Vega Market Anomaly Report:
LDO/USDT-PERP 14/02/24–17/02/24

Summary and scope

This report by the Vega project team covers events occurring on the Vega mainnet market **LDO/USDT-PERP**[1] culminating in the loss of funds by multiple market participants to a single actor, who then attempted to withdraw those funds from the network.

The team analysed the order, trade, mark-to-market, and funding history of the LDO/USDT-PERP market, particularly during the period between 14/02/2024 and 17/02/2024, and the days immediately prior. We also used archive data relating to transfers, deposits, and withdrawals to build a picture of the network of related keys and activities involved.

We present the details below, along with links to the data backing up our findings in service to the community of users of the Vega Protocol software, and our mission to build software for an open, safe, and permissionless financial future. Adoption of any recommendations on the Vega network must be by community action, and the team does not have any direct power over funds nor over the operation of the network or the products and markets available on it at any given time.

All data in the report is from the public Vega blockchain and may be independently verified.

Abstract: The authors of this report find clear evidence of a coordinated and premeditated scheme to manipulate prices on the LDO/USDT-PERP market on Vega mainnet between 14/02/2024 and 17/02/2024 (inclusive).

This includes repeated price manipulation by wash trading between related keys, causing prices to move from around 3.2 to extremes as low as 0.0001 and as high as 99,999. In our view these actions cannot be explained by benign or reasonable market participation, especially given the efforts taken to wash trade and conceal activity using multiple keys.

As is often the case when trading is involved, Vega relies on a combination of automated protections and governance (on-chain, by pseudonymous token holders, in this case) to maintain well-functioning markets. While automated protections can and will be improved, and we have identified many potential enhancements during the alpha phase, it is impossible to prevent all market abuse through code, and governance will remain an important tool for the community to address wrongdoing. It is for this reason that features such as the community controlled bridge stop were built, and that the community chose to activate it in this case.

After careful analysis, the Vega team recommend that the community 'burn' the paused withdrawals, so that they do not succeed, and reallocate the proceeds of the market manipulation to those participants that lost out as a result. This report includes details of two ways that this may be done, in our view fairly. Either approach would require acceptance of a code change, and the course of action to be taken is outside of the control of the project team.

[1] **market id =** `603f891b390fa67ac1a7b8f520c743e776cf58da7b8637e2572d556ba55f2878`

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High level timeline

The below is a timeline of relevant and significant market events[2] occurring on the **LDO/USDT-PERP** market leading up to and during the anomaly.

Prehistory	**Prior to 15:03 on 14/02, LDO/USDT-PERP traded between 2.69 and 4.00** **The price going into the events below was 3.17.**
14/02 15:03	Large trades by `ff2d52` to clear sell side of the book (price **3.25**)
14/02 21:06	`2951b7` trades with `22bb1a` to **3.5** Price monitoring triggered
14/02 21:20	Price monitoring auction ends `22bb1a` trades with `2951b7` at manipulated price **99.0** (up from **3.5** at 21:06)
14/02 23:00	`1d2f37` placed buy volume of 500 at price **0.001** and 991 at price **0.0001** Closeout trades happen at this price
15/02 07:00	`02e677` places volume of 1 at price **99,999.0** Closeout trades happen at this price
15/02 11:16	`Ff2d52` and `f6074d` manipulate price to **1027.9**
17/02 02:50	Last "reasonable looking trade" at **3.22**
17/02 03:02	Key `02e677` clears one side of the book with massive volume Price monitoring triggered
17/02 03:13	Price monitoring auction ends The only trade volume is from keys `22bb1a` and `2951b7` at manipulated price **98.0**
17/02 03:13	**Key `02e677` receives 115963.9275 USDT mark-to-market profit** This is entirely (or almost entirely) due to price manipulation by related keys
17/02 03:31	Another price monitoring auction ends The only trade volume is from keys `2951b7` and `2fb291` at manipulated price **2.26**
17/02 03:33	Keys `22bb1a`, `02e677`, `1d2f37` closed out by the network
17/02 03:46	Trading resumes after another price monitoring auction Prices match external venues, but order book is now empty
17/02 04:23	Price manipulation to **0.5** by `02e677`
17/02 04:35	Price manipulation to **0.001** (after price monitoring auction) by `02e677` and `2951b7`
17/02 04:47	Price manipulation to **99.0** (after price monitoring auction) by `02e677` and `2951b7`
17/02 07:00	**Excessive funding at rate 925% as a result of price manipulation:** `47a263` gets **9396.703786 USDT** `4cccff` gets **292.202047 USDT** `f6074d` gets **484.516027 USDT**
17/02 11:16:59	Ethereum (mainnet) ERC20 bridge stopped by a quorum of validators. 0xde22bcbaa2408265d9835b1b05eec99b9e3713a3ec4e367f9efbdd1e77a695d0

[2] Note: Only the first 6 characters of each Vega key are shown. Full keys are listed on the next page. The keys highlighted in red have been found to be associated via on-chain transfers and are considered to be controlled by the same actor (see Appendix for links to evidence supporting this claim).

Keys involved

Manipulator keys

All of these keys are related to each other via transfers of funds.

Keys directly engaged in flagged trades

- 02e677c3af0fae072012a69ad638702739940b6e8614e1d6862ad05ee7392e02
- ff2d52091a3ac2300cda55cb535b61dc69aa79d28c6a622294e37bdf78900f27
- 2951b76f827b4a5f2ca14e53d9dcd7038e0b9cbf977804c7c5187c89ce77e522
- f6074d2f8924f8c1d73f51bce3faa2e615ef5930ef27a7027576cc8ebaa98d9d
- 4cccff281c9b0a68c768af4b99823755029987e172cbc20427efc1bee0ff1b7e
- 2fb291d23f5cccb65f0355afa04bac7f81a044e9e82c8805a6b710f408d8e962
- 47a263718bb3a274c3230f4f271aad42369a389027a0759141ec4ff3457d47f7
- 7bcbbb7c8d18e58a8adf659d1980c71cd100fb46e63c545da18304c8a16e2d0a
- 1d2f37299f436f3b720b8efbbb6beb4aec9145a2c4f398ccb06280f6fa2503e8
- ff8d21e5ee5b23326cc9d972fa849a81ea1c783c492a03f0284a8de2051ef81f
- 22bb1a69d1c2952289a3a66915ae2f3b18cf43763491f80023bbb0fc288742c9
- 804f90a199a7aacd456b8b3d936b50f61886d1dafc91c3f57527dead12ea0f08

Keys associated by transfers to the above keys

- f4cf15f73a5b9a97ab3a150f200c4bb8d54c5977b5d1858ff50e7364c3658e5f
- f59b265f073a4cc2e55e86fbdc4e8f3871021dfacd0a604b9f98c06e0193ba13
- a857d897cf35d1b2f7f11abb5ec49a33f81c48ce91e8e5d573bee4530a8cacfb
- 5c39b990934434a8518f467f6c1cea80fb9a40509c1b741448f31f48c4a6c555
- ef5c04108a40f4bdfa77cb65e67319dd7b3be33cbf30f6e89821e44484d67af1
- 69f8e3cab40222424ab8f553c9da927f9e772c747dc977291093c6448b238e7e
- 5981a00d74ff2a0c94c09ca75ba296d8b1dfa130036f969387f23ac7327e94a6

Losing parties

The following keys lost money, in some cases substantially, as a result of the market manipulation and abuse apparently perpetrated with the keys listed above:

- 89c98f0e1039935b5d7f5b8d6d0660790a8e507d0c4234b6cafb7dbf88ad25ca
- 1d150c717d349e901cc26e511f776c323c1b8a8dbb0e7717183f2a1e9f3482d7
- 519d2af4058af1bed4e05859afa6a15cb1791166df8f0fe3f70a783a13232440
- c8f5d32a8554dbddfa80946fe9ac42d156356f869256aa0a632e5152d45b1316
- 36e73d371b25f0d97ce7813d688c42e61792bda80c00c9cf6d8bf9424a539bf5
- 426f40b09ea2388c22e7c409b6e979747597316939ed6b422c5b935069ad4814
- 0a9b24a83cb661e68a2069a413cc2603f0f4804b165621806fa8a014fb0ed4b5

Other gainers (no indication of wrongdoing)

- cec6a9c4e8a09342ab2920cd037bf134d842b5c9aa951250ac27baf8c7fb2abc
- e7aaf97ed29d18fe8bb35343da0c587afba0f7642baec8100b16f3390fddd5a9
- e1dcdff5e6affeadd137e900d1d03f823caee40f637ef7cfeabcc345481c1146
- 6834c53c8997999268befa0f567b2a7327f4e6ed198db9f2062b36d536dc1aa1
- c642243d65b458334a860a35adf1227474b3273c57a5e0f8ca3cf74ccf0a8ce6
- a2388b885b947eb683e14961dd94a1225643c4093a494a68bf2641b2a97de63a

Manipulation evidence

Below is a list of key trades used to set prices far outside the reasonable and normal price range for the market by trading between keys that are provably linked together by transfers.

These keys at least share a common source of funding, with which they carried out the manipulation, and in our opinion are very likely also controlled by the same entity. Therefore trades between these keys also amount to wash trading, circumventing Vega's necessarily limited[3] automated wash trading prevention by using multiple keys.

This is clear evidence of manipulation. The entity (or entities) trading with these keys planned and executed trades at prices far (multiple orders of magnitude) away from the fair market price for LDO and/or the price at which it trades on other venues.

They planned and executed these trades at both extreme low (0.0001) and high (99,999) prices, and were willing to allow one of their keys to trade on the *very unattractive* side at both the high and low end. In our view, the only plausible reason for taking such a position is in order to manipulate the market price in order to gain via other means.

Key manipulated trades

The below trades are a selection of the key manipulated trades also highlighted in the timeline:

14/02 21:20	`22bb1a` trades with `2951b7` to uncross an auction at **99.0** (up from **3.5** at 21:06)
14/02 23:00	`1d2f37` placed buy volume of 500 at price **0.001** and 991 at price **0.0001**, closeout trades happen at this price
15/02 07:00	`02e677` places volume of 1 at price **99,999.0** and a network closeout trade takes place at this manipulated price
15/02 11:16	`ff2d52` and `f6074d` manipulate price to **1027.9**
17/02 03:13	Price monitoring auction ends with the only volume provided by keys `22bb1a` and `2951b7` at manipulated price **98.0**
17/02 04:35	Price manipulation to **0.001** (after price monitoring auction) by `02e677` and `2951b7`
17/02 04:47	Price manipulation to **99.0** (after price monitoring auction) by `02e677` and `2951b7`

Full list of flagged trades

Appendix 1 contains an extract from the trade analysis sheet containing all flagged trades. That is, trades happening at prices with around 15% or more (in many cases a lot more) deviation from the 12-hour VWAP price in the market at the time.

Not all of these trades are necessarily part of a manipulation or other market abuse, however it can be plainly seen that some are. In general these trades show a pattern of market manipulation and abuse, particularly given the knowledge of the mark-to-market and funding gains achieved, and the fact that linked keys wash-traded at highly undesirable prices far from any reasonable fair market price in the process.

[3] Due to the pseudonymous nature of blockchains and decentralised systems in general.

Vega protections

Price monitoring

Price monitoring was triggered, and the auction was resolved with one or more trades 37 times between 14/02/2024 17:58 and 17/02/2024 7:13 (based on trades where aggressor == SIDE_UNSPECIFIED, which indicates auction uncrossing). It is possible that other monitoring auctions occurred but one or both sides removed their crossed orders causing the auction to end without trading.

There are two interrelated reasons why price monitoring didn't prevent price manipulation:

1) The price monitoring auctions were (too) short, contributing to (2) below.
2) No other market participants reacted to the prices posted in the auction in time. Since the auctions uncrossed e.g. at 99 (instead of ~3.2) the aggressor must have posted both buy and sell orders; the buy order at 99 was clearly open to arbitrage.

Note that when price monitoring is triggered, the orders that are crossed do not have the chance to trade prior to the market entering the monitoring auction. This means that price monitoring can entirely prevent any manipulation that attempts to move the price outside monitoring bounds. However, this can happen if (and only if) other market participants step in to take the arbitrage offered by the manipulator by posting reasonable prices and preventing the auction from uncrossing at a manipulated price.

Given the data discussed in this report, we recommend:

- Use of longer price monitoring auctions when creating markets and via updates to existing markets, especially for markets with lower liquidity/trading volume.
- Addition of a "backstop" price monitoring auction trigger for particularly extreme moves that creates a very long auction (≥24 hours).
- Advocating best practice for professional and programmatic traders, especially market makers and LPs, to create alerts for markets entering monitoring auctions. This would provide the opportunity to react before any extreme trade is matched, and optionally post reasonably priced orders to assist price formation in the market and take advantage of arbitrage opportunities that arise due to manipulation attempts.

The Vega team will also investigate enhancements to the protocol to:

- Add additional trigger conditions for monitoring auctions.
- Allow for indefinite monitoring auctions (only ending by governance).
- Otherwise improve Vega's automated market protections.

We welcome discussion and suggestions of potential community actions and protocol improvements in the Vega community forums, on Discord, and in Github issues and discussions.

Liquidity mechanism and LPs

Two Liquidity Providers (LPs) were active in the market throughout the incident:

- `89c98f0e1039935b5d7f5b8d6d0660790a8e507d0c4234b6cafb7dbf88ad25ca` (ELS: **0.6**)
- `cec6a9c4e8a09342ab2920cd037bf134d842b5c9aa951250ac27baf8c7fb2abc` (ELS: **0.4**)

We found that the `current_epoch_fraction_of_time_on_book` dropped for both LPs around price manipulation events, as the LPs stepped away from the order books. One of these LPs lost a very significant amount by being present during these events, the other posted modest gains. Neither LP is suspected of any involvement in the coordinated manipulation of the market.

Although we discuss the SLA and liquidity mechanism in general below, we do not believe that there is any solution to be found in trying to force or push LPs to take on further risks during or after manipulation attempts like this. In fact, we are far more likely to recommend changes that reduce LP risk and friction in future releases than increase.

The SLA liquidity mechanism with 85% time-on-book (as set in LDO/USDT-PERP during these events) allows LPs to provide no volume for up to 15% of each of the 24h epochs. This "permissive" configuration is relatively weak compared with the design goals of the mechanism, and means that LPs can choose to stop quoting on one or both sides of the book without significant consequences when and if they hit internal risk and/or inventory limits, and for other reasons. This is further weakened by the rejection of the LP bond and bond-slashing mechanism by the community of LPs.

These facts may have contributed to the low liquidity on LDO/USDT-PERP and the relative ease with which it was possible to clear the order book and manipulate prices.

However, even if the market was configured at a much stricter 99% time-on-book, a determined manipulator with sufficient funds would potentially be able push any LP into a position beyond their limit in the absence of other safeguards. In such a situation, a rational LP would abandon the liquidity fees and rewards, as well as accept any bond slashing for the epoch rather than take on more risk.

It is not the case that this mechanism would be expected to prevent market manipulation and abuse, as it is part of the liquidity incentivisation portion of the protocol, not market monitoring and protections. However, we consider the speed with which order books were cleared and the ephemerality of liquidity to be evidence that some of the original design goals of the liquidity mechanism (unrelated to marker protection) cannot be achieved with the current system. While further refinements are necessary, the discussion of these is out of scope for this document.

Fundamentally, no incentive or penalty mechanism will force LPs to provide capital or post liquidity beyond their risk tolerance. The liquidity mechanism cannot be expected and is not designed to prevent active and premeditated manipulation such as this, unlike other systems such as price and liquidity monitoring.

LPs provide a critical service to the Vega network and ecosystem. As the network grows, and innovative features like hybrid liquidity make being an LP a possibility for more users, we believe it is essential that Vega becomes more attractive and less risky for LPs.

Suspicious ledger movements

Mark-to-market gains and losses

In order to identify the funds lost as a direct result of market manipulation, ledger movements and trade data have been analysed and suspicious mark-to-market (MTM) and funding gains and losses identified based on the status of the preceding trade.

A trade was deemed suspicious, if BOTH of the following conditions were true:

1. The trade involved any of the “manipulator keys” listed previously in this document as either the buyer or seller.
2. The trade was at a price at least 20% away from the volume weighted average price of all trades over the previous 12 hours (NB: Appendix 1 shows all trades with a ≥15% delta, along with the delta, so can be used to identify the trades in question).

Applying the above conditions identifies the net MTM gains and losses for each party which were a direct result of market manipulation. MTM gains/losses from normal trading activity are not included in these numbers.

Public key key: loser, gainer, manipulator	**Relevant MTM gains/losses**
89c98f0e1039935b5d7f5b8d6d0660790a8e507d0c4234b6cafb7dbf88ad25ca	-104,959.68
c8f5d32a8554dbddfa80946fe9ac42d156356f869256aa0a632e5152d45b1316	-2,147.52
2fb291d23f5cccb65f0355afa04bac7f81a044e9e82c8805a6b710f408d8e962	-300.32
22bb1a69d1c2952289a3a66915ae2f3b18cf43763491f80023bbb0fc288742c9	-201.54
426f40b09ea2388c22e7c409b6e979747597316939ed6b422c5b935069ad4814	-103.72
519d2af4058af1bed4e05859afa6a15cb1791166df8f0fe3f70a783a13232440	-101.21
36e73d371b25f0d97ce7813d688c42e61792bda80c00c9cf6d8bf9424a539bf5	-89.34
1d150c717d349e901cc26e511f776c323c1b8a8dbb0e7717183f2a1e9f3482d7	-88.89
1d2f37299f436f3b720b8efbbb6beb4aec9145a2c4f398ccb06280f6fa2503e8	-51.42
ff8d21e5ee5b23326cc9d972fa849a81ea1c783c492a03f0284a8de2051ef81f	-21.98
0a9b24a83cb661e68a2069a413cc2603f0f4804b165621806fa8a014fb0ed4b5	-10.15
ff2d52091a3ac2300cda55cb535b61dc69aa79d28c6a622294e37bdf78900f27	0.09
2951b76f827b4a5f2ca14e53d9dcd7038e0b9cbf977804c7c5187c89ce77e522	1.96
a2388b885b947eb683e14961dd94a1225643c4093a494a68bf2641b2a97de63a	2.05
6834c53c8997999268befa0f567b2a7327f4e6ed198db9f2062b36d536dc1aa1	2,495.66
cec6a9c4e8a09342ab2920cd037bf134d842b5c9aa951250ac27baf8c7fb2abc	5,927.45
47a263718bb3a274c3230f4f271aad42369a389027a0759141ec4ff3457d47f7	9,277.63
02e677c3af0fae072012a69ad638702739940b6e8614e1d6862ad05ee7392e02	90,365.27

The manipulator’s mark-to-market gains due to manipulation were therefore **99,069.69 USDT.**

Margin confiscation (liquidation)

If a party was put into a distressed state and closed out following a manipulated MTM payment they would have had margin confiscated as a direct result of market manipulation.

Using the same methodology as was used to identify MTM losses due to manipulation (see above), we also identify confiscated margin during liquidations.

Public key key: loser, gainer, manipulator	**Relevant margin confiscation**
6834c53c8997999268befa0f567b2a7327f4e6ed198db9f2062b36d536dc1aa1	-1,674.851
ff2d52091a3ac2300cda55cb535b61dc69aa79d28c6a622294e37bdf78900f27	-60.102
0a9b24a83cb661e68a2069a413cc2603f0f4804b165621806fa8a014fb0ed4b5	-24.89
804f90a199a7aacd456b8b3d936b50f61886d1dafc91c3f57527dead12ea0f08	-24.146
7bcbbb7c8d18e58a8adf659d1980c71cd100fb46e63c545da18304c8a16e2d0a	-19.33
519d2af4058af1bed4e05859afa6a15cb1791166df8f0fe3f70a783a13232440	-15.51
f6074d2f8924f8c1d73f51bce3faa2e615ef5930ef27a7027576cc8ebaa98d9d	-9.64
a2388b885b947eb683e14961dd94a1225643c4093a494a68bf2641b2a97de63a	-2.12

The amount lost to the network during liquidations caused by manipulation was **1,830.59 USDT.**

Funding payments

Given the complexity of attribution and the scale of the distortion in funding rates, we treat all losses where funding rates include manipulated prices as being at the hands of the manipulator.

Therefore a funding rate was considered a manipulated if BOTH of the following were true:

1. The internal data point derived from a trade involving any of the “manipulator keys” listed previously in this document as either the buyer or seller.
2. The internal data point was at a price at least 20% away from the volume weighted average price of all trades over the previous 12 hours.

Applying the above conditions identifies the net funding gains and losses for each party which were a direct result of market manipulation. Funding gains/losses from normal trading activity are not included in the below numbers.

Public key key: loser, gainer, manipulator	**Relevant funding gains/losses**
89c98f0e1039935b5d7f5b8d6d0660790a8e507d0c4234b6cafb7dbf88ad25ca	-11,619.81
c8f5d32a8554dbddfa80946fe9ac42d156356f869256aa0a632e5152d45b1316	-896.42
6834c53c8997999268befa0f567b2a7327f4e6ed198db9f2062b36d536dc1aa1	-466.98
cec6a9c4e8a09342ab2920cd037bf134d842b5c9aa951250ac27baf8c7fb2abc	-159.26
0a9b24a83cb661e68a2069a413cc2603f0f4804b165621806fa8a014fb0ed4b5	-40.27
426f40b09ea2388c22e7c409b6e979747597316939ed6b422c5b935069ad4814	-32.46
519d2af4058af1bed4e05859afa6a15cb1791166df8f0fe3f70a783a13232440	-4.18
2fb291d23f5cccb65f0355afa04bac7f81a044e9e82c8805a6b710f408d8e962	-0.17
1d150c717d349e901cc26e511f776c323c1b8a8dbb0e7717183f2a1e9f3482d7	3.24
02e677c3af0fae072012a69ad638702739940b6e8614e1d6862ad05ee7392e02	4.04
804f90a199a7aacd456b8b3d936b50f61886d1dafc91c3f57527dead12ea0f08	6.09
e1dcdff5e6affeadd137e900d1d03f823caee40f637ef7cfeabcc345481c1146	10.22
36e73d371b25f0d97ce7813d688c42e61792bda80c00c9cf6d8bf9424a539bf5	35.68
e7aaf97ed29d18fe8bb35343da0c587afba0f7642baec8100b16f3390fddd5a9	47.27
a2388b885b947eb683e14961dd94a1225643c4093a494a68bf2641b2a97de63a	113.37
ff2d52091a3ac2300cda55cb535b61dc69aa79d28c6a622294e37bdf78900f27	369.14
c642243d65b458334a860a35adf1227474b3273c57a5e0f8ca3cf74ccf0a8ce6	431.06
1d2f37299f436f3b720b8efbbb6beb4aec9145a2c4f398ccb06280f6fa2503e8	445.64
f6074d2f8924f8c1d73f51bce3faa2e615ef5930ef27a7027576cc8ebaa98d9d	484.52
4cccff281c9b0a68c768af4b99823755029987e172cbc20427efc1bee0ff1b7e	612.54
5981a00d74ff2a0c94c09ca75ba296d8b1dfa130036f969387f23ac7327e94a6	1,280.02
7bcbbb7c8d18e58a8adf659d1980c71cd100fb46e63c545da18304c8a16e2d0a	1,659.02
47a263718bb3a274c3230f4f271aad42369a389027a0759141ec4ff3457d47f7	9,415.33

The manipulator’s net funding gains as a result of manipulation were therefore **14,276.18 USDT.**

Withdrawals

Below are the withdrawals initiated to remove gains made during these events. These withdrawals will complete once the Ethereum ERC20 bridge is restarted unless the nonce is 'burnt' first.

- 0xAB6D8ECF7333618523E343E3EEB39297DF2D44930A792562F1DA68AC96B2FD96
- 0xDF029EE77141711FE781BB011C1761375364AD4FAB368E6203CD217DA916487D
- 0xA1337F3AAB6CAE8403CABC7E5CCDF95E41C3833B6E952905A7EA734F58B34A94

These withdrawals total **114,739.14 USDT.**

That is, the perpetrator of the manipulation quickly tried to withdraw all of their gains after several months of what otherwise appeared to be normal trading. This strongly suggests that they understood that what they had done was wrong and expected the community to act.

The community did indeed act, and the Ethereum ERC20 bridge contract was stopped by a quorum of validator power at the request of community members (view transaction).

The community now has to decide how and when to restart the bridge, whether to block these withdrawals, and if so, how to [re-]allocate the funds from the withdrawals.

Flagged withdrawals vs. losses

One possible way to re-allocate the funds from the manipulator's withdrawals to victims of the market abuse is described below.

The methodology here is to allocate the entirety of the recovered funds pro-rata based on the amount lost by non-manipulator keys, as calculated in the previous section.

Across all identified "manipulator keys", the net MTM and funding gains as a direct result of market manipulation were **99,070.47 USDT** and **14,276.18 USDT** respectively, totalling **113,346.65 USDT**.

Therefore of the **114,739.14 USDT** currently being withdrawn, **113,345.87 USDT** (i.e. the total identified losses in the section above) would be distributed amongst the losing parties. The remaining **1,393.27** which was linked in this analysis to market manipulation would be returned.

The pro-rata distribution would result in the following transfers to losing keys:

Public key	Total loss	Share of loss	Recommended return amount
89c98f0e1039935b5d7f5b8d6d0660790a8e507d0c4234b6cafb7dbf88ad25ca	-116,579.49	97.07%	110,027.79
c8f5d32a8554dbddfa80946fe9ac42d156356f869256aa0a632e5152d45b1316	-3,043.95	2.53%	2,872.88
426f40b09ea2388c22e7c409b6e979747597316939ed6b422c5b935069ad4814	-136.19	0.11%	128.53
519d2af4058af1bed4e05859afa6a15cb1791166df8f0fe3f70a783a13232440	-120.90	0.10%	114.11
1d150c717d349e901cc26e511f776c323c1b8a8dbb0e7717183f2a1e9f3482d7	-85.66	0.07%	80.84
0a9b24a83cb661e68a2069a413cc2603f0f4804b165621806fa8a014fb0ed4b5	-75.31	0.06%	71.08
36e73d371b25f0d97ce7813d688c42e61792bda80c00c9cf6d8bf9424a539bf5	-53.66	0.04%	50.64

NB: this distribution would not fully cover losses due to fee etc. and other parties incidental gains.

Perpetrator profile

This section contains a short summary of what is known about the person or entity behind the market abuse and manipulation detailed in this document. As the purpose of this section is not to doxx them, but to provide supplementary data and evidence that we believe supports the conclusions, some specifics have been omitted.

The actor responsible for this market manipulation:

- Used at least 19 keys to wash trade and obfuscate manipulative activities
- Claims to be a long term community member
- Immediately withdrew their gains from market manipulation on 17/02
- Has possibly manipulated other markets on Vega, likely to increase their funding gains
- Has deposited **28,557.00 USDT**
- Has already withdrawn **77,414.32 USDT**
- Has withdrawals for another **114,739.14 USDT** pending, which we recommend blocking
- Was allowed[4] to keep gains due to manipulation combined with a bug as a bug bounty
- Announced themselves on Discord and argued they should be allowed to keep their gains
- Did not associate themselves with any known identity when doing the above
- Is connected with a known Fairground user and two identified Twitter profiles
- Claims to want to help the community and be rewarded with bug bounties

Our assessment is that this user is not participating in good faith. It is clear that they have been testing and honing manipulation strategies over some weeks. They have taken steps to hide their identity and tried to immediately withdraw their gains from manipulation.

We believe they were fully aware of what they were doing, and that their activities would likely cause financial harm to others. They were also explicitly notified at the time of their original bug bounty about the bridge stop and the fact that in similar circumstances not involving new bugs, or with larger sums, they would likely not be allowed by the community to leave with any gains.

We would like to offer them the opportunity to engage more constructively with the community, but blatant and direct market manipulation is not a valid way to earn bug bounties.

[4] The community was aware of losses (~20k USDT) but the team suggested not stopping the bridge and instead rewarded those who had helped identify the existence of a bug, including this participant, with a bug bounty. In that case, unlike this one, a newly identified bug played a part in their ability to make large, unreasonable gains quickly, rather than simply pure manipulation as in this instance.

Conclusion

We conclude that this was a clear case of coordinated and premeditated market manipulation by an actor or actors with intention to take funds from other participants via market abuse and manipulation, and to conceal their intentions and identities while doing so.

We believe that it is not possible for a protocol like Vega that aims to be able to perform decentralised price formation for real-world use cases to operate on purely automated protections. To that end, the protocol includes governance based protections which were used by the community, worked in this case (however crudely), and will be improved and extended in future to ensure the Vega project is able to realise its mission.

There are many detailed learnings and recommendations below and throughout this report, however the key and primary recommendations regarding the immediate actions following the stopping of the Ethereum bridge are as follows:

1. ~~We recommend suspending all markets by governance if the community agrees.~~ **(Done.)**
2. We recommend preventing the completion of the three withdrawal transactions by burning the withdrawal nonces on the Vega to Ethereum ERC20 bridge.
3. We recommend reenabling the bridge once this is done.
4. **We recommend reallocating the funds from those withdrawals to the parties that lost out from the same market manipulation and abuse (as identified in this report).** Once the withdrawals are burned (step 2), this can be done directly via protocol upgrade to transfer the funds directly to the target accounts. Alternatively, it would be possible to transfer the funds to the on-chain treasury and then use on-chain governance to re-allocate them to the intended targets. The first option is simpler and faster, but in case there is insufficient agreement between validators that this is the correct approach, the second option would put it to a more direct community vote, at the expense of speed and complexity.
5. We recommend using a batch governance proposal to update markets using the best practices and recommendations below (or similar configurations), and taking advantage of the newly released Palazzo Mistero features that can help prevent or mitigate manipulation.
6. We recommend continued discussion and focus on how to improve both the automated protections in the Vega protocol and the governance features to reduce the likelihood of similar events even further, and to reduce the impact on users when governance is needed to deal with issues in future. We look forward to discussing these potential enhancements in the forums and on Discord.

The project team will continue to monitor the network and markets in order to notify the community of unusual/suspicious activity, or misconfigured markets, and continue to work to deliver features that improve the Vega software for the entire community.

Finally, we want to especially mention LPs who take on particular risks with a system like Vega in its alpha phase, and without whom there would be no trading. LPs have been a great source of feedback and engagement for Vega and we encourage everyone to prioritise and vote for changes that help them to service the community.

Appendix 1: Detailed recommendations

These are governance and/or node operator and/or LP and/or general community actions recommended by the team to prevent and mitigate similar incidents in future.

Safeguarding existing markets

1. ~~Suspend markets via governance until configurations can be reviewed.~~ **(Done.)**

2. Add a new "backstop" price monitoring tier which would prevent market cashflows if the price is manipulated to extreme levels:
    - **Approx. 6h horizon and 99.99999% confidence**
    - Triggers a very long price monitoring auction of e.g. 24h (consider even 48h).

   For example, the resulting price monitoring bounds would be:
    - **LDO/USDT-PERP** (reference price 3.20): 2.59-3.94 (19% down, 23% up)
    - **SNX/USDT-PERP** (reference price 3.75): 3.04-4.62 (19% down, 23% up)
    - **INJ/USDT-PERP** (reference price 38.5): 31.21-47.42 (19% down, 23% up)
    - **ETH/USDT-PERP** (reference price 2,900): 2,351.17-3,571.52 (19% down, 23% up)
    - **BTC/USDT-PERP** (reference price 52,000): 45,220-59,756 (13% down, 15% up)

   JSON excerpt for the new trigger (24h extension):
   ```
   {
      "horizon": "21600",          // 6 hours
      "probability": "0.9999999",
      "auctionExtension": "86400"  // 24 hours
   }
   ```

3. Increase the length of auctions triggered by existing price monitoring configurations. All of these should be longer to be effective, and this is particularly true for markets with lower trading interest, liquidity, and volume.

4. Add funding rate caps to all perpetual futures markets.

5. Use oracle prices in mark price where available, and consider using oracle for funding rates as well, as a fallback if Vega prices are stale.

6. Avoid using only the last traded price for mark price or funding rate.

Resuming the Vega-Ethereum bridge

If, as we recommend, the flagged withdrawals are to be blocked, the bridge may be resumed once the nonces for all three withdrawals have been burned. If not, it may be resumed at any time.

Palazzo launch considerations

Palazzo provides additional features that can be used to mitigate the impact of manipulation if it occurs, as discussed in "Safeguarding existing markets" above. It does not include any new market monitoring and protection capabilities.

Appendix 2: Potential future work

Protocol enhancements

These are potential enhancements. They vary in complexity and likely value, and are included here to begin a discussion about additions to the Vega roadmap, not as a commitment to delivery.

1. Allow price monitoring to trigger an auction of infinite length (combine with 2)
2. Allow governance to end a long or infinite price monitoring auction
3. Allow supermajority of validators to vote in a rapid governance proposal.
4. Allow for additional monitoring trigger conditions other than the current price excursion triggers, for example, spread, slippage, low liquidity, suspicious trading patterns, etc.
5. Consider adding different (higher) participation thresholds to governance proposals that have shorter voting and enactment durations so that urgent proposals can be made quickly if enough of the community cares to vote.
6. Count recent transfer recipients for wash trading prevention.
7. Have some Vega-side withdrawal delays and stop options, potentially triggered by personal and network-wide withdrawals over a rolling window / time decayed withdrawals.
8. Introduce more protection for potential erroneous cashflows, for example quarantining unusually large cashflows or restricting cross-margining for some markets/situations.
9. Enable more governance controls such as rollbacks, potentially alongside (8), or market governance (available to LPs and token holders) driven trading bans/limits.

Documentation and resources

1. Improve documentation of key protocol features and protections
2. Provide tooling to help set market parameters
3. Clearly explain the value of features that seem like a hassle (e.g. price monitoring)
4. Co-create norms and processes for governance and handling situations like this with the community. Standardise anomaly investigation and reporting (this is the first such event).

Tooling and monitoring

1. Improve APIs to make investigation easier
2. Build tools for reconstructing market events and general analysis and investigation
3. Improve monitoring to ensure ability to alert the community of future suspicious events
4. Create an auction arbitrage bot to allow users to respond to price monitoring auctions

Appendix 3: Flagged trades

Trades matched at ≥15% delta from 12 hour VWAP price on the market.
Note that price and size decimals have not been applied to the values in this table.

timestamp	trade_id	price	size	vs_vwap	buyer	seller	type
05/02/2024 11:26	2432152dc5997e1ecfb179db8a488ecc8b27c4fd6698396c82dfefa51216a505	18300	10	-31.98%	cec6a9	5c39b9	AUCTION
05/02/2024 12:06	99329faf2e98b57b39584340c5418f37cd4eadb96365f6e432411812c4f776b1	22750	10	-15.35%	e1dcdf	1d2f37	AUCTION
05/02/2024 12:29	0e801cd393091930c0327d1f90857346e997d46d6a97af557f0602248e560949	40000	10	45.43%	e1dcdf	1d2f37	AUCTION
14/02/2024 21:20	4fe8a0c2f9a494938ad69845b8eb8ffb5d101857bf4945cac98fcd87cf00b65a	990000	1	2956.31%	22bb1a	2951b7	AUCTION
14/02/2024 21:39	820ff7e18d653f331dd875e52378a5633aec96abc7093074423fe0857a33e9c0	980000	1	2925.23%	02e677	1d2f37	NORMAL
14/02/2024 21:58	6f39627cd772c3b8b7f1208b1b5783a31e44d23ea2a467ca66beda148fe09b51	20000	1	-38.26%	1d2f37	02e677	AUCTION
14/02/2024 23:00	5c38818e0236fc2b078fb2c718ee8719699228d9c0f2ebdc3ccdaca0592255b8	4	501	-99.99%	networ	22bb1a	CLOSE_OUT_BAD
14/02/2024 23:00	63c462f131574694a14a3ec9be71fa7c950c61f4cdda78845ac8591b36d3ba14	4	990	-99.99%	networ	c8f5d3	CLOSE_OUT_BAD
14/02/2024 23:00	4d70b492049d357d52a0e4a802261e8dd78db2607595821e40f4156ae6afba08	1	991	-100.00%	1d2f37	networ	CLOSE_OUT_GOOD
14/02/2024 23:00	820b3730625df207567e9b8f752b789ade84b5b489537cc4da94b86f1767d8c7	10	500	-99.97%	1d2f37	networ	CLOSE_OUT_GOOD
14/02/2024 23:20	184a7c29edb5403227fb4c20885d6bc8cebd71895f4f2cd0003c29b2e1970f6d	2000	1	-93.78%	2951b7	2fb291	AUCTION
15/02/2024 07:00	0cbf50875dc3e6b80fe9590e5266dcfdb9f14b5292b130acdf9c34f512ce1292	999990000	1	17819319.33%	2fb291	networ	CLOSE_OUT_BAD
15/02/2024 07:00	c4913eae95e31e5d074a1e86a3e8d7fde16bf44d97662284973240510e1e3637	999990000	1	17819319.33%	networ	02e677	CLOSE_OUT_GOOD
15/02/2024 08:25	9e03a1fcf4c7dcb636b114814e18f2da88ea0e4b966984ebd1306f1b72b46fa0	32100	1	-94.45%	36e73d	426f40	AUCTION
15/02/2024 08:29	1ab9a8318e2e693f3fda2ef2499993b75efffb4c8157a7b16b2217be5404231b	32200	1	-94.43%	426f40	36e73d	NORMAL
15/02/2024 10:30	50699830bcbfe00f941fafe5792afa15934f0f0ddc82b7640d1c70ad68d6d863	15413	1491	-97.70%	networ	1d2f37	CLOSE_OUT_BAD
15/02/2024 10:30	ecf4e6b1cc7469d7af59e72bdcc50d0300c489b6736ab05be9deb021299ba1ce	2000	491	-99.70%	6834c5	networ	CLOSE_OUT_GOOD
15/02/2024 10:30	e8942cad930cade065289c4cd9bdf1f50605ad51952e9f9aeb11cbd73562af73	22000	1000	-96.71%	6834c5	networ	CLOSE_OUT_GOOD
15/02/2024 10:30	5f76eb58ca6a43de3da9ebef01bd9ffa51a687e384694e6f4d8402c67b7d4f3a	22100	1	-96.70%	ff2d52	ff8d21	AUCTION
15/02/2024 10:44	cdad4db8d6c773777518fe9a821166926f6a1cbd7eab4342ca0206ba66d5a66e	31150	1	-90.91%	ff8d21	ff2d52	AUCTION
15/02/2024 11:00	83232a85fe694451d588e3956f383bc6b64c1ef33350ced47043a244fbe633b7	2000	1009	-99.71%	6834c5	ff8d21	AUCTION
15/02/2024 11:16	f95029529a8467cc81eeef0ce9f76c4ab496166a8e87d1d9d364ade96d01d358	10000000	1	1852.07%	ff2d52	f6074d	AUCTION
15/02/2024 11:19	385fcfce011acdb959dfc0a01937121813e6adadf5fd8c8a4f8ff00331001d6d	10000000	5	1843.07%	ff2d52	f6074d	NORMAL
15/02/2024 12:11	1e35a56489eb745fecef476cf5f17ab0833d25e1dc46b074c20220b39e5a163a	10279000	1	1851.86%	6d4c7e	83c0b6	AUCTION
15/02/2024 12:21	dcafed85297b3e3b75752e5f05f6a811fc7d521855373bcc87f291e2e722b982	10280000	1	1843.07%	83c0b6	6d4c7e	NORMAL
15/02/2024 12:26	4e25f94a661fc613502aa2940c13661ea790650d12655c4007fe63ee40d3a579	10500000	1	1875.56%	6d4c7e	83c0b6	NORMAL
15/02/2024 12:37	cb5458e5e7cad04fb3df6e705286802e7992dba4c510ce348a28b32409c0ccdf	32000	1	-94.01%	83c0b6	6d4c7e	AUCTION
15/02/2024 14:18	22ce66131dcb4c6a2a2d44f034a3eb05e831fa3d6382a0fb6ca5498437f707d1	32000	400	-94.01%	0a9b24	a2388b	NORMAL
15/02/2024 14:18	71469830ed54bfb1d2d81a49ee849563d57a38170956ee1641dbae31a6188132	28000	400	-94.27%	networ	0a9b24	CLOSE_OUT_BAD
15/02/2024 14:18	ea65f555556a8fde5a84f3b3ac8f5fefa3d3cea78f87026973e5b0b0dfb94198	28000	400	-94.27%	a2388b	networ	CLOSE_OUT_GOOD
15/02/2024 14:21	009a59f861612356c7e2ff6e7bff0c68549d62da3ffcb616700837554bdc151a	32000	410	-92.34%	0a9b24	a2388b	NORMAL
15/02/2024 14:54	aee0adda2e92d55998d0880a95fa263ef1c59b18a1eb8a7ec1bb1b38dffb9114	31500	6000	-91.91%	804f90	7bcbbb	NORMAL
15/02/2024 22:59	99f5479890ffde4ea5ed8c8214d56294e5e2820f36d2d150b1a20e42fc6e09fa	32286	29986	-15.69%	4cccff	89c98f	NORMAL
15/02/2024 22:59	6000c7f01cb815ac781dddec20b52a06dfb26b6f77e8c8bc26f9dc6d776301c2	32281	18496	-15.70%	4cccff	89c98f	NORMAL
15/02/2024 22:59	35b660d29475ccadf2519dad59f4f5cd1af1e2b3014b480f8bf39bbfe083443f	32279	2364	-15.70%	4cccff	89c98f	NORMAL
15/02/2024 22:59	1eea144e94bec8c1462c8840c287b437c6b358a406bf5fadac746490539739de	32242	1079	-15.80%	4cccff	89c98f	NORMAL
15/02/2024 22:59	cec148a8794ad2ef4334e66a8af43b020ecccfe83fca601d000fba12b5952215	32234	775	-15.82%	4cccff	89c98f	NORMAL
17/02/2024 03:13	f7abbf7bc056e816fcced023cd272080a36ddbe08b096cc3b1b1275c0dd6a92d	980000	1	2928.92%	22bb1a	2951b7	AUCTION
17/02/2024 03:13	44c251ba07ceb75cc8f9d8bf46f07eee6d7be4d50e4756050587e3e6207c814c	980000	10	2928.92%	22bb1a	1d150c	AUCTION
17/02/2024 03:13	fac2e75a995aeea3a4b18d20e269d0e534167201ff1a99d0cc10b02ea8a049de	980000	9	2928.92%	22bb1a	1d150c	AUCTION
17/02/2024 03:13	1b3cb426bd103e285fb8acb8cfba3f3feae897cd537119a5742be1ac2b765f5f	980000	1	2928.92%	22bb1a	1d150c	AUCTION
17/02/2024 03:31	5d303de3f19cc93eee804d105abb6e0be1ea3cac940eceed9e3ba4f7cad09095	22600	1	-30.59%	2951b7	2fb291	AUCTION
17/02/2024 03:33	8d7f5d97a1b40a6f5142b5c695c51ea3c3a77933c07b7794a4a79145511f618e	22100	3113	-32.13%	89c98f	2fb291	NORMAL
17/02/2024 03:33	254779c3430b4c88a9417a18ac8e5260e522a0058a1a215ea526e6d43cbe5c10	22048	71	-31.60%	networ	22bb1a	CLOSE_OUT_BAD
17/02/2024 03:33	0a6d6c3f7298fd20391753a04f04d9d56c600f0108771b83df8b068248f44baf	22048	84393	-31.60%	networ	02e677	CLOSE_OUT_BAD
17/02/2024 03:33	85a9c00b15fc05565945ae351eda0b4c92d1ee5dfebd1fadc87211c3d081f474	22048	2	-31.60%	networ	1d2f37	CLOSE_OUT_BAD
17/02/2024 03:33	0652eaf735c6f0ec06317f992b6f8d02984f155649d8680f0f9466d7379e41a0	22048	410	-31.60%	networ	0a9b24	CLOSE_OUT_BAD
17/02/2024 03:33	0f2c86adce42813d9489aed88a1da94565a1b5ea91b13fc415218d2c903ec194	22042	12855	-31.62%	89c98f	networ	CLOSE_OUT_GOOD
17/02/2024 03:33	d2c7f645ba57dfda77f1ade35e9b2a594eca9cb13ed36dc298168e386d241aa5	22045	58646	-31.61%	89c98f	networ	CLOSE_OUT_GOOD
17/02/2024 03:33	5609c8f511315210b72bae1463a20554d08b2e96732e0fc05adaa6763c56d09a	22046	7497	-31.61%	89c98f	networ	CLOSE_OUT_GOOD
17/02/2024 03:33	9f0a3d67ee603912b00a40f5fe21c6cfb3c8ab22f916eda4ff8167017e6429d1	22091	3421	-31.47%	89c98f	networ	CLOSE_OUT_GOOD
17/02/2024 03:33	33710f0dea1c283aa39f56019983544a34471fa5266317f36a4b0fe811298450	22099	2457	-31.44%	89c98f	networ	CLOSE_OUT_GOOD
17/02/2024 03:33	ee11cbc5cea19e0ee315f496fecbadc7699e1559590ba1c86fc13b58c45a3b59	22100	25977	-14.40%	cec6a9	2fb291	NORMAL
17/02/2024 03:46	a1b10cf8132892cab4bb0608e56795bae1f40614ad0c506b76f9df7135544204	32040	29091	25.69%	2fb291	networ	CLOSE_OUT_BAD
17/02/2024 03:46	1890187df8d767051f7756b1d19c26b67caea3b0ff5e1b77fbef2a1e504e2d13	32040	29091	25.69%	networ	47a263	CLOSE_OUT_GOOD
17/02/2024 03:46	00ba3a8a3792c187c3d55f7695b6c033c988b4c3bcb57b7419b835ef2c4468c2	32070	1	25.81%	47a263	47a263	AUCTION
17/02/2024 03:46	f00e2e142690136bdf56a667f16d926637b9c281d09c71fffd0cc1080d6bc415	31936	1	20.20%	426f40	36e73d	NORMAL
17/02/2024 03:58	6782db2e19d3f59d74641f6217d4b2adc981be7e74c22229056854afd953d45c	31936	1	20.20%	426f40	36e73d	NORMAL
17/02/2024 04:01	1938aee2aa2f6b64134e8c8c96e2070977f0d801ab10b2f4a4ea44908dde3816	31936	1	20.20%	426f40	36e73d	NORMAL
17/02/2024 04:11	8de90b24758e6db2e73cd4153b3b663f399d291007542c9964dd0dc08d232b30	31936	2	21.06%	426f40	36e73d	NORMAL
17/02/2024 04:23	2b8dfff8b0cd5a123804c9253f4155913a7ebdc5cd3698c02f69bf4f1dd77d75	5000	10	-81.05%	1d150c	02e677	AUCTION
17/02/2024 04:23	3fa912d1c21ebbd91cc7495c44700f164a3fe9767891a8e4c40acec6e9f1c546	5000	1	-81.05%	02e677	02e677	AUCTION
17/02/2024 04:23	bd8779cd59e59ada67c31e1057fe8785ea45cf671cbe512c57d7419d9ef38e0d	5000	3	-81.05%	426f40	02e677	NORMAL
17/02/2024 04:35	f4dbc0f2a30bb25b593fbe82168b3f03813bb7fd11a36ae7afad7184da251be6	10	1	-99.96%	2951b7	02e677	AUCTION
17/02/2024 04:47	ed3b8ed38517172d6c71801c8c96f95bff39f71436a1c962bd5f0d1036ccd6d6	990000	1	3652.94%	02e677	2951b7	AUCTION
17/02/2024 06:51	95bdfdb52f5abf613f414314591acc94815c07d5e8d4285f55f40f8f017d5dc8	990000	1500	3652.59%	ff2d52	f6074d	NORMAL

Appendix 4: Perpetrator's other activity

Trading on other markets

This table shows the amount of trading done by the keys identified in this report on other markets.

Market	No. trades	USDT notional	% of notional[5]	Trading from	Trading to
BTC/USD-PERP	**13**	**74.61**	**0.02%**	20/01/24 05:53:20	23/01/24 08:53:20
SNX/USDT-PERP	**4**	**12.38**	**23.69%**	04/02/24 20:53:20	05/02/24 19:06:40
LINK/USD-PERP	**153**	**437,726.26**	**32.06%**	19/01/24 02:06:40	26/01/24 09:06:40
INJ/USDT-PERP	**7**	**263.58**	**26.18%**	04/02/24 20:53:20	05/02/24 19:06:40
ETH/USD-PERP	**275**	**5,689,448.56**	**76.59%**	20/01/24 14:13:20	15/02/24 18:00:00
SOL/USD-PERP	**67**	**607,816.56**	**44.78%**	26/01/24 09:06:40	26/01/24 09:06:40

Previous manipulation

Further analysis shows that the perpetrator also manipulated the SOL/USD-PERP market just before it was closed by governance. This was not initially noticed as the market was effectively abandoned by traders, so funding and prices were expected to be volatile and likely unreasonable.

Based on an analysis of trade prices vs. available market data for all other markets, we do not see evidence of other significant or sustained manipulation by the perpetrator, despite their high share of volume. We believe the perpetrator likely entered Vega markets initially to profit from price and funding arbitrage absent manipulation, before planning and executing manipulations on SOL/USD-PERP (once, at closure) followed by LDO/USDT-PERP on a more sustained basis.

Staking and governance

None of the "manipulator keys" identified in this document have ever had VEGA staked to them, delegated VEGA to a validator, or participated in governance by proposing or voting.

The perpetrator did state "*I've been involved in the Vega ecosystem for a long time, and I'm also a heavy staker*", but this is either untrue or they are using unrelated keys.

Deposits and withdrawals

Has deposited **28,557.00 USDT** and successfully withdrawn **77,414.32 USDT** across all keys**.**

[5] "% of notional" is the ratio of perpetrator's notional trading volume to the total notional traded in the market in the period when perpetrator was actively trading.

Appendix 5: Data and other resources

Overview

Below are links to key data, APIs, and tools used in this analysis. Where possible we have included RAW data in the Google Sheets. We have also included a link to the API documentation if you are interested in querying the data node yourself.

For some types of data, the full data set is too large for a spreadsheet. To analyse this, you will need access to the Postgres + TimecaleDB database on a data node. Because Vega is open source and an open public network, anyone can run a data node and we have included a link to the documentation in case this interests you.

Data analysis

- **Sheet of analysis data (web page):** https://docs.google.com/spreadsheets/d/e/2PACX-1vRF0D1PRr10I6OMGO3LjGQWaZtNpMhatVxoQsWp-uDYT9d4DShQjv1-_dmbu1kXbkb_nut8m19mVNkt/pubhtml
- **Sheet of analysis data (Google Sheets):** https://docs.google.com/spreadsheets/d/1BKADUtiPa5qdKR-9FKjCANGUQjSaC12ZWKLFslbgVRQ

Data node and APIs

- **REST API documentation:** https://docs.vega.xyz/mainnet/api/rest/overview
- **Running your own data node:** https://docs.vega.xyz/mainnet/node-operators/get-started/setup-datanode

Further queries

If you have other questions or would like help with the data or APIs, please reach out to a member of the Vega team on Discord and they will try to help if they have time and are able.