Divirod Water Level Index Methodology

November 2023

Background

The purpose of Divirod's Water Level Index (WLI) Map is to provide a high-level overview of the 'state of water' by enabling users to quickly identify regions at potential risk of either flooding or water stress. The WLI Map is built on measured water level data from providers from around the world that has been consolidated into Divirod's data lake. Unlike existing resources that use model-based estimates to infer water levels, this tool and underlying dataset are solely rooted in actual measurements. This empirical approach ensures the reliability of the water level data and equips industry leaders, insurance companies, and policymakers with actionable insights. These insights are crucial for effective water resource management, enabling informed decision-making in areas such as flood risk management, agricultural planning, and urban water resource allocation. The introduction of the WLI, paired with Divirod's data analytics platform, bridges the gap between theoretical models and practical, data-driven solutions in the increasingly complex realm of global water management. This document outlines the current methodology used to quantify real-time water levels in relation to the historical water levels for each gauge dating back to the start of 2020.

Water Level Status Classification

Divirod has chosen to assign one of five water level status codes to each gauge in the data lake: 'extremely high,' 'high,' 'normal,' 'low,' and 'extremely low.' For all water body systems, these classifications are assigned based on the statistical distribution of all the data records for each gauge.

$$WL_e = \mu_{wl} \pm X_e \cdot \sigma_{wl}$$

$$WL_{hl} = \mu_{wl} \pm X_{hl} \cdot \sigma_{wl}$$

Where:

- WL_e = Extreme water level
- X_e = Extreme multiplier
- WL_{hl} = High/low water level
- X_{hl} = High/low multiplier
- μ_{wl} = mean water level
- σ_{wl} = standard deviation of recorded water levels

The standard deviation multipliers for river systems are different than the multipliers for coastal and reservoir systems. Reasons for this will be further detailed in the next sections.

Because the primary goal of the WLI is to identify extreme conditions, the multipliers are selected such that a majority of the data (~90-95%) fall into the 'normal' classification.

River Systems

River systems display a unique seasonal water level pattern. Heavily influenced by winter run off and spring rainstorms, both river stage (water level) and flow rate tend to increase very rapidly in the months coming out of winter, slowly tapering off later into the summer. Because of the unique system characteristics of rivers and their relationship to spring runoff, the annual water levels for a specific river location generally do not follow a normal distribution. An analysis of all records associated with river systems in our data lake indicated that the data is heavily right skewed. To account for this, the water level readings for river systems were transformed by taking their natural log before applying the statistical method described above. While not always a perfect fit, this transformation brought the series much closer to a normal distribution. After the extreme and high/low thresholds are calculated in the log space, they are transformed back into the original units before each record is assigned a status.

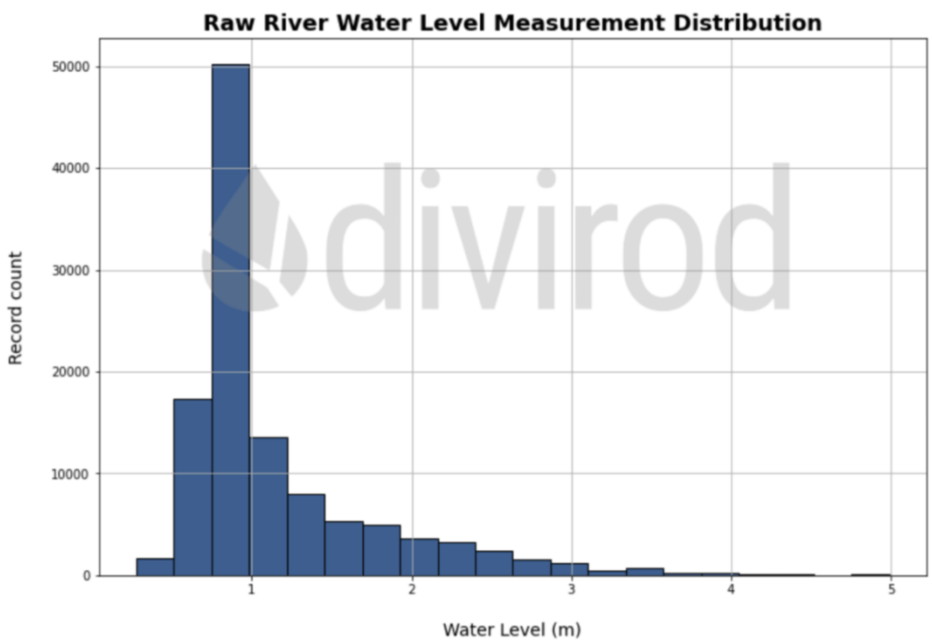

Figure 1: Raw water level records for the past three years from a single USGS river gauge 06214500.

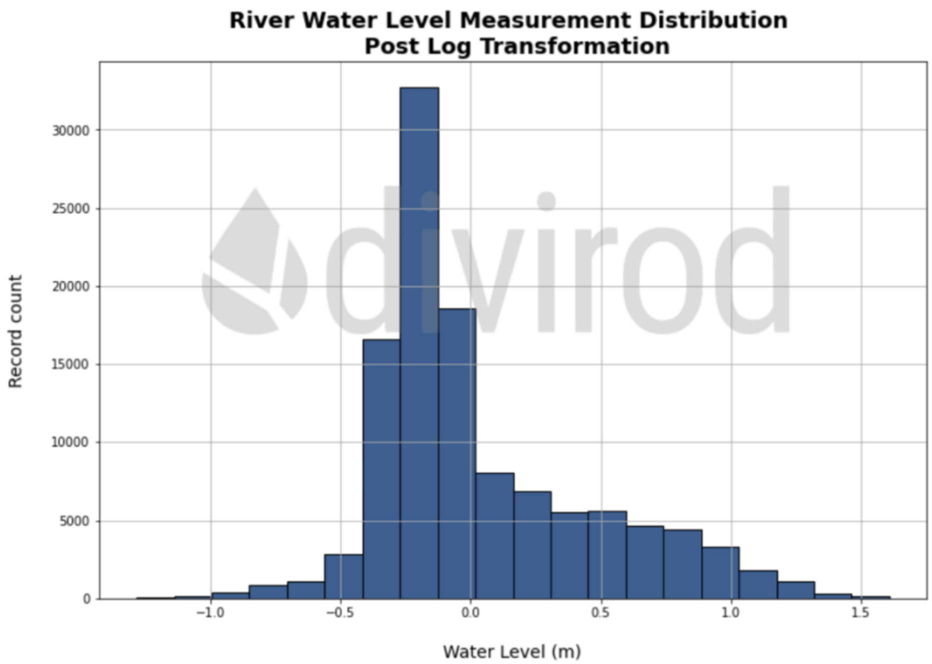

Figure 2: Log transform of water level records for the past three years from a single USGS river gauge 06214500.

The selected extreme multiplier for river systems is a value of 3, meaning that anything greater than 3 standard deviations away from the mean in the log space is classified as an "extreme condition". The high/low multiplier for river systems is a value of 2, meaning any value within 2 standard deviations of the mean are classified as a "normal condition". The below Figure illustrates this classification for a river gauge on the Yellowstone River at Billings Montana (USGS: 06214500).

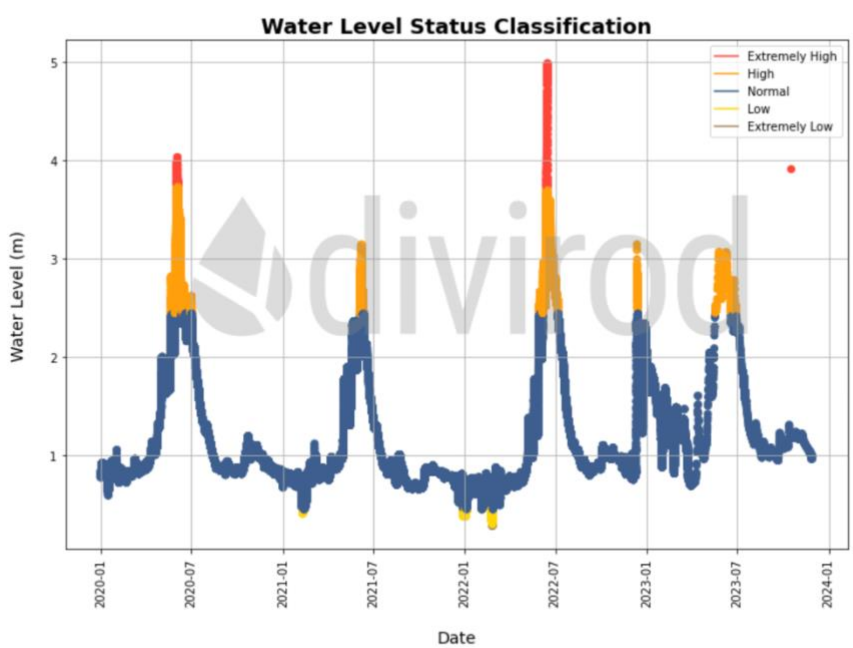

Figure 3: Water level status classification for historical records from USGS river gauge 06214500.

Coastal and Reservoir Systems

Coastal and reservoir systems generally display a more consistent water level pattern following the seasonal and tidal cycles. Because water levels in these systems typically follow a more normal distribution, no log transform is applied.

The selected extreme multiplier for coastal and reservoir systems is a value of 2, meaning that anything greater than 2 standard deviations away from the mean (in the log space) is classified as an "extreme condition". The high/low multiplier for river systems is a value of 1.5, meaning any value within 1.5 standard deviations of the mean are classified as a "normal condition." The below Figure illustrates this classification for a reservoir gauge at Willow Creek reservoir near Heppner Oregon (USGS: 14034490).

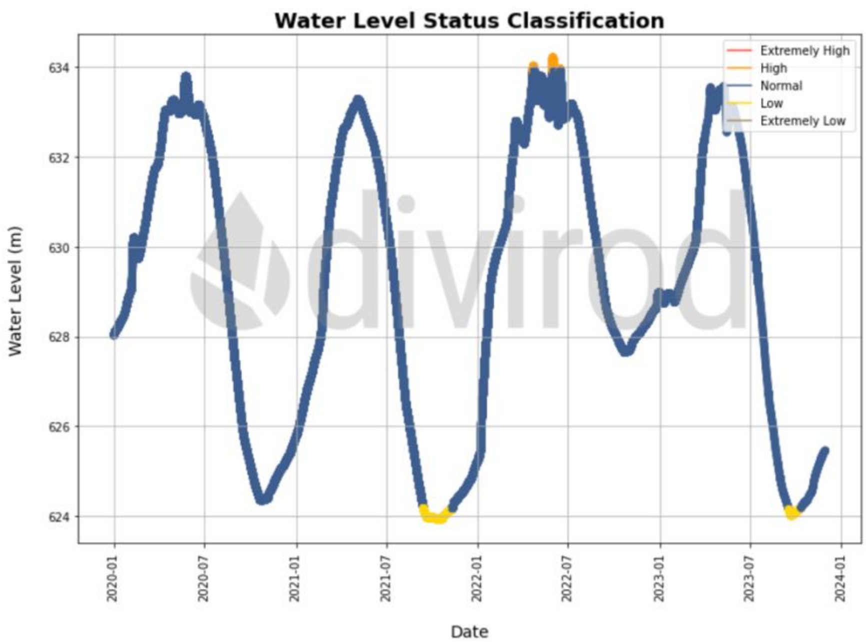

Figure 4: Water level status classification for historical records from USGS reservoir gauge 14034490.

Water Level Index Value Assignment

The above sections outline how relative water level is calculated at the gauge level and the resulting water level status assignment. The final water level index value indicates where the latest water level reading for each gauge lies on a linear scale between the "extreme high" and "extreme low" thresholds for each sensor. Values at and above the "extreme high" threshold have a WLI of 100, and values at or below the "extreme low" threshold have a WLI of –100. Values within this range are linearly scaled using the equation below.

$$WLI = \left(\frac{WL - WL_{el}}{WL_{eh} - WL_{el}} \times 2 - 1\right) \cdot 100$$

Where:

- WL = Most recent water level record
- WL_{el} = Extreme low water level threshold
- WL_{eh} = Extreme high water level threshold

Divirod offers a free tier of the WLI map which aggregates these WLI values up to a regional level. The individual gauge WLI values are then averaged within a defined area. Divirod uses the [H3 geospatial indexing system]() to perform this geospatial aggregation. The current version of the map uses level 3, equating to ~12,400 km2 (about the area of Connecticut) in each hexagonal region.

Top Ten Wettest and Driest Locations

The Top 10 Wettest and driest locations in the data lake are determined by the z-score of the most recent water level reading for each gauge. The z-score quantifies the number of standard deviations away from the mean that a data point lies.

$$z - score = \frac{(WL - \mu_{wl})}{\sigma_{wl}}$$

The z-score for river systems is calculated in the log space to ensure comparability across river systems. The top ten highest z-scores represent the “wettest” locations in the data lake relative to historic data, while the top ten lowest z-scores represent the “driest” locations in the data lake relative to historic data.

Differentiating Factors

While there are a host of other variations of water risk maps available to the public, the differentiating factor of Divirod’s WLI map is that it is founded in *measurements,* not *models.* All inputs into the WLI are measured values from governmental and climate organizations around the world, as well as from Divirod sensors. Every data point used to make the WLI map can be accessed via Divirod’s Data Analytics Platform, each with a data quality metric assigned. Using the data analytics platform along with the methodology outlined in this document, customers can re-create the WLI map and dive into the underlying data on their own. This level of transparency and interactivity is lacking in similar publicly available datasets.

Next Steps

Because the data represented in WLI is based purely on measurements, global coverage is not yet complete. Divirod is continuously working to expand the geographic footprint of our data lake. The WLI map will be updated as new data is ingested. This ensures that every data point represented can be validated, rather than extrapolated.

The water status thresholds will be recalculated monthly. If determined, these values can be re-calculated more frequently to ensure more accurate representation.

Divirod's WLI is meant to provide a high-level overview of the 'state of water' around the globe. The methodology outlined above sets the foundation for continued improvement. For example, the seasonality of water systems is critical to provide a full understanding of the water stress within a system. Divirod plans to account for seasonality in future renditions of the WLI.