Final published article can be accessed in Oil & Gas Journal here

Using Satellite-Based Synthetic Aperture Radar Data to Assess China's Management of Its Key Oil Import Pipelines and Associated Inventories

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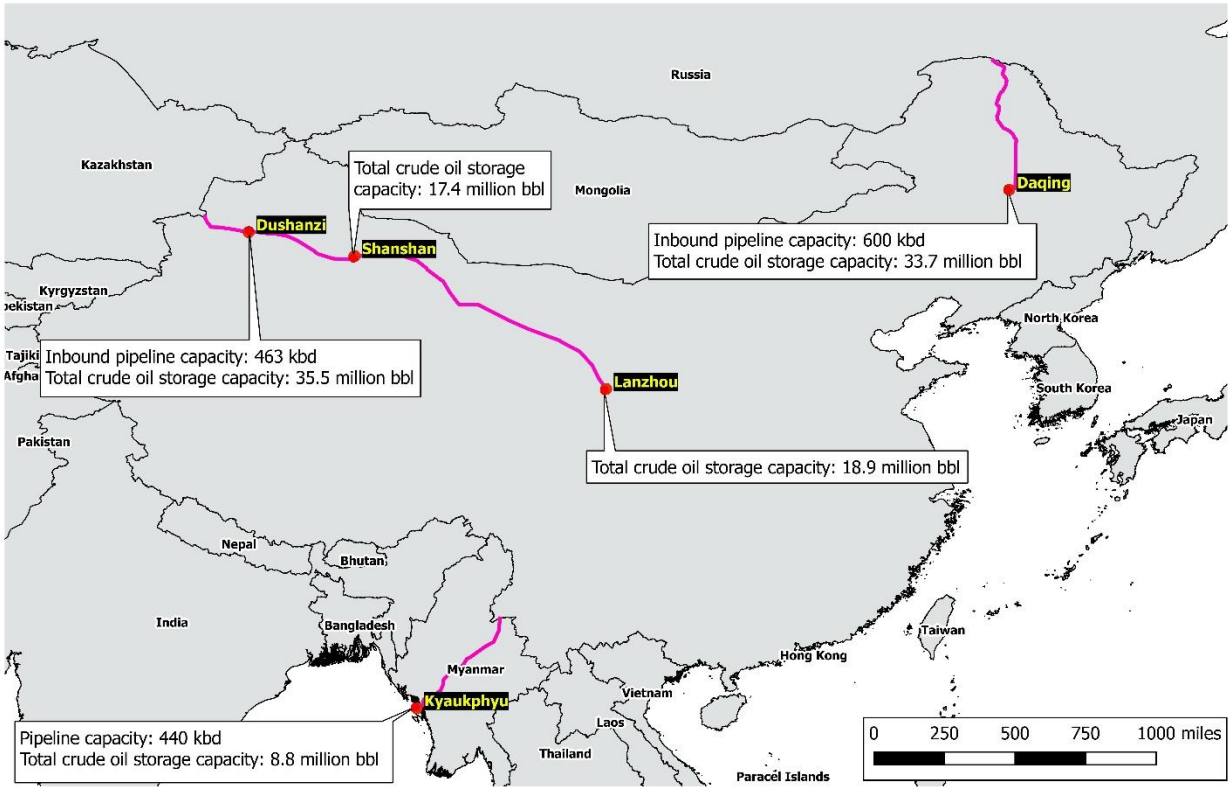
Oil inventory data measured by satellite-based synthetic aperture radar can help market participants and policymakers more accurately assess how CNPC—China's flagship state-controlled oil major—is managing the pipelines that carry crude oil into China from Kazakhstan, Myanmar, and Russia. With a combined capacity of nearly 1.5 million barrels per day, these four oil lines (one from Kazakhstan, one from Myanmar, and two from Russia) are meaningfully-sized blood vessels in the global crude circulatory system (**Exhibit 1**).

Exhibit 1: China Key Overland Oil Import Pipelines and Their Capacities



Source: Baker Institute China Oil Map, GADM, Ursa Space Systems, Author's Analysis

Methodology

This analysis is among the first academic, public consumption research projects to employ oil inventory data derived from satellite-based synthetic aperture radar. It is also the first such project to use such data to assess the operations of strategic oil supply assets in China. Ursa

Space Systems generously provided approximately 2 years of weekly inventory data for this project, which covers facilities at Kyaukphyu, Myanmar (Myanmar-China oil pipeline), Daqing (Russia-China oil pipeline), and Dushanzi and Lanzhou (Kazakhstan-China oil pipeline).[1] These facilities' combined storage capacity is approximately 105 million barrels of crude according to Ursa's measurements--roughly 25% larger than the massive storage hub at Cushing, Oklahoma. I then fuse and cross-reference the Ursa satellite data with other sources including Energy Information Administration data, local Chinese and Russian language sources, and company reports.

Satellite Data: Analytical Importance Plus Potential Blind Spots

Before the advent of satellite inventory data, import pipeline activity could be approximated using monthly information published by China's General Administration of Customs for crude oil imports at specific customs entry points. But in March 2018 the Chinese government stopped providing this monthly port-level oil import data to Bloomberg, leaving a major data gap for analysts.[2]

As a result, access to data like Ursa's is revolutionary. By collaborating with the company, academics can obtain weekly insights into oil inventory levels worldwide—a feat not possible even 5 years ago—and one that is especially difficult in China given that Beijing treats oil storage information as a closely-guarded state secret.[3] The Chinese government and its state oil firms have historically disclosed little information about operations of the country's crude import pipelines. Such reticence may stem from a belief that the pipelines can provide a strategic hedge against potential maritime interdiction of oil imports into China and are thus national security assets.[4]

In addition, Ursa's radar-based approach yields accurate oil inventory measurements regardless of cloud cover, air pollution, or other meteorological obstacles. Satellites also allow researchers to efficiently and accurately cover a huge geographical span. In North American geographical terms, the storage bases examined in this analysis are located further apart than New Orleans (Kyaukphyu), Seattle (Dushanzi), Chicago (Lanzhou), and Montreal (Daqing) are from each other.

Radar observation of oil storage has limits. Future oil storage facilities in China might either be built underground or use fixed-roof tanks that thwart radar measurement of tank level changes.[5] Existing tanks could be retrofitted with fixed aluminum roofs, although this can cost more than $1 million per tank.[6] Yet overall it is likely that a substantial proportion of crude oil storage capacity in China will remain accessible to space-based observation for years to come. As such, the pathways opened by satellite commodity tracking data like Ursa's are still only in the early stages of analytical exploitation.

What Inventories Can Tell Us About How CNPC Manages the Pipelines

Oil storage facilities associated with pipelines serve three core purposes. First, storage helps provide a buffer to offset changes to oil supplies into a pipeline/refinery or shifts in operations at a refinery—for instance, shutdowns for maintenance and operational upsets. Second, storage capacity can allow traders to capitalize on shifts in the forward oil price curve. Finally, storage terminals can also "carve out" strategic petroleum reserve capacity that is specifically dedicated to protecting against disruption of supplies by natural disasters, geopolitical events, or other factors. The data used in this analysis suggest that the oil storage facilities associated with China's oil import pipelines primarily fulfill commercial and operational stability purposes.

A. Myanmar-China Pipeline

The Myanmar-China pipeline entered service in April of 2017 and runs approximately 1,400 kilometers from the Indian Ocean port of Kyaukphyu to CNPC's Anning refinery in Yunnan Province, just outside the city of Kunming.[7] Several factors drove the pipeline's construction. These included central government concerns about the security of oil imports through the Malacca Strait, the central government's desire to use large infrastructure projects to promote development in certain regions of China, and finally, the Yunnan provincial government and local officials' concern about high gasoline and diesel fuel prices in Yunnan due to constrained crude oil supplies, which the pipeline could help alleviate.[8]

The blend of economic and strategic motivations underpinning the pipeline offers a useful analytical test case. The initial data suggest that the line is (1) running in a volatile "feast or famine" mode dictated by the frequency of incoming tankers, (2) it is still generally running significantly below nameplate capacity, and (3) line operations have not yet been optimized for stability in the way that analogous projects elsewhere in the world such as the Trans-Alaska Pipeline system are.

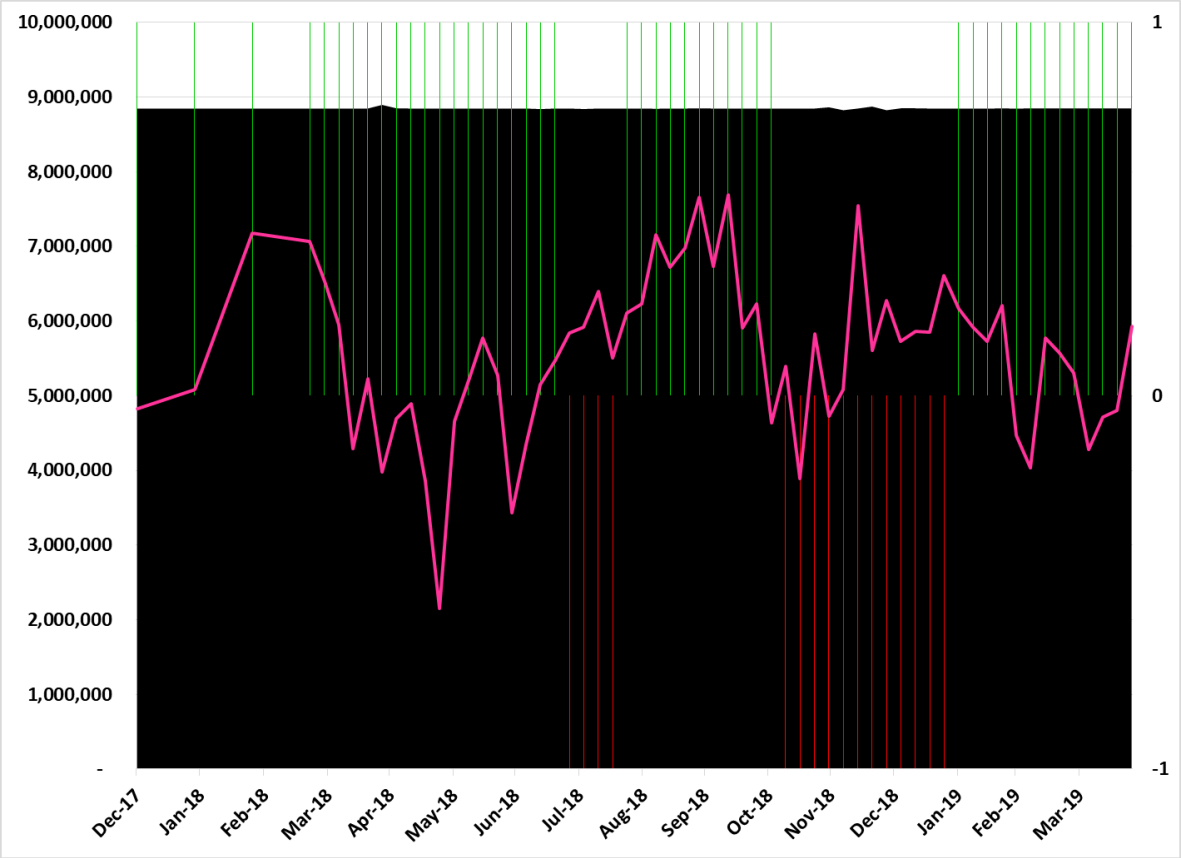
The Kyaukphyu terminal is used as a proxy for Myanmar-China oil pipeline operations. No other large-scale crude oil pipelines serve the Kunming area and thus, the Myanmar-China pipeline's run rate likely reflects the Anning Refinery's own run rates. As of 17 April 2019, local media reported that since its inception, the Myanmar-China Oil Pipeline had delivered 17.8 million tonnes of crude, an average flow rate of 192 thousand bpd.[9] Using the average outbound rate implies that the pipeline can effectively drain a very large crude carrier in about 10 days. Crude can likely be offloaded much more quickly than that into the storage tanks. For instance, the Louisiana Offshore Oil Port can offload tankers at rates as high as 2.4 million barrels per day.[10]

Ursa's data show significant volatility in the Kyaukphyu Terminal's capacity utilization rate for the 8.8 million bbl of storage capacity at the site. For instance, in late February 2018 the terminal was more than 80% full and by late May of that year, was only about 24% full (**Exhibit 2**). Total storage capacity remained steady during that time and thus did not meaningfully influence utilization rates. Utilization volatility makes sense when one takes into account that inbound oil shipments

all come by tanker and that a single very large crude carrier (VLCC) can haul 2 million barrels of oil—nearly 25% of the facility's total storage capacity—and offload that amount within 2-4 days of docking.

Exhibit 2: Total Storage Capacity and Oil Inventory at Kyaukphyu, Myanmar (barrels)

Note: Contango oil price periods denoted in red, backwardation in green



Source: Ursa Space Systems, Author's Analysis

The dataset for Kyaukphyu is still brief—with less than 2 years of history at this point. Such limitations notwithstanding, the data thus far suggest that operational concerns dominate CNPC's management of the facility, as flows appear much more driven by ship arrivals than by oil price shifts.

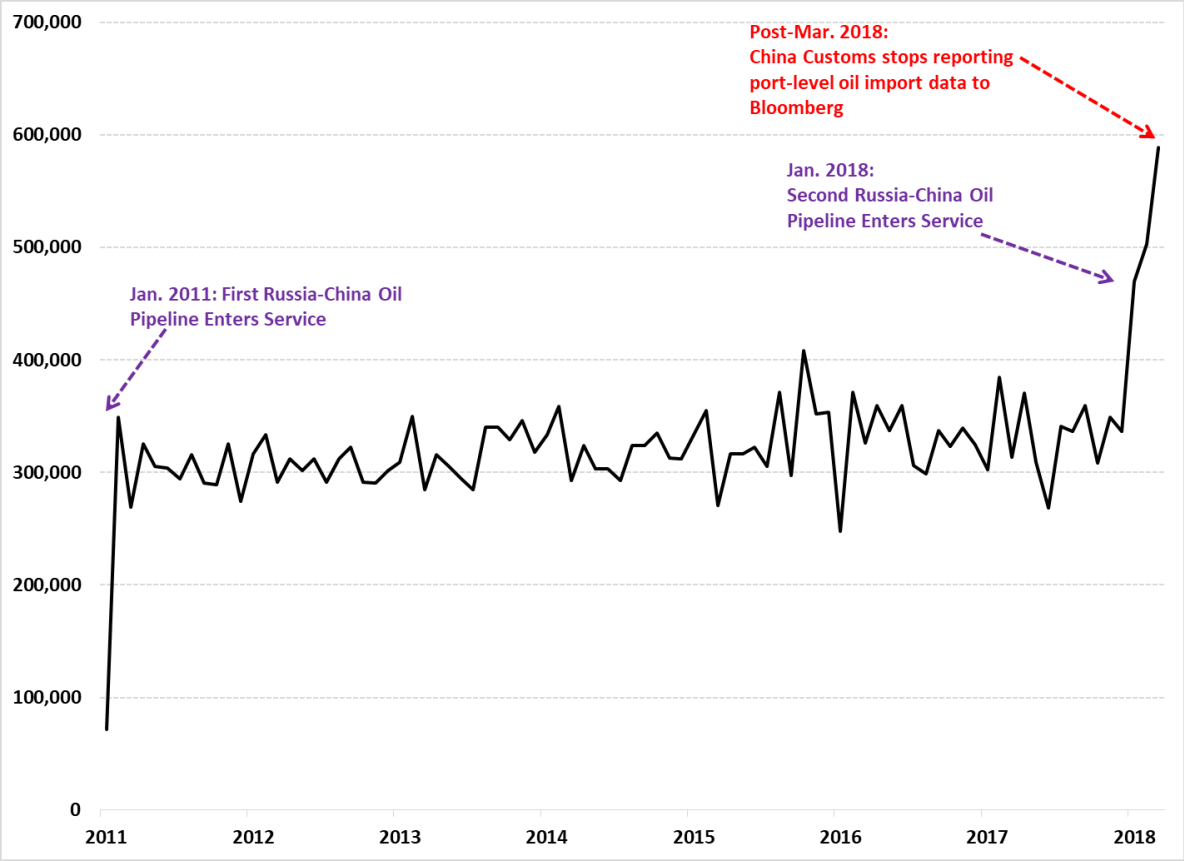
B. Russia-China Pipeline

The Russia-China pipeline system links the East Siberia-Pacific Ocean pipeline at Skovorodino (70 km north of the Chinese border) to the oil center of Daqing approximately 1,000 km south. Trunk pipelines originating in Daqing can move crude to multiple refining centers on the Bohai Gulf near

Beijing, Tianjin, and Dalian. Line 1 entered service in January 2011 and the second in January 2018.[11] Each line can pump about 300 thousand bpd of oil.

Russian sources say the pipeline will operate at its full designed rate of approximately 600 thousand bpd in 2019.[12] Crude oil import data for the Harbin Customs district shows that by March 2018—when the Chinese government stopped reporting such data to Bloomberg—the area already had crude imports of nearly 600 thousand bpd (**Exhibit 3**). Railborne imports from Russia have become minimal with the pipelines entering service and northeast China imports oil from no other countries at this time, making the Harbin inbound oil data a strong proxy for oil volumes imported from Russia via pipeline.

Exhibit 3: Oil Imports into Harbin Customs District, Barrels/Day



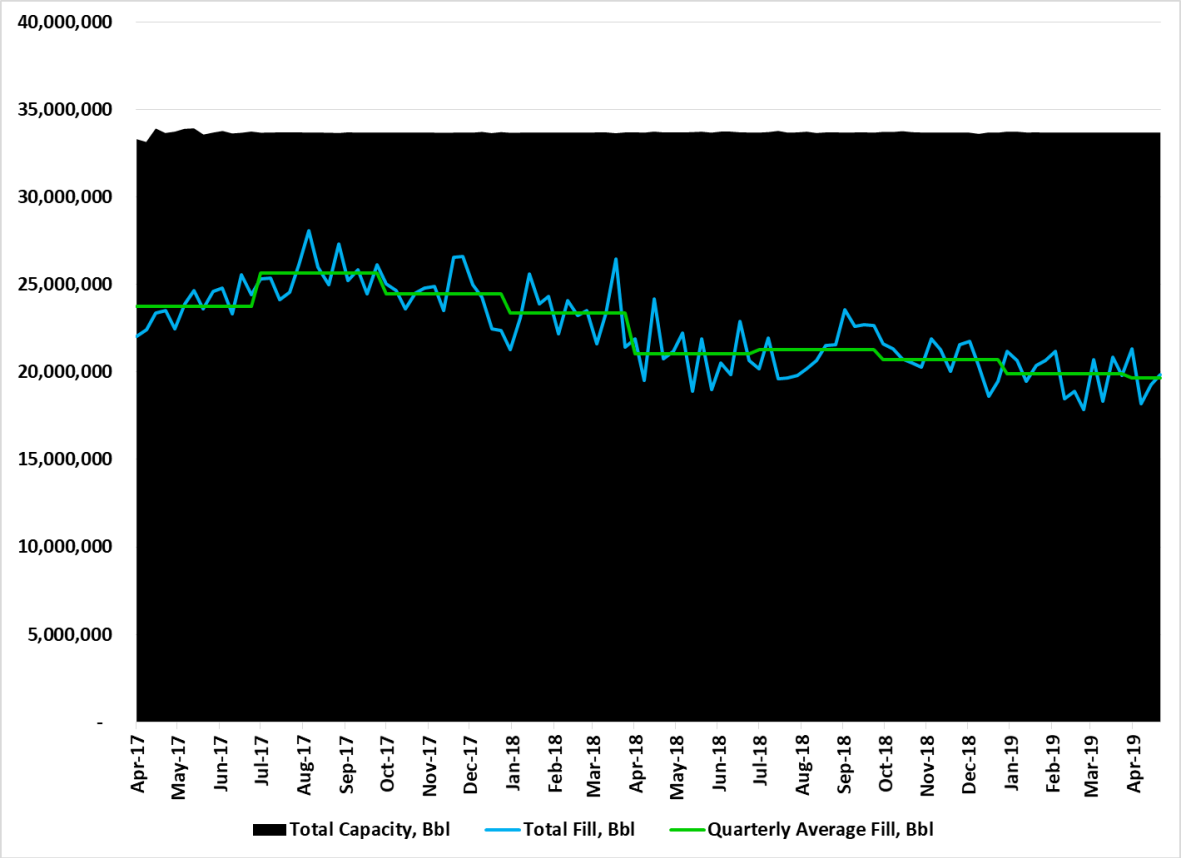
Source: China Customs (via Bloomberg)

While imports of oil from Russia have climbed significantly in the past two years, local production in the Daqing Field (China's largest) has steadily fallen since 2014 and now stands slightly above 600 thousand bpd—roughly the same as the volume now coming in by pipe from Russia. Despite a net increase in oil availability of more than 250 thousand bpd since 2018 (36 kbd decline in Daqing output offset by 300 kbd increase from Russia), Daqing's inventory levels have actually steadily trended downward since late 2017. This suggests more of the Russian oil is headed to refineries than is being stored long-term in the local tanks at Daqing (**Exhibit 4**). The area has two

large refineries with a combined capacity of 300 kbd and total local refining capacity (including teapots) of about 580 kbd.

Daqing also sits astride high-capacity crude pipelines connecting it to Dalian and other major refining centers along the Bohai Gulf. These coastal refineries also lie near some of China's largest gasoline markets, such as Beijing and Tianjin, and refining and product transport economics may be creating a situation where it makes more sense to send Russian pipeline crude south and refine it next door to major end user markets. The fact that CNPC has not expanded its storage capacity at Daqing despite a significant net increase in crude oil supplies also signals that the company likely plans to (1) emphasize moving oil to refineries rather than using the area as a strategic storage base and (2) that CNPC planners believe that the Daqing Field's terminal decline moving forward will preserve sufficient spare storage capacity, should the need to increase stored volumes arise in the future.

Exhibit 4: Total Storage Capacity and Oil Inventory at Daqing (barrels)



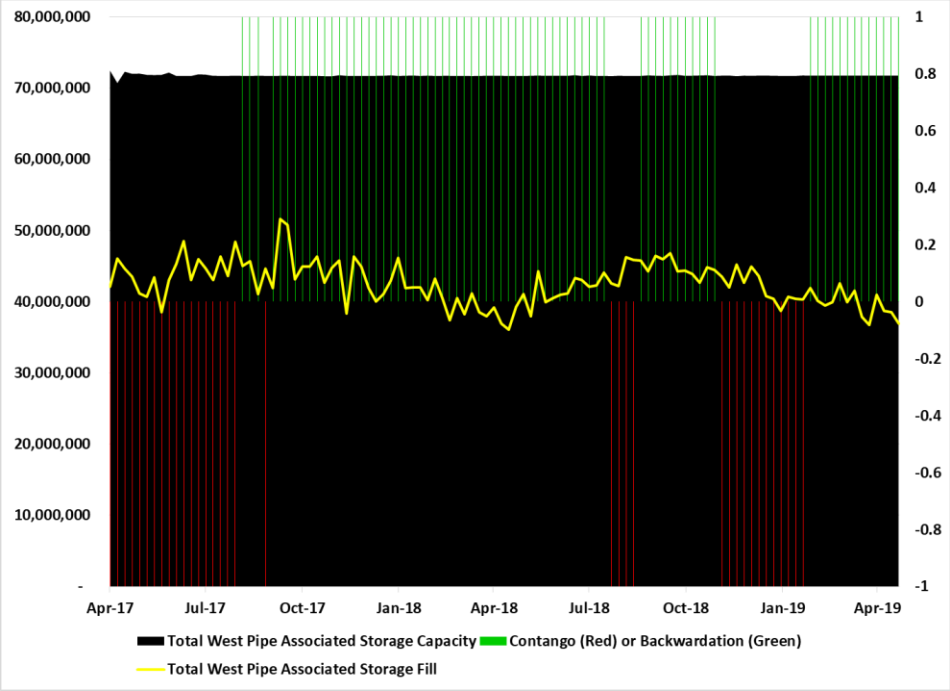
Source: Ursa Space Systems, Author's Analysis

C. Kazakhstan-China Pipeline

The Kazakhstan-China Pipeline entered service in 2006 and by 2017, delivered an average of 330 thousand bpd of Kazakh and Russian crude to the Chinese market.[13] These supplies complement Xinjiang's local crude production, which amounted to roughly 530 kbd in 2018.[14] Refineries at Dushanzi, Urumqi, and Lanzhou that are connected to the Kazakhstan-China pipeline and the Western Crude Pipeline that it empties into can collectively process 670 kbd of crude.[15] Refineries at Tahe and Karamay, which are located in Xinjiang but away from the trunk oil line can process a combined 200 kbd. There is also a lesser volume of other local production (~55 kbd) from Qinghai and Gansu that is refined locally. In summary, this means that approximately 915 kbd of crude oil supplies flow in an area where actual working refinery capacity at any given time is likely around 700 kbd (assuming 80% capacity utilization).

Flows along the pipeline are balanced by 72 million barrels of storage capacity at Dushanzi, Shanshan, and Lanzhou (**Exhibit 5**). Storage utilization ranged between 50% and 72% over the past two years, and generally clusters around the 60% level. As such, the "surplus" barrels suggested by the simple arithmetic above generally do not appear to be flowing into storage. Their most probable destination is the Pengzhou refinery in Sichuan, which is connected to Lanzhou by a 232 kbd oil pipeline and sources its crude from Xinjiang, Kazakhstan, and Russia.[16] Pengzhou's stated capacity of 200 thousand bpd reasonably matches the roughly 215 thousand bpd difference between crude availability and refining capacity further upstream in the Western China pipeline system.

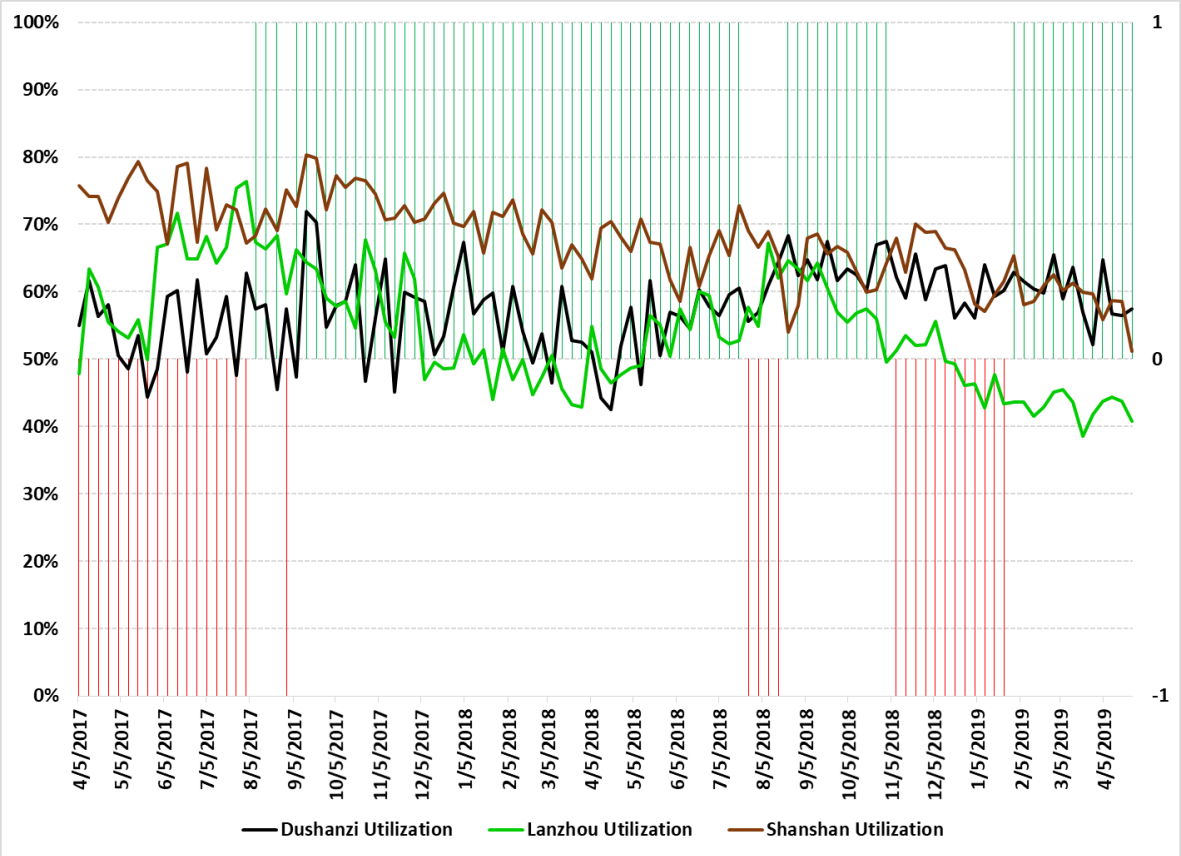
Exhibit 5: Total Western Pipeline-Associated Storage Capacity and Oil Inventory (barrels)



Source: Ursa Space Systems, Author's Analysis

From April 2017 through April 2019, the four storage sites on the trunk oil pipeline through Western China had an average capacity utilization of between 45% and 80% (**Exhibit 6**). Interestingly, despite China's growing crude oil demand growth, the storage facilities' utilization rate has generally trended downward, while raw storage capacity has not been expanded. This suggests several interesting things.

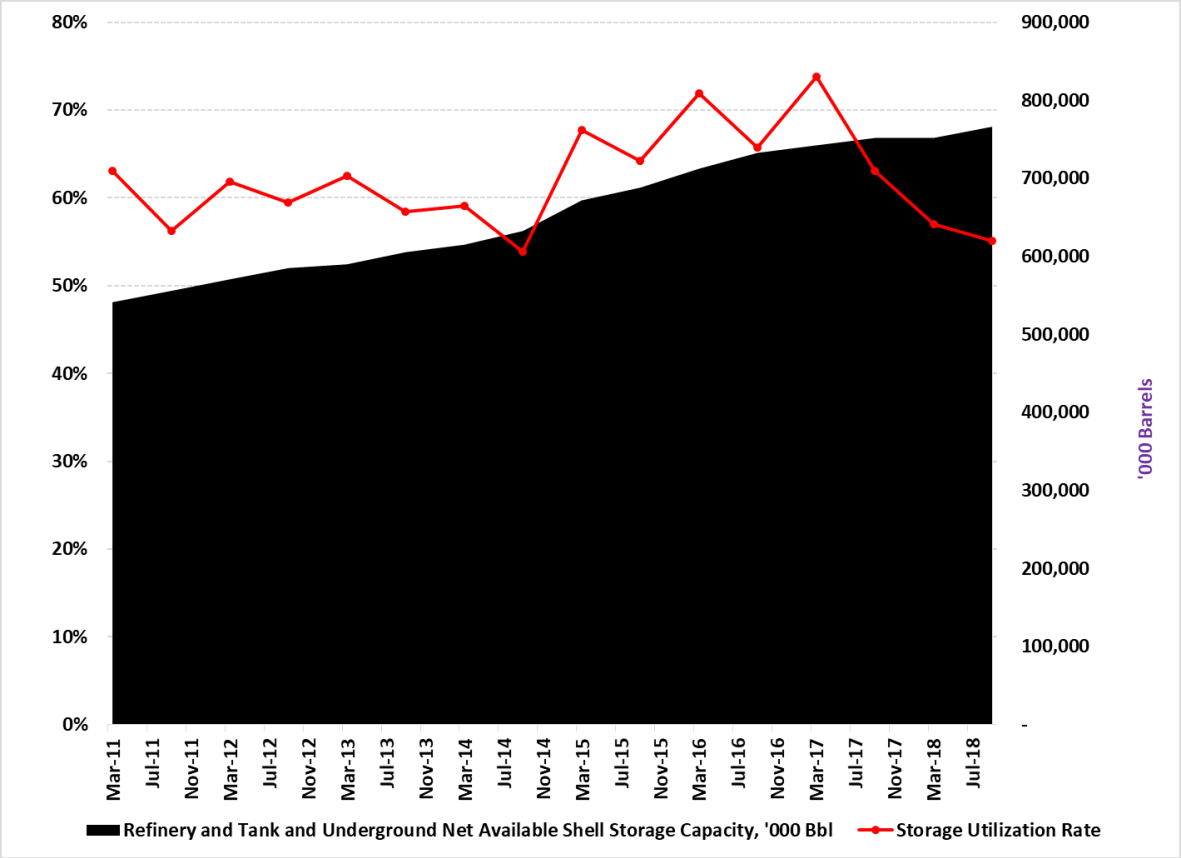
Exhibit 6: Storage Capacity Utilization By Site Along Kazakhstan-China Pipeline



Source: Ursa Space Systems, Author's Analysis

First, despite political emphasis on overland import routes, the Chinese government likely recognizes that the Central Asian energy vector has limited potential for expanding crude oil supplies. Second, the current storage utilization band of between 50% and 70% is similar to the overall commercial crude oil storage rates seen in the United States over the past 7 years (**Exhibit 7**). In other words, while Dushanzi is one of China's official SPR bases and Shanshan in some ways is discussed as a quasi-SPR location, the facilities really do seem to be operated in a broadly commercial manner. This may in part be a product of limited connectivity and a lack of true trading opportunities (i.e. one pipe in and one or two pipes out, three sources of supply).

Exhibit 7: US Commercial Crude Oil Storage Utilization Rate vs. Storage Capacity



Source: Energy Information Administration, Form EIA-810 "Monthly Refinery Report" and Form EIA-813 "Monthly Crude Oil Report"

Third, CNPC has not boosted overall storage capacity on the Western Pipeline Corridor during the past two years despite China's substantial national oil demand growth. This yields several important insights (**Exhibit 8**). First, oil demand growth is primarily driven by the country's East Coast and populous central region. Second, Kazakhstan's ability to expand oil exports to China is likely constrained, which reduces the need to expand tankage. Finally, strategic petroleum reserves are most effective when located near high-capacity refining and demand centers and strongly interconnected pipeline networks for distribution of the resulting refined products. Western China generally lacks these characteristics.

Exhibit 8: Total Crude Oil Storage Capacity at Duzhanzi, Shanshan, and Lanzhou Has Remained Static for Two Years Despite China's Overall Oil Demand Growth

Source: Ursa Space Systems, Author's Analysis

How Oil Prices Do (Or Don't) Factor Into Chinese Oil Import Pipelines' Operational Patterns

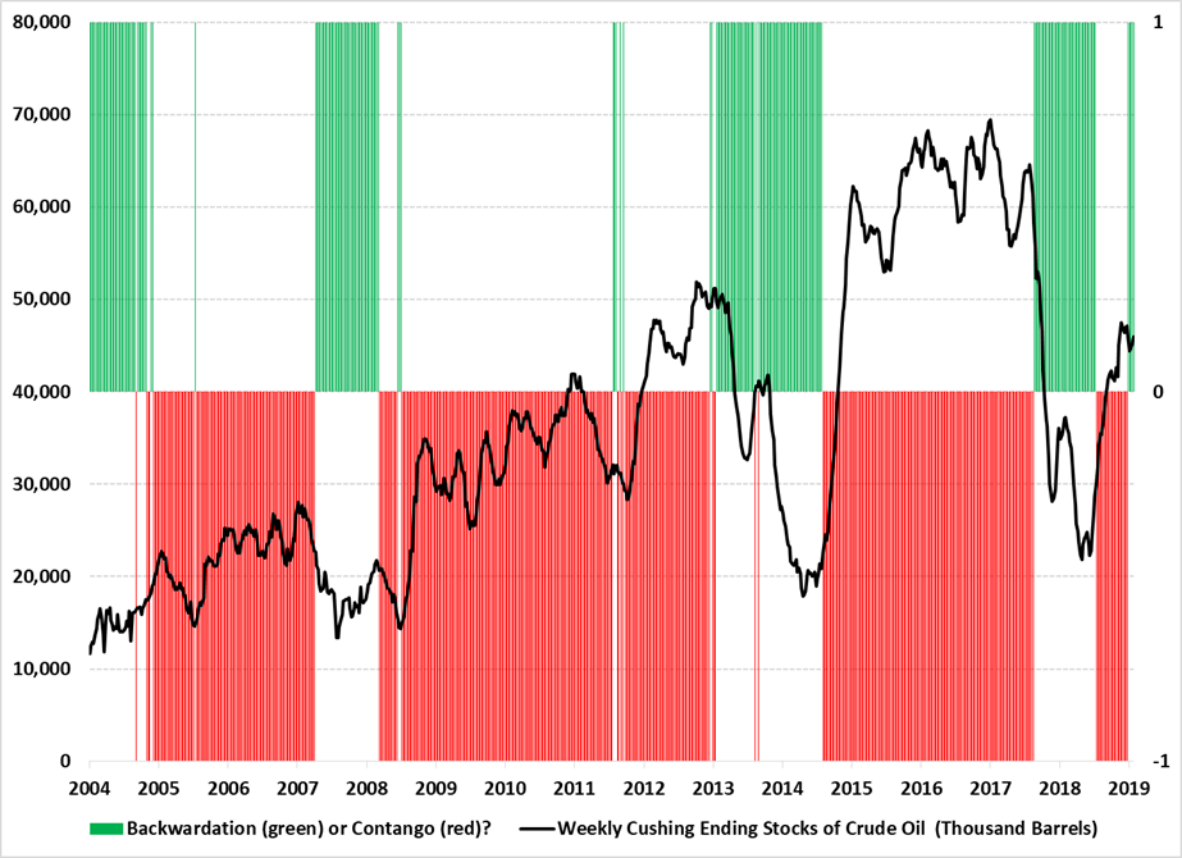
The Ursa data strongly suggest that CNPC is operating its overland oil pipelines based first and foremost on supply stability concerns, with maintenance of some "strategic" barrels along the Western China route from Kazakhstan. This accords with other investigators' findings. For instance, one set of academic researchers concluded that based on how inventories and sales moved between 1990 and 2012, CNPC did not meaningfully engage in speculative trading of crude oil.[17]

More recently, none of the storage hubs covered in the data Ursa shared with us appear to have hosted meaningful speculative trading activity between April 2017 and April 2019. Neither Dushanzi, Shanshan, Lanzhou, Daqing, nor Kyaukphyu showed clear or significant responses to shifts in the futures price curve relative to front-month crude prices during that time. In contrast, consider Cushing, Oklahoma, home to more than 80 million barrels of some of the best-connected crude oil storage in the world, with 3.8 million bpd of inbound pipelines, 3.1 million

bpd of outbound pipelines, and systemic linkages to more than a dozen refineries.[18] Cushing's inventory levels generally responded rapidly and dramatically to changes in the futures markets, which are measured here using the difference between the Month 6 and Front Month Brent contracts (**Exhibit 9**).

In facilities like Cushing, storage levels typically decrease when the oil market is in a so-called state of "backwardation" where oil is worth more today than in the future, and traders have an incentive to sell their stored volumes.[19] Conversely, when the oil market is in a "contango" condition where oil is worth more in the future than at present, traders tend to store oil and sell it forward in the futures market to try and lock in a profit, causing inventories to rise.[20] On a global level, Cushing is exceptional for its connectivity and market liquidity. But it is also a great comparative example for assessing how inventories change in relation to market shifts when a storage hub's tanks are populated by many speculative traders.

Exhibit 9: Cushing Inventory Levels vs. Backwardation and Contango in Oil Market, Million Barrels



Source: EIA

Conclusion

The Ursa data suggest that China's overland oil supply pipelines primarily operate as commercial assets for which flow stability is a paramount concern. Second, they are volume constrained and strategic reserves stored in the associated tank farms would not be able to move to market at a scale large enough to replace import disruptions from the seaborne routes that China relies on most heavily. Third, the lack of storage expansion at the sites over the past two years suggests that CNPC believes its storage capacity is sufficient to handle operational needs associated with the expected import pipeline flows . Fourth, the lines allow crude oil from Russia and Kazakhstan to penetrate deep into the Chinese continental refining market—to Central Sichuan from the Western pipeline system via Lanzhou and all the way to the Bohai Gulf via Daqing. Future domestic crude oil pipeline network expansion would only enhance this connectivity. At that point, if Chinese oil security policy began to more overtly emphasize security of supply over cost of supply, the existing corridors from Kazakhstan and Russia could see capacity expansions aimed at offsetting the country's growing reliance on seaborne crude oil imports.

Finally, refinery-level storage change data, refinery runs, and tanker arrivals at the Myanmar terminal would allow an analyst to make more granular estimate of pipeline flows. Thus, the analysis set forth above naturally lends itself to follow-on research by analysts with access to such data.

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[1] For more on Ursa Space Systems, please see https://www.ursaspace.com/

[2] Bloomberg has no port-level oil import data updates after March 2018 and the author could not locate replacement data online. It is possible that China Customs still provides these port-by-port oil volume updates to other data providers such as Reuters or Wind Info, but as of the time of publication, I've not been able to verify that.

[3] Gabriel Collins and Elsie Hung, "Using Satellite Data to Crack the Great Wall of Secrecy Around China's Internal Oil Flows," Baker Institute Report no. 09.07.18. Baker Institute for Public Policy, Houston, Texas. https://www.bakerinstitute.org/research/using-satellites-study-chinese-oil/

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[6] Ibid.

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[18] Housely Carr, "Oklahoma Swing, Part 4 - The Pipelines That Flow Out Of The Crude Hub At Cushing," RBN Energy, 7 October 2018, https://rbnenergy.com/oklahoma-swing-part-4-the-pipelines-that-flow-out-of-the-crude-hub-at-cushing
[19] For a more detailed explanation, please see: "Storage, Oil Backwardation, and Implications for MLPs," Alerian, 17 April 2018, https://www.alerian.com/storage-oil-backwardation-and-implications-for-mlps/
[20] Ibid.