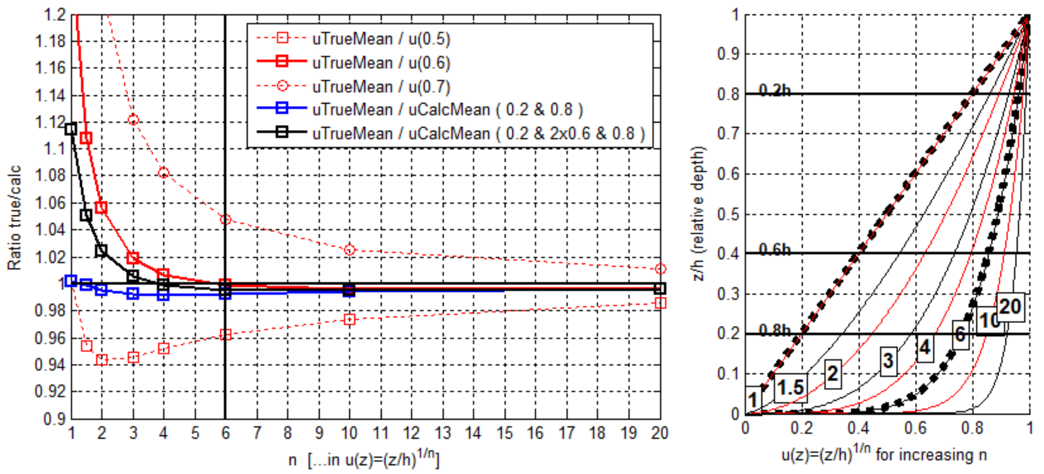



**Figure 1.1 Mean velocity from point velocities**

Un-published NVE-studies show that on average, there is no systematic difference when comparing discharge from current meter measurements and ADCP measurements. These, however, were made before we started using Extrap/Qrev to find the best extrapolation method for the ADCP measurements. This extrapolation is key to calculate ADCP discharge.

An ADCP (Acoustic Doppler Current Profiler) measures boat speed, water depth and water velocities to calculate discharge. It measures these approximately once per second as the ADCP traverses the river. One set of water depth, boat speed and water speed is called an ensemble. One crossing of the river is called a transect. A transect typically last for at least 3 minutes, and a complete discharge measurement consists of at least four transects.

An ADCP cannot measure water velocities all the way to the banks, to the surface and to the bottom due to physical limitations. To calculate discharge, the software must extrapolate the velocities in the un-measured regions. This study only deals with the extrapolation to the top and to the bottom. See Figure 1.5.

Software from the manufacturers by default use the theoretical power law vertical velocity distribution to extrapolate data to the surface and to the bottom. The velocity distribution can be expressed as

**Eq. 1** $$\mathbf{U(z) = C\left(\frac{z}{H}\right)^{1/n}}$$

C and n are constants. H is total depth, and z is distance from the riverbed. The value of C determines the magnitude of the velocities in the theoretical profile, or equivalently, C is the surface velocity since z/H=1 at the surface. The value of n sets the shape of the profile. See Figure 1.2! The default value for n is 6 but it can be altered by the user. The velocities are extrapolated to the surface and the bottom ensemble by ensemble. C is calculated by saying that the mean of measured velocities and U(z) shall be equal for the range where there are measured velocities. The shape of the power law function is very similar to the logarithmic velocity profile in turbulence boundary layer theory.

The manufacturers often express the equation slightly differently, with a constant k that includes C and depth, and with the exponent expressed as N=1/n.

**Eq. 2** $$\mathbf{U(z) = kz^{\boldsymbol{N}}}$$

The default value for N is 1/6 and it is rounded to 0.1667. Extrapolation using the default method is often referred to as "one sixth power law extrapolation". When processing a measurement, the user can change the value of the exponent and choose between the following methods to extrapolate data:

- To the surface
  - Power (top) to extend the power law function to the surface
  - Constant (top) to choose a constant value from the topmost measured velocity to the surface.
  - 3-point (top) to fit a straight line through the 3 topmost measured velocities
- To the bottom
  - Power (bottom) to extend the power law function to the riverbed
  - No-slip (bottom) to use a power law curve from the lowermost measured velocity to the riverbed. (Some use the mean of the 3 lowermost)

See Figure 1.3!

To choose the best extrapolation method, the users previously only had plots like Figure 1.3 to decide which method to use. It was an option in some software to average several ensembles ("verticals") to average out some of the noise. But for many rivers, it was not possible to average over a large enough section of the river to get rid of enough noise and to see clearly what the vertical velocity profile looked like. We should not average over a section of the river with different depths, since only bins at the same distance from the surface are averaged together. If depths are too different, this would have averaged velocities from different relative depths, and they do not belong together. In addition, if the velocities changes across the river, and they do, then averaging them together does not make sense when the aim is to find the shape of the vertical velocity profile.

In Eq. 1 the constant C is the surface velocity, since z/H=1 at the surface. If we divide both sides by the surface velocity C and by the depth H, we will get relative distance from the bottom (z/H) instead of distance (z) and relative velocity (U/C) instead of velocity. This means that Eq. 1 can be re-written using relative velocities and relative depths:

**Eq. 3** $$\boldsymbol{U_r(z_r) = {z_r}^N}$$

$U_r$ is the relative velocity u(z)/U(surface) and $z_r$ is the relative depth z/H, where z=H is depth for an ensemble, and u(H) is the surface velocity. N =1/n.

If the shape of the vertical velocity profile is the same across the river, plots of relative velocity versus relative depth from the *entire* river will plot on top of each other and form a point cloud that tells us the shape of the vertical velocity profile for the river.

A very similar approach was utilized by USGS Software Extrap, which was first released in 2010. Extrap plots relative water speed, or unit discharge[1], versus relative depth. It also calculates the median values for velocities at 5, 10, 15,…,95 percent of the relative depth, and suggests which extrapolation method to use. Extrap is included in USGS' open source Qrev software, and in QrevInt which is the international branch of Qrev.

See Figure 1.4.

## 1.2 Aims for this study

Like described previously, an ADCP cannot measure water velocities all the way to the banks, to the surface and to the bottom. To calculate discharge, the software must extrapolate the velocities in the un-measured regions. This study deals with the extrapolation to the top and to the bottom.

Soon after we started using Extrap/Qrev we started noting how choice of extrapolation method changed, and we suspected that this would change the calculated discharge for ADCP measurements systematically. Several initial studies were conducted. This report repeat and expand the initial studies, utilizing a larger dataset consisting of previous and present subsets of data. The aim is to answer these questions:

1. Which data sources do we have and how do we combine/merge them?
2. To which extent have we used the different instruments and methods?
3. What kind of extrapolation did we use before Extrap/Qrev and what do we use now?
4. How do river/cross-section characteristics affect choice of extrapolation methods? ("What kind of extrap where?")
5. If there is a change in extrapolation methods, how does it affect the calculated discharge?
6. How do river/cross-section characteristics affect change in calculated discharge?

[1] Magnitude of vector cross product of boat speed and water speed divided by median value and not by surface value. Plotting the cross product is equivalent to plotting water speed (D.S. Mueller / Computers & Geosciences 54 (2013) 211-218)

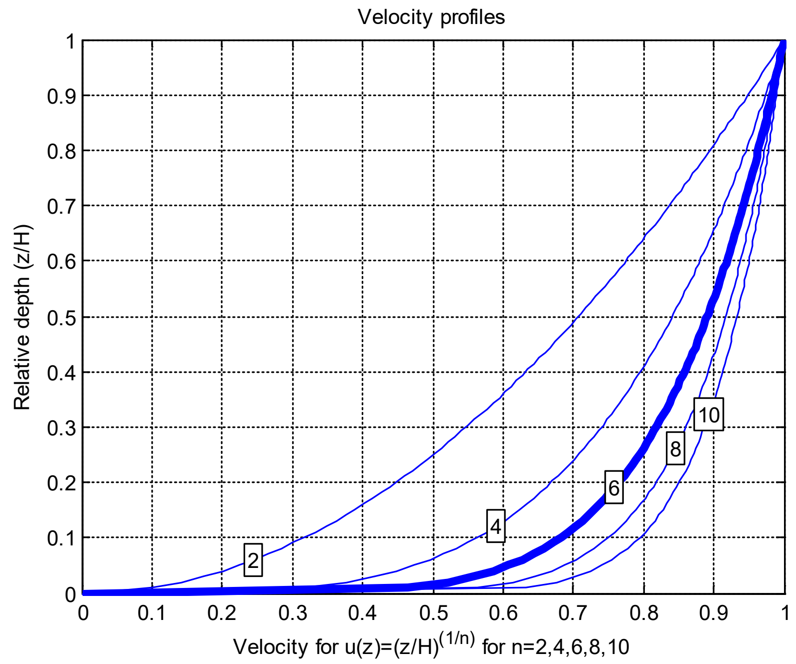



Figure 1.2 Power law velocity profiles

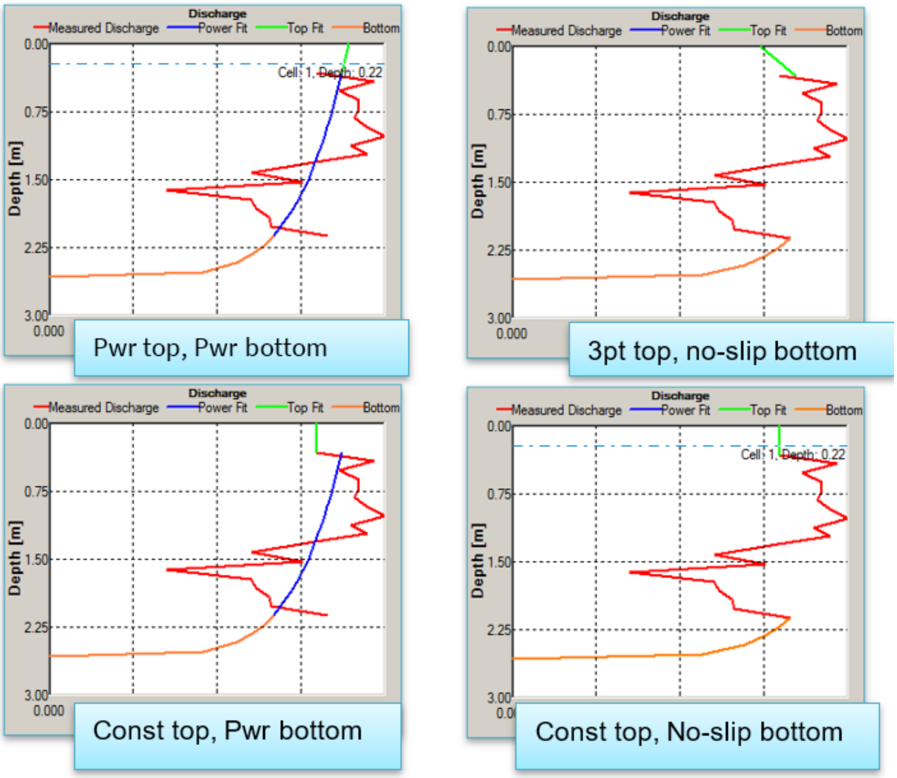



Figure 1.3 Different extrapolation methods

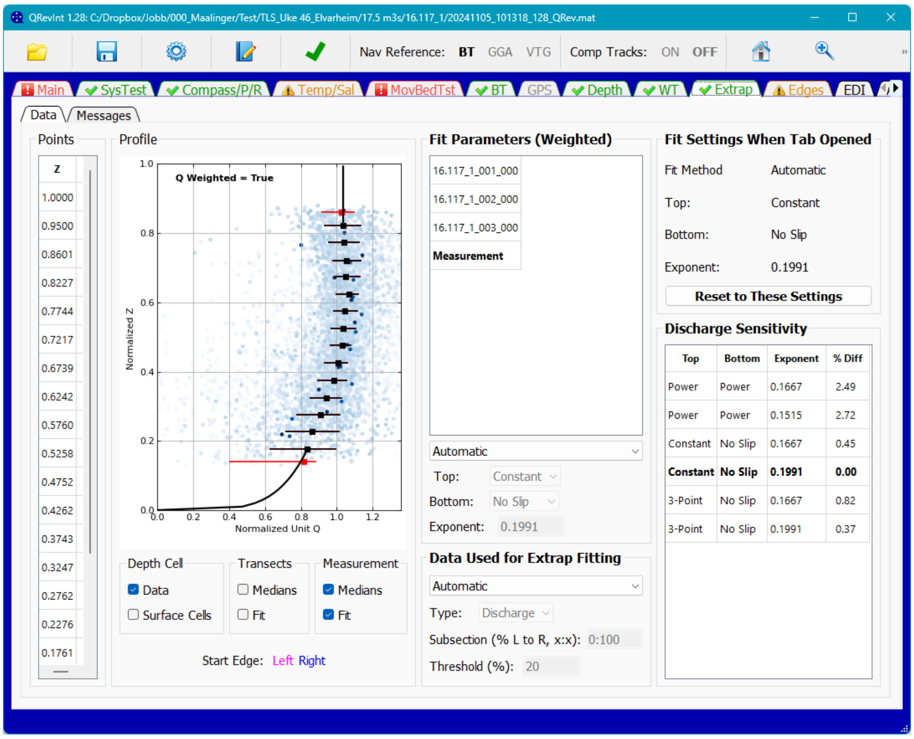



Figure 1.4 Extrap (in QrevInt)

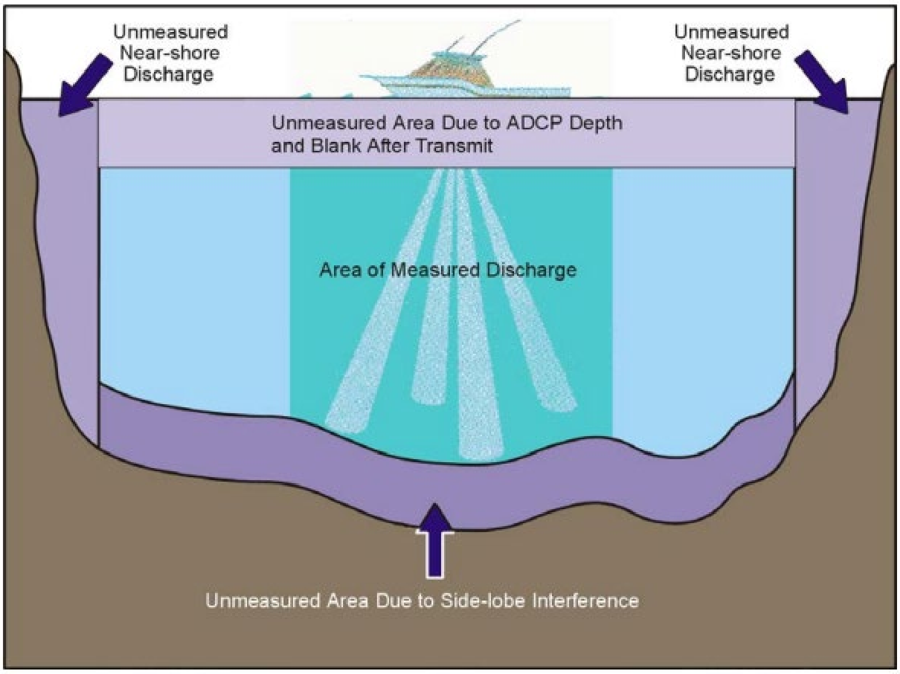



Figure 1.5 Un-measured areas close to surface, bottom and edges (Figure: TRD WinRiver II Software User's Guide 2018)

## 1.3 Terminology/wording

Terminology, nomenclature, choice of words. This report uses the words and abbreviations we usually use in hydrometry.

- Bias. The phrase *biased data* strictly means that the mean or median in a dataset is systematically different from a *true* value, but bias can also mean a systematic change in data if we think of “before” as the truth or the benchmark. In this report *bias* and *systematic change* is used interchangeably.

- For the various extrapolation methods, see the terms in the list below.

  - Top extrapolation, extrap top, surface extrapolation:
    The choice of method to extrapolate from the topmost measured velocity to the surface
  - Bottom extrapolation, extrap bottom, bottom extrapolation:
    The choice of method to extrapolate from the lowermost measured velocity to the bottom
  - Power/power, pwr/pwr, PP, power law:
    Top and bottom extrapolation using the power law velocity distribution
  - Power/power/0.1667, pwr/pwr/0.1667, PP1667, default, default extrapolation, 1/6 power law, one sixth power law:
    Same as above, using 1/6 (0.1667) as the exponent.
  - Constant/no-slip, const/no-slip, CNS:
    Top extrapolation using a constant value and bottom extrapolation using the no-slip option.
  - 3-points/no-slip, 3pt/no-slip:
    Top extrapolation using a straight line through the3 topmost measured velocities and bottom extrapolation using the no-slip option.

# 2 Data collection

Data from ADCP measurements are stored in datafiles and in NVE's database Hydra2. Historically, only basic data was saved in the database, with limited additional information (metadata). During the past 10 years, the amount of additional information has expanded gradually. In addition, for many discharge measurements, we have ADCP-reports stored as pdf-files, excel-files or printed and stored in our physical archive. These reports, and in particular the printed reports, are not easily accessible for analyses. We also have "shadow databases" containing additional information.

The timeline in this chapter is based on emails, our internal documentation (HydWiki) and the author's memory.

The initial investigations utilized a dataset where the field hydrologists had entered data in an Excel spreadsheet manually. Data was collected from January to October 2014, and it contained data from 209 measurements. The data included choice of extrapolation method, and discharge calculated using the default extrapolation and using the selected extrapolation method.

The initial investigations revealed a need for a larger dataset. We automated the collection of data as much as possible, to avoid too much extra work for our colleagues.
For many years, we had used an Excel file/template to generate reports. We copied data into the report from WinRiverII's F12 summary window. We modified this report in 2014. The new report had macros that read WinRiverII mmt datafiles. From June 2015 we included a wizard that guided the field hydrologists to load datafiles created after two, three or four levels of processing. The first step was optional: To load data from the original datafile. That is, the file generated when collecting data in the field, regardless of software version being used. The second step was to read in un-processed data after opening and re-calculating the measurement using the most recent version of the software. This step was also optional, and we only asked for it if data was not collected using the most recent software (TRDI WinRiverII or Sontek RSSL).
The third step was required: To reprocess data using the most recent software and to apply all post-processing steps except changing the extrapolation. The fourth and last step was to use Extrap to find the correct extrapolation and to apply it to the measurement. This was, naturally, also required.
Even if a lot was automated, the use of the report meant extra work for the field hydrologists since they had to either skip back and forth between WinRiverII and the Excel-report, or they had to make 4 (at least 2) different mmt-files for the macro to read. The macro-versions of the ADCP-report wrote data and metadata from the measurements to a shared background excel file, and this file became a "shadow database" for data that at the time was not stored in our proper database.

NVE did not start using M9 ADCP to a large extent until 2019-2020, and these initial Extrap investigations did not include Sontek-data.

USGS released the Qrev software in 2016, and Qrev contains Extrap. NVE used Qrev increasingly, and we decided to only allow data processed by Qrev to be stored in the national database from 2018 and onwards. From July 2017 we had a modified version of the ADCP report that read Qrev xml datafiles, and that stored data to a similar “shadow database” as the MMT report. The Qrev-version of the report did not require the user to load data 2-4 times, since all required data is already stored in the Qrev XML file. (This includes Q as it would have been if using the standard power/power/0.1667 extrapolation).

The ”shadow databases” and the original files have similar formats, and they are easy to merge.

For the automated ADCP reports, the Excel macro generated a long text field that the users were encouraged to copy into the comment field for discharge measurements in the Hydra2 database. This text contains additional data and metadata, and if the text is not edited manually, it is possible to read relevant information automatically by querying the database and then extracting data using Matlab or similar. Some of the text was also intended to be cut and pasted into relevant fields in the proper database editor.

From 2022 the Hydra2 database was extended even more, with new tables for discharge measurement data and metadata, and we got HIRA, a new tool to automatically upload measurement data to the database. This new tool saves the entire Qrev XML-file to an XML-field in the Hydra2 database. The XML data can then be extracted almost as easily as regular data using SQL.

The data described above do not provide information on which extrapolation-methods the users selected in the years before 2014, when we first started to use Extrap. This information, however, is stored in the WinRIverII mmt datafiles. We wrote a “file crawler” to read all mmt files in our file archive to collect the required information.

Data from the mmt files tells us which extrapolation method the user selected but not discharge using both the default and the selected extrapolation methods.

To combine data from the different sources, we first use SQL to extract data from all ADCP measurements in the database. This dataset includes the Qrev XML field and the comment text field where they exist. Then, for each measurement, we check if there is information in XML on (1) Extrap result, that is, discharge using default extrap method and discharge using selected method and (2) Extrap method, that is, the method the user selected when processing the measurement.

If both exist, ok. If not, check next data source for what is missing, and stepwise generate a new, more and more complete data set. This is repeated for all data sources until we have a dataset that is as complete as possible. The data sources are read in this order:

1. XML field in database (from qrev xml-files)
2. Comment-field in database (from excel report reading WinRiverII mmt-files or Qrev xml-files)
3. database-table (manual entry or copied from comment field)
4. Shadow Database (from excel report reading mmt or xml)
5. mmt-data. (WinRiverII datafile) but not overwriting *Extrap method* for measurements older than 2016.

We match data from the different sources by station number and date. For the cases where there is more than one match, for instance when matching database data with the Shadow Database, there might several data entries for each measurement. In such cases, we chose the data set with discharge closest to the discharge stored in the database, since we assume that this data set contains the finalized measurement.

There is one important issue that disrupts this logic. We want to find data from the initial processing of the ADCP measurements. If the field hydrologists have reprocessed a measurement, any of the “new” data sources (1-4 above) might contain data that is different from the original data. We do not have version information on the processing. The macro-generated shadow database had, but it was badly programmed and not well enough tested, so it cannot be trusted. What we do know, however, is that prior to the launch of Qrev in 2016, the only “discharge calculator” was WinRiverII. The field hydrologist might have used Extrap to find the extrapolation and might have entered or loaded data into the shadow databases, but the same extrapolation information will be in the mmt files. This means that for measurements that are older than 2016, we assume that if there is data both in the newer sources and in mmt-files, the mmt-files contain the original data. But if data was reprocessed before we started using Qrev, the mmt-files too might contain reprocessed data. We must ignore this and assume it is not the case for a significant number of measurements. For the cases when there are more than one mmt-file per measurement, the one with discharge closest to the discharge in the database is chosen. This might cause reprocessed data to be interpreted as original data, but the alternative is to check all cases manually and that requires too much labour.

After 2018 it was required to use Qrev, and we had a macro to read measurements and to copy data both to a shadow database and to a text the user should copy into a comment field in our database editing software (Hysopp) to make it easy to copy & paste information into the relevant fields for the measurement. We can assume that this was done in the majority of the cases, and the user would probably not have generated new mmt files when reprocessing old data.

This leads us to assume that for data collected before 2016, we prioritize mmt-data over more recent data sources. For 2016 and onwards, we prioritize data from the more recent data sources. An unknown number of measurements from before 2016 might be reprocessed after we started using Extrap, but there is no way to tell how many. The count of how we initially chose to extrapolate data for measurements that are older than 2018 might be slightly erroneous, and probably showing more constant/no-slip and less power/power/0.1667 measurements that there should be.

For data combined, we have information about chosen extrapolation method for around 5500 measurements and about discharge with default extrapolation and chosen extrapolation method for around 3200 measurements. See Figure 2.1.

There are more details about data sources in the appendix, ch 9.1.

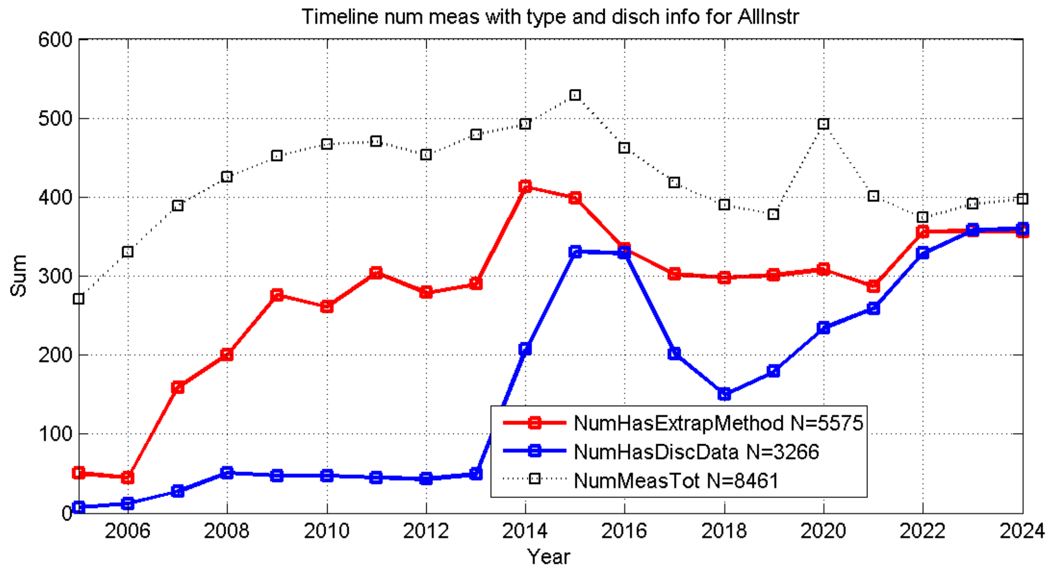



**Figure 2.1 Number of measurements with different kinds of information**

# 3 Observations

We have enough data from 2007 and onwards to tell what kind of extrapolation the users and/or software have chosen, and the impact it has had, if we look at data from all instruments combined. The number of measurements per year varies between the instruments.

The number of measurements containing extrap-information is larger than the number of measurements containing discharge-information. In this context “extrap-information” means information about which extrapolation methods the user has chosen and “discharge-information” means discharge calculated using the default one sixth power law method and discharge calculated using the selected method.

The observations are structured in this manner:

- Change in which instruments/methods we use.
- Impact on data, instrument by instrument
  - Change in extrapolation methods over time
  - Extrapolation methods and cross-section characteristics
  - Change in calculated discharge
  - Change in calculated discharge vs cross-section characteristics

# 4 Change in which instruments/methods we use

In 1995, Norway had a major flood. At that time NVE mainly used current meters, and to some extent salt dilution, to measure discharge in our rivers. During this flood, NVE hired crew from SMHI (Sweden) who brought ADCPs to assist in measuring this flood. The event led NVE to start purchasing and using ADCPs. Today, and for many years, the various ADCPs have gained popularity over the current meter, see Figure 4.4. Note that the dilution method has gained even more popularity and is used a lot.

Figure 4.5 shows the cumulative number of measurements for various methods from the start of registering in Hydra 2 until the year noted on the x-axis. The current meter is, by far, the most used instrument. Figure 4.6 show the same for ADCP measurements only. As of 2025, there more or less the same number of StreamPro-measurements and dilution measurements. The RioGrande is the 4'th most common instrument. If looking at ADCP instruments only, at the time of writing, StreamPro has the highest number of ADCP measurements, and the RioGrande is number two. The more modern, autoadaptive ADCPs, Sontek M9 and TRDI RiverPro, are gaining popularity. They are still far behind the older instruments in total number of measurements, but their numbers are growing.

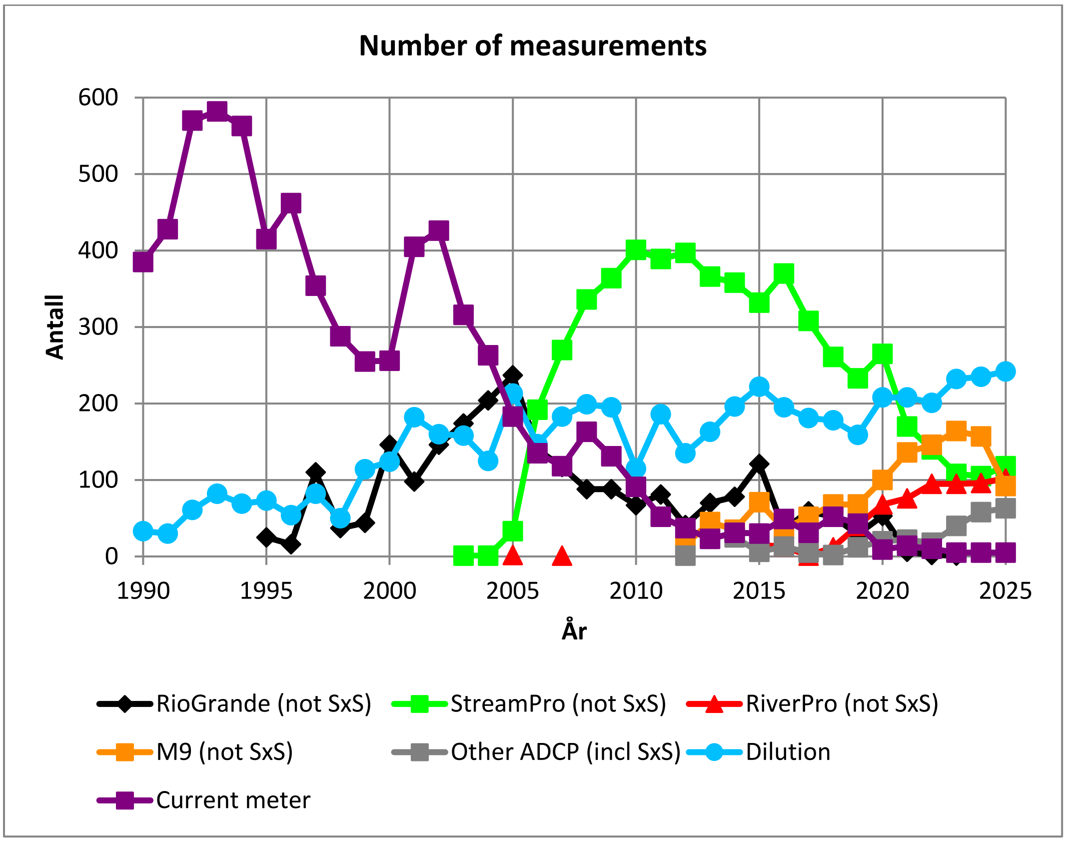



**Figure 4.1 Number of measurements per year**

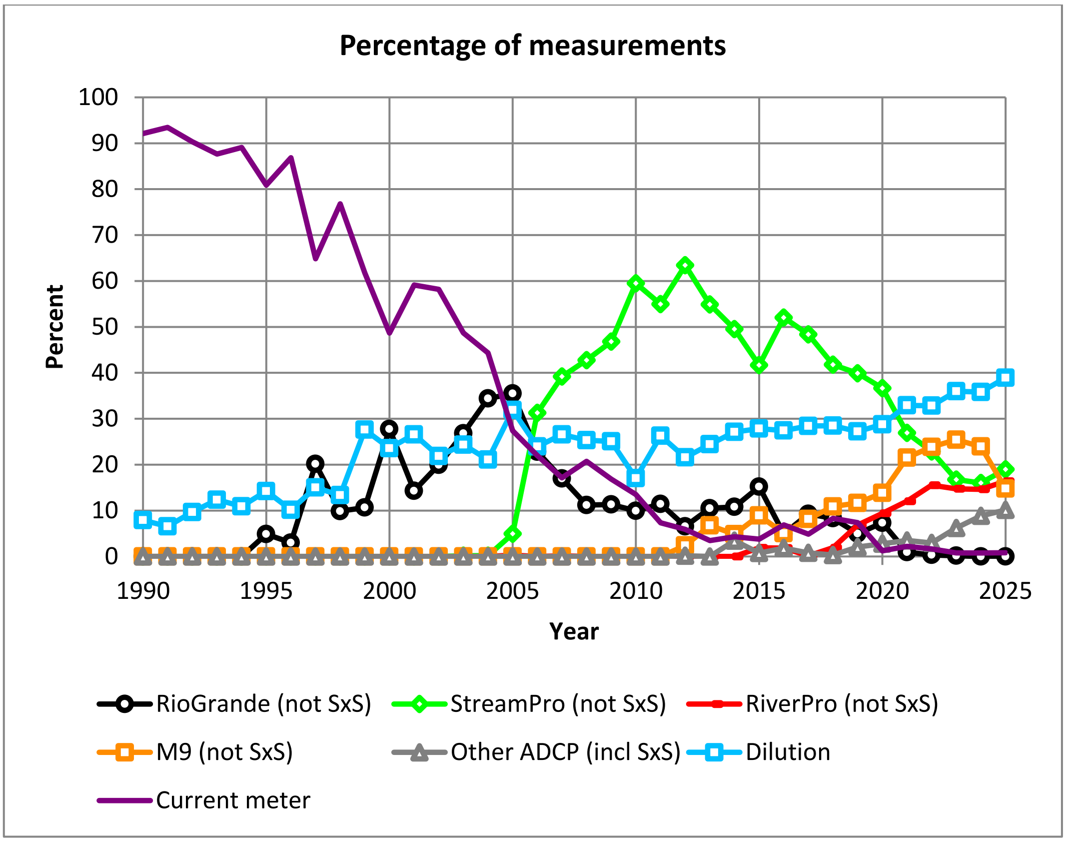



**Figure 4.2 Percentage of measurements per year**

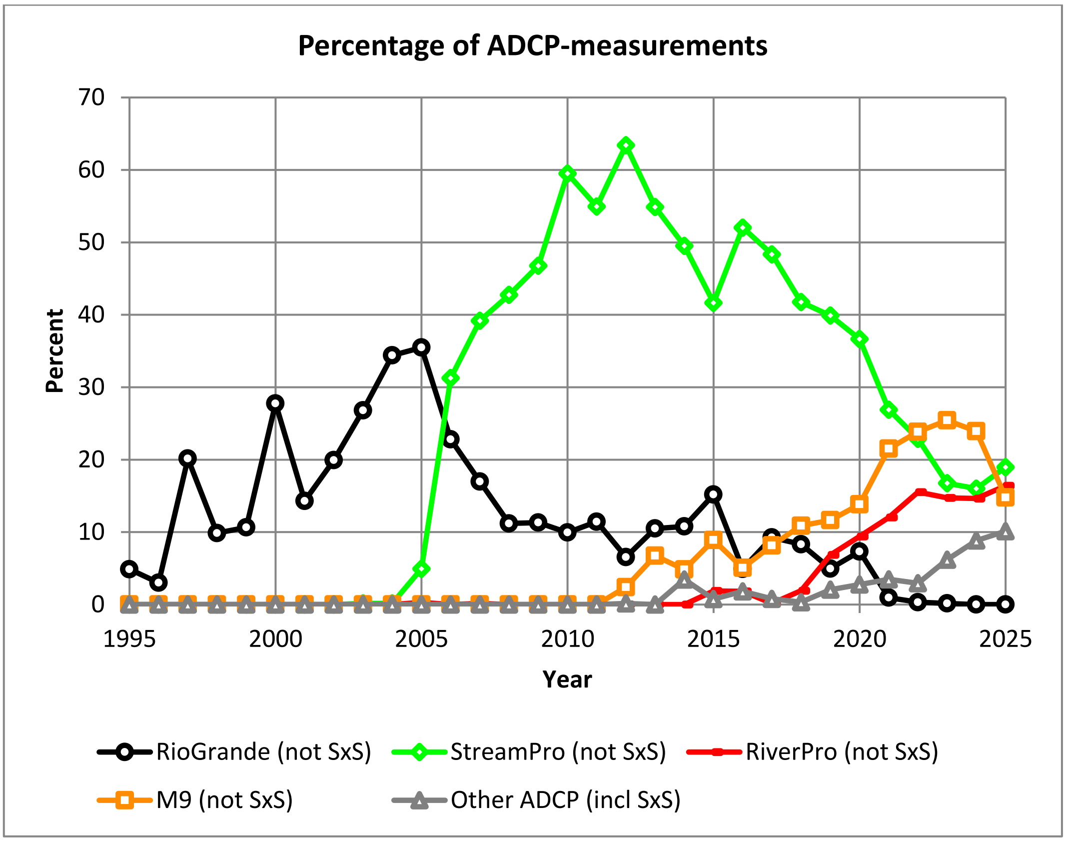



**Figure 4.3 Percentage of measurements per year (ADCP only)**

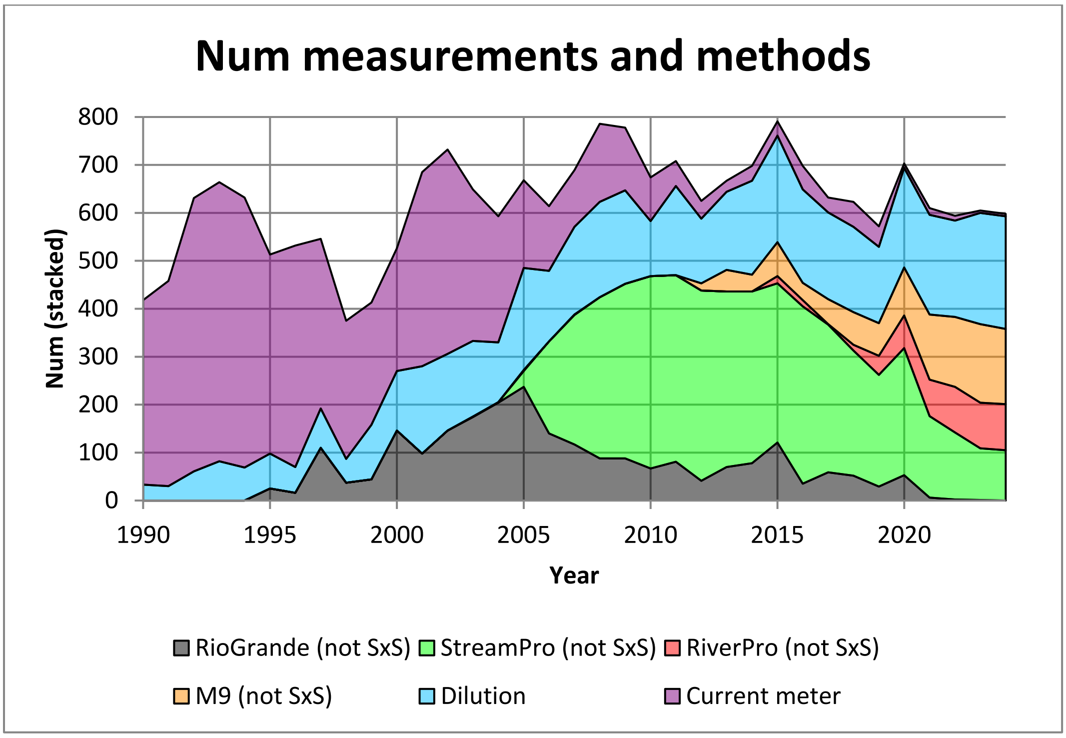



**Figure 4.4 Number of measurements per year (stacked plot)**

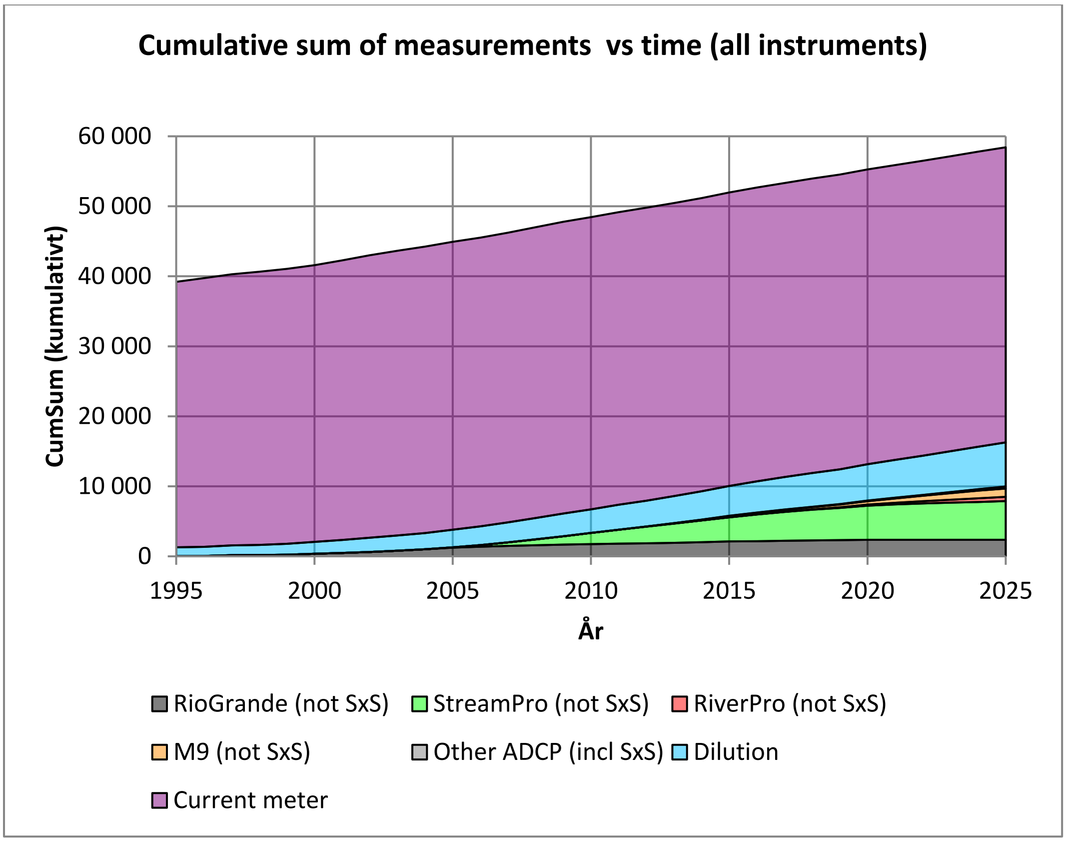



**Figure 4.5 Cumulative sum of measurements, year by year (stacked plot)**

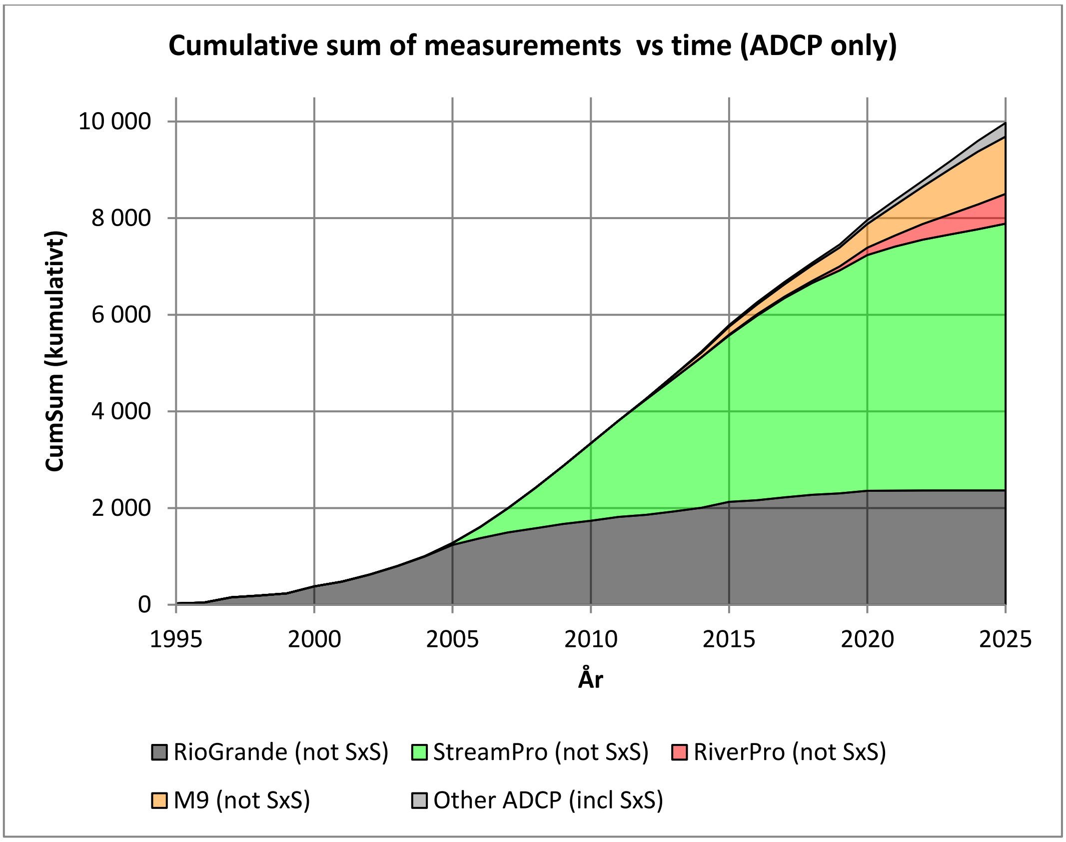



**Figure 4.6 Cumulative sum of measurements, year by year (stacked plot, ADCP only)**

## 4.1 Change in which ADCP instruments we use

During the years 1995-2005 NVE used "big" ADCPs, namely the TRDI BB (broad band) ADCP and the TRDI RioGrande 1200 hHz ADCP. The majority of these are the Rio Grande. The "big" ADCPs are not suited for shallow rivers, and the current meter still had widespread use. The TRDI StreamPro ADCP was introduced from 2005 and onwards. It soon became the preferred instrument for shallow and medium deep rivers, probably due to it being less bulky and easier to use then the Rio Grande, but also because it is well suited for shallow rivers. During the period 2005-2015 The StreamPro took over for both the current meter and the RioGrande, and in particular for the current meter.

In 2011-2013 we started purchasing and using new autoadaptive ADCPs, namely TRDI RiverPro and Sontek M9. At the same time, more or less, we started using remote controlled (RC) boats to deploy the ADCPs. At first, the ARC-boat from HR Wallingford, and then Sontek's rQpod. These, and in particular the rQpod gained great popularity and widespread use. The rQpod is smaller and weighs a lot less than the ARC-boat, and this probably contributes to the widespread use. The autoadaptive ADCPs took over for the Rio Grande, and to quite a large extent, for the StreamPro. See Figure 4.3.

# 5 Impact on data

## 5.1 Introduction

This chapter presents data on how Extrap and Qrev changed the way we extrapolate ADCP measurements. There are several ways to look at this. In this chapter we will look at the number/fraction of measurements where the users have chosen the different extrapolation methods, and we will look at the change in calculated discharge. When looking at numbers/fractions it is important to look at time series or the period before and the period after the introduction of Extrap/Qrev separately. When looking at how Extrap/Qrev change calculated discharge, there is no need to look at time series or periods separately.

The plots and tables that show change in calculated discharge looks at percent difference between discharge calculated using the default extrapolation and discharge calculated using the chosen extrapolation method:

**Eq. 4** **dQ% = 100*[Q(extrap)-Q(pp1667)] / Q(extrap)**

Q(extrap), is the discharge calculated after using Extrap/Qrev to find the proper extrapolation. Q(pp1667), short for Q(power/power/0.1667), is discharge calculated using the default one sixth power law extrapolation method.

If dQ% is less than zero, Q(extrap) is less than Q(pp1667).

Some plots (and corresponding tables) show values on the y-axis versus Cross Section characteristics on the x-axis. The Cross Section characteristics are grouped in intervals for low, medium and high values so that “low” is the lower 25% of data (for instance the 25% narrowest rivers). “High” is the 25% highest group of data (for instance the 25% widest rivers). “Medium” is the 50% that is neither “low” or “high”. Low/medium/high is for the instrument and method in question, not for the entire dataset.

Some of the tables and plots are not completely self-explaining. These are described in the first sub-chapter (All ADCP instruments combined) and then referred to for similar tables and plots in the later sub-chapters.

## 5.2 All ADCP instruments combined

### 5.2.1 Change in extrapolation methods over time

NVE started testing a beta-version of Extrap in 2009, the release version in 2010 and version 3 in 2012. Qrev, including Extrap, was mandatory from 2018. Extrap v3 and Qrev are a lot more user friendly than earlier versions of Extrap.

See tables and timeline plot below. We see that the years 2013-2015, after introducing Extrap v3, were years of transition. Before 2013, 78% of all measurements used the default extrapolation pwr/pwr/0.1667. This fell to 9% from 2016 and onwards. The percentage of measurements using constant/no-slip extrapolation increased quite abruptly from 10% to 56%. The percentage of measurements using power/power and an exponent that is different from 0.1667 increased more gradually from 8% to 32%. The percentage of other types of extrapolation was and is still very low. These numbers are the mean values from the summary table. The plot and the detailed table show that there are variations from year to year.

| yrs | Num total | Pwr/pwr (0.1667) | | Pwr/pwr (not 0,1667) | | Const/NoSlip | | Pwr/pwr (total) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Num | % | Num | % | Num | % | Num | % |
| 2005-2012 | 1548 | 1213 | 78 | 122 | 8 | 159 | 10 | 1335 | 86 |
| 2016-2025 | 2903 | 258 | 9 | 938 | 32 | 1631 | 56 | 1196 | 41 |

**Table 5.1 Extrapolation methods vs time (summary, all ADCP)**

*Percentages are rounded to nearest integer.*

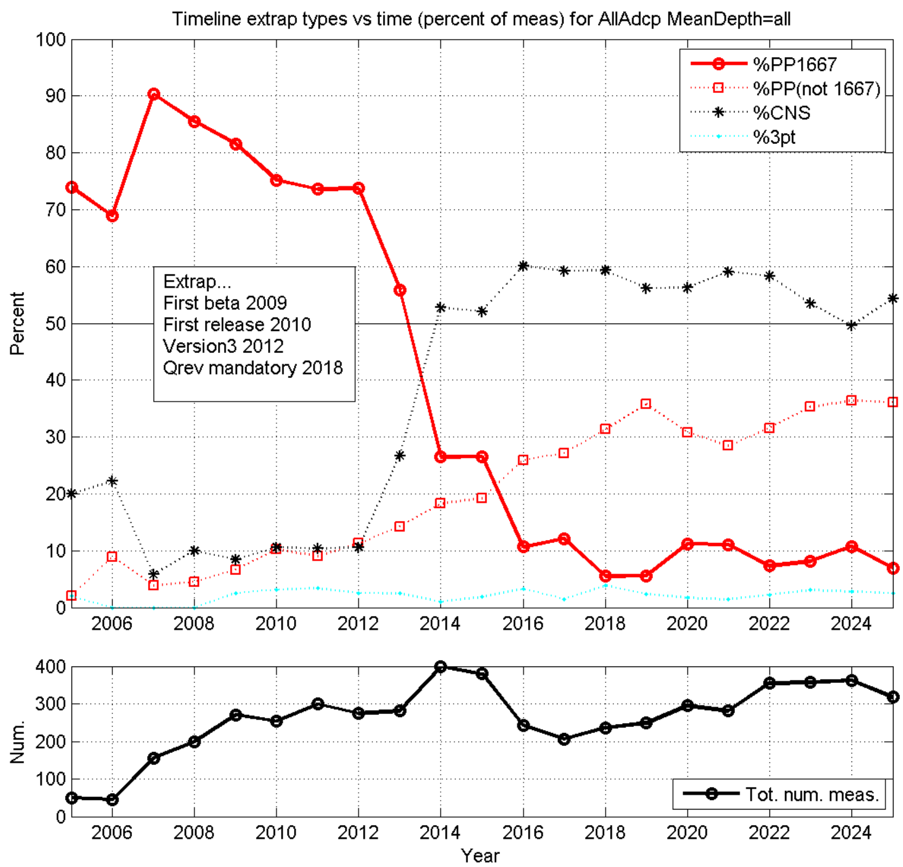



**Figure 5.1 Extrapolation methods vs time (percent of total number of measurements)**

*PP1667 means Power top, Power at bottom, exponent 0,1667*
*PPnot1667 means Power top, Power at bottom, exponent different from 0,1667*
*CNS means constant at top, no-slip at bottom*
*3pt means 3-point extrapolation at top and either no-slip or power at bottom*
*Lower plot shows total number of measurements that contain information on extrap method for this instrument. (This number is lower than the total number of ADCP-measurements)*

***AllAdcp***

| yrs | Num | PP1667 | | PPnot1667 | | CNS | | PP all | | 3pt | | Other | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | N | % | N | % | N | % | N | % | N | % | N | % |
| 2005 | 50 | 37 | 74 | 1 | 2 | 10 | 20 | 38 | 76 | 1 | 2 | 1 | 2 |

| yrs | Num | PP1667 | | PPnot1667 | | CNS | | PP all | | 3pt | | Other | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006 | 45 | 31 | 68,89 | 4 | 8,89 | 10 | 22,22 | 35 | 77,78 | 0 | 0 | 0 | 0 |
| 2007 | 155 | 140 | 90,32 | 6 | 3,87 | 9 | 5,81 | 146 | 94,19 | 0 | 0 | 0 | 0 |
| 2008 | 200 | 171 | 85,5 | 9 | 4,5 | 20 | 10 | 180 | 90 | 0 | 0 | 0 | 0 |
| 2009 | 271 | 221 | 81,55 | 18 | 6,64 | 23 | 8,49 | 239 | 88,19 | 7 | 2,58 | 2 | 0,74 |
| 2010 | 254 | 191 | 75,2 | 26 | 10,24 | 27 | 10,63 | 217 | 85,43 | 8 | 3,15 | 2 | 0,79 |
| 2011 | 299 | 220 | 73,58 | 27 | 9,03 | 31 | 10,37 | 247 | 82,61 | 10 | 3,34 | 11 | 3,68 |
| 2012 | 274 | 202 | 73,72 | 31 | 11,31 | 29 | 10,58 | 233 | 85,04 | 7 | 2,55 | 5 | 1,82 |
| 2013 | 281 | 157 | 55,87 | 40 | 14,23 | 75 | 26,69 | 197 | 70,11 | 7 | 2,49 | 2 | 0,71 |
| 2014 | 400 | 106 | 26,5 | 73 | 18,25 | 211 | 52,75 | 179 | 44,75 | 4 | 1 | 6 | 1,5 |
| 2015 | 380 | 101 | 26,58 | 73 | 19,21 | 198 | 52,11 | 174 | 45,79 | 7 | 1,84 | 1 | 0,26 |
| 2016 | 243 | 26 | 10,7 | 63 | 25,93 | 146 | 60,08 | 89 | 36,63 | 8 | 3,29 | 0 | 0 |
| 2017 | 206 | 25 | 12,14 | 56 | 27,18 | 122 | 59,22 | 81 | 39,32 | 3 | 1,46 | 0 | 0 |
| 2018 | 236 | 13 | 5,51 | 74 | 31,36 | 140 | 59,32 | 87 | 36,86 | 9 | 3,81 | 0 | 0 |
| 2019 | 249 | 14 | 5,62 | 89 | 35,74 | 140 | 56,22 | 103 | 41,37 | 6 | 2,41 | 0 | 0 |
| 2020 | 295 | 33 | 11,19 | 91 | 30,85 | 166 | 56,27 | 124 | 42,03 | 5 | 1,69 | 0 | 0 |
| 2021 | 281 | 31 | 11,03 | 80 | 28,47 | 166 | 59,07 | 111 | 39,5 | 4 | 1,42 | 0 | 0 |
| 2022 | 355 | 26 | 7,32 | 112 | 31,55 | 207 | 58,31 | 138 | 38,87 | 8 | 2,25 | 2 | 0,56 |
| 2023 | 357 | 29 | 8,12 | 126 | 35,29 | 191 | 53,5 | 155 | 43,42 | 11 | 3,08 | 0 | 0 |
| 2024 | 363 | 39 | 10,74 | 132 | 36,36 | 180 | 49,59 | 171 | 47,11 | 10 | 2,75 | 2 | 0,55 |
| 2025 | 318 | 22 | 6,92 | 115 | 36,16 | 173 | 54,4 | 137 | 43,08 | 8 | 2,52 | 0 | 0 |

**Table 5.2 Extrapolation methods vs time (detail)**

### 5.2.2 Extrapolation methods and cross-section characteristics

The plots and tables below show data from 2016 and onwards, when the use of Extrap/Qrev had become an established routine. Various cross-section characteristics might affect the vertical velocity distribution, and hence the extrapolation method the user has chosen. Cross-section characteristics are features of the measurement site or features caused by a combination of the selected ADCP instrument and the measurement site.

- Width to depth ratio (W/D)
- Width
- Mean depth (area/width)
- Mean water speed (Q/area)
- Discharge
- Percent measured (total Q divided by Q in the measured area).

The measurements are grouped so that for each cross-section characteristics (for instance width) the measurements with the 25% lowest values are in one group (the 25% with the narrowest cross sections), the measurements with the 25% highest values are in one group (the 25% with the widest cross sections) and the remaining 50% are in the “medium” group (the 50% that are neither narrow or wide).
For each of these groups the percentage of measurements using three different kinds of extrapolation is calculated, namely the default power/power/0.1667 extrapolation, power/power/not 0.1667 extrapolation and constant/no-slip extrapolation.

For all ADCPs combined, we observe this

Width to depth ratio. For increasing width to depth ratio, the percentage of constant/no-slip measurements decrease steadily and notably from 67% to 47%. The percentage of power/power (not 1667) measurements increase accordingly from 23% to 37%. Power/power (1667) measurements increase from 7% to 13%.

Width. For increasing width, the percentage of constant/no-slip measurements decrease steadily and notably from 67% to 43%. The percentage of power/power (not 1667) measurements increase accordingly from 24% to 41%. Power/power (1667) measurements increase from 7% to 13%.

Mean depth. 58% of the measurements are constant/no-slip for shallow and medium deep rivers. For deep rivers, the percentage of constant/no-slip measurements decrease to 49%. Power/power (not 1667) increases from 28% to 32% and from 32% to 38% when depth goes from shallow to medium and form medium to deep. Power/power (1667) is almost unaffected by depth and varies between 8-10%.

Mean water speed (Q/area). For increasing water speed, the percentage of constant/no-slip measurements decrease steadily and notably from 66% to 49%. The percentage of power/power (not 1667) measurements increase accordingly from 21% to 42%. Power/power (1667) measurements are almost unchanged but decrease from 10% to 8%.

Discharge. For increasing discharge, the percentage of constant/no-slip measurements decrease steadily and notably from 67% to 45%. The percentage of power/power (not 1667) measurements increase accordingly from 23% to 42%. Power/power (1667) measurements are almost unchanged and varies between 7% and 10%.

Percent measured. The image is reversed: For increasing percentage of measured discharge, the percentage of constant/no-slip measurements *in*crease steadily and notably from 48% to 61%. The percentage of power/power (not 1667) measurements *de*crease accordingly from 40% to 28%. Power/power (1667) measurements are almost unchanged and varies between 7% and 10%.

Extrap methods, AllAdcp

| Range, WidthToDepth | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 2,207(min)-15,4(Q25) | 676 | 455 | 67 | 155 | 23 | 44 | 7 |
| 15,4(Q25)-34,9(Q75) | 1354 | 744 | 55 | 473 | 35 | 107 | 8 |
| 34,9(Q75)-205,7(max) | 676 | 315 | 47 | 249 | 37 | 89 | 13 |

| Range, Width | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 2,030(min)-15,2(Q25) | 676 | 451 | 67 | 159 | 24 | 48 | 7 |
| 15,2(Q25)-51,9(Q75) | 1354 | 769 | 57 | 439 | 32 | 103 | 8 |
| 51,9(Q75)-577,4(max) | 676 | 294 | 43 | 279 | 41 | 89 | 13 |

| Range, mean depth | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 0,168(min)-0,8(Q25) | 720 | 420 | 58 | 203 | 28 | 76 | 11 |
| 0,8(Q25)-1,8(Q75) | 1444 | 842 | 58 | 456 | 32 | 107 | 7 |
| 1,8(Q75)-10,3(max) | 720 | 354 | 49 | 276 | 38 | 74 | 10 |

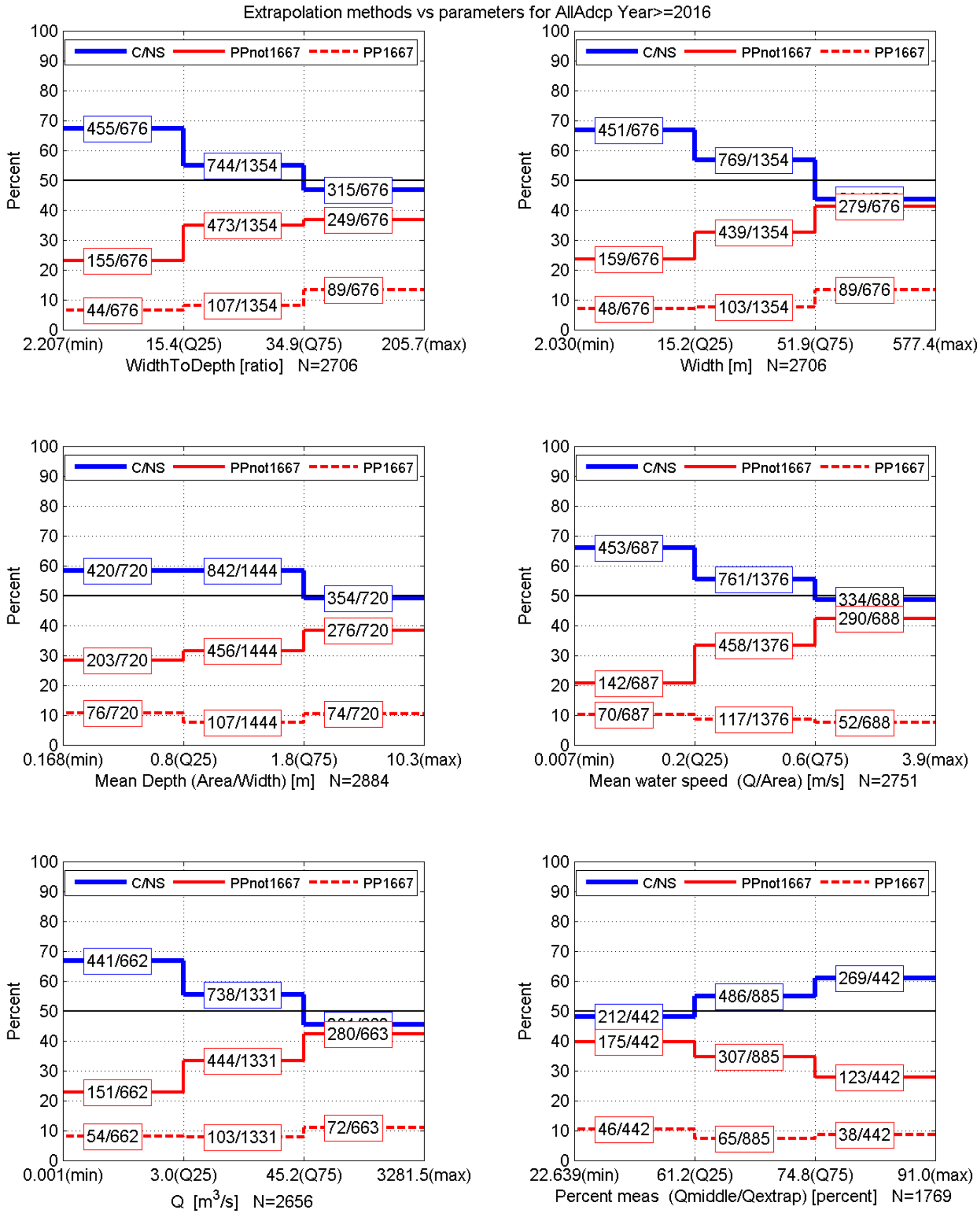
| Range, Mean water speed | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 0,007(min)-0,2(Q25) | 687 | 453 | 66 | 142 | 21 | 70 | 10 |
| 0,2(Q25)-0,6(Q75) | 1376 | 761 | 55 | 458 | 33 | 117 | 9 |
| 0,6(Q75)-3,9(max) | 688 | 334 | 49 | 290 | 42 | 52 | 8 |

| Range, Q | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 0,001(min)-3,0(Q25) | 662 | 441 | 67 | 151 | 23 | 54 | 8 |
| 3,0(Q25)-45,2(Q75) | 1331 | 738 | 55 | 444 | 33 | 103 | 8 |
| 45,2(Q75)-3281,5(max) | 663 | 301 | 45 | 280 | 42 | 72 | 11 |

| Range, Percent meas | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 22,639(min)-61,2(Q25) | 442 | 212 | 48 | 175 | 40 | 46 | 10 |
| 61,2(Q25)-74,8(Q75) | 885 | 486 | 55 | 307 | 35 | 65 | 7 |
| 74,8(Q75)-91,0(max) | 442 | 269 | 61 | 123 | 28 | 38 | 9 |

*nXXX ~ number of measurements*

*%XXX ~ percentage of measurements*




### 5.2.3 Change in calculated discharge

Looking at the entire dataset, that is, all the instruments and all the methods combined, we observe that the median percent difference between discharge calculated using the default extrapolation and discharge calculated using the chosen extrapolation method is quite small. See the histogram below. For around 3000 measurements, the median percent difference is -1.5%. This means that when using Extrap/Qrev, the calculated discharge is down by 1,5% compared to what it would have been if we used default one sixth power law extrapolation. The quartile values are 0% and -3,8%, and this means that for 50% of the measurements, discharge is down between 0 and 3,8%.

For the constant/no-slip measurements, there are around 1800 measurements. The median is -2.9% and quartiles are -1.1% and -5.1%.

There are 967 measurements with power/power extrapolation and an altered exponent. For these, the median is -0.3% and the quartiles are -1.3% and 0.7%. This means, as we might suspect, that power/power measurements do not get a large change in calculated discharge compared to the default power/power/0.1667 measurements.

*For the histograms below:*
*Qex, short for Q(extrap), is the discharge calculated after using Extrap/Qrev to find the proper extrapolation. Qpp1667, short for Q(power/power/0.1667), is discharge calculated using the default extrapolation method. Percent difference is*
*dQ = 100*(Qex-Qpp1667) / Qex*
*When dQ is negative, Qex is lower than Qpp1667.*

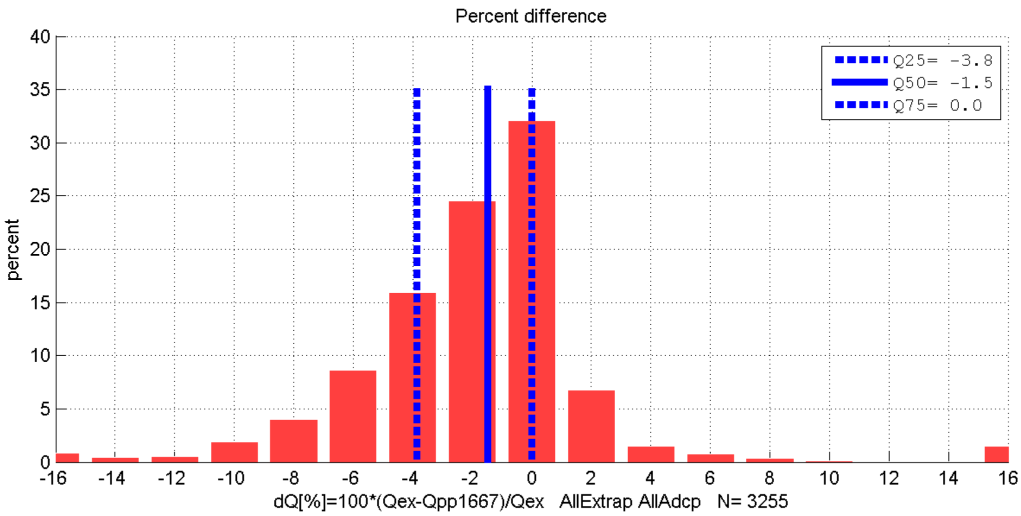



**Figure 5.2 Change in calculated discharge (All methods, all instruments)**

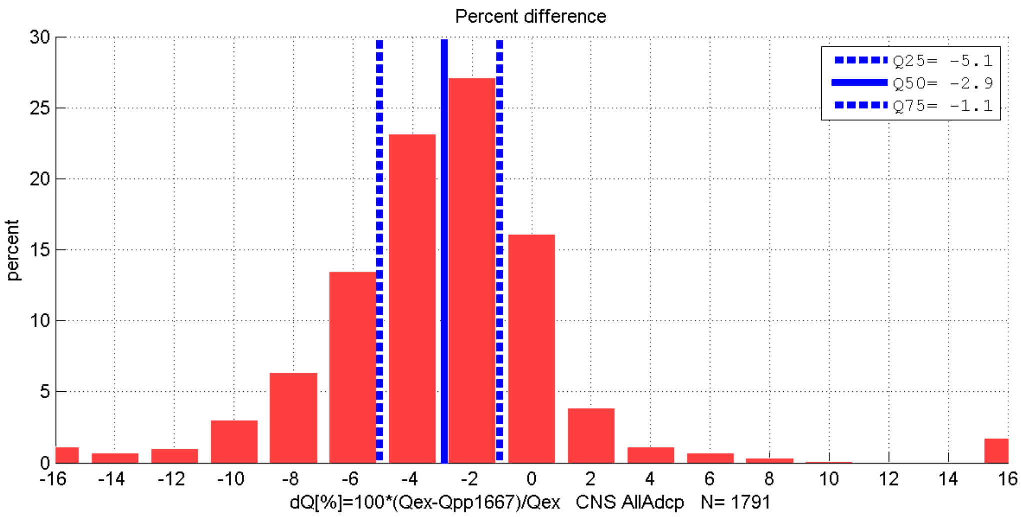



**Figure 5.3 Change in calculated discharge (const/no-slip, all instruments)**

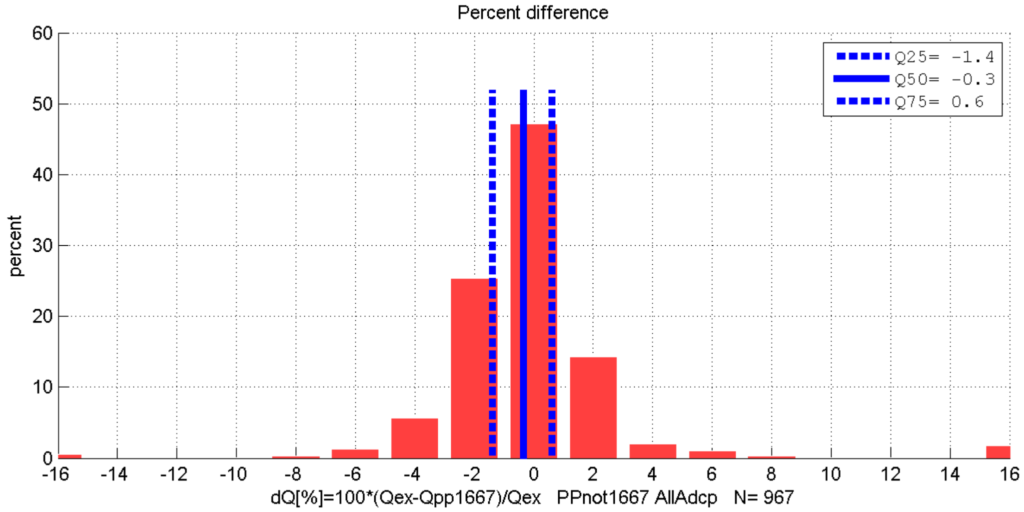



**Figure 5.4 Change in calculated discharge (pwr/pwr/not 0.1667)**

### 5.2.4 Change in calculated discharge and cross-section characteristics

Various cross-section characteristics might affect the vertical velocity profile, and thus the choice of extrapolation method which in turn impacts the calculated discharge. Since we are looking at the change in calculated discharge between the methods, there is no need to look at the measurements before and after introducing Extrap/Qrev separately.

We observe that median dQ values are always negative. This means that when looking at data from all ADCPs and all extrapolation methods, the discharge calculated using the chosen extrapolation is lower than it would have been if using the default method.

For all instruments and all extrapolation methods the changes in median values for dQ are as listed below. (Note that “dQ increases” means that dQ moves towards zero / dQ gets less negative when the dQ values are less than zero)

Width to depth. dQ increases slightly and gradually from -2.1% to -1.3% when width to depth ratios increase from less than 15 to more than 35.

Width. dQ increases gradually from -2.6% to -0.5% when the width of the rivers increases from less than 15 meters to more than 50 meters. The change is bigger between medium wide and wide rivers, than between narrow and medium wide.

Depth. dQ is approximately the same (-2.4% and -2.2%) for rivers with low and medium depth. For rivers that are more than 1.9 meters deep the median value for dQ jumps to -0.3%

Water speed. dQ increases gradually from -2.2% to -1.1% when mean water speed increases from less than 0.2 m/s to more than 0.7 m/s. The change is bigger between medium fast and fast flowing rivers, than between slow and medium.

Discharge. dQ increases gradually from -2.6% to -0.6% when the discharge increases from less than 3.3 $m^3/s$ to more than 43.1 $m^3/s$.

<u>Percent measured</u>. For percent measured dQ decreases from -0.8% to -1.6% when the percentage of Q measured to Q total increases from less than 61% to between 61% and 75%. dQ increases slightly (from -1.6% to -1.4%) for percent measured above 75%.

dQ[%] for AllExtrap AllAdcp

| Range, Width To Depth | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 2,2(min)-15(Q25) | -2,1 | -4,6 | -0,1 | -9,8 | 2,3 | 749 |
| 15(Q25)-34(Q75) | -1,6 | -3,9 | 0 | -8,1 | 2,1 | 1500 |
| 34(Q75)-206(max) | -1,3 | -3,4 | 0 | -6,4 | 1,9 | 749 |

| Range, Width | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 2,0(min)-15(Q25) | -2,6 | -5,3 | -0,6 | -9,9 | 2,1 | 750 |
| 15(Q25)-50(Q75) | -2 | -4,2 | -0,2 | -8,1 | 1,5 | 1501 |
| 50(Q75)-577(max) | -0,5 | -2 | 0,4 | -4,5 | 3,7 | 750 |

| Range, mean depth | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 0,17(min)-0,8(Q25) | -2,4 | -5,2 | -0,3 | -9,3 | 2 | 762 |
| 0,8(Q25)-1,9(Q75) | -2,2 | -4,2 | -0,4 | -8,3 | 1,4 | 1523 |
| 1,9(Q75)-10,3(max) | -0,3 | -1,8 | 0,7 | -5,9 | 3,5 | 762 |

| Range, water speed | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 0,01(min)-0,2(Q25) | -2,2 | -4,6 | -0,1 | -9,8 | 2,9 | 755 |
| 0,2(Q25)-0,7(Q75) | -1,8 | -4,2 | -0,1 | -8,1 | 1,6 | 1512 |
| 0,7(Q75)-3,9(max) | -1,1 | -2,7 | 0 | -6,1 | 2,9 | 755 |

| Range, Discharge | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 0,002(min)-3,3(Q25) | -2,6 | -5,4 | -0,6 | -10,6 | 2 | 763 |
| 3,3(Q25)-43,1(Q75) | -2 | -4,2 | -0,2 | -7,8 | 1,7 | 1528 |
| 43,1(Q75)-3281(max) | -0,6 | -2 | 0,5 | -4,7 | 3,6 | 764 |

| Range, Percent Meas | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 23(min)-61(Q25) | -0,8 | -3,2 | 0 | -7,3 | 2 | 468 |
| 61(Q25)-75(Q75) | -1,6 | -4 | 0 | -8,3 | 2,3 | 937 |
| 75(Q75)-91(max) | -1,4 | -3,6 | 0 | -7,8 | 2 | 468 |

**Table 5.3 dQ vs cross-section characteristics (All ADCP, all extrap)**

*See explanation below box plot.*

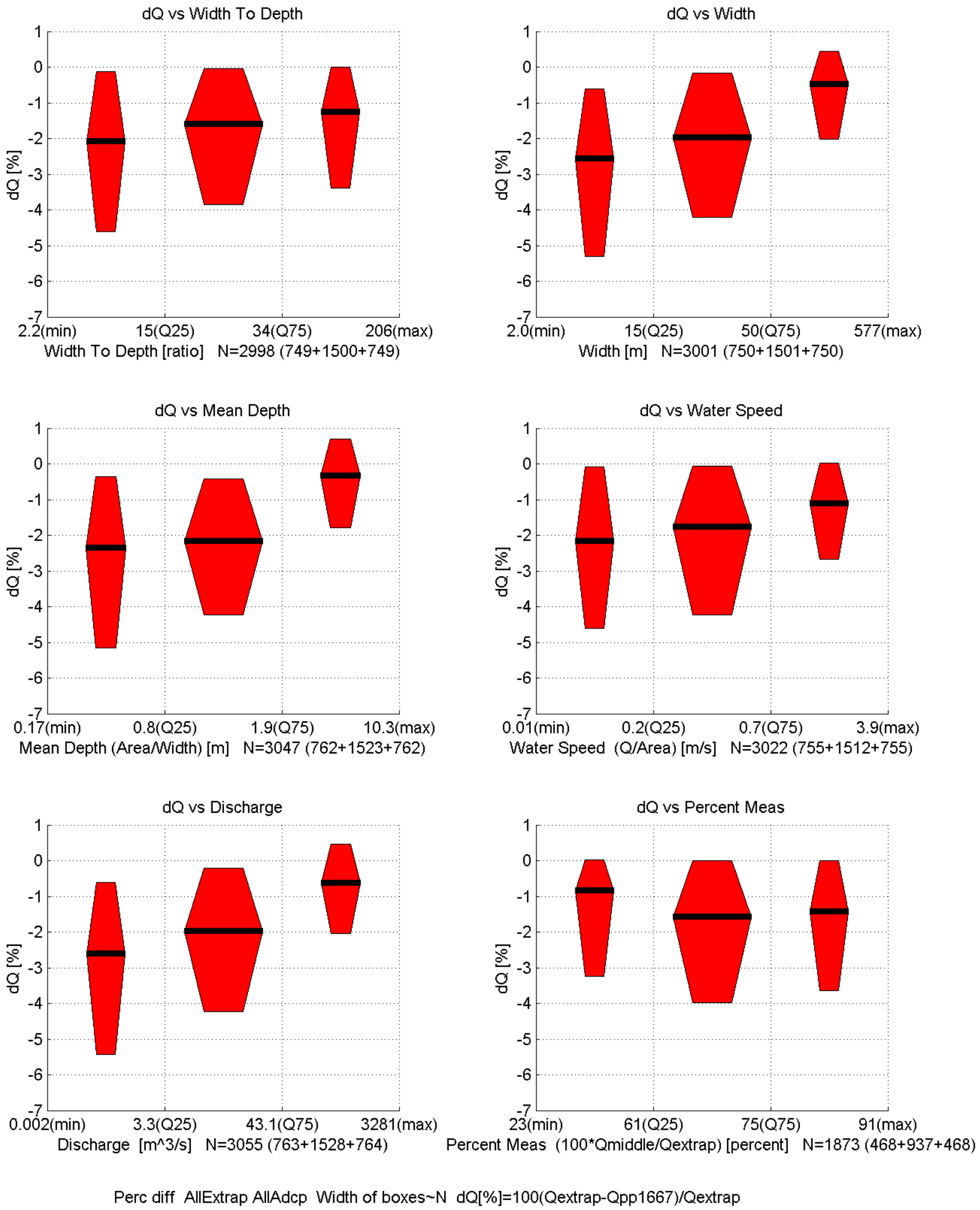



**Figure 5.5 dQ vs cross-section characteristics (All ADCP, all extrap)**

*Explanation for table and box plots*

*Percent difference is dQ% = 100*[Q(extrap)-Q(pp1667)] / Q(extrap).*
*Q(extrap) is the discharge calculated after using Extrap/Qrev to find the proper extrapolation method.*
*Q(pp1667), short for Q(power/power/0.1667), is discharge calculated using the default extrapolation method.*
*When dQ is negative, Q(extrap) is lower than Q(pp1667).*
*Q 50 ("equator" on the boxes) is the median values for dQ. Q25-Q75 is the interquartile range and is marked as the bottom and top of the boxes.*
*Data is grouped in low, medium and high value-groups for the characteristics in question. For instance, Low water speed is the group of measurements with water speed*

*less than the lower quartile for water speed. Medium water speed is the measurements that falls within the interquartile range, and high water speed is the measurements with water speed greater than the upper quartile for water speed. The number of measurements (N) in total and in the groups is included in the x-label.*
*In the table, Qnn means the nn-quartile. The box plot and the table show the same, but the table has the 5 and 95 quartiles in addition.*

## 5.3 StreamPro

### 5.3.1 Change in extrapolation methods over time

For the StreamPro, the years 2013-2015, after introducing Extrap v3, were years of transition, see timeline plot below. For the years 2005-2012, 78% of the measurements had the default one sixth power law extrapolation. This fell to 8% after 2015. The percentage of measurements using constant/no-slip extrapolation increased from 10% to 71%. The percentage of measurements using power/power and an exponent that is different from 0.1667 increased more gradually from 8% to 18%.

These numbers are the mean values from the summary table. The timeline plot shows that there are variations from year to year.

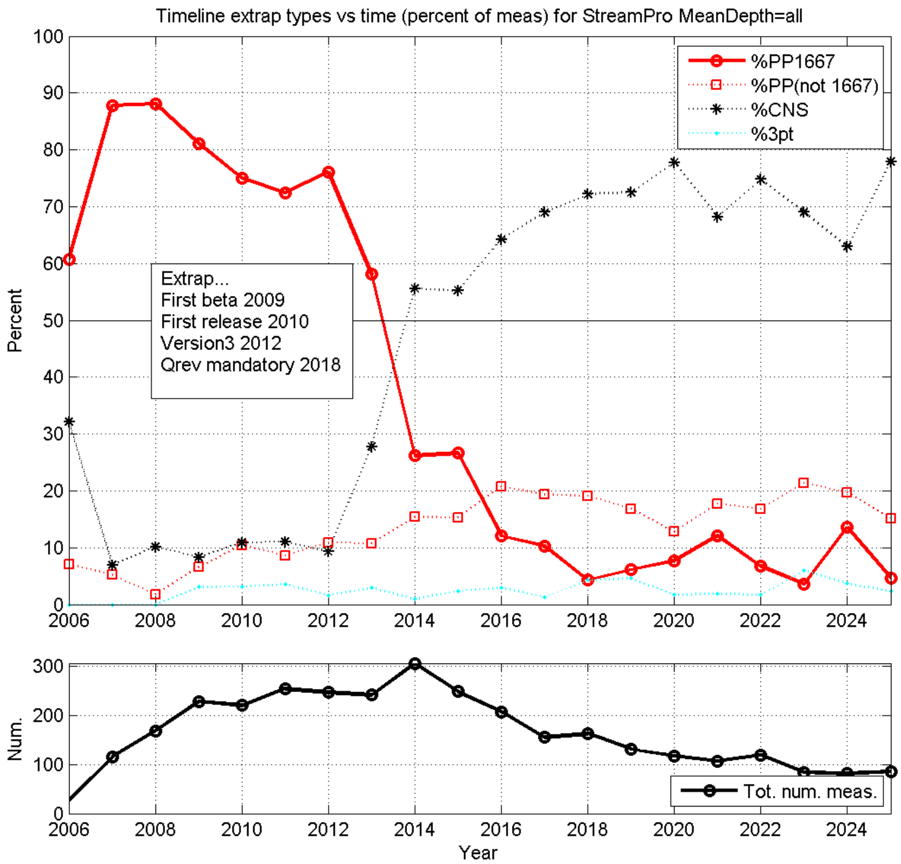



**Figure 5.6 Extrapolation methods vs time (percent of total number of StreamPro-measurements)**

*Meaning of captions, see Figure 5.1 page 24.*

| Yrs (SP) | Num | Pwr/pwr (0.1667) | | Pwr/pwr (not 0,1667) | | Const/NoSlip | | Pwr/pwr(total) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Num | % | Num | % | Num | % | Num | % |
| 2005-2012 | 1265 | 991 | 78 | 98 | 8 | 129 | 10 | 1089 | 86 |
| 2016-2025 | 1249 | 104 | 8 | 227 | 18 | 881 | 71 | 331 | 27 |

**Table 5.4 Extrapolation methods vs time (summary, StreamPro)**

### 5.3.2 Extrapolation methods and cross-section characteristics

The plots and tables below show data from 2016 and onwards, when the use of Extrap/Qrev had become an established routine. Various cross-section characteristics might affect the vertical velocity distribution, and hence the extrapolation method the user has chosen. Cross-section characteristics are features of the measurement site or features caused by a combination of the selected ADCP instrument and the measurement site.

- Width to depth ratio (W/D)
- Width
- Mean depth (area/width)
- Mean water speed (Q/area)
- Discharge
- Percent measured (total Q divided by Q in the measured area).

The measurements are grouped so that for each cross-section characteristics (for instance width) the measurements with the 25% lowest values are in one group (the 25% with the narrowest cross sections), the measurements with the 25% highest values are in one group (the 25% with the widest cross sections) and the remaining 50% are in the “medium” group (the 50% that are neither narrow or wide).
For each of these groups the percentage of measurements using three different kinds of extrapolation is calculated, namely the default power/power/0.1667 extrapolation, power/power/not 0.1667 extrapolation and constant/no-slip extrapolation.

For all the StreamPro ADCP, we observe that constant/no-slip dominates almost completely, but there are some nuances.

Width to depth ratio. For increasing width to depth ratio, the percentage of constant/no-slip measurements decrease steadily, but not very notably, from 76% to 64%. The percentage of power/power (not 1667) measurements increase accordingly from 13% to 20%. Power/power (1667) measurements constitute 7% of the measurements on low and medium width/depth rivers, and 12% on high width/depth rivers.

Width. 72% of the measurements are constant/no-slip for narrow and medium wide rivers. For wide rivers, the percentage of constant/no-slip measurements decrease a little, to 66%. Power/power (not 1667) increases from 15% to 19% when width increases from narrow to medium. Rounded to integer values, the percentage for Power/power (not 1667) is unchanged for wide rivers, namely 19%. Power/power (1667) is almost unaffected by width and varies between 8-10%.

Mean depth. For increasing depth, the percentage of constant/no-slip measurements *in*crease steadily and notably from 62% to 77%. The percentage of power/power (not

1667) measurements *de*crease slightly and steadily from 22% to 14%. The percentage of power/power (1667) measurements decrease from 15% to 6%, it but is the same (6%) for medium deep and deep rivers.

Mean water speed (Q/area). For increasing water speed, the percentage of constant/no-slip measurements decrease slightly from 74%, via 72% to 66%. The percentage of power/power (not 1667) measurements increase from 11% to 25%. Power/power (1667) measurements decrease from 13% to 6%.

Discharge. There is almost no changes between low, medium and high Q. Constant/no-slip vary between 70% and 71%, power/power (not 1667) between 18% and 20% and power/power (1667) decrease from 9% to 5%.

Percent measured (*). For increasing percentage of measured Q, the percentage of constant/no-slip measurements *in*crease notably from 59% via 76% to 79%. The percentage of power/power (not 1667) measurements *de*crease steadily from 26% to 12%. The percentage of power/power (1667) measurements decrease from 14% to 5%, it but is the same (5%) for medium and high percentage.

(*) Percent measured Discharge is 100*Q (in the bins) / Q (total). In other words, the opposite of percent extrapolated. We assume edge Q is a lot smaller than top Q and bottom Q.

Extrap methods, StreamPro

| Range, WidthToDepth | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 2,207(min)-13,5(Q25) | 291 | 222 | 76 | 39 | 13 | 20 | 7 |
| 13,5(Q25)-32,3(Q75) | 583 | 412 | 71 | 114 | 20 | 40 | 7 |
| 32,3(Q75)-190,4(max) | 291 | 187 | 64 | 59 | 20 | 36 | 12 |

| Range, Width | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 2,030(min)-10,6(Q25) | 291 | 209 | 72 | 44 | 15 | 26 | 9 |
| 10,6(Q25)-32,6(Q75) | 583 | 419 | 72 | 113 | 19 | 36 | 6 |
| 32,6(Q75)-268,0(max) | 291 | 193 | 66 | 55 | 19 | 34 | 12 |

| Range, mean depth | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 0,168(min)-0,6(Q25) | 309 | 191 | 62 | 67 | 22 | 45 | 15 |
| 0,6(Q25)-1,2(Q75) | 626 | 448 | 72 | 116 | 19 | 40 | 6 |
| 1,2(Q75)-4,0(max) | 308 | 238 | 77 | 43 | 14 | 18 | 6 |

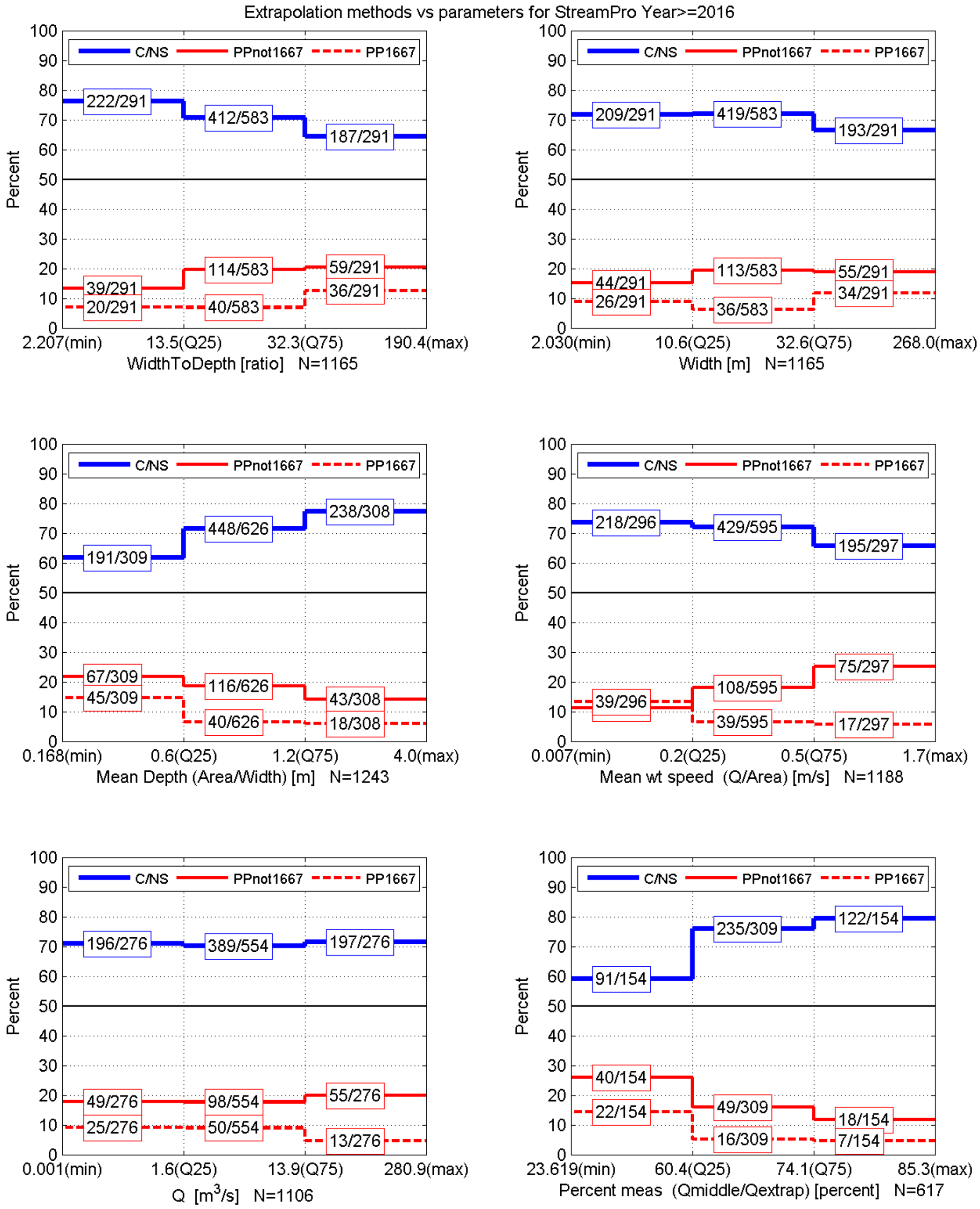
| Range, Mean water speed | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 0,007(min)-0,2(Q25) | 296 | 218 | 74 | 33 | 11 | 39 | 13 |
| 0,2(Q25)-0,5(Q75) | 595 | 429 | 72 | 108 | 18 | 39 | 7 |
| 0,5(Q75)-1,7(max) | 297 | 195 | 66 | 75 | 25 | 17 | 6 |

| Range, Q | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 0,001(min)-1,6(Q25) | 276 | 196 | 71 | 49 | 18 | 25 | 9 |
| 1,6(Q25)-13,9(Q75) | 554 | 389 | 70 | 98 | 18 | 50 | 9 |
| 13,9(Q75)-280,9(max) | 276 | 197 | 71 | 55 | 20 | 13 | 5 |

| Range, Percent meas | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 23,619(min)-60,4(Q25) | 154 | 91 | 59 | 40 | 26 | 22 | 14 |
| 60,4(Q25)-74,1(Q75) | 309 | 235 | 76 | 49 | 16 | 16 | 5 |
| 74,1(Q75)-85,3(max) | 154 | 122 | 79 | 18 | 12 | 7 | 5 |

*nXXX ~ number of measurements*

*%XXX ~ percentage of measurements*




### 5.3.3 Change in calculated discharge

If not filtering out any extrapolation methods, we have discharge data for 1560 StreamPro- measurements. The median percent difference between discharge calculated using the default extrapolation and the discharge calculated using the extrapolation method the user has chosen is -2.7%. This means that the discharge is typically 2.7% lower than it would have been if we used the default extrapolation. The quartile values are -5.0% and -0.8%. This means that for 50% of the measurements, the discharge is between 5.0% and 0.8% lower when using Extrap/Qrev to find the best extrapolation method than when using the default extrapolation method. See Figure 5.7.

For all instruments and methods combined, the median value -1.4%, and this means that there is more difference for the StreamPro than for all instruments and methods combined.

For the StreamPro, the most common extrapolation method after 2012 is constant/no-slip. If looking only at those StreamPro-measurements that have constant/no-slip extrapolation, we see that for 1007 measurements the median percent difference is -3.6%. See Figure 5.8. This means that when using Extrap/Qrev, the calculated discharge is down by 3.6% compared to what it would have been if we used default extrapolation. The quartile values are -1.7% and -6.1%, and this means that for 50% of the measurements, discharge is down between 1.7% and 6.1%.

For the measurements using power/power (not 0.1667) the median dQ is -1.3% and the quartiles are -2.4% and -0.5%.

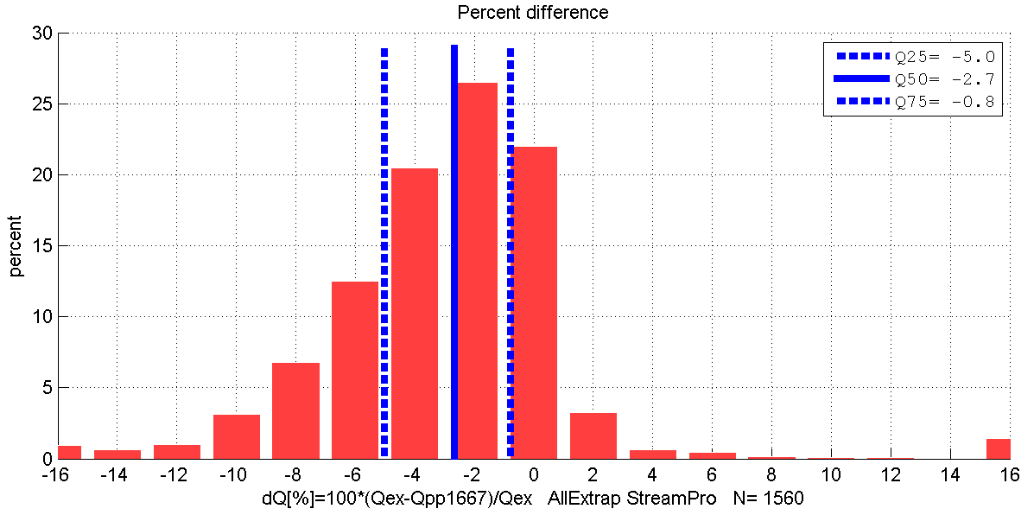



**Figure 5.7 Change in calculated discharge (All methods, StreamPro)**

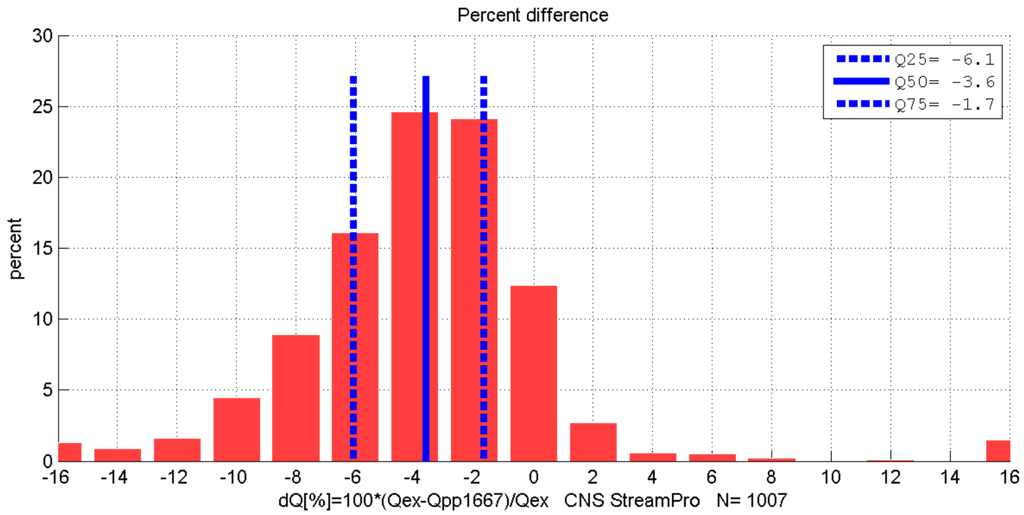



**Figure 5.8 Change in calculated discharge (Constant/no-slip, StreamPro)**

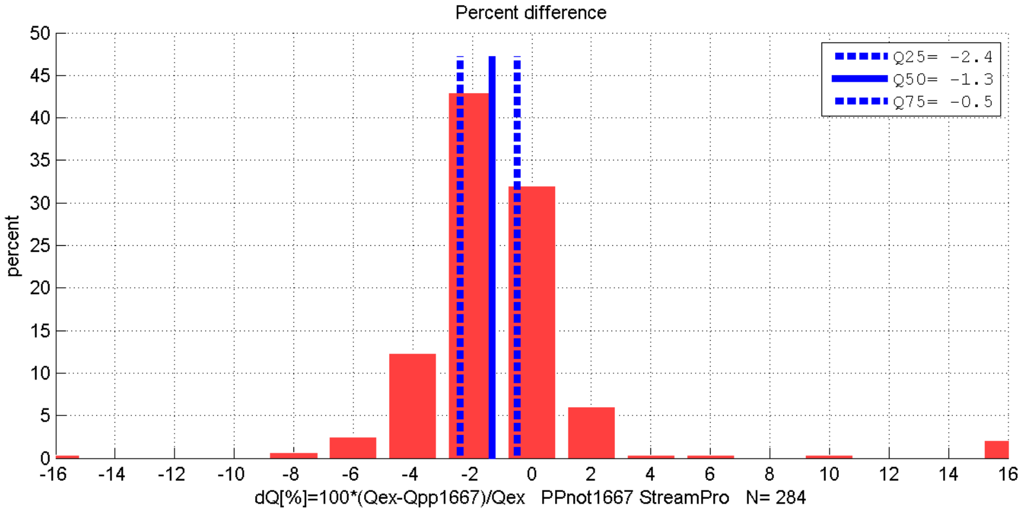



**Figure 5.9 Change in calculated discharge (pwr/pwr/not 0.1667, StreamPro)**

### 5.3.4 Change in calculated discharge and cross-section characteristics

Various cross-section characteristics might affect the vertical velocity profile, and thus the choice of extrapolation method which in turn impacts the calculated discharge.

For the StreamPro we focus on the measurements using Constant/No-Slip extrapolation. This is the most common extrapolation method after 2016.

We observe that median dQ values are always negative. This means that when looking at data from all ADCPs and all extrapolation methods, the discharge calculated using the chosen extrapolation is lower than it would have been if using the default one sixth power law method.

For the StremPro's Constant/No-Slip measurements, the changes in median values for dQ are as listed below. (Note that "dQ increases" means that dQ moves towards zero / dQ gets less negative when the dQ values are less than zero)

Width to depth. dQ is almost the same but varies between -3.9% and -3.7% when width to depth ratios increase from less than 13 to more than 31.

Width. dQ is almost the same (-4.0% and -3.9%) for rivers with low and medium width. For rivers that are more than 32 meters wide the median value for dQ jumps to -3.2%

Depth. dQ is close to un-changed (-4.3% and -4.2%) for rivers with low and medium depth. For rivers that are more than 1.3 meters deep the median value for dQ jumps to -2.7%

Water speed. dQ *decreases* from –3.7% to -4.2% when mean water speed increases from slow (less than 0.2 m/s) to medium (0.2 m/s - 0.5 m/s), and it increases from -4.2% to -3.3% for water speed above 0.5 m/s. The interquartile range is wider for the slow rivers.

Discharge. dQ *decreases* slightly from –3.8% to -4.2% when discharge increases from low (less than 1.8 $m^3$/s) to medium (1.8 $m^3$/s - 15.1 $m^3$/s). dQ increases from -4.2% to -3.0% for discharge above 15.1 $m^3$/s.

Percent Measured (*). dQ decreases from -3.3% to -4.2% when the percentage of Q measured increases from less than 62% to between 62% and 75%. dQ increases from -4.2% to -3.8% for percent measured above 75%.

(*) Percent measured Discharge is 100*Q (in the bins) / Q (total). In other words, the opposite of percent extrapolated. We assume edge Q is a lot smaller than top Q and bottom Q.

The variation in dQ, as indicated by the interquartile range, is narrower for higher values of the characteristics.

dQ[%] for CNS StreamPro

| Range, Width To Depth | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 3,0(min)-13(Q25) | -3,9 | -6,2 | -1,4 | -12,8 | 1,6 | 232 |
| 13(Q25)-31(Q75) | -3,7 | -6,1 | -1,7 | -9,3 | 1,1 | 467 |
| 31(Q75)-190(max) | -3,7 | -5,5 | -2,3 | -9,3 | -0,2 | 233 |

| Range, Width | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 2,5(min)-11(Q25) | -4 | -6,7 | -1,5 | -12,6 | 1,6 | 233 |
| 11(Q25)-32(Q75) | -3,9 | -6,3 | -2 | -9,8 | 0,7 | 468 |
| 32(Q75)-268(max) | -3,2 | -4,8 | -1,9 | -8,1 | 0,5 | 234 |

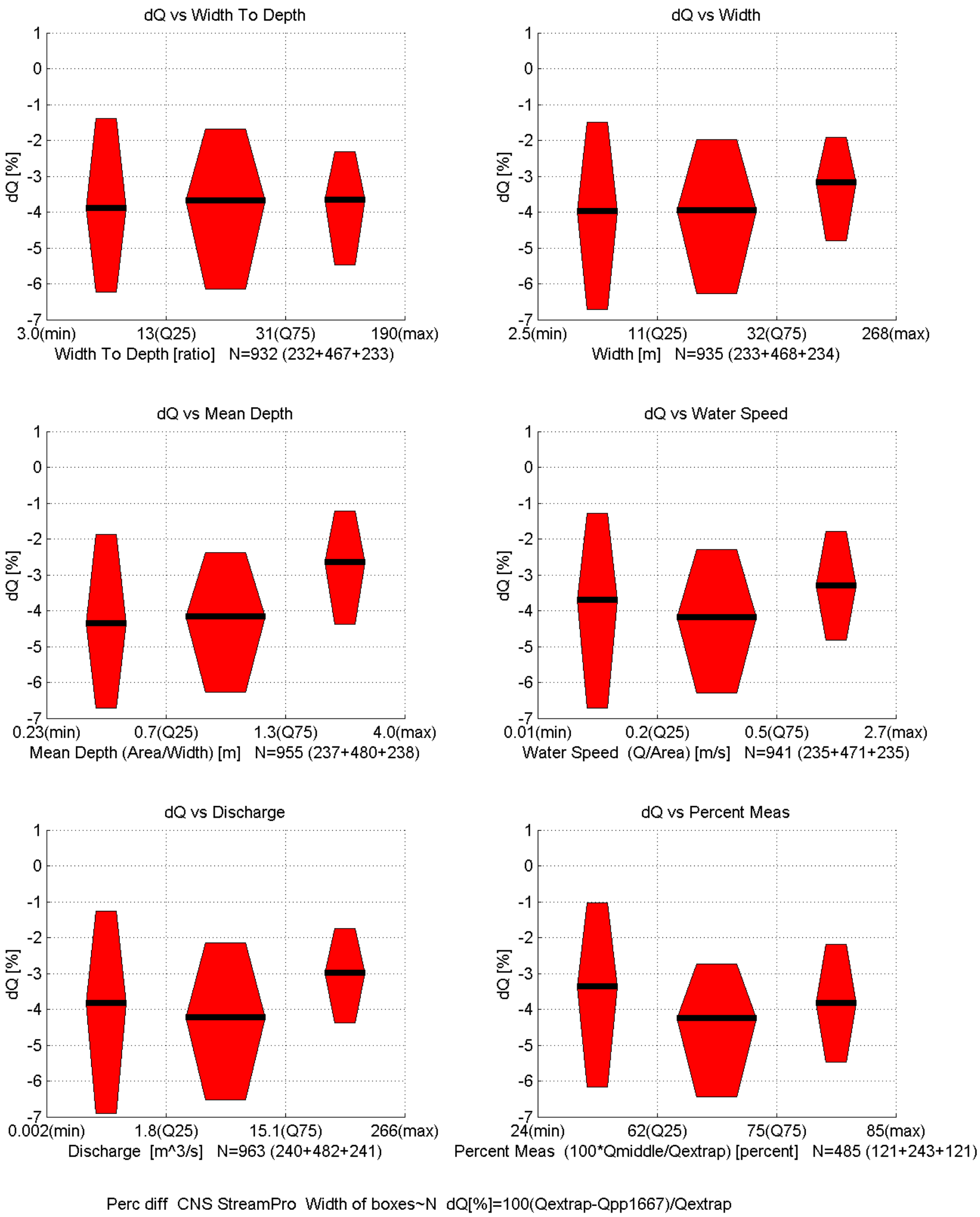
| Range, mean depth | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 0,23(min)-0,7(Q25) | -4,3 | -6,7 | -1,9 | -11,4 | 1,4 | 237 |
| 0,7(Q25)-1,3(Q75) | -4,2 | -6,3 | -2,4 | -10 | -0,1 | 480 |
| 1,3(Q75)-4,0(max) | -2,7 | -4,4 | -1,2 | -8,8 | 1 | 238 |

| Range, water speed | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 0,01(min)-0,2(Q25) | -3,7 | -6,7 | -1,3 | -12,2 | 2,1 | 235 |
| 0,2(Q25)-0,5(Q75) | -4,2 | -6,3 | -2,3 | -10,6 | -0,1 | 471 |
| 0,5(Q75)-2,7(max) | -3,3 | -4,8 | -1,8 | -8,6 | 0,6 | 235 |

| Range, Discharge | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 0,002(min)-1,8(Q25) | -3,8 | -6,9 | -1,3 | -13,1 | 2,1 | 240 |
| 1,8(Q25)-15,1(Q75) | -4,2 | -6,5 | -2,2 | -10 | 0,1 | 482 |
| 15,1(Q75)-266(max) | -3 | -4,4 | -1,7 | -7,4 | 0,2 | 241 |

| Range, Percent Meas | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 24(min)-62(Q25) | -3,4 | -6,2 | -1 | -10,1 | 1,6 | 121 |
| 62(Q25)-75(Q75) | -4,2 | -6,4 | -2,7 | -10,4 | 0,2 | 243 |
| 75(Q75)-85(max) | -3,8 | -5,5 | -2,2 | -10,6 | 0,1 | 121 |

*See explanation below box plots in Figure 5.5, page 32*




*See explanation below box plots in Figure 5.5, page 32*

# 5.4 Rio Grande

## 5.4.1 Change in extrapolation methods over time

For the Rio Grande there are relatively few measurements. See Figure 5.10. For most of the years 2005-2020 there are 30-40 measurements per year, but for 2015 and 2016 there are 70-100 measurements per year. After 2020 there are less than 10 Rio Grande-measurements per year. This is not the total number of measurements, but the number of measurements where there is relevant information in the dataset. The low number of measurements makes it difficult to be certain of trends.

There was a shift in the choice of extrapolation methods for Rio Grande measurements in the years 2013-2015, after Extrap version 3 was introduced. Before 2012 around 78% of the measurements were extrapolated using the default power/power/0.1667 extrapolation, and after 2015 the percentage has fallen to 8%.

After 2015, the distribution of methods seems “noisy”. It is probably due to a low total number of Rio Grande-measurements. For the years 2016 and onwards 59% of the measurements were reprocessed using power/power extrapolation with an exponent different from the default 0.1667 (one sixth power law). For the years 2005-2012 only 9 percent had this extrapolation. The percentage of constant/no-slip measurements increased from 11% to 31%.

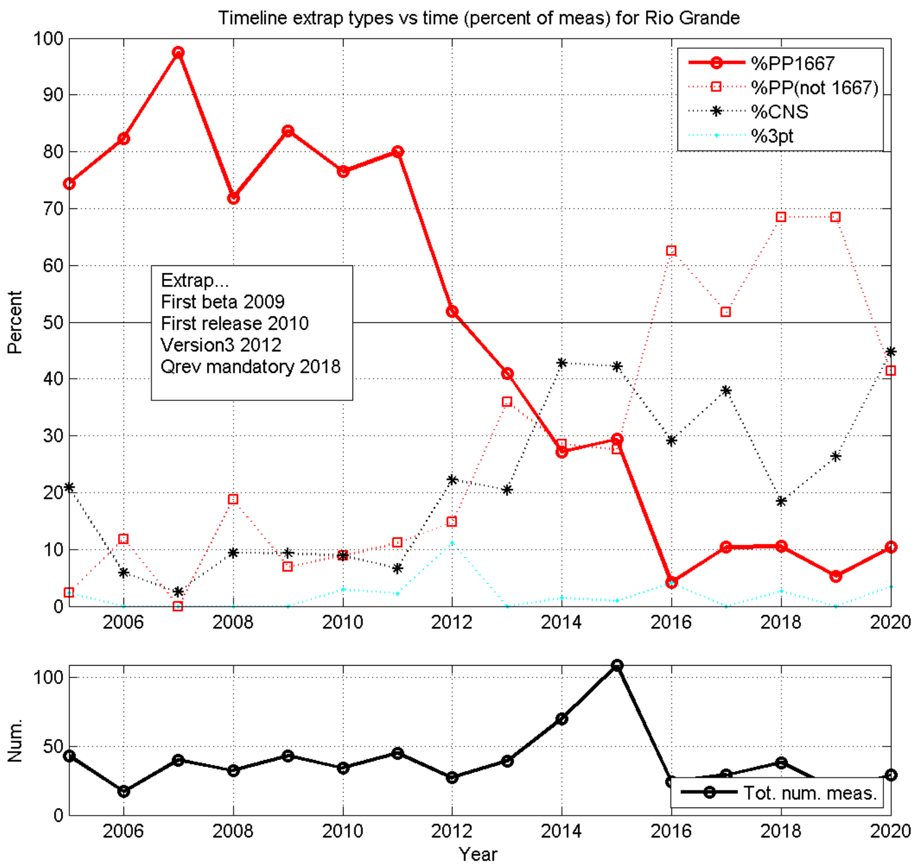



**Figure 5.10 Extrapolation methods vs time (percent of total number of Rio Grande measurements)**

*Meaning of captions, see Figure 5.1 page 24. Years with more than 10 measurements are included.*

| Yrs (RG) | Num tot | Pwr/pwr (0.1667) | | Pwr/pwr (not 0,1667) | | Const/NoSlip | | Pwr/pwr (total) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Num | % | Num | % | Num | % | Num | % |
| 2005-2012 | 281 | 220 | 78 | 24 | 9 | 30 | 11 | 244 | 87 |
| 2016-2025 | 145 | 12 | 8 | 85 | 59 | 45 | 31 | 97 | 67 |

### 5.4.2 Extrapolation methods and cross-section characteristics

The plots and tables below show data from 2016 and onwards, when the use of Extrap/Qrev had become an established routine. Various cross-section characteristics might affect the vertical velocity distribution, and hence the extrapolation method the user has chosen. Cross-section characteristics are features of the measurement site or features caused by a combination of the selected ADCP instrument and the measurement site.

- Width to depth ratio (W/D)
- Width
- Mean depth (area/width)
- Mean water speed (Q/area)
- Discharge
- Percent measured (total Q divided by Q in the measured area).

The measurements are grouped so that for each cross-section characteristics (for instance width) the measurements with the 25% lowest values are in one group (the 25% with the narrowest cross sections), the measurements with the 25% highest values are in one group (the 25% with the widest cross sections) and the remaining 50% are in the "medium" group (the 50% that are neither narrow or wide).
For each of these groups the percentage of measurements using three different kinds of extrapolation is calculated, namely the default power/power/0.1667 extrapolation, power/power/not 0.1667 extrapolation and constant/no-slip extrapolation.

Note that there are very few measurements in some intervals, since there are few RioGrande measurements in total, and even less (in the dataset) that contain the desired information. This means that even a few measurements can alter the percentages notably.

Width to depth ratio. For increasing width to depth ratio, the percentage of constant/no-slip measurements decrease steadily and notably from 44% to 15%. The percentage of power/power (not 1667) measurements increase from 53% to 62%. Power/power (1667) measurements increase from 3% to 18%. (These 3% are 1 out of 34 measurements, see the numbers on the plot or in the table!)

Width. 38 and 36% of the measurements are constant/no-slip for narrow and medium wide rivers. For wide rivers, the percentage of constant/no-slip measurements decrease to 12%. Power/power (not 1667) is almost the same (56% and 53%) when width increases from narrow to medium. For wide rivers power/power (not 1667) jumps to 74%. Power/power (1667) increases from 3% to 12%.

Mean depth. For increasing depth, the percentage of constant/no-slip measurements decrease from 31% via 34% to 22%. The percentage of power/power (not 1667) measurements increase notably and steadily from 46% to 72%. The percentage of power/power (1667) measurements decrease from 14% to 7%.

Mean water speed (Q/area). For increasing water speed, the percentage of constant/no-slip measurements decrease from 37% for slow rivers to 29% for the medium fast and fast ones. The percentage of power/power (not 1667) measurements increase from 43% via 63% to 64%, so it is almost the same for medium fast and fast water speed. Power/power (1667) measurements decrease from 14% via 6% to 9%.

Discharge. For increasing Q, the percentage of constant/no-slip measurements decrease notably and steadily from 49% to 11%. The percentage of power/power (not 1667) measurements increase equally notably and steadily from 37% to 80%. The percentage of power/power (1667) measurements vary between 8% and 9%.

Percent measured (*). For increasing percentage of measured Q, the percentage of constant/no-slip measurements decrease slightly from 29% via 25% to 24%. The percentage of power/power (not 1667) measurements increase from 52% via 70% to 71%. The percentage of power/power (1667) measurements decrease from 14% via 2% (1/44) to 5%.

(*) Percent measured Discharge is 100*Q (in the bins) / Q (total). In other words, the opposite of percent extrapolated. We assume edge Q is a lot smaller than top Q and bottom Q.

**Extrap methods, RioGrande**

| Range, WidthToDepth | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 6,800(min)-17,0(Q25) | 34 | 15 | 44 | 18 | 53 | 1 | 3 |
| 17,0(Q25)-35,4(Q75) | 70 | 22 | 31 | 42 | 60 | 5 | 7 |
| 35,4(Q75)-83,4(max) | 34 | 5 | 15 | 21 | 62 | 6 | 18 |

| Range, Width | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 9,835(min)-48,8(Q25) | 34 | 13 | 38 | 19 | 56 | 1 | 3 |
| 48,8(Q25)-124(Q75) | 70 | 25 | 36 | 37 | 53 | 7 | 10 |
| 124(Q75)-352(max) | 34 | 4 | 12 | 25 | 74 | 4 | 12 |

| Range, mean depth | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 0,520(min)-2,3(Q25) | 35 | 11 | 31 | 16 | 46 | 5 | 14 |
| 2,3(Q25)-4,5(Q75) | 73 | 25 | 34 | 43 | 59 | 5 | 7 |
| 4,5(Q75)-9,0(max) | 36 | 8 | 22 | 26 | 72 | 2 | 6 |

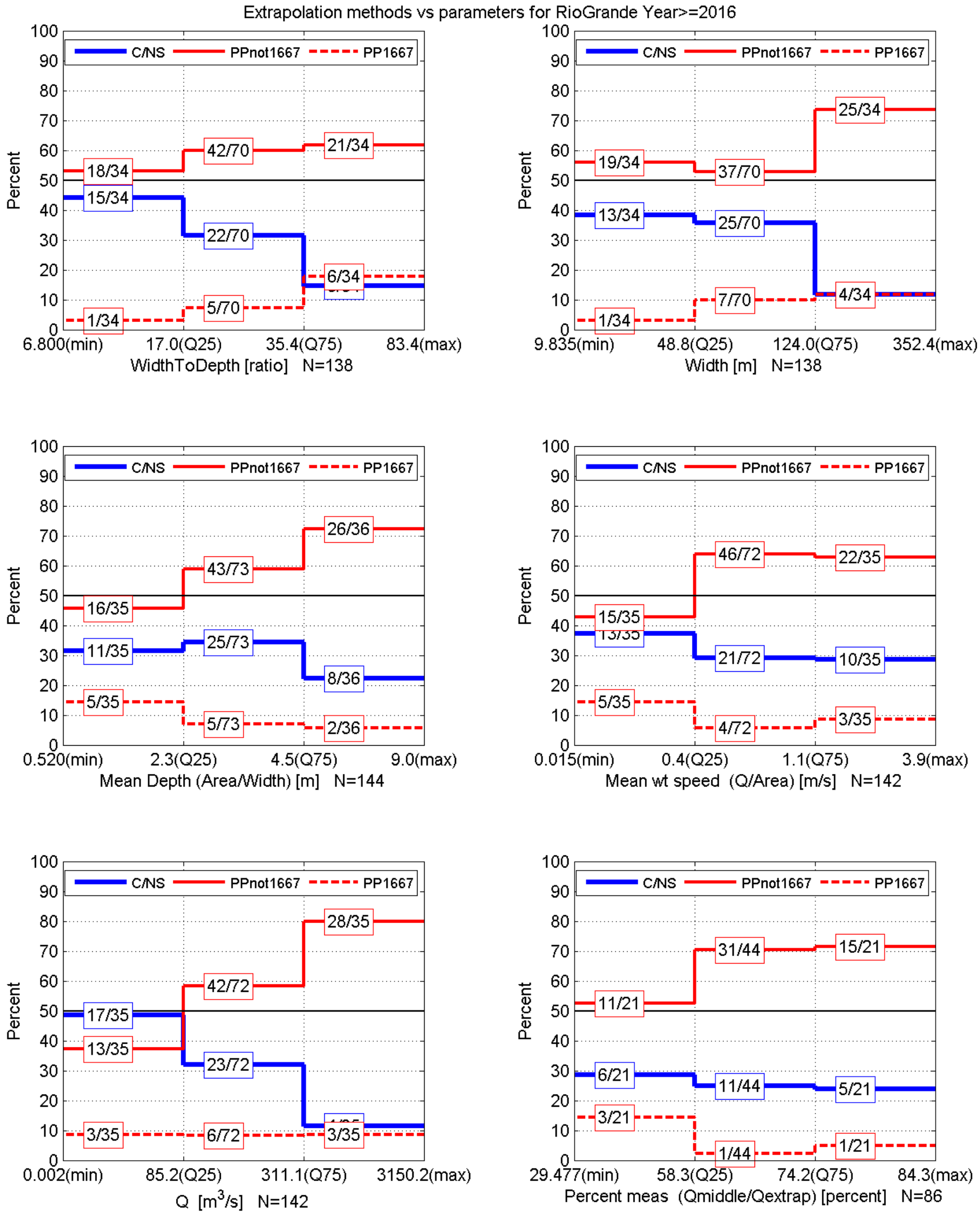
| Range, Mean water speed | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 0,015(min)-0,4(Q25) | 35 | 13 | 37 | 15 | 43 | 5 | 14 |
| 0,4(Q25)-1,1(Q75) | 72 | 21 | 29 | 46 | 64 | 4 | 6 |
| 1,1(Q75)-3,9(max) | 35 | 10 | 29 | 22 | 63 | 3 | 9 |

| Range, Q | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 0,002(min)-85,2(Q25) | 35 | 17 | 49 | 13 | 37 | 3 | 9 |
| 85,2(Q25)-311,1(Q75) | 72 | 23 | 32 | 42 | 58 | 6 | 8 |
| 311(Q75)-3150(max) | 35 | 4 | 11 | 28 | 80 | 3 | 9 |

| Range, Percent meas | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 29,477(min)-58,3(Q25) | 21 | 6 | 29 | 11 | 52 | 3 | 14 |
| 58,3(Q25)-74,2(Q75) | 44 | 11 | 25 | 31 | 70 | 1 | 2 |
| 74,2(Q75)-84,3(max) | 21 | 5 | 24 | 15 | 71 | 1 | 5 |

*nXXX ~ number of measurements*

*%XXX ~ percentage of measurements*



### 5.4.3 Change in calculated discharge

We have discharge data ("Q with and without extrap") for 266 Rio Grande-measurements. The median percent difference between discharge calculated using the default extrapolation and the discharge calculated using the extrapolation method the user has chosen is -0.4%. This means that the discharge is typically 0.4% lower than it would have been if we used the default extrapolation only. Or, in other words, the median difference is close to zero. The quartile values are -2.2% and 0.4%. This means that for 50% of the measurements, the discharge is between 2.2% lower and 0.4% higher when using Extrap/Qrev to find the best extrapolation method than when using the default extrapolation method. See Figure 3.12.

For all instruments and methods combined, the median value -1.5%, and this means that there is a smaller difference for the Rio Grande than for all instruments and methods combined.

For the Rio Grande, the most common extrapolation method after 2015 is power/power with an exponent not equal to 0.1667. If looking only at those Rio Grande-measurements that have power/power/ not 0.1667 extrapolation, we see that for 101 measurements the median percent difference is 0%. See Figure 5.13. This means that when using Extrap/Qrev, the calculated discharge typically is the same as what it would have been if we used default extrapolation. The quartile values are minus 1.3% and 0.8%. This means that for 50% of the measurements, the discharge is between 1.2% lower and 0.9% higher when using Extrap/Qrev to find the best extrapolation method than when using the one sixth power law extrapolation method.

These changes are probably neglectable. There are relatively few measurements containing discharge for "extrap'ed" data and "un'extrap'ed" data, so these observations might be due to random variations.

For the measurements using constant/no-slip the median dQ is -1.8% and the quartiles are -3.7% and -0.0%.

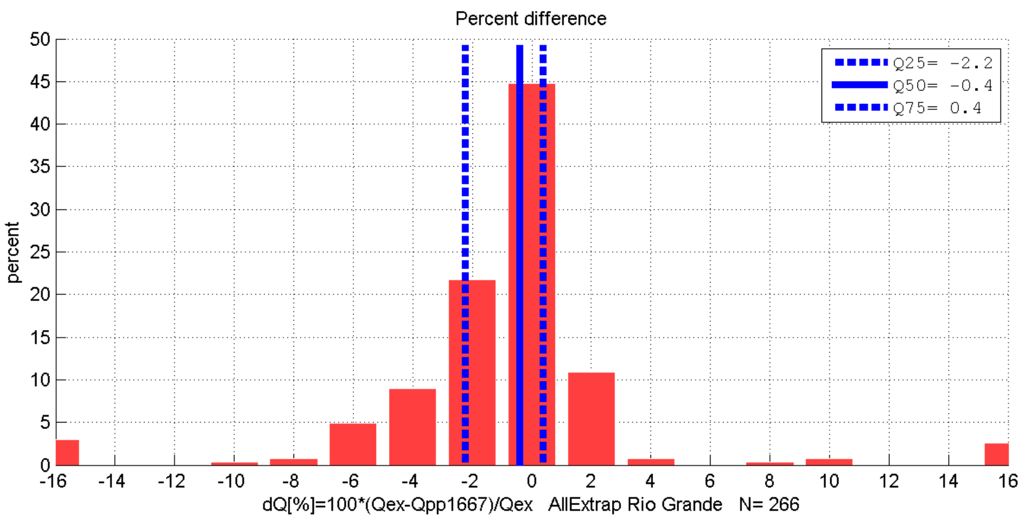



**Figure 5.11 Change in calculated discharge (All methods, Rio Grande)**

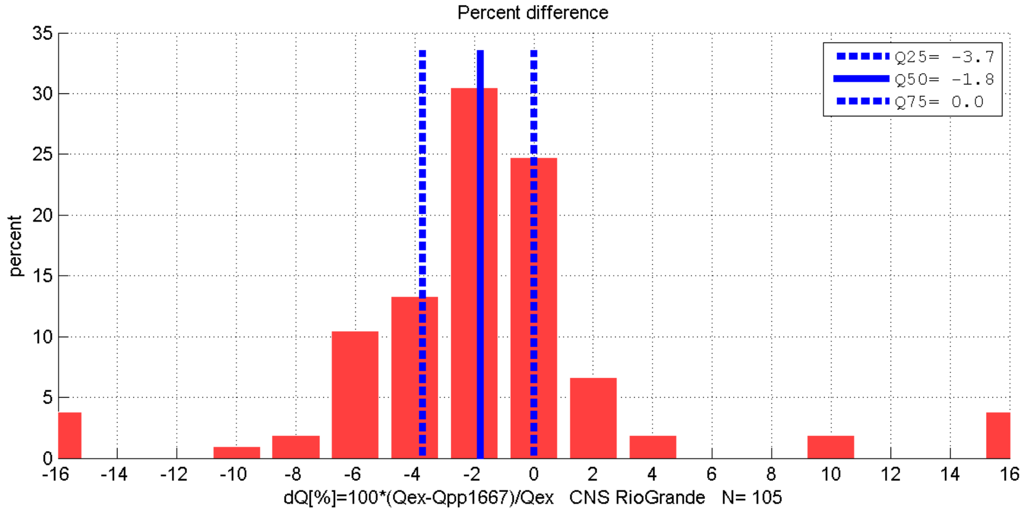



**Figure 5.12 Change in calculated discharge (Constant/no-slip, Rio Grande)**

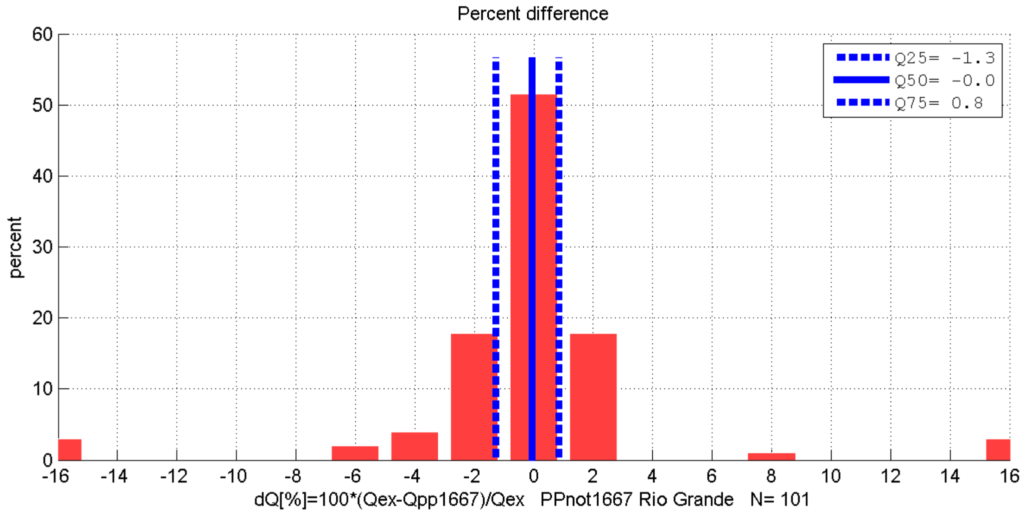
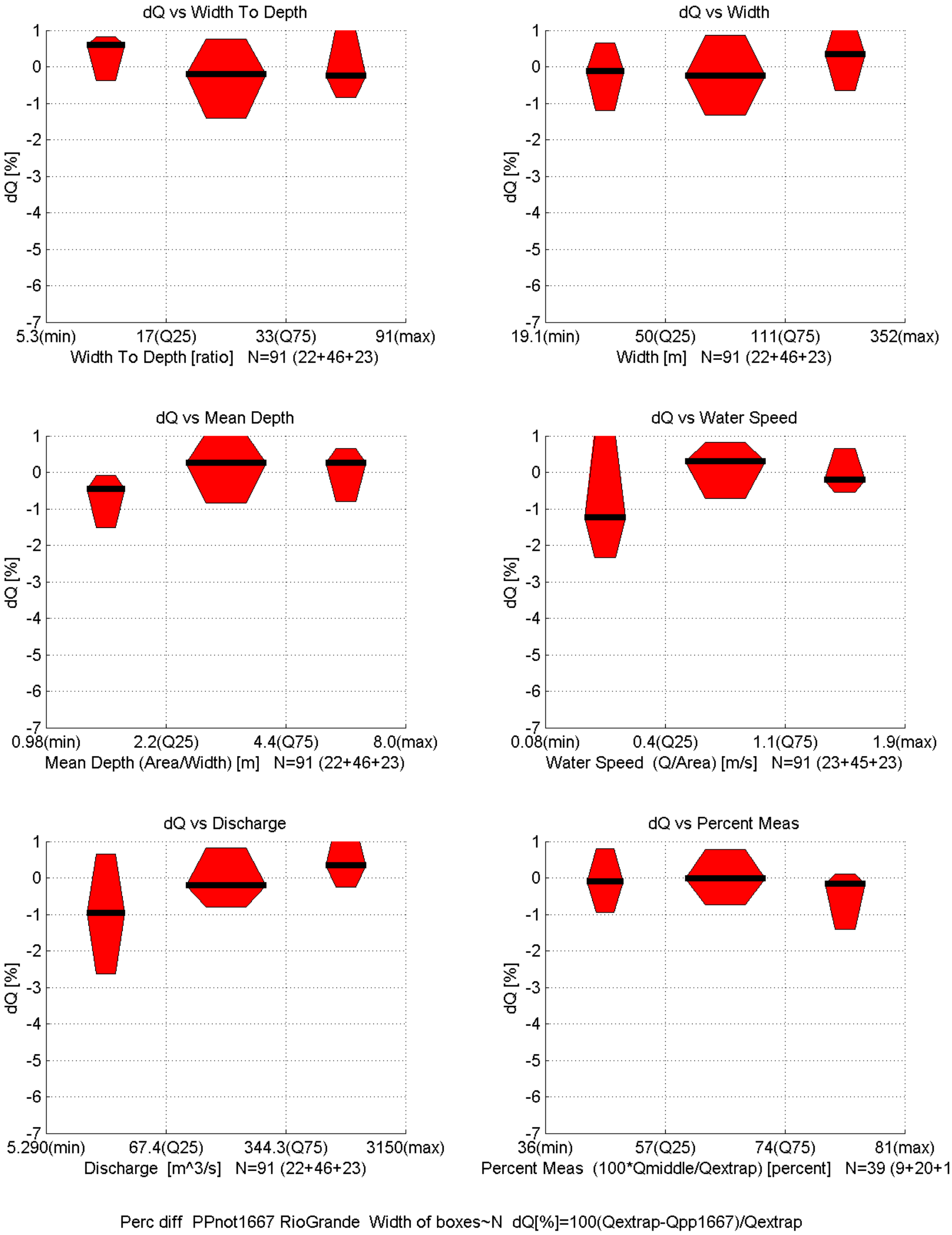



**Figure 5.13 Change in calculated discharge (Power/power/not 0.1667, Rio Grande)**

### 5.4.4 Change in calculated discharge and cross-section characteristics

For the RioGrande ADCP, we observe that there are more power/power measurements than constant/no-slip measurements. In total, around 2/3 are power/power.

There are too few measurements to look detailed into the very small changes in discharge, but from the boxplot below we see that the median values for dQ is in the range zero to -1% for all cross-section characteristics and all low/medium/high intervals.




*See explanation below box plots in Figure 5.5, page 32*

dQ[%] for PPnot1667 RioGrande

| Range, Width To Depth | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 5,3(min)-17(Q25) | 0,6 | -0,4 | 0,8 | -4,7 | 1,8 | 22 |
| 17(Q25)-33(Q75) | -0,2 | -1,4 | 0,7 | -3,5 | 1,6 | 46 |
| 33(Q75)-91(max) | -0,3 | -0,9 | 1 | -3,8 | 2,1 | 23 |

| Range, Width | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 19,1(min)-50(Q25) | -0,1 | -1,2 | 0,6 | -6,8 | 1,4 | 22 |
| 50(Q25)-111(Q75) | -0,3 | -1,3 | 0,9 | -3,1 | 1,8 | 46 |
| 111(Q75)-352(max) | 0,3 | -0,6 | 1,2 | -3,8 | 2,1 | 23 |

| Range, mean depth | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 0,98(min)-2,2(Q25) | -0,5 | -1,5 | -0,1 | -6,8 | 1,1 | 22 |
| 2,2(Q25)-4,4(Q75) | 0,3 | -0,9 | 1,1 | -2,8 | 1,9 | 46 |
| 4,4(Q75)-8,0(max) | 0,3 | -0,8 | 0,7 | -6,8 | 1,9 | 23 |

| Range, water speed | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 0,08(min)-0,4(Q25) | -1,2 | -2,3 | 1,1 | -6,8 | 1,9 | 23 |
| 0,4(Q25)-1,1(Q75) | 0,3 | -0,7 | 0,8 | -4,7 | 1,8 | 45 |
| 1,1(Q75)-1,9(max) | -0,2 | -0,5 | 0,6 | -1,6 | 1,6 | 23 |

| Range, Discharge | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 5,290(min)-67,4(Q25) | -1 | -2,6 | 0,6 | -6,8 | 1,4 | 22 |
| 67,4(Q25)-344,3(Q75) | -0,2 | -0,8 | 0,8 | -2,8 | 1,8 | 46 |
| 344,3(Q75)-3150(max) | 0,3 | -0,2 | 1,5 | -1,4 | 2,1 | 23 |

| Range, Percent Meas | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 36(min)-57(Q25) | -0,1 | -0,9 | 0,8 | -3,5 | 1,4 | 9 |
| 57(Q25)-74(Q75) | 0 | -0,7 | 0,8 | -2,3 | 1,9 | 20 |
| 74(Q75)-81(max) | -0,2 | -1,4 | 0,1 | -1,5 | 0,6 | 10 |

*See explanation below box plots in Figure 5.5, page 32*

# 5.5 M9

## 5.5.1 Change in extrapolation methods over time

For the M9, we have no data for the years before we started using Extrap and very few measurements before 2017.

The timeline plot and the table below show that since 2017 there are equally many measurements using constant/no-slip extrapolation and power/power extrapolation with an exponent different from 0.1667. If we include the p/p/0.1667 measurements, there are in total 53% power/power measurements.

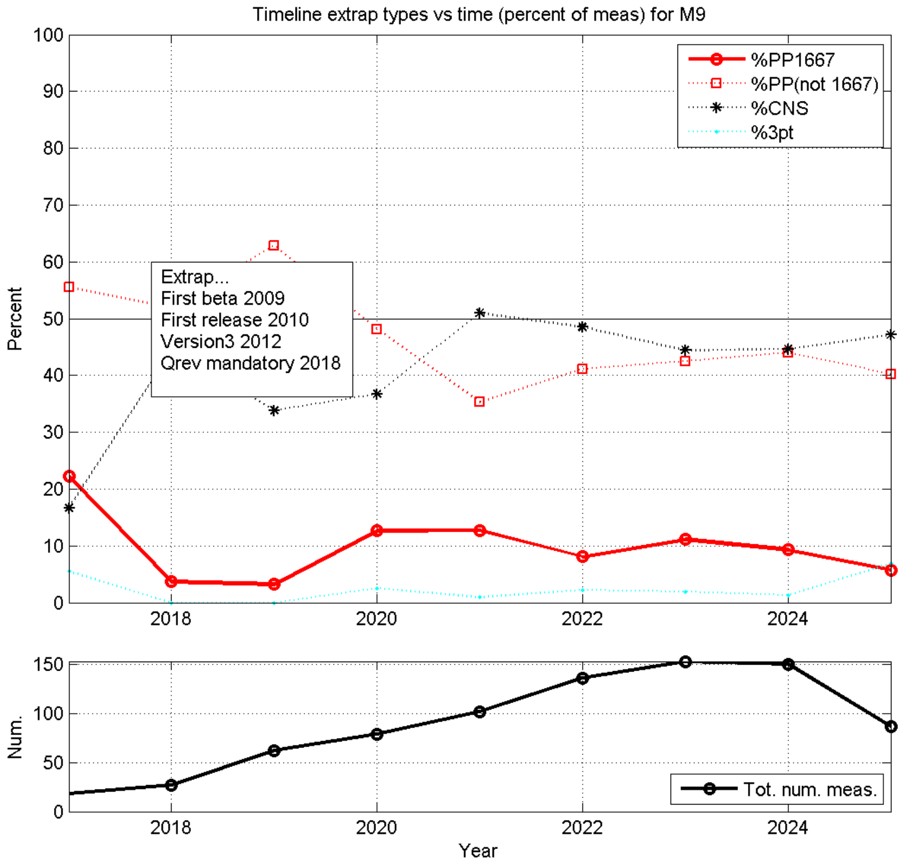



**Figure 5.14 Extrapolation methods vs time (percent of total number of M9 measurements)**

*Meaning of captions, see Figure 5.1 page 24. Years with more than 10 measurements are included.*

| Yrs (m9) | Num tot | Pwr/pwr (0.1667) | | Pwr/pwr (not 0,1667) | | Const/NoSlip | | Pwr/pwr (total) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Num | % | Num | % | Num | % | Num | % |
| 2005-2012 | 0 | 0 | X | 0 | X | 0 | X | 0 | X |
| 2016-2025 | 815 | 77 | 9 | 359 | 44 | 359 | 44 | 436 | 53 |

### 5.5.2 Extrapolation methods and cross-section characteristics

The plots and tables below show data from 2016 and onwards, when the use of Extrap/Qrev had become an established routine. Various cross-section characteristics might affect the vertical velocity distribution, and hence the extrapolation method the user has chosen. Cross-section characteristics are features of the measurement site or features caused by a combination of the selected ADCP instrument and the measurement site.

- Width to depth ratio (W/D)

- Width
- Mean depth (area/width)
- Mean water speed (Q/area)
- Discharge
- Percent measured (total Q divided by Q in the measured area).

The measurements are grouped so that for each cross-section characteristics (for instance width) the measurements with the 25% lowest values are in one group (the 25% with the narrowest cross sections), the measurements with the 25% highest values are in one group (the 25% with the widest cross sections) and the remaining 50% are in the “medium” group (the 50% that are neither narrow or wide).
For each of these groups the percentage of measurements using three different kinds of extrapolation is calculated, namely the default power/power/0.1667 extrapolation, power/power/not 0.1667 extrapolation and constant/no-slip extrapolation.
For the M9, we observe that constant/no-slip and power/power are more or less equally chosen.

Width to depth ratio. For increasing width to depth ratio, the percentage of constant/no-slip measurements decrease notably but not steadily from 57% to 37%. The percentage of power/power (not 1667) measurements increase accordingly from 34% to 50%. Power/power (1667) measurements constitute 5% of the measurements on low width/depth rivers, and 11% on and medium and high width/depth rivers.

Width. For increasing width, the percentage of constant/no-slip measurements decrease quite steadily from 52% via 41 to 38%. The percentage of power/power (not 1667) measurements increase inconsequently from 40% via 47% to 43%. Power/power (1667) measurements decrease quite steadily from 5% via 8% to 16%.

Mean depth. For increasing depth, the percentage of constant/no-slip measurements vary from 38% to 48%, but in a “strange” way: For shallow, medium and deep rivers, the constant/no-slip percentages are 38%, 48% and 40%. There are approximately the same percentage of constant/no-slip measurements for deep and for shallow rivers, and higher for the rivers in between.
The percentage of power/power (not 1667) measurements decrease slightly and steadily from 50% to 41%. The percentage of power/power (1667) measurements jump from 10% to 6% to 16% for shallow, medium and deep rivers.
M9 data show inconsistent behaviour for varying mean depth.

Mean water speed (Q/area). For increasing water speed, the percentage of constant/no-slip measurements decrease from 59%, via 38% to 39% (almost the same for medium and high). The percentage of power/power (not 1667) measurements increase from 30% via 51% to 47%. Power/power (1667) measurements increase from 7% to 12%.

Discharge. The percentage of constant/no-slip measurements is 53% for low discharge and decreases to 41% and 40% for medium and high discharge. The percentages of power/power (not 1667) jump from 36% to 50% to 44% for low, medium and high discharge. For power/power (not 1667) the percentages are 8, 7 and 14.
M9 data show inconsistent behaviour for varying discharge.

Percent measured (*). For increasing percentage of measured Q, the percentage of constant/no-slip measurements increase from 38% via 45% to 46%. The percentage of power/power (not 1667) measurements decrease steadily from 51% to 36%. The percentage of power/power (1667) measurements vary from 10% to 7% to 15% for low, medium and high values for percent measured.

(*) Percent measured Discharge is 100*Q (in the bins) / Q (total). In other words, the opposite of percent extrapolated. We assume edge Q is a lot smaller than top Q and bottom Q.

Extrap methods, M9

| Range, WidthToDepth | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 2,836(min)-18,6(Q25) | 184 | 105 | 57 | 62 | 34 | 10 | 5 |
| 18,6(Q25)-38,4(Q75) | 369 | 146 | 40 | 174 | 47 | 40 | 11 |
| 38,4(Q75)-205,7(max) | 184 | 68 | 37 | 92 | 50 | 20 | 11 |

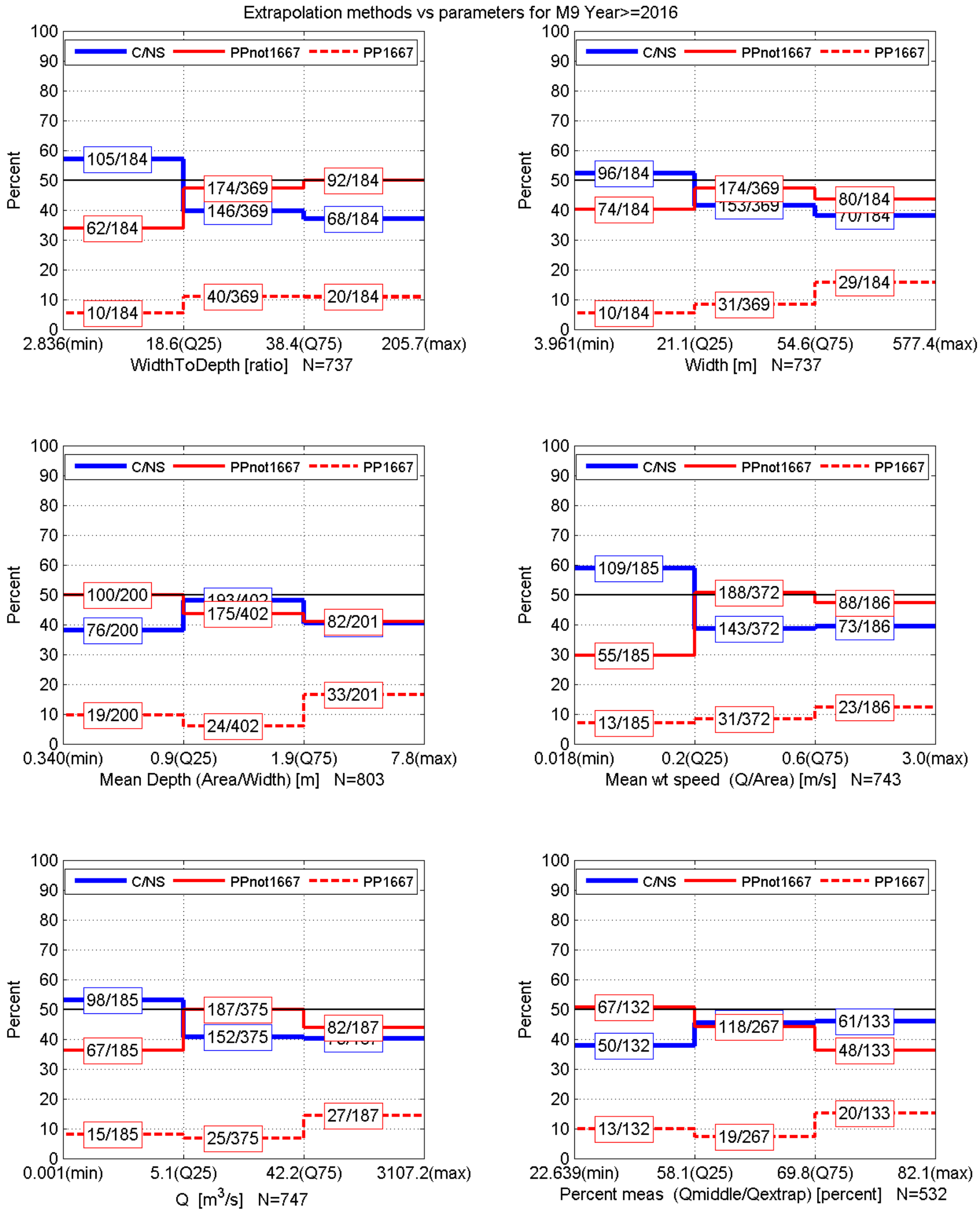
| Range, Width | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 3,961(min)-21,1(Q25) | 184 | 96 | 52 | 74 | 40 | 10 | 5 |
| 21,1(Q25)-54,6(Q75) | 369 | 153 | 41 | 174 | 47 | 31 | 8 |
| 54,6(Q75)-577,4(max) | 184 | 70 | 38 | 80 | 43 | 29 | 16 |

| Range, mean depth | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 0,340(min)-0,9(Q25) | 200 | 76 | 38 | 100 | 50 | 19 | 10 |
| 0,9(Q25)-1,9(Q75) | 402 | 193 | 48 | 175 | 44 | 24 | 6 |
| 1,9(Q75)-7,8(max) | 201 | 81 | 40 | 82 | 41 | 33 | 16 |

| Range, Mean water speed | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 0,018(min)-0,2(Q25) | 185 | 109 | 59 | 55 | 30 | 13 | 7 |
| 0,2(Q25)-0,6(Q75) | 372 | 143 | 38 | 188 | 51 | 31 | 8 |
| 0,6(Q75)-3,0(max) | 186 | 73 | 39 | 88 | 47 | 23 | 12 |

| Range, Q | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 0,001(min)-5,1(Q25) | 185 | 98 | 53 | 67 | 36 | 15 | 8 |
| 5,1(Q25)-42,2(Q75) | 375 | 152 | 41 | 187 | 50 | 25 | 7 |
| 42,2(Q75)-3107,2(max) | 187 | 75 | 40 | 82 | 44 | 27 | 14 |

| Range, Percent meas | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 22,639(min)-58,1(Q25) | 132 | 50 | 38 | 67 | 51 | 13 | 10 |
| 58,1(Q25)-69,8(Q75) | 267 | 121 | 45 | 118 | 44 | 19 | 7 |
| 69,8(Q75)-82,1(max) | 133 | 61 | 46 | 48 | 36 | 20 | 15 |




### 5.5.3 Change in calculated discharge

If not filtering out any extrapolation methods, we have discharge data for 740 M9-measurements. The median percent difference between discharge calculated using the default extrapolation and the discharge calculated using the extrapolation method the user has chosen is -0.4%. This means that the discharge is typically 0.4% lower than it would have been if we used the default extrapolation. The quartile values are -2.6% and 0.3%, and this means that for 50% of the measurements, change in discharge between 2.6% lower and 0.3% higher when using Extrap/Qrev to find the best extrapolation method instead of using the default extrapolation method. See Figure 5.15.

For all instruments and methods combined, the median value -1.5%, and this means that there is a smaller difference for the M9 than for all instruments and methods combined.

For the M9, the most common extrapolation methods after 2012 are constant/no-slip and power/power with an exponent not equal to 0.1667.

If looking only at those M9-measurements that have constant/no-slip extrapolation, we see that for 332 measurements the median percent difference -2.6%. See Figure 5.16. This means that the discharge is typically 2.6% lower than it would have been if we used the default extrapolation. The quartile values are -4.2% and -1.0%. This means that for 50% of the measurements, the discharge is between 4.2% and 1% lower when using Extrap/Qrev to find the best extrapolation method than when using the default extrapolation method.

If looking only at those M9-measurements that have power/power/not0.1667 extrapolation, we see that for 324 measurements the median percent difference is 0.1%. See Figure 5.17. This means that the discharge is typically 0.1% higher than it would have been if we used the default extrapolation. The quartile values are -0.5% and 1.0%. This means that for 50% of the measurements, the discharge is between 0.5% lower and 1.0 higher when using Extrap/Qrev to find the best extrapolation method than when using the default extrapolation method. These are probably neglectable differences.

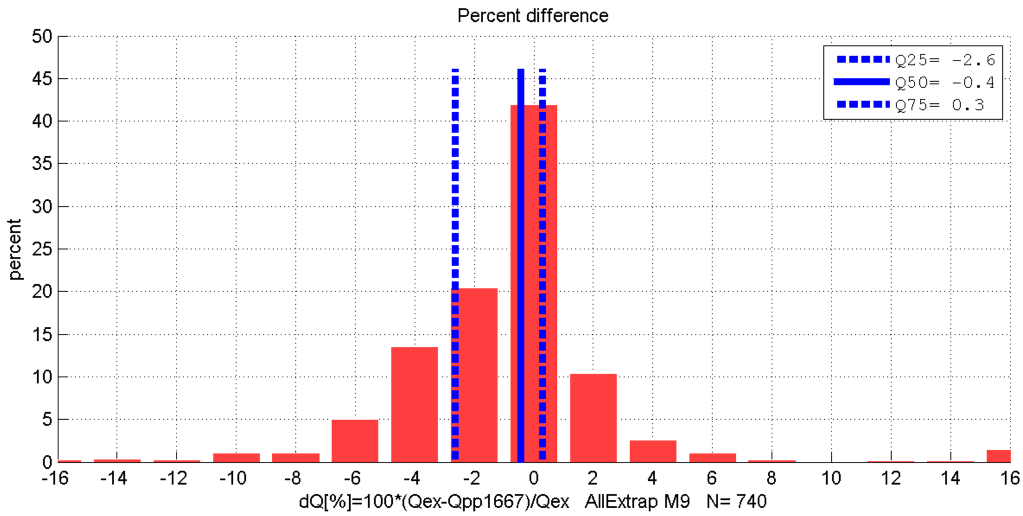



**Figure 5.15 Change in calculated discharge (All methods, M9)**

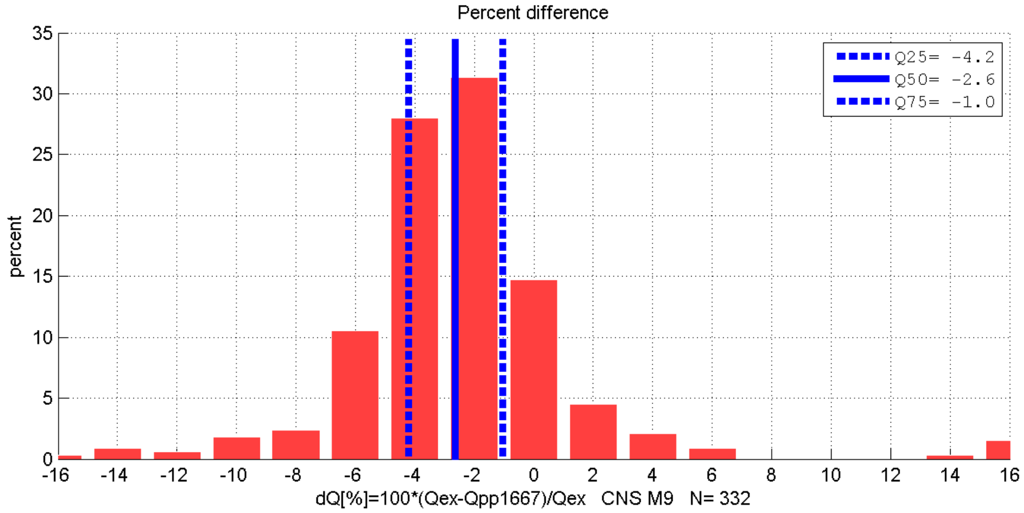



**Figure 5.16 Change in calculated discharge (Constant/no-slip, M9)**

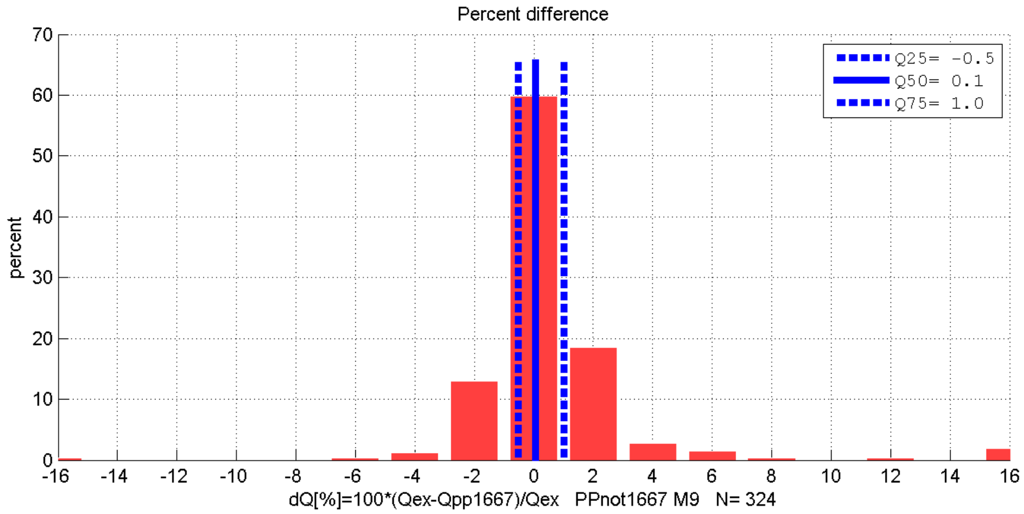



**Figure 5.17 Change in calculated discharge (Power/power/not 0.1667, M9)**

### 5.5.4 Change in calculated discharge and cross-section characteristics

Various cross-section characteristics might affect the vertical velocity profile, and thus the choice of extrapolation method which in turn impacts the calculated discharge.

For the M9 we focus on the measurements using Constant/No-Slip extrapolation. Constant/No-Slip and power/power(not 0.1667) extrapolation is close to equally common, but dQ% for the latter is very small.

We observe that median dQ values are always negative. This means that when looking at constant/no-slip M9 measurements, the calculated discharge is lower than it would have been if using the default one sixth power law method.

For the M9 Constant/No-Slip measurements, the changes in median values for dQ are as listed below. (Note that "dQ increases" means that dQ moves towards zero / dQ gets less negative when the dQ values are less than zero).

Width to depth. dQ decreases from -1.9% to -3.0% when width to depth ratios increase from less than 16 to more than 36.

Width. dQ goes from -2.1% to -3.2% to -1.9% for rivers with low, medium and high width. M9 data show inconsistent behaviour for varying width.

Depth. Median dQ is close to un-changed (-3.3% and -3.1%) for rivers with low and medium depth. For rivers that are more than 1.9 meters deep the median value for dQ jumps to -0.9%

Water speed. dQ increases consistently from –3.4% to -2.0% when mean water speed increases from slow (less than 0.2 m/s) to fast (above 0.6 m/s)

Discharge. dQ increases consistently from –3.2% to -1.4% when discharge increases from low (less than 3.9 $m^3$/s) to high (above 38.9 $m^3$/s)

Percent Measured (*). The median value for dQ decreases from
-2.9% via -2.1% to -3.2% when the percentage of Q measured increases from low (less than 59%) via medium to high (more than 82%).

(*) Percent measured Discharge is 100*Q (in the bins) / Q (total). In other words, the opposite of percent extrapolated. We assume edge Q is a lot smaller than top Q and bottom Q.

The variation in dQ, as indicated by the interquartile range, is notably narrower for higher values of the discharge. Not so much for the others.

dQ[%] for CNS M9

| Range, Width To Depth | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 2,8(min)-16(Q25) | -1,9 | -4,1 | -0,2 | -12,3 | 4 | 77 |
| 16(Q25)-36(Q75) | -2,7 | -4,1 | -1,2 | -8,1 | 2,8 | 155 |
| 36(Q75)-156(max) | -3 | -4,6 | -1,8 | -6,4 | 0,2 | 77 |

| Range, Width | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 4,0(min)-20(Q25) | -2,1 | -4,3 | -1 | -14 | 1,4 | 77 |
| 20(Q25)-53(Q75) | -3,2 | -4,9 | -1,4 | -8,5 | 2 | 155 |
| 53(Q75)-577(max) | -1,9 | -3,4 | -0,8 | -5,2 | 3 | 77 |

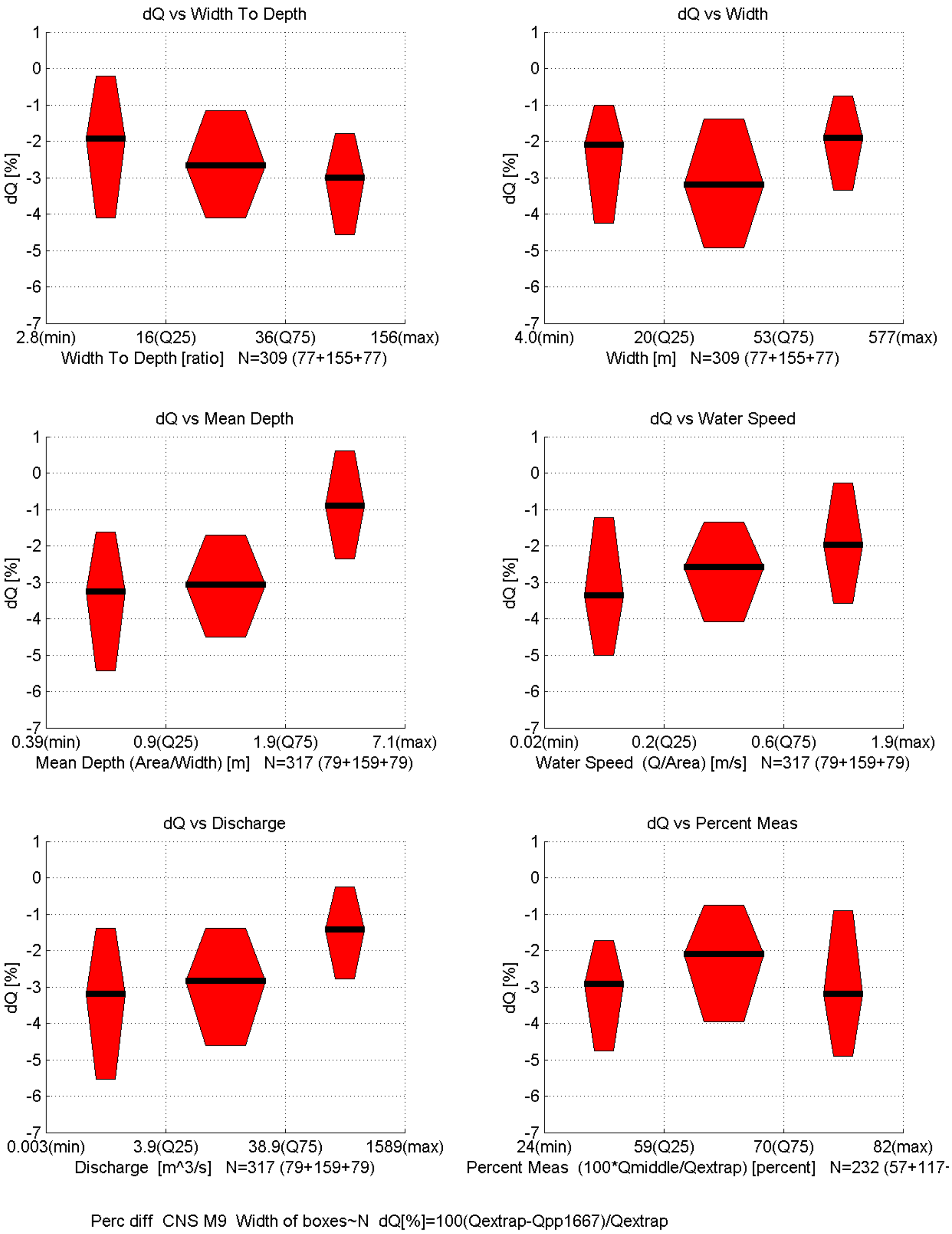
| Range, mean depth | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 0,39(min)-0,9(Q25) | -3,3 | -5,4 | -1,6 | -12,9 | 0,2 | 79 |
| 0,9(Q25)-1,9(Q75) | -3,1 | -4,5 | -1,7 | -8,1 | 1,4 | 159 |
| 1,9(Q75)-7,1(max) | -0,9 | -2,3 | 0,6 | -8,5 | 3,6 | 79 |

| Range, water speed | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 0,02(min)-0,2(Q25) | -3,4 | -5 | -1,2 | -14 | 3,6 | 79 |
| 0,2(Q25)-0,6(Q75) | -2,6 | -4,1 | -1,3 | -7,3 | 0,8 | 159 |
| 0,6(Q75)-1,9(max) | -2 | -3,6 | -0,3 | -5,9 | 4,1 | 79 |

| Range, Discharge | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 0,003(min)-3,9(Q25) | -3,2 | -5,5 | -1,4 | -14 | 1,8 | 79 |
| 3,9(Q25)-38,9(Q75) | -2,9 | -4,6 | -1,4 | -7,3 | 2,2 | 159 |
| 38,9(Q75)-1589(max) | -1,4 | -2,8 | -0,2 | -4,7 | 2,8 | 79 |

| Range, Percent Meas | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 24(min)-59(Q25) | -2,9 | -4,8 | -1,7 | -7,3 | 0,2 | 57 |
| 59(Q25)-70(Q75) | -2,1 | -3,9 | -0,7 | -8,1 | 2,8 | 117 |
| 70(Q75)-82(max) | -3,2 | -4,9 | -0,9 | -9,8 | 1,6 | 58 |

*See explanation below box plots in Figure 5.5, page 32*




*See explanation below box plots in Figure 5.5, page 32*

# 5.6 River Pro

## 5.6.1 Change in extrapolation methods over time

For the RiverPro, we have no data for the years before we started using Extrap.

The plot and the table below show that the most abundant extrapolation method for RiverPro is constant/no-slip extrapolation. 51% of the measurements use constant/no-slip. This is followed by Pwr/pwr (not 0,1667) with 38% and Pwr/pwr (0.1667) with 10%. Power/power in total is 48%.

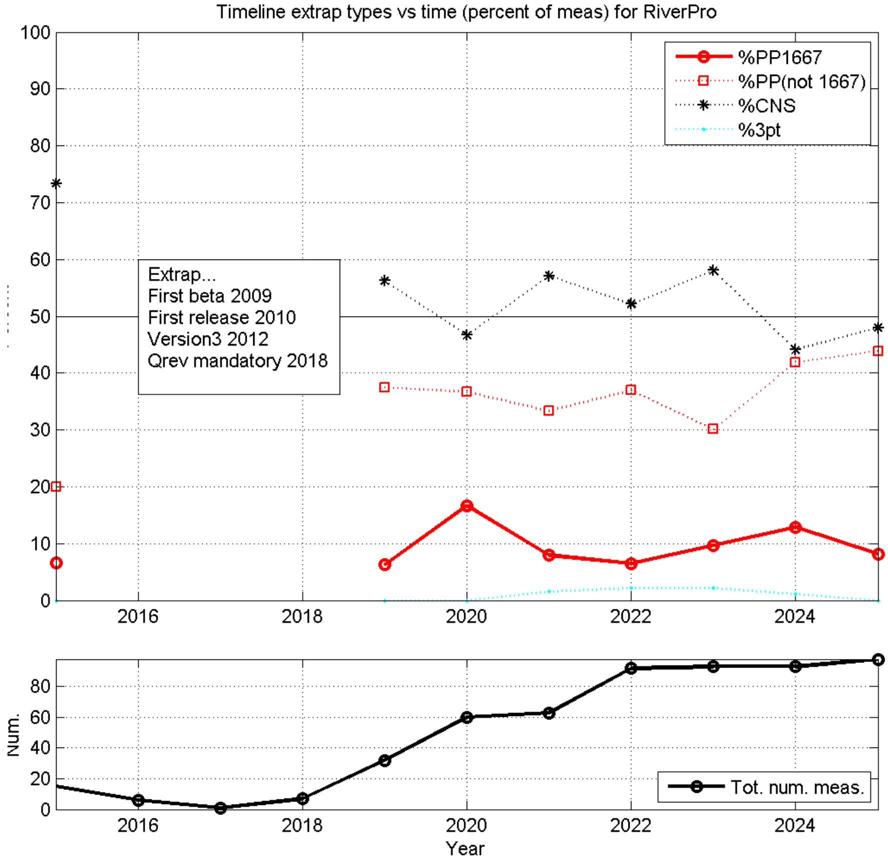



**Figure 5.18 Extrapolation methods vs time (percent of total number of RiverPro measurements)**

*Meaning of captions, see Figure 5.1 page 24. Years with more than 10 measurements are included.*

| Yrs (RPro) | Num tot | Pwr/pwr (0.1667) | | Pwr/pwr (not 0,1667) | | Const/NoSlip | | Pwr/pwr (total) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Num | % | Num | % | Num | % | Num | % |
| 2005-2012 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2016-2025 | 545 | 54 | 10 | 205 | 38 | 277 | 51 | 259 | 48 |

## 5.6.2 Extrapolation methods and cross-section characteristics

The plots and tables below show data from 2016 and onwards, when the use of Extrap/Qrev had become an established routine. Various cross-section characteristics might affect the vertical velocity distribution, and hence the extrapolation method the user has chosen. Cross-section characteristics are features of the measurement site or features caused by a combination of the selected ADCP instrument and the measurement site.

- Width to depth ratio (W/D)

- Width
- Mean depth (area/width)
- Mean water speed (Q/area)
- Discharge
- Percent measured (total Q divided by Q in the measured area).

The measurements are grouped so that for each cross-section characteristics (for instance width) the measurements with the 25% lowest values are in one group (the 25% with the narrowest cross sections), the measurements with the 25% highest values are in one group (the 25% with the widest cross sections) and the remaining 50% are in the “medium” group (the 50% that are neither narrow or wide).
For each of these groups the percentage of measurements using three different kinds of extrapolation is calculated, namely the default power/power/0.1667 extrapolation, power/power/not 0.1667 extrapolation and constant/no-slip extrapolation.

For the RiverPro, we observe that constant/no-slip is the most commonly used extrapolation method.

<u>Width to depth ratio</u>. For increasing width to depth ratio, the percentage of constant/no-slip measurements decrease steadily and notably from 60% to 43%. The percentage of power/power (not 1667) measurements increase from 30% to 40% when the width/depth ratio goes from low to medium, and it stays at 40% for high ratios. The percentage of power/power (1667) measurements goes from 9% to 8% to 16% for low/medium/high width to depth ratios.

<u>Width</u>. The percentage of constant/no-slip measurements is 54% and 56% for narrow and medium wide rivers (inconsequent). It falls to 38% for wide rivers. It is more or less a mirrored image for power/power (not 1667) measurements: 35% and 34% for narrow and medium wide rivers and increasing to 47% for wide rivers. The percentage of power/power (1667) measurements goes from 10% to 8% to 14% for low/medium/high width.

<u>Mean depth</u>. The percentage of constant/no-slip measurements is 41% for shallow rivers. It increases to 55% for medium deep rivers and falls slightly to 52% for deep rivers. It is (once again) more or less a mirrored image for power/power (not 1667) measurements: 46% for shallow rivers, and down to 35% for medium deep and deep rivers. The percentage of power/power (1667) measurements goes from 10% to 9% to 13% for shallow/medium/deep rivers.

<u>Mean water speed</u> (Q/area). For increasing water speed, the percentage of constant/no-slip measurements decrease slightly from 55%, via 49% to 51%. The percentage of power/power (not 1667) measurements increase more “orderly” from 33% to 48%. The percentage of power/power (1667) measurements are 11% for slow and medium fast rivers. It falls a little, to 7%, for fast flowing rivers.

<u>Discharge</u>. The percentage of constant/no-slip measurements is 57% for low discharge. It decreases gradually to 44% for high discharge. The percentage of power/power (not 1667) is 32% for low discharge. It increases gradually to 41% for high discharge. For power/power (not 1667) the percentages are 9%, 8% and 14% for low, medium and high discharge.

<u>Percent measured</u> (*). For increasing percentage of measured Q, the percentage of constant/no-slip measurements increase from 46% via 53% to 51%. The percentage of

power/power (not 1667) measurements decrease slightly and steadily from 41% to 35%. The percentage of power/power (1667) measurements vary from 10% to 8% to 12% for low, medium and high values for percent measured.

(*) Percent measured Discharge is 100*Q (in the bins) / Q (total). In other words, the opposite of percent extrapolated. We assume edge Q is a lot smaller than top Q and bottom Q.

Extrap methods, RiverPro

| Range, WidthToDepth | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 2,907(min)-17,7(Q25) | 128 | 77 | 60 | 39 | 30 | 11 | 9 |
| 17,7(Q25)-36,7(Q75) | 259 | 130 | 50 | 104 | 40 | 20 | 8 |
| 36,7(Q75)-176,0(max) | 129 | 55 | 43 | 51 | 40 | 20 | 16 |

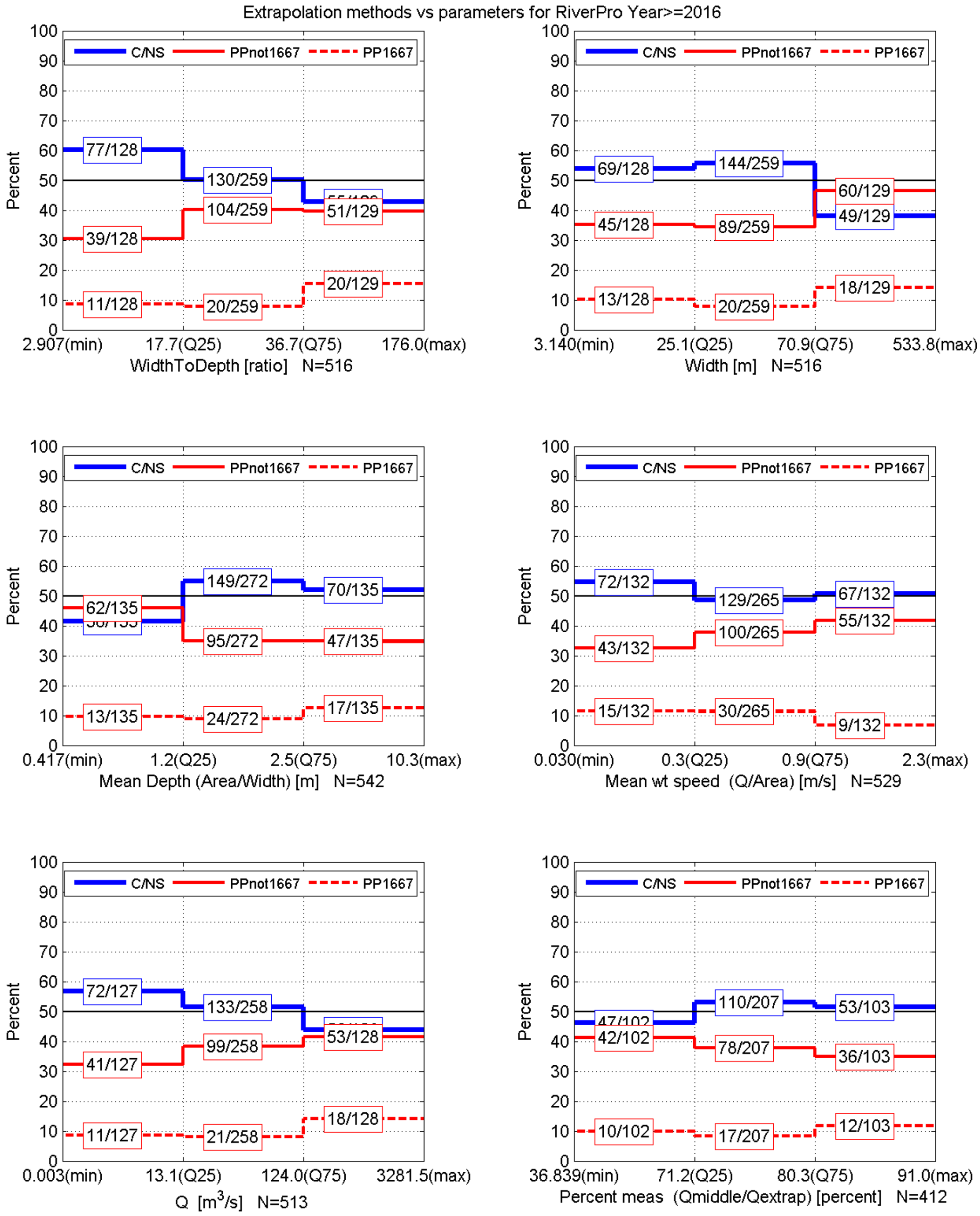
| Range, Width | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 3,140(min)-25,1(Q25) | 128 | 69 | 54 | 45 | 35 | 13 | 10 |
| 25,1(Q25)-70,9(Q75) | 259 | 144 | 56 | 89 | 34 | 20 | 8 |
| 70,9(Q75)-533,8(max) | 129 | 49 | 38 | 60 | 47 | 18 | 14 |

| Range, mean depth | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 0,417(min)-1,2(Q25) | 135 | 56 | 41 | 62 | 46 | 13 | 10 |
| 1,2(Q25)-2,5(Q75) | 272 | 149 | 55 | 95 | 35 | 24 | 9 |
| 2,5(Q75)-10,3(max) | 135 | 70 | 52 | 47 | 35 | 17 | 13 |

| Range, Mean water speed | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 0,030(min)-0,3(Q25) | 132 | 72 | 55 | 43 | 33 | 15 | 11 |
| 0,3(Q25)-0,9(Q75) | 265 | 129 | 49 | 100 | 38 | 30 | 11 |
| 0,9(Q75)-2,3(max) | 132 | 67 | 51 | 55 | 42 | 9 | 7 |

| Range, Q | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 0,003(min)-13,1(Q25) | 127 | 72 | 57 | 41 | 32 | 11 | 9 |
| 13,1(Q25)-124,0(Q75) | 258 | 133 | 52 | 99 | 38 | 21 | 8 |
| 124,0(Q75)-3281,5(max) | 128 | 56 | 44 | 53 | 41 | 18 | 14 |

| Range, Percent meas | nTot | nCNS | %CNS | nPPnot1667 | %PPnot1667 | nPP1667 | %PP1667 |
|---|---|---|---|---|---|---|---|
| 36,839(min)-71,2(Q25) | 102 | 47 | 46 | 42 | 41 | 10 | 10 |
| 71,2(Q25)-80,3(Q75) | 207 | 110 | 53 | 78 | 38 | 17 | 8 |
| 80,3(Q75)-91,0(max) | 103 | 53 | 51 | 36 | 35 | 12 | 12 |




### 5.6.3 Change in calculated discharge

If not filtering out any extrapolation methods, we have discharge data for 533 RiverPro- measurements. The median percent difference between discharge calculated using the default extrapolation and the discharge calculated using the extrapolation methods the user has chosen is -0.6%. This means that the discharge is typically 0.6% lower than it would have been if we used the default extrapolation. The quartile values are -2.2% and 0.3%. This means that for 50% of the measurements, the discharge is between 2.2% lower and 0.3% higher when using Extrap/Qrev to find the best extrapolation method than when using the default extrapolation method. See Figure 5.19.

For all instruments and methods combined, the median value -1.5%, and this means that there is a smaller difference for the RiverPro than for all instruments and methods combined.

For the RiverPro there are very few measurements with discharge data before 2019, that is, measurements where discharge has been calculated with and without applying Extrap/Qrev. After 2019, there are more constant/no-slip measurements than any other method. If looking only at those RiverPro-measurements that have constant/no-slip extrapolation, we see that for 275 measurements the median percent difference is -1.5%. See figure below.  This means that the discharge is typically 1.5% lower than it would have been if we used the default extrapolation. The quartile values are -3.4% and -0.1%. This means that for 50% of the measurements, the discharge is between 3.3% and 0.1% lower when using Extrap/Qrev to find the best extrapolation method than when using the default one sixth power law extrapolation method.

The corresponding numbers for the power/power measurements with exponent different from 0.1667 are median -0.2% and quartiles -1.2% and 0.8%. This is close to no difference at all.

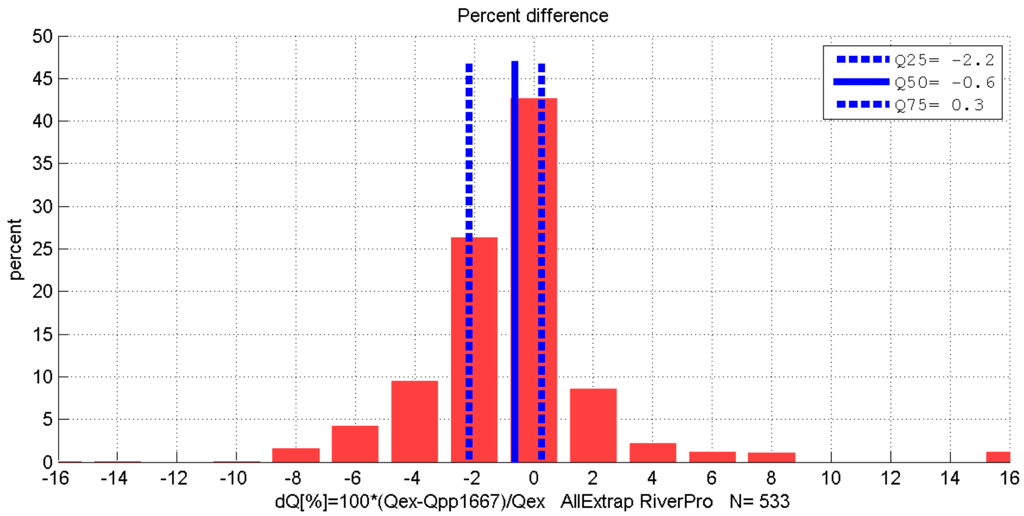



**Figure 5.19 Change in calculated discharge (All methods, RiverPro)**

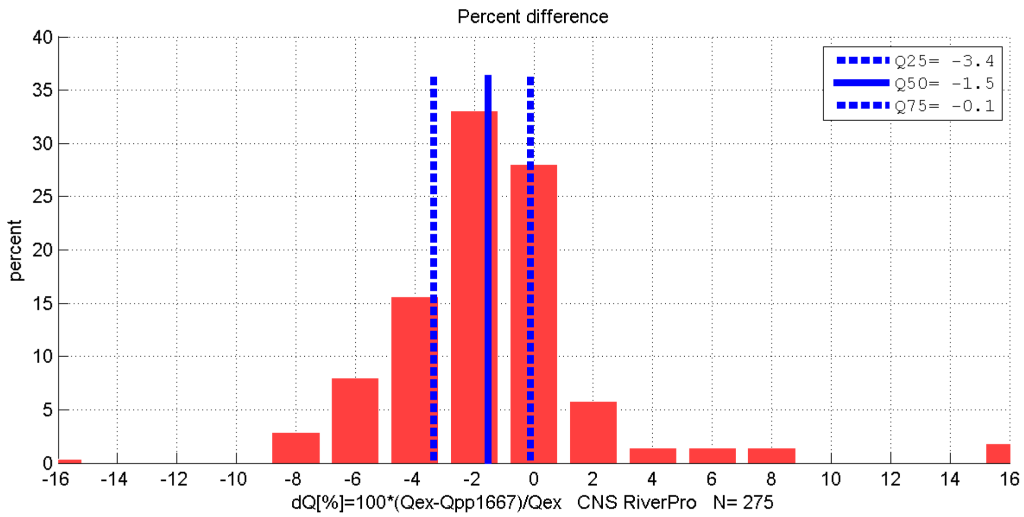
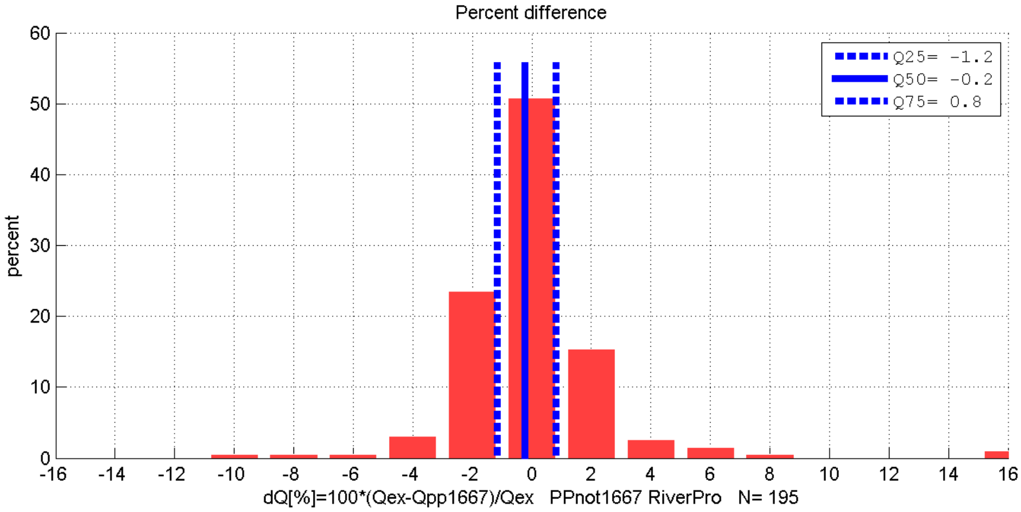



**Figure 5.20 Change in calculated discharge (Constant/no-slip, RiverPro)**




**Change in calculated discharge (Power/power/not 0.1667, RiverPro)**

### 5.6.4 Change in calculated discharge vs cross-section characteristics

Various cross-section characteristics might affect the vertical velocity profile, and thus the choice of extrapolation method which in turn impacts the calculated discharge.

For the RiverPro we focus on the measurements using Constant/No-Slip extrapolation. Constant/No-Slip, since it is the most commonly used method.

We observe that median dQ values are always negative. This means that when looking at constant/no-slip M9 measurements, the calculated discharge is lower than it would have been if using the default method.

For the RiverPro's Constant/No-Slip measurements, the changes in median values for dQ are as listed below. (Note that "dQ increases" means that dQ moves towards zero / dQ gets less negative when the dQ values are less than zero).

Width to depth. Median values for dQ are virtually unchanged (between -1.5% and -1.7%) for varying width to depth ratios.

Width. dQ goes from -2.5% to -1.9% and a large jump to -0.4% when width goes from narrow rivers (less than 25 meters) to medium wide rivers and to wide rivers (more than 62 meters).

Depth. Median dQ is increases a lot (from -3.5% to -1.4%) when depth increases from less than 1.3 meters to 1.3-2.6 meters. For rivers that are more than 2.6 meters deep the median value for dQ decreases further, to -0.4%.

Water speed. dQ increases from –2.6% to -1.4% when mean water speed increases from slow (less than 0.3 m/s) to medium (0.3-0.9 m/s). dQ stays the same (-1.4%) when water speed increases from medium to fast (above 0.9 m/s).

Discharge. dQ increases consistently and notably from –3.7% to -0.4% when discharge increases from low (less than 12 $m^3/s$) to high (above 107.6 $m^3/s$).

Percent Measured (*). The median value for dQ decreases from
-2.6% via -1.3% to -0.8% when the percentage of Q measured increases from low (less

than 72%) via medium to high (more than 80%). The change is greater between low and medium than between medium and high.

(*) Percent measured Discharge is 100*Q (in the bins) / Q (total). In other words, the opposite of percent extrapolated. We assume edge Q is a lot smaller than top Q and bottom Q.

The variation in dQ, as indicated by the interquartile range, is notably narrower for higher values of width and percent measured. Not for the others.

dQ[%] for CNS RiverPro

| Range, Width To Depth | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 4,9(min)-16(Q25) | -1,5 | -4,2 | -0,1 | -8,3 | 2,2 | 64 |
| 16(Q25)-34(Q75) | -1,7 | -2,9 | -0,3 | -5,6 | 2 | 131 |
| 34(Q75)-105(max) | -1,5 | -3,9 | -0,3 | -6,3 | 8,1 | 65 |

| Range, Width | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 5,6(min)-25(Q25) | -2,5 | -4,5 | -0,7 | -7,1 | 0,9 | 64 |
| 25(Q25)-62(Q75) | -1,9 | -3,9 | -0,7 | -7,1 | 2,1 | 131 |
| 62(Q75)-534(max) | -0,4 | -1,5 | 0,6 | -4,3 | 8,1 | 65 |

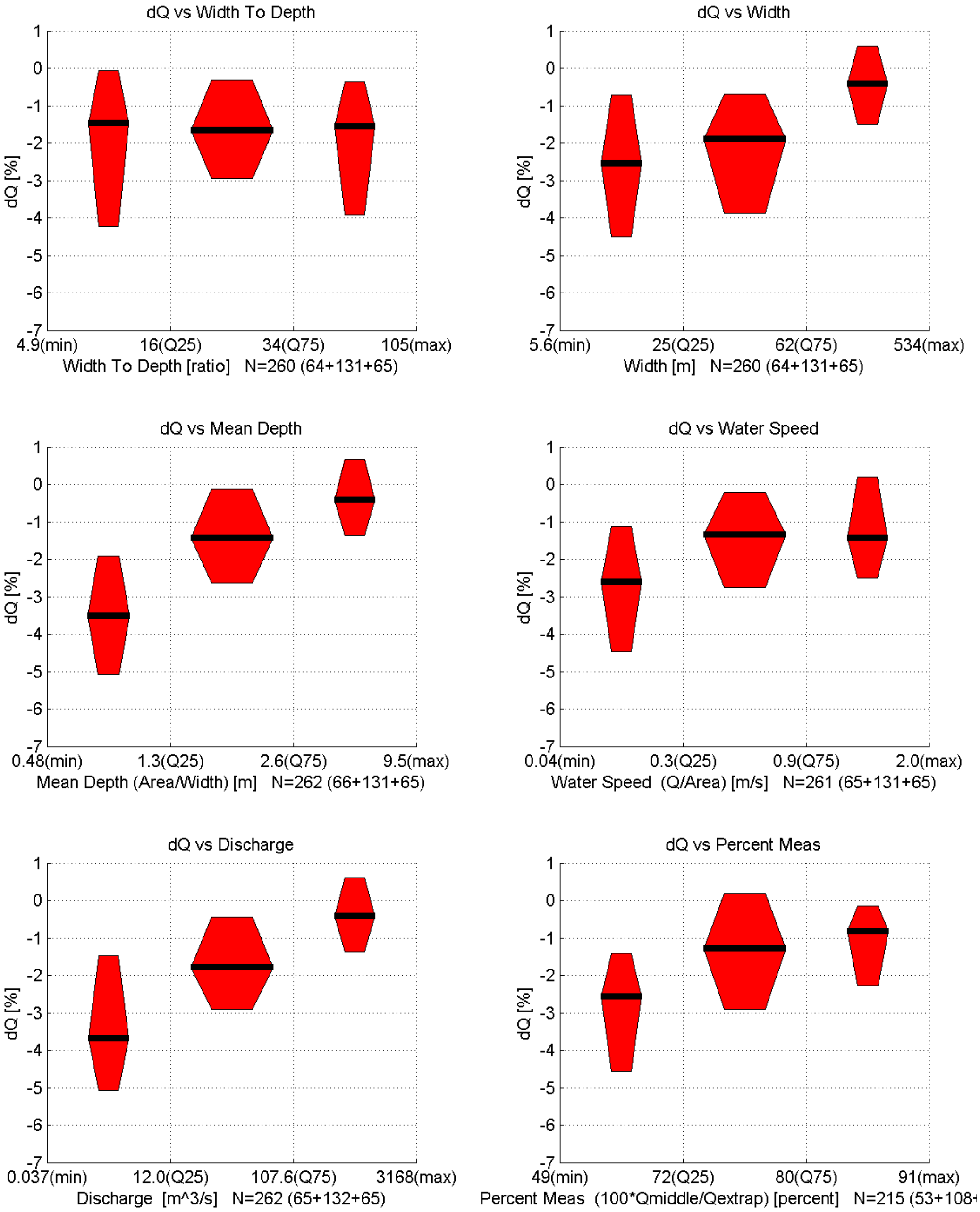
| Range, mean depth | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 0,48(min)-1,3(Q25) | -3,5 | -5,1 | -1,9 | -7,3 | -0,9 | 66 |
| 1,3(Q25)-2,6(Q75) | -1,4 | -2,6 | -0,1 | -5,9 | 2,6 | 131 |
| 2,6(Q75)-9,5(max) | -0,4 | -1,4 | 0,7 | -5,4 | 5,9 | 65 |

| Range, water speed | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 0,04(min)-0,3(Q25) | -2,6 | -4,5 | -1,1 | -7,1 | 3,2 | 65 |
| 0,3(Q25)-0,9(Q75) | -1,4 | -2,8 | -0,2 | -7 | 1,7 | 131 |
| 0,9(Q75)-2,0(max) | -1,4 | -2,5 | 0,2 | -5,5 | 4,5 | 65 |

| Range, Discharge | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 0,037(min)-12,0(Q25) | -3,7 | -5,1 | -1,5 | -7,3 | 0,3 | 65 |
| 12,0(Q25)-107,6(Q75) | -1,8 | -2,9 | -0,4 | -6,3 | 2,6 | 132 |
| 107,6(Q75)-3168(max) | -0,4 | -1,4 | 0,6 | -3,3 | 5,9 | 65 |

| Range, Percent Meas | Q50 | Q25 | Q75 | Q5 | Q95 | N |
|---|---|---|---|---|---|---|
| 49(min)-72(Q25) | -2,6 | -4,6 | -1,4 | -7,3 | 2,1 | 53 |
| 72(Q25)-80(Q75) | -1,3 | -2,9 | 0,2 | -5,6 | 5,9 | 108 |
| 80(Q75)-91(max) | -0,8 | -2,3 | -0,1 | -7,3 | 2 | 54 |

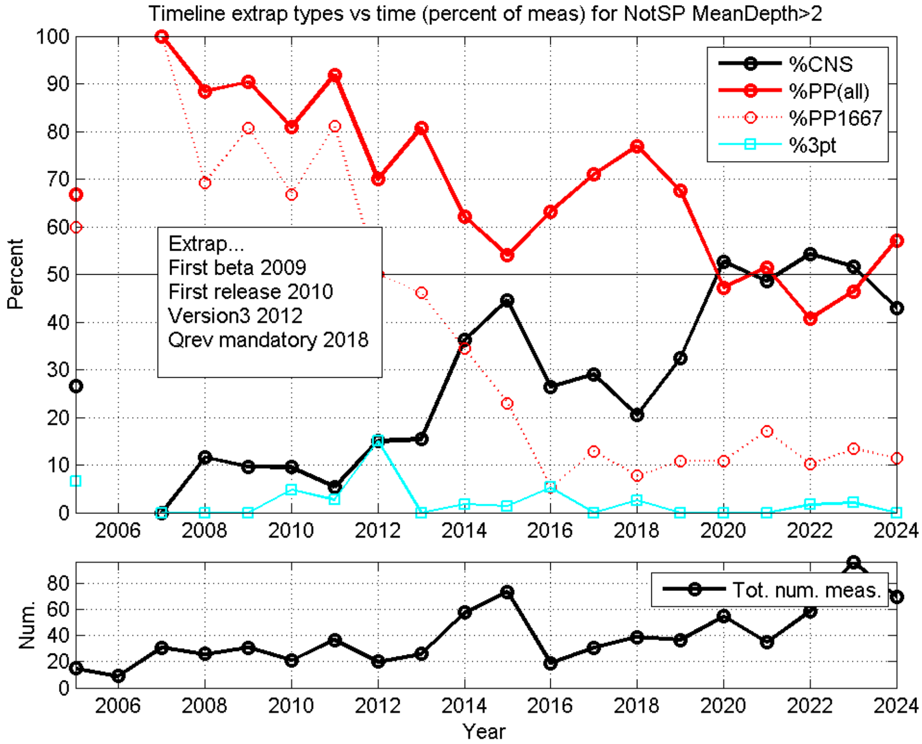
*See explanation below box plots in Figure 5.5, page 32*




*See explanation below box plots in Figure 5.5, page 32*

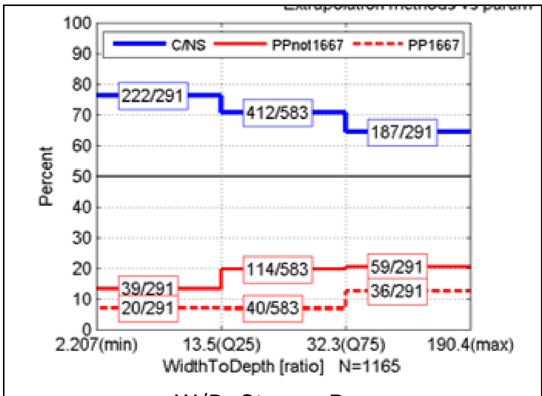
## 5.7 Big ADCP

Attempts at making “a combined imaginary instruments” to extend the timelines for methods for RioGrande, M9 and RiverPro has not been successful. The plot below shows an attempt to make a timeline for the “instrument” *Not StreamPro & mean depth greater than 2 meters*. We end up with rather few measurements, and it does not really tell a lot more about the change in extrapolation method than the previous plots and tables for the separate instruments: The RioGrande had around 10% constant/no-slip measurements *before* we started using Extrap, and the M9 and RivePro have around 50% constant/no-slip measurements *after* 2020 when using Extrap. There seems to be a long transition period 2012-2020.

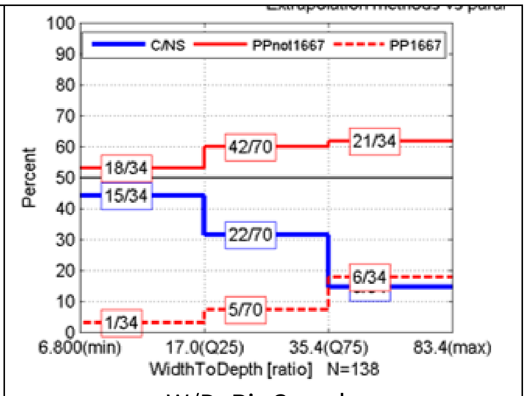



## 5.8 Comparing instruments: Extrapolation methods and cross-section characteristics

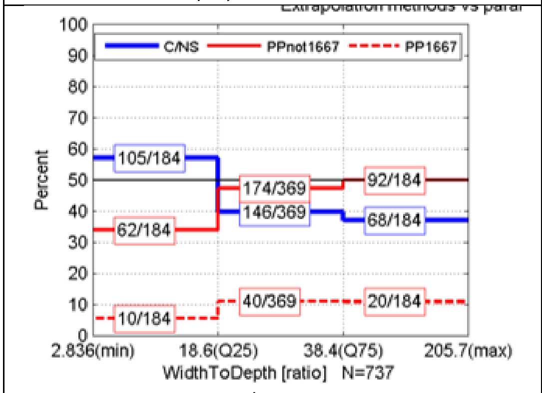
The plots below are copied and gathered from previous chapters. They will not be described further but are included for readers who prefer to see plots instrument by instrument, instead of cross section characteristic by cross section characteristic.



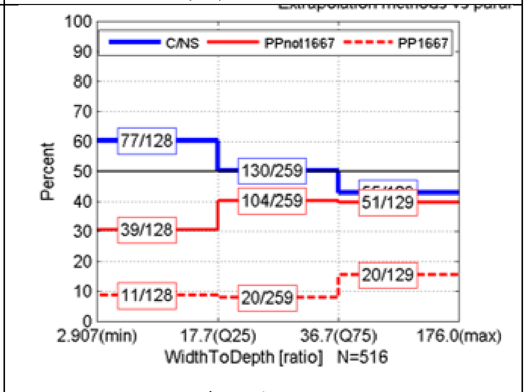

W/D, StreamPro



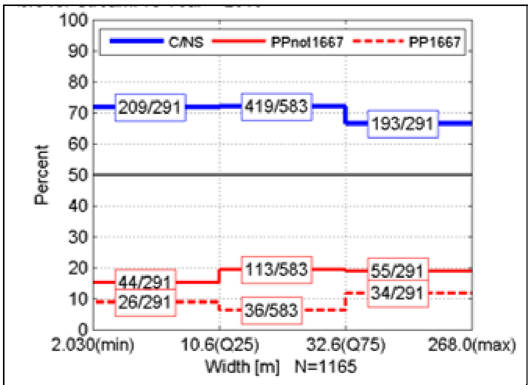

W/D, RioGrande



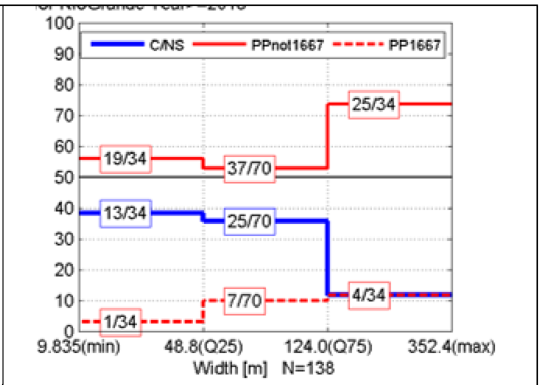

W/D, M9



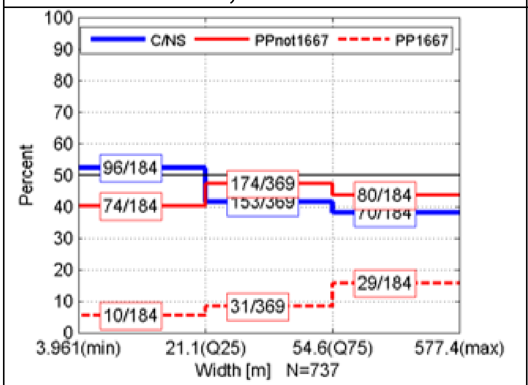

W/D, RiverPro



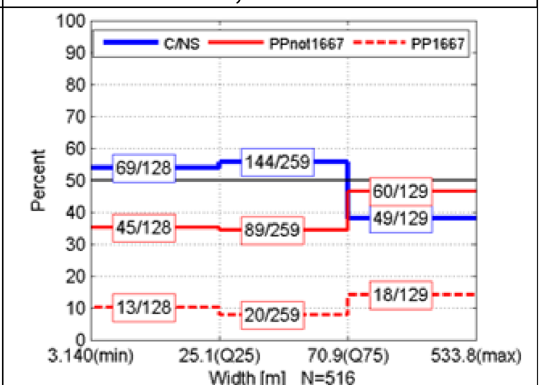

Width, StreamPro



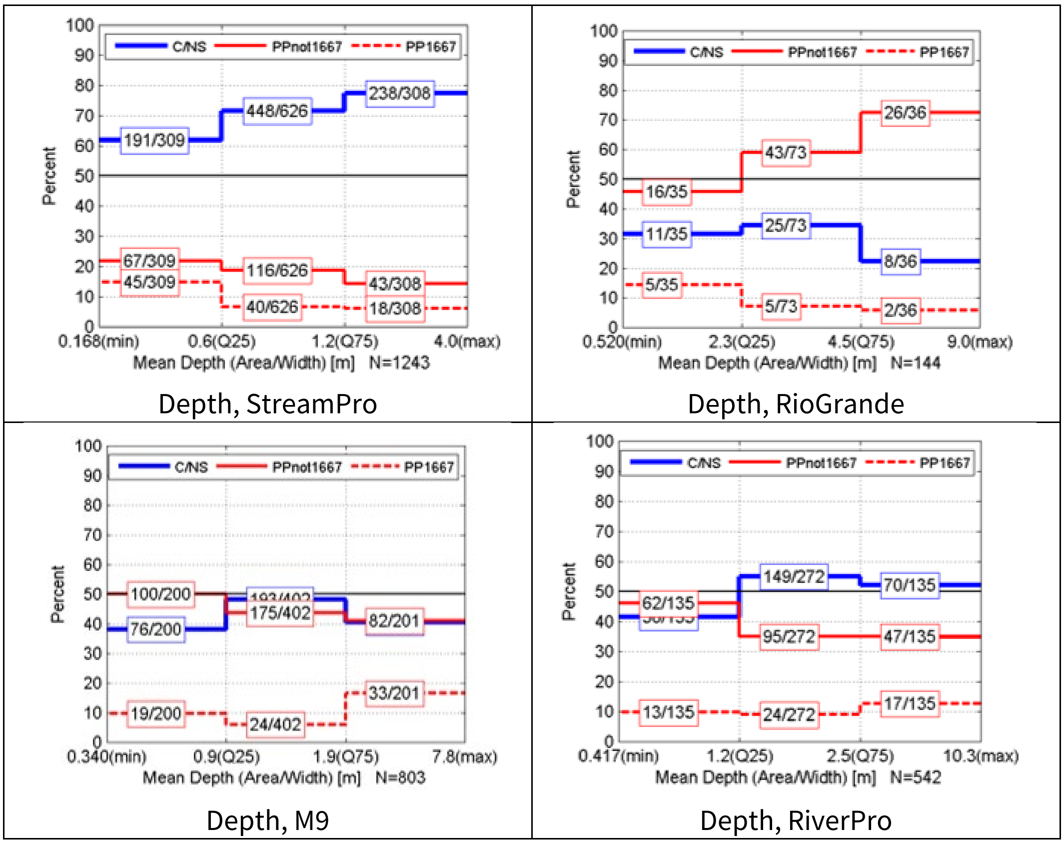

Width, RioGrande

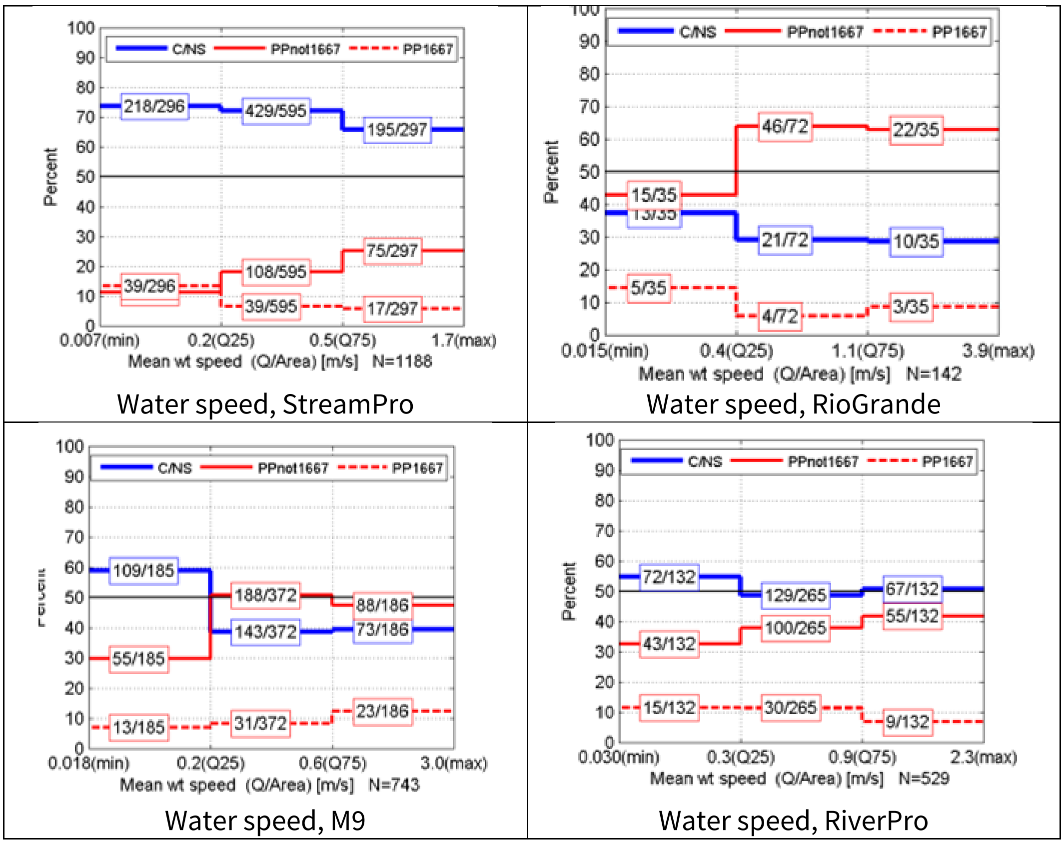


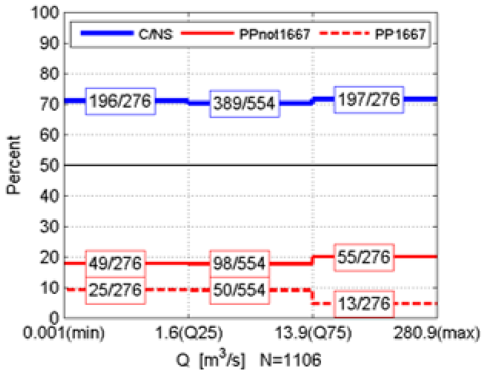

Width, M9



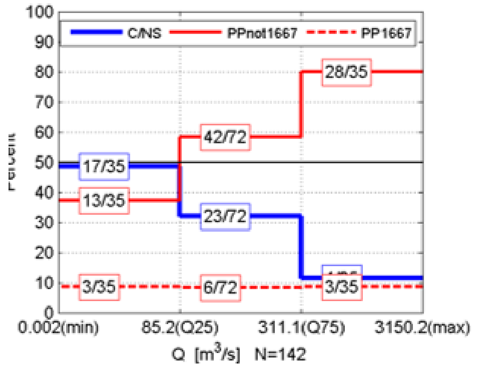

Width, RiverPro


C/NS PPnot1667 PP1667
Percent
191/309
448/626
238/308
67/309
45/309
116/626
40/626
43/308
18/308
0.168(min) 0.6(Q25) 1.2(Q75) 4.0(max)
Mean Depth (Area/Width) [m] N=1243
Depth, StreamPro
16/35
43/73
26/36
11/35
25/73
8/36
5/35
5/73
2/36
0.520(min) 2.3(Q25) 4.5(Q75) 9.0(max)
Mean Depth (Area/Width) [m] N=144
Depth, RioGrande
100/200
175/402
82/201
76/200
19/200
24/402
33/201
0.340(min) 0.9(Q25) 1.9(Q75) 7.8(max)
Mean Depth (Area/Width) [m] N=803
Depth, M9
62/135
149/272
70/135
95/272
47/135
13/135
24/272
17/135
0.417(min) 1.2(Q25) 2.5(Q75) 10.3(max)
Mean Depth (Area/Width) [m] N=542
Depth, RiverPro

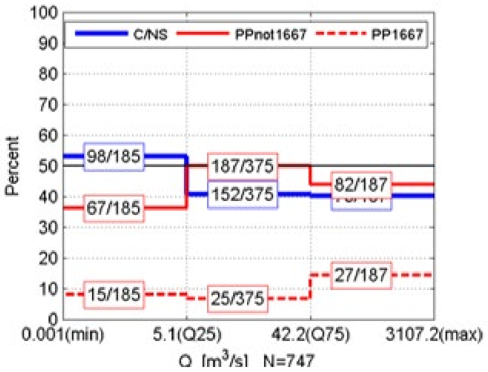

C/NS PPnot1667 PP1667
Percent
218/296
429/595
195/297
39/296
108/595
75/297
39/595
17/297
0.007(min) 0.2(Q25) 0.5(Q75) 1.7(max)
Mean wt speed (Q/Area) [m/s] N=1188
Water speed, StreamPro
15/35
46/72
22/35
21/72
10/35
5/35
4/72
3/35
0.015(min) 0.4(Q25) 1.1(Q75) 3.9(max)
Mean wt speed (Q/Area) [m/s] N=142
Water speed, RioGrande
109/185
188/372
88/186
143/372
73/186
55/185
13/185
31/372
23/186
0.018(min) 0.2(Q25) 0.6(Q75) 3.0(max)
Mean wt speed (Q/Area) [m/s] N=743
Water speed, M9
72/132
129/265
67/132
100/265
55/132
43/132
15/132
30/265
9/132
0.030(min) 0.3(Q25) 0.9(Q75) 2.3(max)
Mean wt speed (Q/Area) [m/s] N=529
Water speed, RiverPro



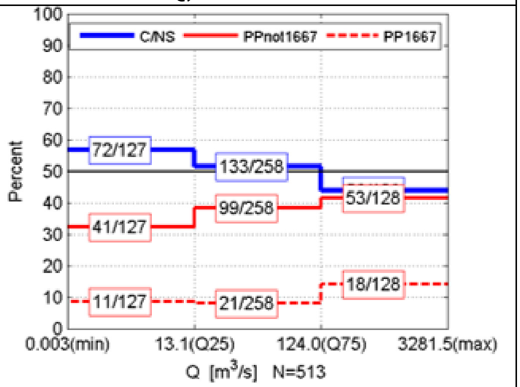

Q, StreamPro



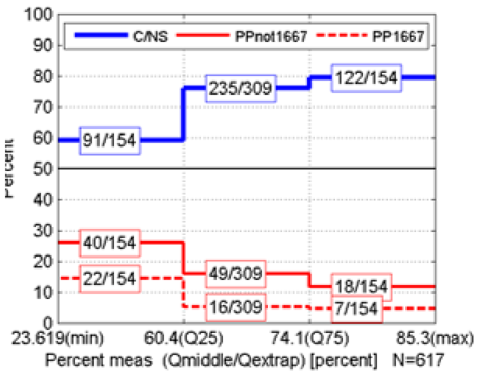

Q, RioGrande



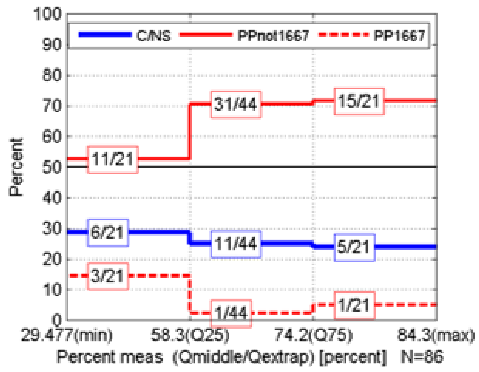

Q, M9



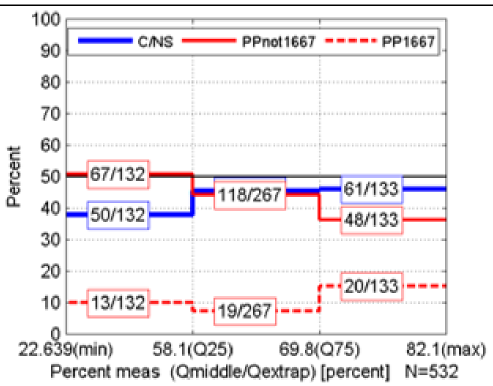

Q, RiverPro



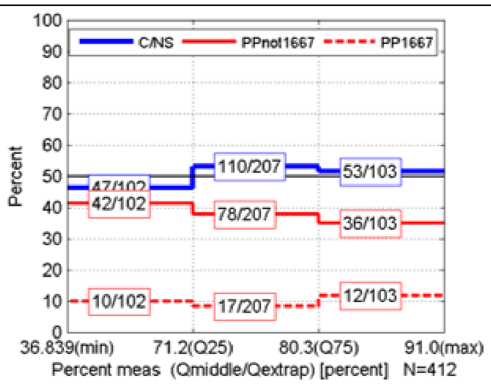

Percent meas, StreamPro




Percent meas, RioGrande




Percent meas, M9




Percent meas, RiverPro

# 6 Summary and discussion

In the introduction, the following questions were asked:

1. Which data sources do we have and how do we combine/merge them?
2. To which extent have we used the different instruments and methods?
3. What kind of extrapolation did we use before Extrap/Qrev and what do we use now?
4. How do river/cross-section characteristics affect choice of extrapolation methods? (“What kind of extrap where?”)
5. If there is a change in extrapolation methods, how does it affect the calculated discharge?
6. How do river/cross-section characteristics affect change in calculated discharge?

The first two question was addressed in Ch 2 Data collection, and will not be discussed further.

## 6.1 Changes in instruments and software

There is no doubt that ADCPs has taken over for the current meter to a very large extent. Previous unpublished investigations showed that on average, the introduction of ADCPs did not introduce a systematic change. This, however, was carried out before the introduction of Extrap/Qrev.

We started to use Extrap/Qrev increasingly during the years 2013-2015, and around the same time as we started purchasing and using the new generation of autoadaptive ADCPs. This has made it challenging to compare “before Extrap” to “after Extrap”.

Before Extrap, we used the StreamPro and RioGrande ADCPs, and the StreamPro approximately four to five times more often than the RioGrande.

After Extrap, we have very few RioGrande-measurements and a rapidly decreasing number of StreamPro-measurements. The number of M9 and RiverPro measurements increases, but in total the number of StreamPro, M9 and RiverPro measurements after 2015 are comparable. The tables in the 5.x.1 chapters “Change in extrapolation methods over time ” (5.1.1 – 5.6.1) show the number of measurements where we have found data on extrapolation methods, and these numbers are gathered in the table below.

| Yrs | In total | StreamPro | RioGrande | M9 | RiverPro |
|---|---|---|---|---|---|
| 2005-2012 | 1548 | 1265 | 281 | 0 | 0 |
| 2016-2025 | 2903 | 1249 | 145 | 815 | 545 |

*Number of measurements included in this report*

The year-by-year timelines for individual ADCP types in these chapters (5.x.1) become noisy when there are too few measurements per year, and the new ADCPs were hardly in use at all before Extrap. The StreamPro has more data. There are enough measurements to see the change in choice of extrapolation methods clearly.

For the other instruments, the solution is to collect data for periods in tables, and these will be presented in the next summary-chapters.

## 6.2 Change in Extrapolation methods

We have seen that the introduction of Extrap/Qrev has changed which extrapolation methods we choose, and that the change of extrapolation methods has changed the calculated discharge. Data presented in ch 5.2.1 “Change in extrapolation methods over time” shows that for data collected prior to 2012, before we started using Extrap/Qrev, 78% of the measurements have discharge calculated using the default one sixth power law extrapolation. 2013 to 2015 was a transition period.

After 2015, it varies a little, but for the years, 2016-2025, only 9% uses the default extrapolation. The use of the default extrapolation is down from 78% to 9%. This is if we include data from M9 and RiverPro. We started using Extrap around the same time as we started using M9 and RiverPro, so we only have “after extrap”-data for M9 and RiverPro. To find the change in choice of extrapolation, it is better to look at the StreamPro and the RioGrande. By chance, and when rounding to integer percentages, both are down equally much in the use of the default extrapolation method.

| | %PP1667 (default) | | %PP not 1667 | | %CNS | |
|---|---|---|---|---|---|---|
| | 2005-2012 | 2016-2025 | 2005-2012 | 2016-2025 | 2005-2012 | 2016-2025 |
| All | 78 | 9 | 7 | 30 | 10 | 56 |
| StreamPro | 78 | 8 | 8 | 18 | 10 | 71 |
| RioGrande | 78 | 8 | 9 | 59 | 11 | 31 |
| M9 | - | 9 | - | 44 | - | 44 |
| RiverPro | - | 10 | - | 38 | - | 51 |

Both for StreamPro and RioGrande we almost stopped using the default one sixth power law extrapolation after we started using Extrap/Qrev. For both instruments the choice of extrapolation method changed from 78% default extrapolation to 8% default extrapolation. In other words, from 22% to 92% “not default” extrapolation. They differ in what we have chosen as extrapolation methods instead. For StreamPro measurements, we have mainly chosen constant/no-slip extrapolation and for the RioGrande, mainly power/power (not 1667). 71% of the StreamPro measurements are constant/no-slip, and 18% are power/power (not 1667). For the RioGrande 59% are power/power (not 1667) and 31% are constant/no-slip.

The M9 and the RiverPro have not changed *from* anything, but since 2016 they lie between the StreamPro and the RioGrande. M9 measurements are split 44/44 between power/power (not 1667) and constant/no-slip. RiverPro measurements are more inclined towards constant/no-slip: 51% are constant/no-slip and 38% are power/power (not 1667).

The changes for StreamPro and RioGrande measurements are major changes, and they are probably even more profound than data in this report shows: Data from the early years contain measurements that was reprocessed many years later. They cannot be filtered out automatically. This means that the percentage of one sixth power law was probably even higher in the first period (2005-2012). Figure 2.1, page 18 might serve as an indication on how many measurements this is the case for. The number of measurements prior to 2012 that contain data for discharge with and without Extrap (the blue line) shows that up to 50 measurements per year have been reprocessed. This data is either from the Hydra2 database or from the "shadow database", and it means that the date of reprocessing was after we started using Qrev/Extrap.

It is a notable difference between the M9 and the RiverPro: 44% of the M9 measurements have constant/no-slip extrapolation, while 51% of the RiverPro measurements have constant/no-slip extrapolation. This report will not investigate this difference, but there is one possible explanation: The results in USGS' and NVE's reports on flow disturbance (Mueller 2015 and NVE report No. 1/2023) led us to recommend that we must have have a strong indication of constant/no-slip extrapolation for M9 data before choosing constant/no-slip, in particular if *not* discarding the top 16 cm of data.

## 6.3 Extrapolation methods and cross-section characteristics

The question "what kind of extrapolation where?" has many answers. The chapters *5.x.2 Extrapolation methods and cross-section characteristics* (5.2.2 – 5.6.2) describe how cross section characteristics affect the choice of extrapolation methods, instrument by instrument. There are many combinations of instruments, cross section characteristics and extrapolation methods, even if only the most common methods are included. The most notable distinction, however, is whether the measurements use constant/no-slip extrapolation or not. The summary tables below include the percentages of constant/no-slip measurements only. They contain data from the tables and plots in ch 5.2.2 – 5.6.2 and show data from 2016 and onwards, when the use of Extrap/Qrev had become an established routine. The various cross-section and/or measurement characteristics that might affect the vertical velocity distribution, and hence the extrapolation method the user has chosen are:

- Width to depth ratio (W/D)
- Width
- Mean depth (area/width)
- Mean water speed (Q/area)
- Discharge
- Percent measured (total Q divided by Q in the measured area).

The measurements are grouped so that for each cross-section characteristics (for instance width) the measurements with the 25% lowest values are in one group (the 25% with the narrowest cross sections), the measurements with the 25% highest values are in one group (the 25% with the widest cross sections) and the remaining 50% are in the "medium" group (the 50% that are neither narrow nor wide).

For each of these groups, the summary tables contain the percentages of measurements constant/no-slip extrapolation. (There are more details in ch 5.2.2 – 5.6.2)

Note that the group limits are calculated individually for each instrument and parameter. A "low discharge" RioGrande measurement is not the same as a "Low discharge" StreamPro measurement. Attempts to make fixed group-limits that fit for all instruments and parameters failed, since different instruments are used on different kinds of rivers. The rows "All instr." In the summary tables are for all instruments, and even if the numbers are affected by the large total number of StreamPro measurements, "All instr." gives a general impression of how different characteristics affect the choice of extrapolation methods.

The text in in the first summary table describes how the percentages of constant/no-slip changes when the parameter in question changes from low to medium to high, for instance when depth increases from shallow to medium to deep. The text is extracted from the descriptions of the plots in the aforesaid chapters (5.2.2 – 5.6.2). Decrease/no trend/increase refers to the change in percentage constant/no-slip when the parameter in question increases from low to high. The numbers in parentheses below the text are the percentages of measurements that have constant/no-slip extrapolation for low/medium/high values of the parameter.

*Example: M9 and discharge.*
*Text: "Decrease unsteadily and not very notably.". Describes how the plot looks, subjectively.*
*Numbers: "(53-41-40)", meaning that 53% of the M9 measurements in high discharge rivers have constant/no-slip extrapolation, 41% in medium discharge rivers have constant/no-slip extrapolation and 40% in low discharge rivers have constant/no-slip extrapolation.*

The second summary table contain percentages of constant/no-slip measurements and "Diff", the increase/decrease in percentage of constant/no-slip measurements between the "High" and "Low" groups for the cross-section characteristics. For instance, for the RioGrande there is a difference ("Diff") of 12-38=-26 between the percentage of constant/no-slip for deep rivers (high depth) and for shallow rivers (low depth). This means that the wider the river is, the smaller is the percentage of constant/no-slip measurements. Or the other way around: The wider the river, the more power/power there is. In general, a negative "Diff" value in the table means that when the value for the cross-section characteristic increases the percentage of constant/no-slip measurements decreases.

We see that the clearest signal for all instruments is for width to depth ratio, as indicated by the last column in the table (the mean of the "Diff" values for the instruments). This is in accordance with theory: Less constant/no-slip and more power/power for increasing width to depth ratio. The same is true a little less clearly for width, water speed and discharge: The wider the river, the higher the water speed or greater the discharge, the less constant/no-slip and more power/power. For depth and for percent measured, the percentage of constant/no-slip measurements *in*creases and consequently, the percentage of power/power measurements *de*creases, for deeper rivers and/or higher percent measured (not extrapolated) discharge. Initially this was a little surprising, but depth is not the important parameter for the shape of the velocity profile, but the width to depth ratio is. This means that theory and data agree. This report is not looking into all causes, but the fact that constant/no-slip mainly *in*crease with increasing percent measured, is probably due to the algorithms in Extrap/Qrev which default to power/power extrapolations unless data suggest otherwise, see QrevInt technical manual in the Qrev help menu or Mueller (2013). If too small parts of the velocity profiles are measured, there is probably not enough evidence to *not* use power/power extrapolation.

The last row in the table (Mean of Medium) is the mean of the percentages of constant/no-slip measurements for medium groups for the cross-section characteristics. This serves as an indicator for the difference between the instruments when it comes to having data processed with constant/no-slip extrapolation or with power/power extrapolation. We see that StreamPro has the highest percentage of constant/no-slip. It is a big step down to RiverPro, and smaller steps further down to M9 and RioGrande. In other words, StreamPro is “the most constant/no-slip instrument” and RioGrande least. This observation combined with the fact that constant/no-slip is more common on rivers with low width to depth ratio might indicate that the StreamPro is used more on rivers with low width to depth ratio than the other instruments, but that hast not been investigated in this report.

| **%CNS for low/medium/high…** | | | | | |
|---|---|---|---|---|---|
| | All instr. | StreamPro | RioGrande | M9 | RiverPro |
| W/D ratio | Decrease steadily and notably (67-55-47) | Decrease steadily, but not very notably. High values. (76-71-64) | Decrease steadily and very notably. Low values (44-31-15) | Decrease unsteadily but notably (57-40-37) | Decrease steadily and notably (60-50-43) |
| Width | Decrease steadily and notably (67-57-43) | Decrease unsteadily and slightly. High values (72-72-66) | Decrease unsteadily but very notably. Low values (38-36-12) | Decrease quite steadily and notably (52-41-38) | Decrease inconsequently but notably (54-56-38) |
| Depth | Decrease unsteadily and not very notably (58-58-49) | Increase steadily and quite notably. High values. (62-72-77) | Decrease inconsequently and unnotably. Low values. (31-34-22) | No trend. Inconsequent. (38-48-40) | Increase inconsequently and not very notably (41-55-52) |
| Wt speed | Decrease steadily and quite notably (66-55-49) | Decrease unsteadily and slightly. High values. (74-72-66) | Decrease unsteadily and unnotably. Low values (37-29-29) | Decrease inconsequently but notably (59-38-39) | Decrease inconsequently and unnotably (55-49-51) |
| Q | Decrease steadily and notably (67-55-45) | No trend. Almost constant. High values. (71-70-71) | Decrease steadily and very notably. Low values (49-32-11) | Decrease unsteadily and not very notably (53-41-40) | Decrease steadily and quite notably (57-52-44) |
| %meas. | Increase steadily and quite notably. (48-55-61) | Increase unsteadily but notably. High values. (59-76-79) | Decrease consequently and slightly. Low values. (29-25-24) | Increase consequently and slightly. (38-45-46) | Increase consequently and slightly. (46-53-51) |

| | | All instr. | StreamPro | RioGrande | M9 | RiverPro | Mean of instr. |
|---|---|---|---|---|---|---|---|
| W/D ratio | Low | 67 | 76 | 44 | 57 | 60 | |
| | Medium | 55 | 71 | 31 | 40 | 50 | |
| | High | 47 | 64 | 15 | 37 | 43 | |
| | **Diff** | **-20** | **-12** | **-29** | **-20** | **-17** | **-20** |
| Width | Narrow | 67 | 72 | 38 | 52 | 54 | |
| | Medium | 57 | 72 | 36 | 41 | 56 | |
| | Wide | 43 | 66 | 12 | 38 | 38 | |
| | **Diff** | **-24** | **-6** | **-26** | **-14** | **-16** | **-16** |
| Depth | Shallow | 58 | 62 | 31 | 38 | 41 | |
| | Medium | 58 | 72 | 34 | 48 | 55 | |
| | Deep | 49 | 77 | 22 | 40 | 52 | |
| | **Diff** | **-9** | **15** | **-9** | **2** | **11** | **5** |
| Wt speed | Slow | 66 | 74 | 37 | 59 | 55 | |
| | Medium | 55 | 72 | 29 | 38 | 49 | |
| | Fast | 49 | 66 | 29 | 39 | 51 | |
| | **Diff** | **-17** | **-8** | **-8** | **-20** | **-4** | **-10** |
| Q | Low | 67 | 71 | 49 | 53 | 57 | |
| | Medium | 55 | 70 | 32 | 41 | 52 | |
| | High | 45 | 71 | 11 | 40 | 44 | |
| | **Diff** | **-22** | **0** | **-38** | **-13** | **-13** | **-16** |
| %meas | Low | 48 | 59 | 29 | 38 | 46 | |
| | Medium | 55 | 76 | 25 | 45 | 53 | |
| | High | 61 | 79 | 24 | 46 | 51 | |
| | **Diff** | **13** | **20** | **-5** | **8** | **5** | **7** |
| **Mean of *Medium*** | | **56** | **72** | **31** | **42** | **52** | |

*Percentages of constant/no-slip for Low/Medium/High (L/M/H) values for Width to depth ratio, Width Depth, water speed, discharge and Percent measured discharge.*
*Colour coding:*

| *From* | *to* | *Color* |
|---|---|---|
| *20* | *inf* | *Dark blue* |
| *10* | *19* | *Blue* |
| *0* | *9* | *Light blue* |
| *-9* | *0* | *Yellow* |
| *-19* | *-10* | *orange* |
| *neg inf* | *-20* | *red* |

## 6.4 Change in calculated Discharge

For the majority of the measurements that use constant/no-slip extrapolation, the median change in calculated discharge is minus 2.9%. This means that the discharge is lower than it would have been if we had used the default extrapolation. For all instruments and all extrapolation methods combined, in other words all measurements, discharge is down by 1.5% for half the measurements, and down by 3.8% for a quarter of the measurements.

For the individual instruments it varies. 71% of the StreamPro measurements after 2015 use constant/no-slip extrapolation, and discharge is down by 3.6% or more for 50% of these measurements, and more than 6.1% for 25%. For 25% Q is down by less than 1,7%. For the RioGrande, the majority of the measurements still use power/power extrapolation, but with an exponent different from 0.1667. For these, there is almost no change in calculated discharge. It is in the order of plus/minus one percent.

Small variations are within the measurement uncertainty, as random noise that average to the true value for large numbers of measurements. At least to the “true value” in the sense “no change from what we measured earlier”. But Extrap/Qrev has introduced a bias (systematic change). The mean for a large number of measurements will be different from what we measured earlier. It is important that data users are aware of the bias, both the field hydrologists who are responsible for making and revising rating curves, and also the “end users" who do analysis on our finalized time series for discharge. The climate researchers are looking at changes between 30 years periods that are in the order of one-digit percentages (Huang et al., 2025), so if a 1.5-3% change in calculated discharge for ADCP measurements leads to a 1.5-3% change in the rating curve and to the discharge time series, this small change in ADCP discharge is important.

We could choose to not use Extrap, and to keep calculating discharge using the default one sixth power law extrapolation, but if so, we would report data that are less correct than they could have been. We believe firmly that using Extrap to find the best extrapolation give more correct data.

All median and quartile values for dQ is collected in the table below.

If an end user wants to use data from a gauging station where the rating curve is based on data from a particular instrument, or from many gauging stations and many instruments, this table serve as an indication for potential systematic changes in calculated discharge from ADCP-measurements.

| | dQ | All instr | StreamPro | RioGrande | M9 | RiverPro |
|---|---|---|---|---|---|---|
| All Extrap | Median | -1,5 | -2,4 | -0,4 | -0,4 | -0,6 |
| | Low quartile (Q25) | -3,8 | -4,8 | -2,2 | -2,6 | -2,2 |
| | High quartile (Q75) | 0,0 | -0,2 | 0,4 | 0,3 | 0,3 |
| CNS | Median | **-2,9** | **-3,6** | *-1,8* | **-2,6** | **-1,5** |
| | Low quartile (Q25) | **-5,1** | **-6,1** | *-3,7* | **-4,2** | **-3,4** |
| | High quartile (Q75) | **-1,1** | **-1,7** | *0,0* | **-1,0** | **-0,1** |
| PPnot1667 | Median | *-0,3* | *-1,3* | **0,0** | **0,1** | *-0,2* |
| | Low quartile (Q25) | *-1,4* | *-2,4* | **-1,3** | **-0,5** | *-1,2* |
| | High quartile (Q75) | *0,6* | *-0,5* | **0,8** | **1,0** | *0,8* |

Normal font = All extrap, **bold** font = most used method(s) for instrument, *italic* = less used method.

## 6.5 Change in calculated Discharge versus site characteristics

The table below shows a summary of the chapters describing the Change in calculated Discharge versus site characteristics for the various instruments, ch 5.2.4-5.6.4. The values are for the most commonly used extrapolation methods for the different instruments, namely constant/no-slip for all but the RioGrande, but the RioGrande is not included due to a low number of measurements containing relevant information. The M9 has equally many constant/no-slip and power/power (not 0.1667) extrapolations, but percent difference (dQ%) is larger for constant/no-slip so that is the one that is included.

The value percent difference is the same as in Eq. 4:
dQ% = 100*[Q(extrap)-Q(pp1667)] / Q(extrap)

The value "Diff" in the table is the difference for dQ% between "High" and "Low" for the different parameters. For instance, for the StreamPro there is a difference of
-2,7-(-4,3) = 1,6
between the dQ% for deep rivers (high depth) and for shallow rivers (low depth).

Positive "Diff" means that percent difference gets less negative and moves towards zero, which in turn means that the change in discharge between using default extrapolation and altered extrapolation gets smaller.

Depth and discharge have the most positive "Diff" values, meaning that for the most used extrapolation method (constant/no-slip) the impact of using Extrap/Qrev gets smaller the deeper the river and the higher the discharge. The same is the case for Width and water speed, but not equally prominent.

For width to depth ratio and for percent measured discharge, there are large variations between the instruments. Width to depth ratio should not matter, and dQ% should not depend on it. Width to depth ratio is important for the choice of extrapolation methods, but table below is for constant/no-slip only. For some reason, width to depth ratio does matter for the M9. There is no obvious explanation for this. There are almost 80+160+80 measurements in the low/medium/high groups of data, so it should not be an artifact caused by too few measurements. This report will not investigate it further, but a plausible reason might be that the M9 to a larger extent than the two other instruments is used on rivers where depth increases when width to depth ratio increases, since the impact of using Extrap/Qrev gets smaller the deeper the river is for all instruments, including M9.

Percent measured discharge *should* matter since the more we measure the less we need to add from the extrapolated discharge. But only RiverPro data agree. There are approximately 120+240+120 measurements in the low/medium/high groups for constant/no-slip StreamPro, and ca 60+120+60 for constant/no-slip M9, so the strange behaviour should not be caused by a small number of measurements. The reason for this is not known and will not be investigated further.

| Median dQ% | | StreamPro CNS | M9 CNS | RiverPro CNS | Mean of diff |
|---|---|---|---|---|---|
| W/D ratio | Low | -3,9 | -1,9 | -1,5 | |
| | Medium | -3,7 | -2,7 | -1,7 | |
| | High | -3,7 | -3,0 | -1,5 | |
| | **Diff** | **0,2** | **-1,1** | **0,0** | **-0,3** |
| Width | Narrow | -4,0 | -2,1 | -2,5 | |
| | Medium | -3,9 | -3,2 | -1,9 | |
| | Wide | -3,2 | -1,9 | -0,4 | |
| | **Diff** | **0,8** | **0,2** | **2,1** | **1,0** |
| Depth | Shallow | -4,3 | -3,3 | -3,5 | |
| | Medium | -4,2 | -3,1 | -1,4 | |
| | Deep | -2,7 | -0,9 | -0,4 | |
| | **Diff** | **1,6** | **2,4** | **3,1** | **2,4** |
| Wt speed | Slow | -3,7 | -3,4 | -2,6 | |
| | Medium | -4,2 | -2,6 | -1,4 | |
| | Fast | -3,3 | -2,0 | -1,4 | |
| | **Diff** | **0,4** | **1,4** | **1,2** | **1,0** |
| Q | Low | -3,8 | -3,2 | -3,7 | |
| | Medium | -4,2 | -2,9 | -1,8 | |
| | High | -3,0 | -1,4 | -0,4 | |
| | **Diff** | **0,8** | **1,8** | **3,3** | **2,0** |
| %meas | Low | -3,4 | -2,9 | -2,6 | |
| | Medium | -4,2 | -2,1 | -1,3 | |
| | High | -3,8 | -3,2 | -0,8 | |
| | **Diff** | **-0,4** | **-0,3** | **1,8** | **0,4** |

| *From* | *to* | *Color* |
|---|---|---|
| *2,1* | *inf* | *pink* |
| *1,1* | *2* | *blue* |
| *0,3* | *1,0* | *Light blue* |
| *-0,2* | *0,2* | *grey* |
| *-0,6* | *-0,3* | *yellow* |
| *neg inf* | *-0,7* | *orange* |

*dQ% for Low/Medium/High (L/M/H) values for Width to depth ratio, Width Depth, water speed, discharge and Percent measured discharge.*

## 6.6 Other aspects

### 6.6.1 NVE's policy on Extrap/Qrev and generating rating curves

When ADCP discharge measurements are applied to generate rating curves, it might lead to systematic changes in the time series unless we do extra work to avoid it.

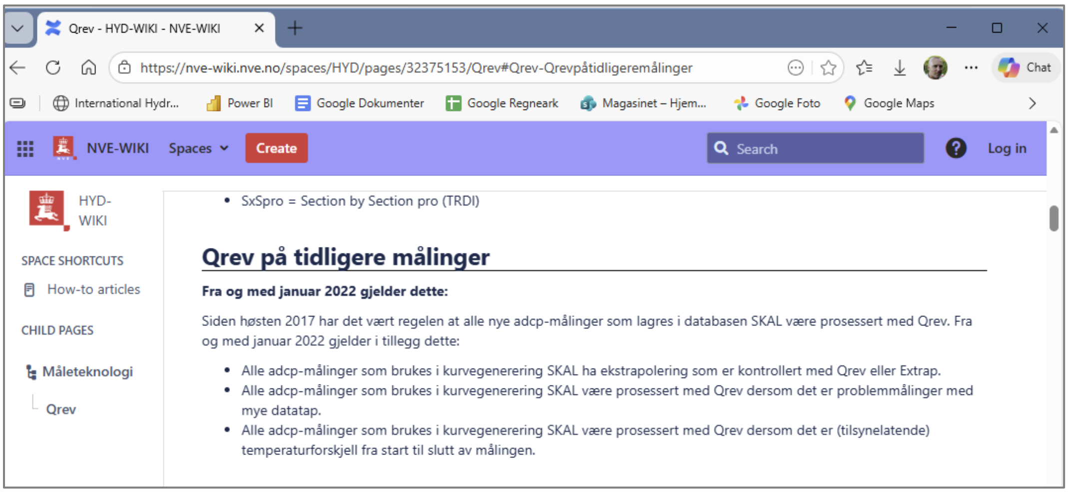
The timeline for practice, recommendations and requirements is not clear, but our internal documentation (online wiki) states this, translated from Norwegian:
*Since autumn 2017, it has been the rule that all new ADCP measurements stored in the database MUST be processed with Qrev. As of January 2022, the following also applies:*

- *All ADCP measurements used in curve generation MUST have extrapolation that is controlled with Qrev or Extrap.*
- *All ADCP measurements used in curve generation MUST be processed with Qrev if there are problem measurements with a lot of data loss.*

- *All ADCP measurements used in curve generation MUST be processed with Qrev if there is an (apparent) temperature difference from the start to the end of the measurement.*

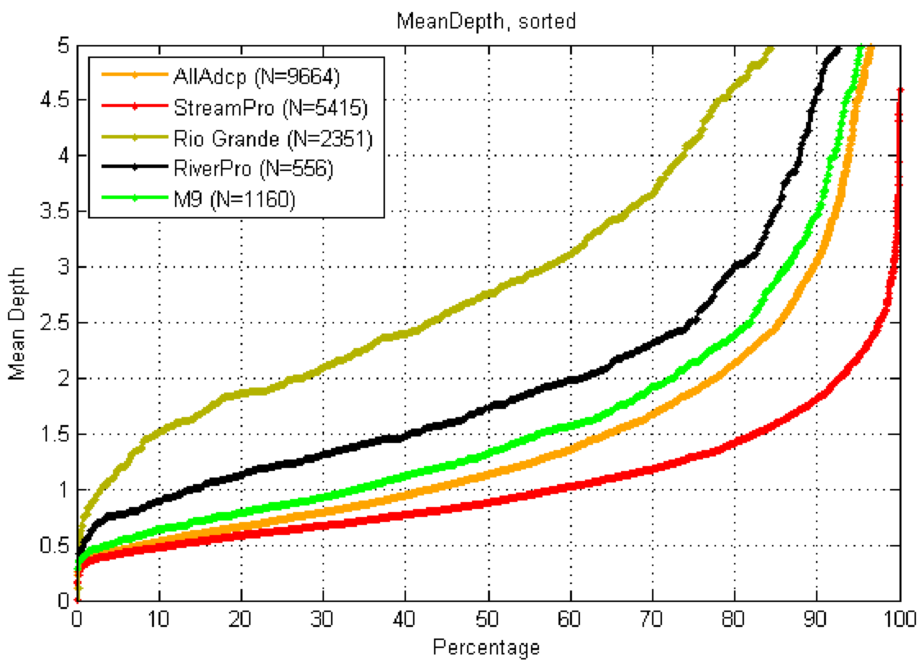
This means that old ADCP measurements will be reprocessed when we re-generate or correct rating curves.

Screenshot for internal (NVE) documentation:




### 6.6.2 Pushing M9 into "*too shallow*" water

Like mentioned before, more or less at the same time as introducing Extrap/Qrev in NVE, we starting using Sontek M9 and TRDI RiverPro ADCPs. The RioGrande is best suited for measuring deep rivers, and the new ones can measure both deep and shallow rivers. They may measure *really* shallow, but we have urged the field hydrologists not to push them into *too* shallow water. Unfortunately, there is yet no good answer to how shallow "too shallow" is, and the combination of Sontek M9 and the rQpod remote controlled float is a very tempting and effective tool-combination to measure almost everywhere. We see this in the plot below that shows the sorted mean depth for measurements performed by each instrument. 30% of the m9-measurements are made on rivers that are less than a meter deep, but without analysing data we do not know if this is too shallow, in the sense that quality becomes too low.




### 6.6.3 Qrev/Extrap, Oursin and percent measured

This is very much related to the previous chapter. An ongoing discussion nationally and internationally is how much of a river do we need to measure before it is enough. How far into shallow water can we push the StreamPro before we should rather use a point velocity meter or dilution in the downstream rapids? Or, what is the minimum depth for the very convenient rQpod + M9 combo before we should set up a rope and use the StreamPro instead?

The uncertainty model Oursin that is built into QrevInt can give a strong indication. Oursin data has been stored automatically since 2022 when we started using the HIRA tool to import data to our database. The answer is there, but it is beyond the scope of this investigation to look into it.

### 6.6.4 Top Q, bottom Q

In this report we have not tried to figure out if the change in calculated discharge comes mainly from top Q or bottom Q or if it is equal contributions from both. That should be the subject for future investigations.

### 6.6.5 Alternative reasons for high percentage of constant/no-slip measurements

A very relevant question is whether the constant/no-slip extrapolation reflects the true velocity distribution in the rivers, or if there are other issues like flow disturbance from the instrument and float or if it is the suggested extrapolation in the software that make us use constant/no-slip.

To address the last one first: Extrap and Qrev uses similar algorithms, see QrevInt technical manual in the Qrev help menu or Mueller (2013). Extrap/Qrev will default to power/power/0.1667 unless data suggest strongly enough that another method shall be used. This indicates that Extrap will not tend to favour constant/no-slip extrapolation. This report will not investigate this matter further.

NVE report No. 1/2023 states that the StreamPro ADCP has very little flow disturbance. This is in agreement with Mueller 2015. The rivers where we have used the StreamPro are probably more constant/no-slip than previously assumed. Or perhaps, more precisely, prior to Extrap we had no tool to tell us to *not* use the standard one sixth power law extrapolation. In the turbulence theory, a river has the “nice, theoretical” logarithmic velocity profile in the centre part of a river that is more than 10 times wider than in is deep. This is the profile we approximate by the power-law profile in Eq. 1. Closer to the edges the maximum velocity will be below the surface, and it is plausible that this will lead to average velocity profiles that have constant extrapolation at the top in many cases.

# 7 Conclusion

Extrap/Qrev has changed how we extrapolate data from ADCP-measurements, and it has changed the discharge we store in our database compared to how we processed data before starting to use Extrap/Qrev. Extrap/Qrev make helps us to apply more correct extrapolation of the velocity profiles, and the discharge we report now is more correct than it was before. When choosing between correct or consistent data, we choose correct. In other words, we will continue to use Extrap/Qrev to produce as correct data as possible.

In NVE we do not have the capacity to check new methods and instruments thoroughly before we start using them operationally, so we lean heavily on other (larger) agencies who have larger testing capacities than us. We do, however, check retrospectively, either by comparing data from new methods/instruments with rated discharge on selected gauging stations for a large number of measurements, or by combining new and old data, datafiles, database entries and manually collected data, like in this report. Previous (unpublished) investigations in systematic changes have not indicated any changes in calculated discharge. This means that after the introduction of Extrap/Qrev it is the first time we see it. Most of the previous investigations are old and almost not documented at all. Re-doing them may or may not lead to other conclusions.

The transition period between “before Extrap/Qrev” and “After Extrap/Qrev” is the years 2013-2015. Before 2013, 78% of all ADCP-measurements had their discharge calculated using the default extrapolation method. After 2015, 8% used default extrapolation. The majority now use constant/no-slip, but it varies between the instruments and the river characteristics in which they are used.

Looking at all instruments and all data, Extrap/Qrev has caused 1.5% lower discharge values to be stored in our database, or 2.9% lower if we only look at the constant/no-slip measurements. 56% of the measurements today are constant/no-slip. If we look at the StreamPro’s constant/no-slip measurements, discharge is down by 6.1% or more for 25% of the measurements. A little more than 15% of our measurements per year are StreamPro measurements.

60-70% of all discharge measurements per year are made by ADCPs. The change in how we calculate discharge might affect calculation of annual runoff from Norway, if we are not careful. Our current procedures and requirements intend to prevent this from happening. For all ADCP measurements that go into rating curves, the hydrologist must at least have used Extrap or Qrev to find the proper extrapolation. In practice these days, it will be QrevInt, since it we have very good tools to import Qrev/QrevInt data into our database.

We are not, at the time of writing, required to reprocess all old measurements to reconstruct rating curves for all periods[2].

The data users must be aware of the potential systematic change (bias) in data, and this report lists values that might be used to estimate these changes, or the bounds for the changes.

[2] NVE stores stage and calculate discharge on the fly. A gauging station might have one or more rating curves that are valid for previous periods and one that is valid for data today. For instance, one curve for 1977-1992, one curve for 1992-2018 and one for 2018 and onwards.

# 8 References

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# 9 Appendix

## 9.1 Data sources, details

### 9.1.1 More about data sources

The data sources described in ch 0 are XML-data, COMMENT-data, Hydra2-data, shadow database data and mmt-data.

***XML-data***. Data files generated by the Qrev software. They get uploaded to the Hydra 2 database when the users use the HIRA software to save data from discharge measurements into the database.
The XML data contains

- Discharge after all processing except change in extrapolation method, and discharge after using Extrap/Qrev to find the correct extrapolation method.
- Which extrapolation method the user has selected.

***COMMENT-data*** is the comment field for a discharge measurement in the Hydra2 database. For many measurements, the users have copied an automatically generated text from the ADCP-report to the comment field in the Hydra2 data base. The ADCP report macro reads WinRIverII mmt files or Qrev xml files to retrieve these values. If the text is not edited by the user, it is possible to automatically read information from it.
The comments contain

- Discharge after all processing except change in extrapolation method, and discharge after using Extrap/Qrev to find the correct extrapolation method.
- Which extrapolation method the user has selected

***Hydra 2-data***, or more precisely, data in regular Hydra2 database-tables are inserted into the database in several ways. It used to be entered manually using the database editor Hysopp. Values from more recent versions of the Excel ADCP report could be entered into Hysopp (or database editing tool) by cutting/copying and pasting from a comment field containing automatically generated values from either WinRiverII mmt files or Qrev xml files. Since 2022 we have used our HIRA software that reads Qrev xml files and inserts values to Hydra2.
Recent Hydra2-data contain

- Discharge after all processing except change in extrapolation method, and discharge after using Extrap/Qrev to find the correct extrapolation method.
- Which extrapolation method the user has selected

Old Hydra2-data contain mainly stage, discharge, user initials, method/instrument and quality.

***Shadow database data*** is data that was written to a shared background worksheet that served as a “shadow database” for data that could not at the time be saved in the Hydra2 database. The data is read from WinRiverII mmt files or Qrev xml files that the user selects to generate an ADCP measurement report. The shadow database contains

- Discharge after all processing except change in extrapolation method, and discharge after using Extrap/Qrev to find the correct extrapolation method.
- Which extrapolation method the user has selected

***Mmt data*** is data harvested by a “crawler” that reads all WinRiverII mmt files in our file archive. That is, a modified version of the ADCP report macro that finds and reads all mmt files, and extracts values to a worksheet. Mmt data contains

- Which extrapolation method the user has selected
- Processed discharge, but *not* with and without using Extrap/Qrev.

XML-data, COMMENT-data and Hydra2-data are retrieved by the SQL-query in ch 0. In case of overlapping data, the data in the final, merged dataset is selected in the order listed in Table 9.1. The order is decided by prioritizing data that not prone to manual errors.

When data from measurements are present both in mmt and in newer sources, and the year of the measurement is before 2016, mmt is prioritized. This is because we want to know how data was processed initially, before starting to use Qrvev/Extrap.

| Data Source | Contain extrapolation method | Contain discharge with and without Extrap | Number of entries for each measurement in the database | From |
|---|---|---|---|---|
| XML | Yes | Yes | 0 or 1 | 2022 |
| COMMENT | Yes | Usually not | 0 or 1 | 2015 |
| Hydra2 | No | Yes | 0 or 1 | 2015 |
| Shadow database (xml) | Yes | Yes | 0 or 1 or more | 2017 |
| Shadow database (mmt) | Yes | Yes | 0 or 1 or more | 2015 |
| Mmt-data | Yes | No | 0 or 1 or more | 2007 |

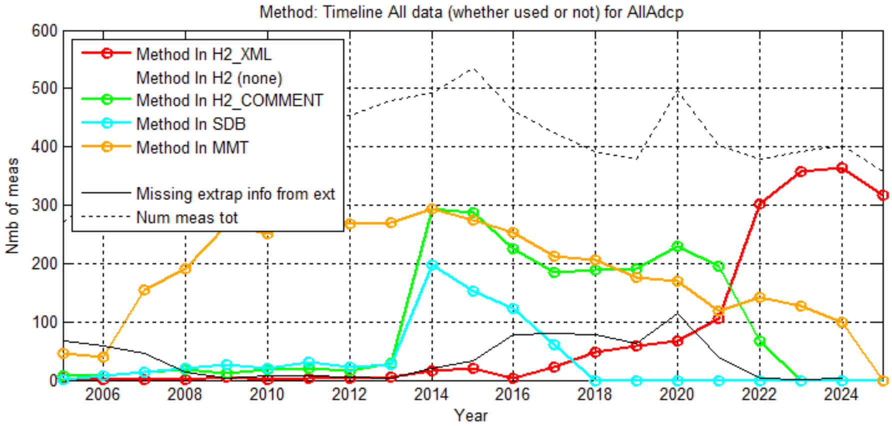
**Table 9.1 order of data in merged dataset**

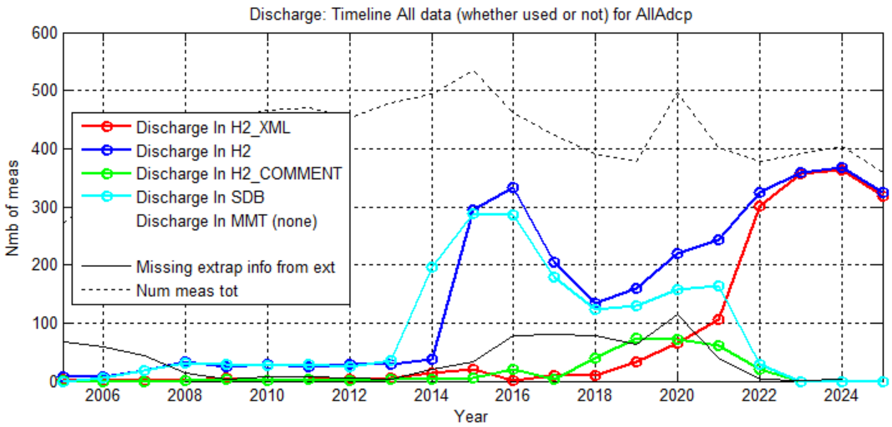
The first pair of plots below show the number of measurements present in the different data sources, year by year, and also toe total number of ADCP measurements.

The next pair of plots show the number of measurements from each data source that are included in the merged dataset, year by year.

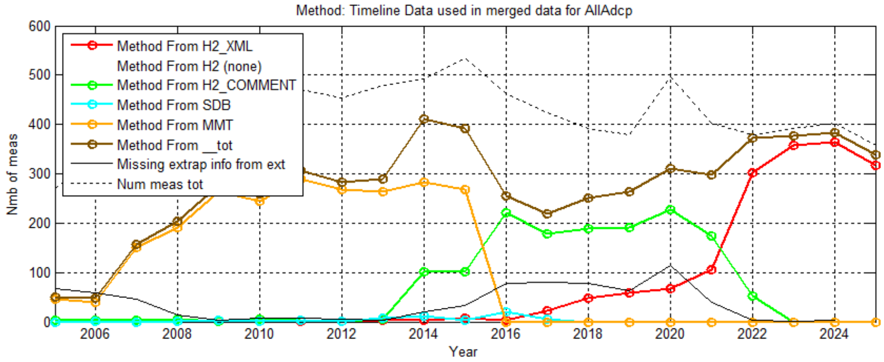
The last plot shows the total number of measurements containing “discharge data” and “method data”. Here, “discharge data” means measurements containing discharge calculated using the default one sixth power law extrapolation and discharge calculated using any other method the users have chosen. “Method data” means information on which extrapolation method the users chose.

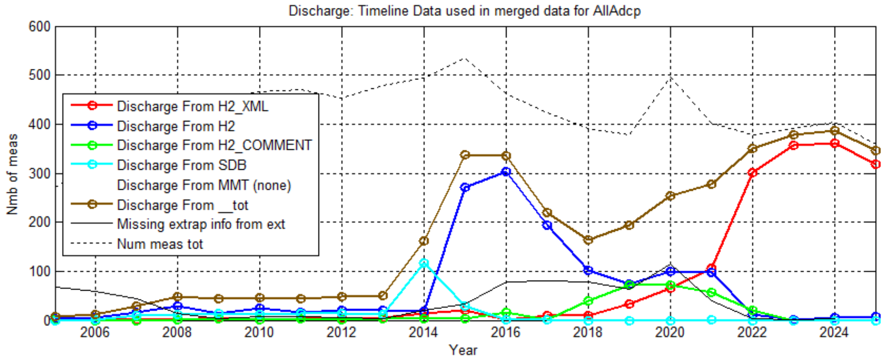
There could have been more “discharge data” from Qrev xml for some earlier years. The first versions of Qrev did not contain “DischargePPDefault”, that is, discharge as it would have been if using the default one sixth power law extrapolation. It was added in version 3.35, early 2018, according to email communication with Travis Knight, USGS. The early versions were very slow, and we did not require reprocessing with and without using extrap to find the correct extrapolation. In addition, some users continued for rather long to use older Qrev versions that did not contain this info, even after it was available.

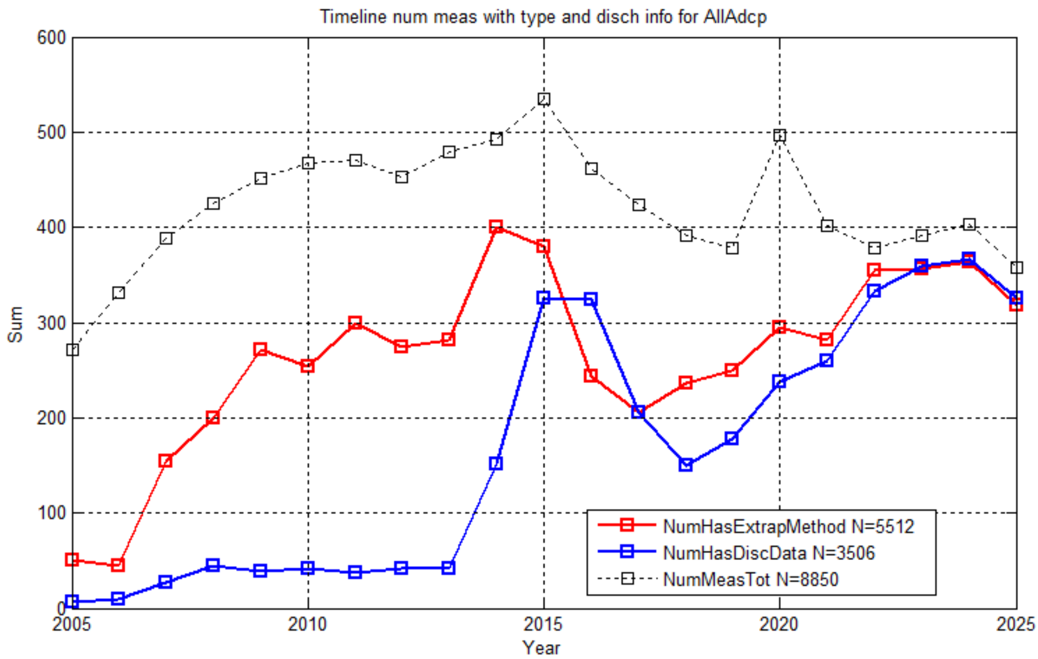



| Data Source/event | In plot legend | From |
|---|---|---|
| Mmt-data (crawler) | MMT | 2007 |
| COMMENT in Hydra 2 | H2_COMMENT | 2015 |
| Hydra2, proper fields | H2 | 2015 |
| Shadow database (mmt) | SDB | 2015 |
| Qrev required | *** | 2017 |
| Shadow database (xml) | SDB | 2017 |
| Discharge (Qpp1667) in xml | *** | 2018 |
| XML in Hydra2 read by HIRA | H2_XML | 2022 |


Method: Timeline Data used in merged data for AllAdcp
Method From H2_XML
Method From H2 (none)
Method From H2_COMMENT
Method From SDB
Method From MMT
Method From __tot
Missing extrap info from ext
Num meas tot
Nmb of meas
Year


Discharge: Timeline Data used in merged data for AllAdcp
Discharge From H2_XML
Discharge From H2
Discharge From H2_COMMENT
Discharge From SDB
Discharge From MMT (none)
Discharge From __tot
Missing extrap info from ext
Num meas tot
Nmb of meas
Year


Timeline num meas with type and disch info for AllAdcp
NumHasExtrapMethod N=5512
NumHasDiscData N=3506
NumMeasTot N=8850
Sum
Year

### 9.1.2 Files and folders

List of folders and files follows. Note that all paths below may not valid anymore, but they serve as a clue on where to start searching

- "Shadow database" from ADCP-report, WinRiver version
  \\nve.no\fil\h\HH\Faggrupper\Måleteknologi\Sammenligningsmålinger\ComparisonMeasurements\Extrap\Extrapskjema.xlsx
- "Shadow database" for ADCP-report, Qrev version
  \\nve.no\fil\h\HH\Faggrupper\Måleteknologi\Sammenligningsmålinger\ComparisonMeasurements\Extrapskjema_QrevVersion.xlsx
- Data from these excel-files have been manually merged into one file.
- Reports (excel macros) filling in these "shadow databases"
  \\nve.no\fil\h\hh\Faggrupper\Måleteknologi\Akustisk\ADCP\Maler

The files used in this report will be saved in P360, NVE's digital document archive. Search for the name of this report.

These are the files in question:

- "Master datafile. One entry per measurement. Data from Qrev xml if it is present.
  Hydra2_data_incl_XML_and_comment.xlsx
- The "Shadow database" manually combined into one file
  ShaddowDatabase_mmt_and_xml.xlsx
- Data from MMT-crawler, including some data from database
  MMT-crawler_with_Hydra2-data.xlsm
- Merged data, used in this report. Four variants with different decimal mark and delimiter.
  Extrap_MergedData__semicolonseparated__decimalcomma.csv
  Extrap_MergedData__semicolonseparated__decimalpoint.csv
  Extrap_MergedData__tabseparated__decimalcomma.csv
  Extrap_MergedData__tabseparated__decimalpoint.csv

### 9.1.3 SQL-query

This Query is used to retrieve data from Hydra2 database.

```
SELECT
sd.regine_area,sd.main_no,st.station_name,sd.init_measure,FORMAT(sd.dt_measured_time,'yyyy.MM.dd HH:mm') as
dt_measured_time,FORMAT(dt_end_stage_time,'yyyy.MM.dd HH:mm') as dt_end_stage_time,
sd.stage,sd.discharge,sd.q_processed_extrap,sd.q_measured,
xml_File.value('(Channel/ChannelSummary/Discharge/Total)[1]','float') as Qtotal_xml,
sd.q_method_key,sd.instr_key,sdm.q_method_name,it.name AS InstrName,it.fullname AS InstrFullName
,sd.serial_no,sd.cross_section_area,sd.cross_section_width,sd.max_depth,sd.max_speed,

xml_File.value('(Channel/ChannelSummary/Discharge/Top)[1]','float') as Qtop_xml,
xml_File.value('(Channel/ChannelSummary/Discharge/Bottom)[1]','float') as Qbottom_xml,
xml_File.value('(Channel/ChannelSummary/Discharge/Left)[1]','float') as Qleft_xml,
xml_File.value('(Channel/ChannelSummary/Discharge/Right)[1]','float') as Qright_xml,
xml_File.value('(Channel/ChannelSummary/Discharge/Middle)[1]','float') as Qmiddle_xml,
xml_File.value('(Channel/ChannelSummary/Other/DischargePPDefault)[1]','float') as Qpp1667_xml,
xml_File.value('(Channel/Processing/Extrapolation/TopMethod)[1]','varchar(10)') as ExtrapTop,
xml_File.value('(Channel/Processing/Extrapolation/BottomMethod)[1]','varchar(10)') as ExtrapBtm,
xml_File.value('(Channel/Processing/Extrapolation/Exponent)[1]','float') as Exponent,
xml_File.value('(Channel/ChannelSummary/QRevUAUncertainty/AutoTotal)[1]','float(2)')  as UncertaintyQRev,
xml_File.value('(Channel/ChannelSummary/OursinUncertainty/AutoTotal95)[1]','float(2)')  as UncertaintyOursin,
--CAST(xml_File.value('(Channel/ChannelSummary/QRevUAUncertainty/AutoTotal)[1]' ,'varchar(10)') AS float(2))  as
UncertaintyQRev,
--CAST(xml_File.value('(Channel/ChannelSummary/OursinUncertainty/AutoTotal95)[1]','varchar(10)') AS float(2))  as
UncertaintyOursin,
sd.comment,sd.xml_file,
sd.q_quality_key as qualTot,sdqTot.q_quality_name as qualTotName,
sd.q_quality_discharge_key as qualDisc,sdqDisc.q_quality_name  as qualDiscName,
sd.q_quality_stage_key as qualStage,sdqStage.q_quality_name as qualStageName
FROM stage_discharge sd
LEFT JOIN station st ON (sd.regine_area=st.regine_area AND sd.main_no=st.main_no AND sd.point_no=st.point_no)
LEFT JOIN stage_disc_method sdm ON (sd.q_method_key=sdm.q_method_key)
LEFT JOIN instrument_type it ON (sdm.instr_key=it.instr_key)
LEFT JOIN stage_disc_quality sdqTot ON  (sd.q_quality_key        =sdqTot.q_quality_key)
LEFT JOIN stage_disc_quality sdqDisc ON (sd.q_quality_discharge_key=sdqDisc.q_quality_key)
LEFT JOIN stage_disc_quality sdqStage ON(sd.q_quality_stage_key    =sdqStage.q_quality_key)
--cross apply xml_File.nodes('ChannelSummary') as qtab(CS)
WHERE sd.q_method_key in (1,18,19,34,20,33,51,52,56,57,28,37,29,35,31,36,43,45)
--WHERE sd.instr_key in (1518,1520,1521,1522,1528,1529,1531,1543) this gives a lot less measurements
AND sd.ice_decide_prof=1 AND sd.ice_measure_prof=1
AND sd.regine_area<400
AND NOT (sd.regine_area=16 and sd.main_no=155 and sd.dt_measured_time='2019-06-18 11:23:00.0000000')  --has
OursinUncertainty inf and that chrashes the query
AND NOT (sd.regine_area=139 and sd.main_no=13 and sd.dt_measured_time='2023-10-05 12:59:00.0000000')  --has
OursinUncertainty inf and that chrashes the query
AND NOT (sd.regine_area=311 and sd.main_no=460 and sd.dt_measured_time='2023-04-04 09:02:00.0000000')  --has
OursinUncertainty inf and that chrashes the query

order by sd.regine_area,sd.main_no,sd.dt_measured_time
```

This query did not include QrevVersion. It can be added to the query by adding this line among the SELECT-items:

```
xml_File.value('(Channel/@QRevVersion)[1]','varchar(20)') as QrevVersion,
```

## 9.2 Previous presentations and meetings

This investigation has been presented internally in NVE and externally on several occasions, and in different stages of refinement.

- Data presented in Wallingford November 2014 (MAKE-workshop, Hydrometry ‘Multi-Agency Knowledge Exchange’ Workshop, Wallingford)
- Environment Agency ADCP Workshop September 16th 2015, Wallingford UK.
- Data presented in TMTW, San Diego 2015 (larger dataset, from “shadow database”)

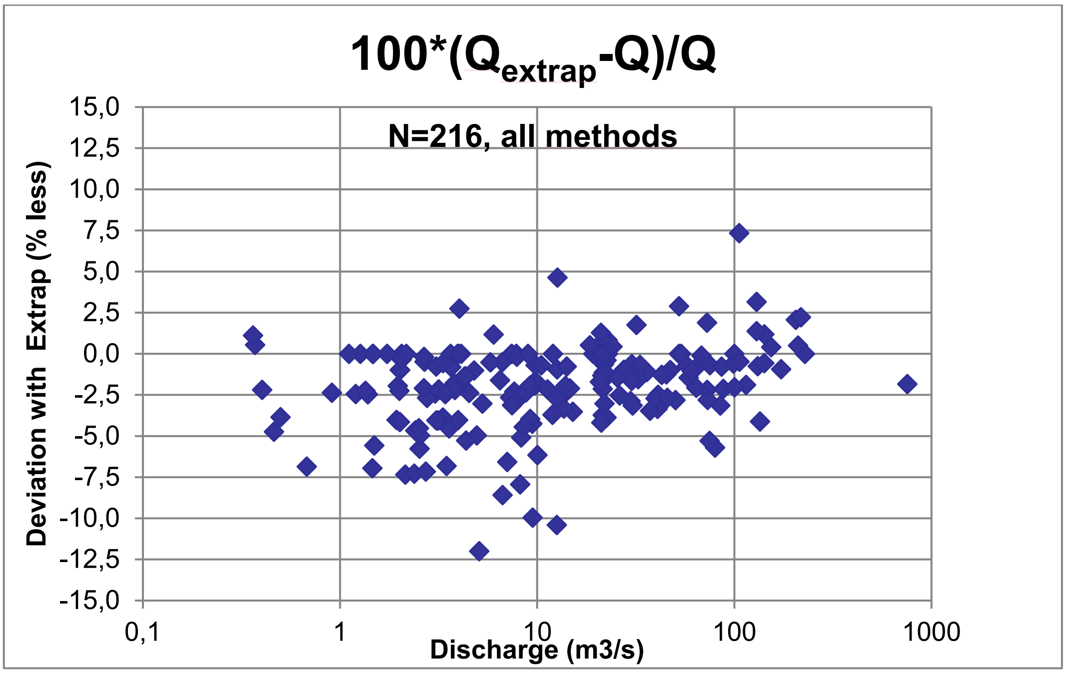
### 9.2.1 Data presented internally 2014

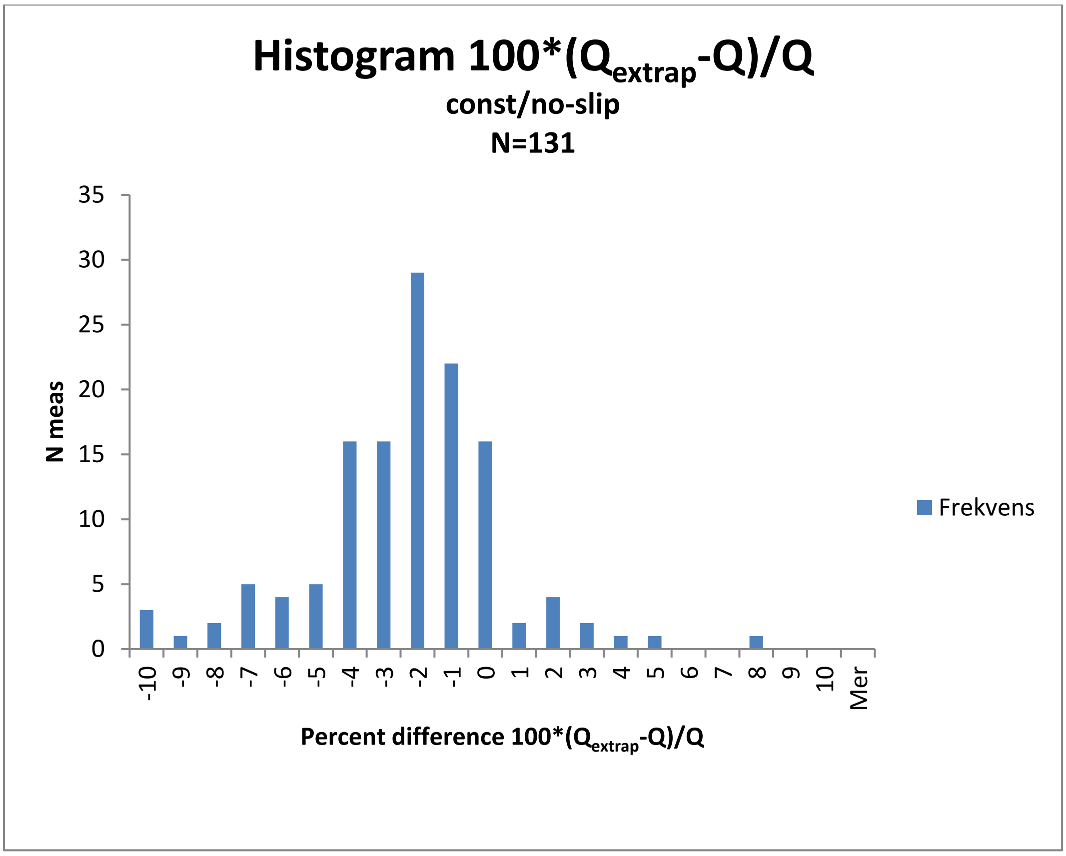
*Data presented at internal meeting NVE November 2014. This is mainly of interest internally.*

Data from the initial investigations were presented for the first time at an Internal meeting for the hydrometry section 10 November 2014. We invited data users as guests. In this meeting we concluded that we were going to use Extrap. Minutes can be found in link below and in ch 0. Data presented in this meeting is probably the same as the data presented at the MAKE workshop later in November.

Data showed that a little more than 60% of the 209 measurements had constant/no-slip extrapolation, and that for the constant/no-slip measurements discharge was down by around 2% on average. There was only visual presentation of these data, i.e. the plots and tables below.

In the meeting where this was presented and discussed, we concluded that NVE should use Extrap, and that it shall be noted in the database if data has been processed using Extrap or not.






*Histogram, same as presented in Wallingford. N=131 is slightly wrong. Correct value is 130.*

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| % Diff | -10 | -9 | -8 | -7 | -6 | -5 | -4 | -3 | -2 | -1 | 0 |
| N | 3 | 1 | 2 | 5 | 4 | 5 | 16 | 16 | 29 | 22 | 16 |
| % Diff | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | >10 |
| N | 2 | 4 | 2 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |

| | Num | Percent |
|---|---|---|
| Constant/no-slip | 130 | 61,03 |
| Power/power | 79 | 37,09 |
| other | 4 | 1,88 |
| Sum | 209 | 100 |

## 9.2.2 Minutes from internal meeting NVE November 2014

Minutes from internal meeting NVE November 2014 below. *This is only of interest internally, and it is not translated from Norwegian to English.*

Referat lagret her:

\\nve.no\fil\h\HH\Administrasjon\Seksjonsmøter\Referater 2014\Møtereferat ukemøter\Møtereferat 17_10.11.2014.docx

(kopiert inn nedenfor, ikke editert eller rettet opp i skrivefeil)

*Til stede: HHD & HHT, IHA, ERI, TCWA, AFL, PBO*

*HHD, HHT = hydrometriseksjonene, IHA=Ingjerd Haddeland, ERI=Erik Holmqvist, TCWA=ukjent, AFL=Anne Kristina Fleig, PBO=Peter Borsányi*

*ExTrap er et lite dataverktøy knyttet til akustiske målemetoder (ADCP) som gjør at HH (kanskje?) gjør bedre ekstrapoleringer i hastighetsprofilet. Verktøyet har alt fra ingen eller svakt positiv effekt til meget negativ effekt (10-15-20%) på målt vannføring. Denne programvaren har vært i bruk i varierende grad siden 2009. Diskusjonen om bruken av ExTrap har vært pågående, og har blitt enda mer aktuell i forbindelse med flomkartprosjektet, samt i forbindelse med flommen på Vestlandet i oktober 2014. Sluttbrukere av data/vf-kurver fra HM og HV ble invitert til dette seksjonsmøtet for å gi innspill.*

*Sluttbrukeres bestilling er:*

*Mest mulig korrekte data trengs til vannbalanseberegninger og avrenningskart.*

*Konsistente data er viktig for trendanalyse og flomfrekvensanalyse.*

*Problemstillinger:*

*Det antydes at bruken av ExTrap I SNITT gir 2-3% lavere vannføring (har ikke representativ utvalg av målinger ennå)*

*Hva må gjøres med gamle målinger der ekstrapolering ikke er blitt gjort (med noen som helst programvare/metode)?*

*Hva med de målingene der et annet ekstrapoleringsverktøy enn ExTrap* [sic], *er brukt?*

*Hvor trekker man skillet mellom før og etter ExTrap tid? Hva blir gjort med gamle målinger (før 2009, før ADCP)? Det er lite populært og dessuten dyrt å gå gjennom alle gamle målinger. Hva med de kurver som må revideres?*

*Må det bli gjort stort antall nye målinger og stort antall nye kurvegenereringer?*

*Støy i data lever vi med, men hvordan håndtere dette som er egentlig bias?*

*Løsninger og forslag:*

*Endringer som skjer gradvis er verre enn et tydelig tidsskille før/etter ExTrap. Bruken av ExTrap burde bli innført så fort som mulig.*

*Det må merkes tydelig hvilke målinger er blitt gjort med eller uten ExTrap.*

*Uansett skal data med ExTrap både kjøres og lagres for fremtidige bruk, i tilfelle det blir frys i bruken av ExTrap.*

*Kort oppsummert:*

*Kurvegenerering fryses ikke, og lar dataen være som den er nå. Hvis vf-kurven blir endret mye pga. ExTrap, genereres det to forskjellige kurver: en med og en uten ExTrap.*

*Det trengs mange målinger før en grundig analyse av feil før/etter ExTrap kan gjøres og total konsekvens vurderes. Derfor: HUSK å fylle ut målinger i excel-arket (også de nye kolonnene):*

*\\vnx\h\HH\Faggrupper\Måleteknologi\Akustisk\ADCP\ComparisonMeasurements\Extrap_2014 og*

*\\vnx\h\HH\Vannføringsmålinger\Akustisk*

*HM og HV gir sin anbefaling helst i løpet av uken (46). Flomkartprosjektet går videre som planlagt ettersom bare få målinger er gjort med ADCP.*

*Elise tar denne saken opp på H-ledermøte.*

*Dette blir et viktig tema under HH-samling i desember i Oslo.*

Notat krdy jan 2025: Jeg finner ikke oppfølging av denne saken (ref. referat ovenfor), men mener å huske at databrukerne ønsker mest mulig korrekte data til enhver tid, og at mulige systematiske endringer (innføring av Extrap) må dokumenteres.

Se også mailveksling (emne "Ekstrapolering") Kristoffer Florvaag-Dybvik og Anne Kristina Fleig 11.11.2014.

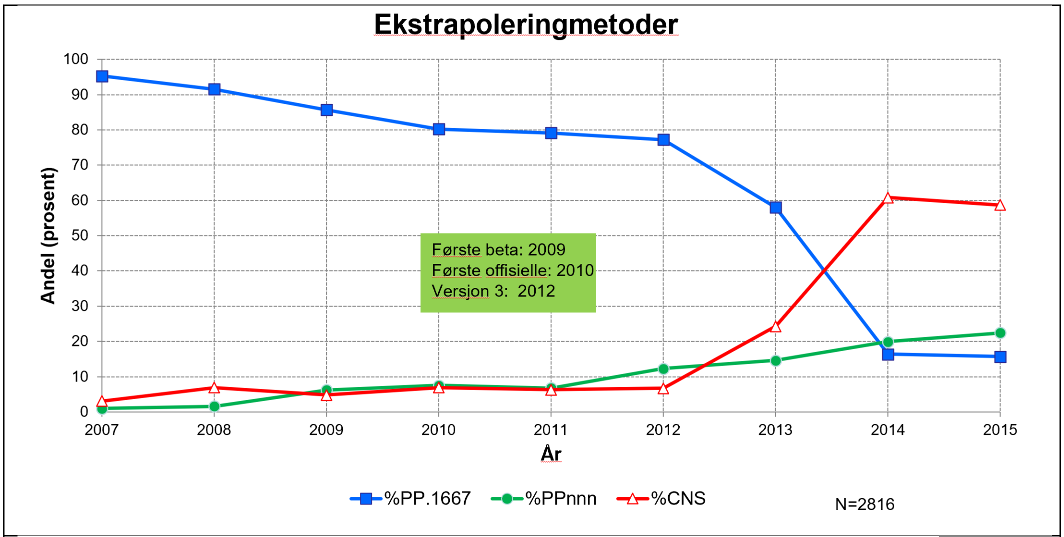
### 9.2.3 Data presented internally 2015

*This is only of interest in NVE. Data were presented in "Faglunsj" (lunch presentation, NVE) 13.11.2015*

*Almost same dataset as TMTW, San Diego, 2015*

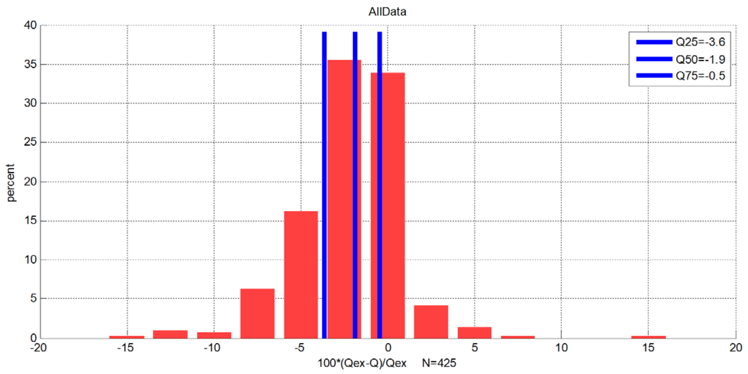
*Summary in presentation, translated by Google Trnaslate*

- *For about 500 ADCP measurements, Extrap appears to have provided changed data*
- *Astrid Vatne and Trond Reitan have run statistical tests on some of the data, and the changes are statistically significant*
- *For all methods: Flow decreases by 2%*
- *For const/no-slip: Flow decreases by 2.6%*
- *60% of measurements in recent years are const/no-slip*
- *For pwr/pwr/not 0.1667: Flow decreases by 0.8%*
- *20% of measurements in recent years are pwr/pwr/not 0.1667*
- *It may appear that flow changes more in shallow than in deep rivers, but there is no obvious trend.*
- *Have not run statistical analysis*
- *The width/depth ratio does not appear to have an impact on flow changes*




## Alle ekstrapoleringsmetoder

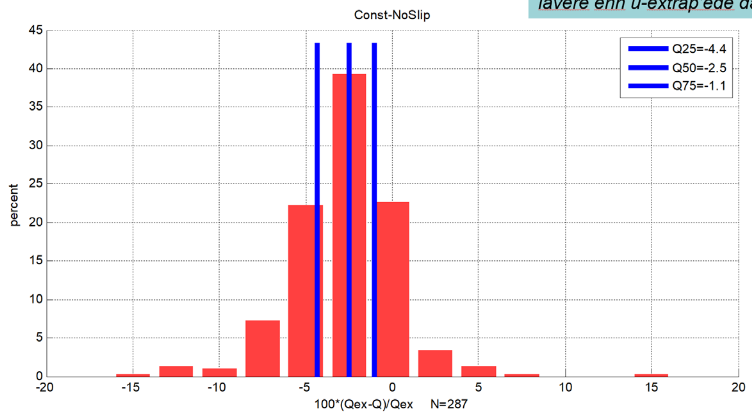
*Extrap'ede data er nnn prosent lavere enn u-extrap'ede data*




| | Point estimate of µ | 95% Confidence Interval | | 99% Confidence Interval | |
|---|---|---|---|---|---|
| | | Lower boundary | Upper boundary | Lower boundary | Upper boundary |
| All data | -2,05 % | -2,30 % | -1,80 % | -2,38 % | -1,72 % |

## Const / no-slip

*Extrap'ede data er nnn prosent lavere enn u-extrap'ede data*




| | Point estimate of µ | 95% Confidence Interval | | 99% Confidence Interval | |
|---|---|---|---|---|---|
| | | Lower boundary | Upper boundary | Lower boundary | Upper boundary |
| c/ns | -2,63 % | 2,30 % | 2,97 % | 2,19 % | 3,07 % |

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